1. Introduction

Although the majority of peatlands are still in a natural state, many peatlands have been drained and degraded. They have been used for centuries for productive purposes such as agriculture, forestry, grazing and peat mining. Globally, the carbon dioxide (CO_2) emissions from drained peatlands (including emissions from peat fires) amount to two gigatonnes per year (Joosten, 2009a) and represent almost 25 percent of the CO_2 emissions from the entire land use, land use change and forestry sector (LULUCF) (Canadell, 2011).

Unlike the emissions associated with forest clearance, which are largely instantaneous, the emissions from drained peatlands continue for as long as the peatland remains drained and the peat keeps oxidizing. This can continue for decades and even centuries. Conserving, restoring and improving the management of organic soils and peatlands can substantially contribute to reducing atmospheric greenhouse gas (GHG) concentrations. Peatlands also provide other vital environmental services and contribute to food security and poverty reduction.

This report aims at providing countries rich in peatlands and organic soils with information on incentives for reducing emissions. The report also provides details on methodological guidance and available data on quantifying GHG emissions from organic soils and offers practical options for addressing the technical complications involved in measuring, reporting and verification (MRV) and accounting.

The information in this report was compiled by a team of expert authors from Wetlands International, the Mitigation of Climate Change in Agriculture (MICCA) Programme of the Food and Agriculture Organization (FAO) of the United Nations, Greifswald University, Climate Focus, ATLAS Environmental Law Advisory and the Michael Succow Foundation. These authors have contributed to different chapters in the report. This is the second amended edition of the report, which was first released in May 2012.

According to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), 14 percent of global GHG emissions are caused by agriculture. Another 17 percent of emissions come from land use change leading to land use systems that contain less carbon than the original natural ecosystems. Dangerous global warming cannot be avoided without emission reductions in the land-based sectors.

Agriculture is the driver for most of the changes in land use. The clearing of forests or grasslands for croplands, pastures or plantations, including biofuel crops, is one major example of agriculture-driven land use change. Demand for energy, which in many developing areas is based on wood, leads to further deforestation and forest degradation.

In order for the land use sector to contribute to the global effort to mitigate climate change, three actions are needed:

1. the avoidance of new emissions from land use change and consequent land use;
2. the improvement of management practices to reduce emissions from existing production systems; and
3. the sequestration of carbon through improved land use and management.

To achieve this, it is necessary to identify 'hotspots' areas where reducing emissions from land use can be the most effective. Other important societal goals, including ensuring food security and maintaining vital environmental services must also be considered. The Box 1 presents an example of efforts to manage sustainably the peatlands of Ruoergai Plateau at the foot of the Himalayas, which provide multiple ecosystem services for millions of people.

Obtaining food security 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 for peaceful development. Climate change will affect all of the world's ecosystems, including agricultural ecosystems. For this reason, it is necessary to adapt land management and use to changing temperatures and rainfall patterns. If global average temperature increases by more than 2 degrees Celsius, it will be difficult to secure enough food for the global population, which is projected to increase to 9 billion people by 2050.

Peatlands and organic soils are an example of emission hotspots that we need to focus on to reverse increases in GHG emissions and prevent further dangerous, anthropogenic climate change. Peatlands and organic soils cover only 3 percent of the world's land area but contain 30 percent of its soil carbon (Parish *et al.*, 2008). Only 15 percent of the world's peatlands have been drained and used for agriculture, livestock and forestry, including bioenergy plantations such as oil palm (Joosten, 2009a). These drained peatlands, which make up 0.3 percent of the world's land cover, emit almost 6 percent of global CO_2 emissions (Joosten, 2009a). Organic soils are prevalent in many agro-ecological zones and ecosystems. These soils should be identified to establish suitable management programmes.

A priority is to conserve peatlands in their undrained state. Peatland conservation is one of the most cost-effective ways to stop increases in emissions. Given the limited area peatlands cover and the huge carbon stocks they contain, this a self-evident strategy that would benefit from a globally focused programme. Where natural peatlands have to be converted to productive use, land use options that are compatible with wet conditions (a practice referred to as paludiculture) should be developed and implemented.

Peatlands that are drained and currently used for agriculture or forestry should be rewetted. Rewetting is often easily done in areas where peatlands have been already abandoned due to severe degradation or where productivity is low. There are already good examples of opportunities, which build on traditional knowledge and new science, for developing sustainable livelihoods from rewetted peatland ecosystems. These opportunities include paludiculture and diversifying income sources through mechanisms such as payments for ecosystem services, climate change mitigation funding and tourism development.

Emissions from drained peatlands are of global significance and constitute a major part of national GHG emissions in many countries. Therefore, less damaging and more sustainable management practices have to be implemented in peatland areas that must be kept in productive use for agriculture, livestock and forestry. Management options for minimizing emissions, including fire control, should be identified. High water tables are essential for reducing 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 for reducing emissions from organic soils according to their drainage conditions. The water table level in peatland is closely associated with the ecosystem services it can provide. Drainage causes most of the environmental problems related to peatlands. This chapter discusses management practices for avoiding or reducing these problems. The different management situations and options are summarized in a decision support tree for the management of peatlands and organic soils (Figure 2).

For peatlands under productive use, this report provides guidance on how to increase the sustainability of land use and outlines the opportunities, benefits and trade-offs of changing management practices. Chapter 3 offers details about finance options in the compliance market, the voluntary market and other mechanisms for reducing emissions and enhancing co-benefits through peatland conservation, restoration and sustainable use. Chapter 4 discusses the methodological guidance and data available for quantifying GHG emissions from organic soils. It also provides practical solutions for the challenges involved in accounting and MRV. Chapter 5 provides examples of the peatland distribution in countries with extensive peatlands. It also looks at the emissions generated from organic soils in these countries and opportunities to reduce these emissions and enhance other ecosystem services. The report is intended for policy makers, technical audiences and the general public.

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

The extensive Ruoergai (Zoige) peatlands on the eastern Tibetan Plateau are major interfaces between the Tibetan uplands and large lowland rivers. These peatlands, which serve as grazing lands, contain an estimated carbon content of 750 megatonnes (Björk, 1993) – a significant proportion of Chinese peat carbon resources. They are important reservoirs for biodiversity conservation, with numerous endangered and endemic species (Tsuyuzaki et al., 1990; Ekstam, 1993; Schaller, 1998).

Since early times, the peatlands on the Ruoergai Plateau have acted like sponges. They absorbed and retained water during periods of when water supplies were abundant and slowly released it in times of water deficit. In this way, the peatlands slowed down peak discharge, prevented erosion, reduced downstream flooding and guaranteed a steady supply of water to the Huanghe (Yellow) River – a water source that millions of people depend on.

The introduction of livestock grazing 5 000 years ago changed the character of the peatlands on the Ruoergai Plateau, making them more susceptible to erosion (Joosten et al., 2008). At the same time, a complex system of land management, which included sharing grazing lands and their rotational use, emerged as part of a unique cultural heritage. Not only in Ruoergai but also in the entire high altitude area of the Himalayan region, peatlands still function as grazing pastures for nomadic herders, especially when the peatlands are frozen or not waterlogged. Eighty percent of the peatlands on the Tibetan Plateau are grazed or browsed by domestic animals in winter and early summer. The herders prefer peatlands for grazing, because of the earlier plant growth, the higher productivity of forage, the better nutrient availability due to the diversity of forage species, and the availability of water for watering and cooling the livestock.

Peatland degradation increased dramatically with the construction of roads in the 1970s and the rising demand for food, fuel and rangeland. Overgrazing and the resulting decrease in the quality of pasture fuelled the demand for new rangeland. This led to increased pressure on untouched peatlands (Wiener et al., 2003, Wang et al., 2006; Gao et al., 2009), of which almost 50 percent were drained (Yang, 2000).

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. Pastures were fenced and more infrastructure was developed. Livestock numbers increased dramatically and migration routes of animals were blocked (Li et al., 1986; Long and Ma 1997), which aggravated overgrazing, peatland degradation and desertification. Peatlands in Ruoergai were leased to individual Tibetan herders, which has led to long-term conflicts between nature conservation and livestock grazing (Yan & Wu 2005). The more sedentary managing system brought about new challenges not only for pastoral development but also for peatland conservation.

During the last forty years the area of degraded peatlands has almost doubled, and less than 20 percent of the peatland remain in good condition (Schumann et al., 2008). Peatland degradation leads to increased GHG emissions, whereas moderate grazing may positively influence methane emissions and carbon sequestration (Chen et al 2008; 2009). For this reason, peatland restoration is considered a low-cost mitigation tool.

During the last decade, the ecological restoration of degraded rangelands and forage cultivation in winter pastures have been encouraged by the government to reduce grazing pressure on peatlands in spring. Additionally, several pilot projects by national and international organizations have supported peatland restoration in the Ruoergai Plateau by replanting vegetation (forage cultivation), rewetting (ditch blocking) and establishing co-management systems that involve multiple stakeholders for the many uses of rangeland resources.

In 2007 and 2010, to promote biodiversity conservation and enhance the livelihood of local communities, the Provincial People's Congresses of Gansu and Sichuan approved Wetland Conservation Regulations, which prohibit drainage, peat mining and the reclamation of peatlands. The regulations encourage local people and organizations to get involved in peatland restoration. They allocate 0.3 percent of its yearly budget to peatland restoration. Since 2008, the Chinese government has been working to establish a payment for ecosystem services (PES) mechanism, which would compensate local herders for reducing the number of livestock.

The Ruoergai example shows how sound peatland management can serve multiple goals. Currently, the peatlands provide irreplaceable grazing ground for thousands of yaks, horses and sheep that are central to the livelihoods of local herder families and provide the country 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 provide a supply of good quality, well-filtered water. In addition, restored peatlands provide important soil carbon storage, and the reduced degradation leads to fewer significant CO_2 emissions.

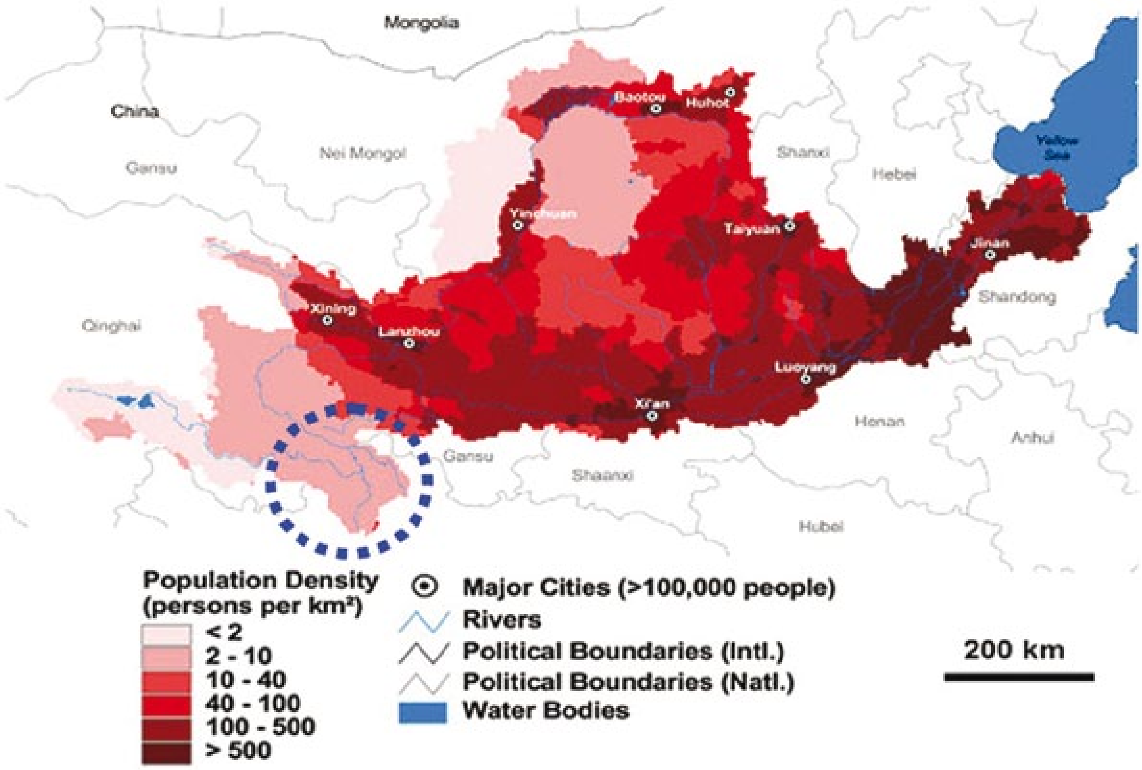
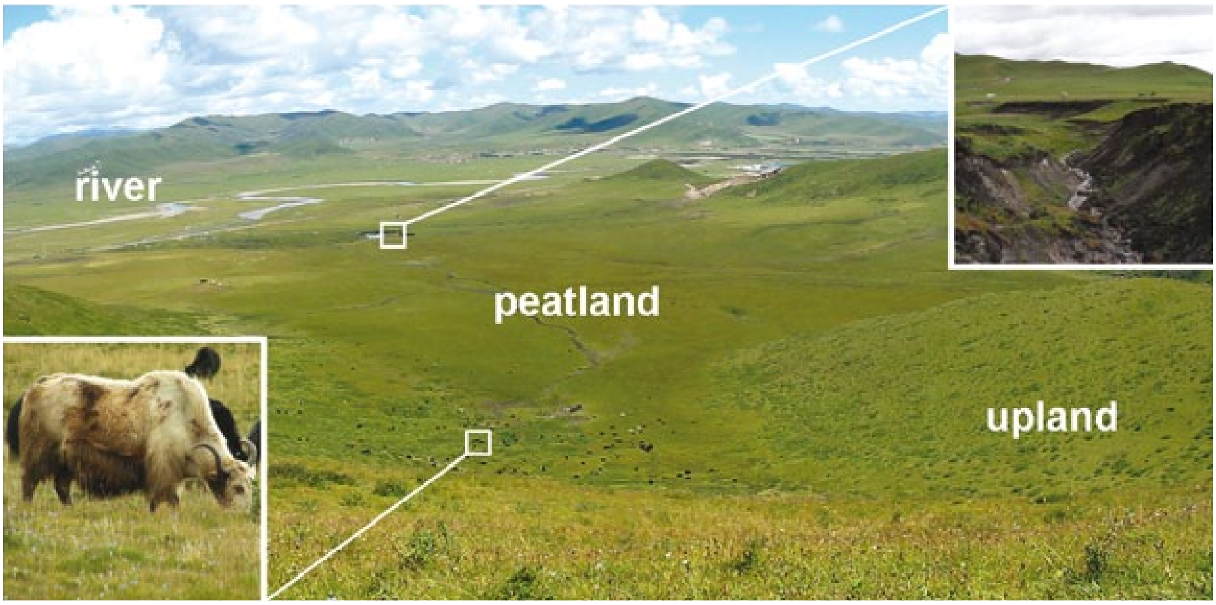


Figure 1. The Ruoergai peatlands on the Tibetan Plateau are crucial for regulating water supply to the lowland Yellow River basin. (Water resource eAtlas, AS09 Huang He (Yellow River), http://earthtrends.wri.org/pdf_library/maps/watersheds/as10.pdf)

The Ruoergai peatland pastures on the Tibetan Plateau: a major milk and meat producing area in China
Photo: Chen Kelin



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

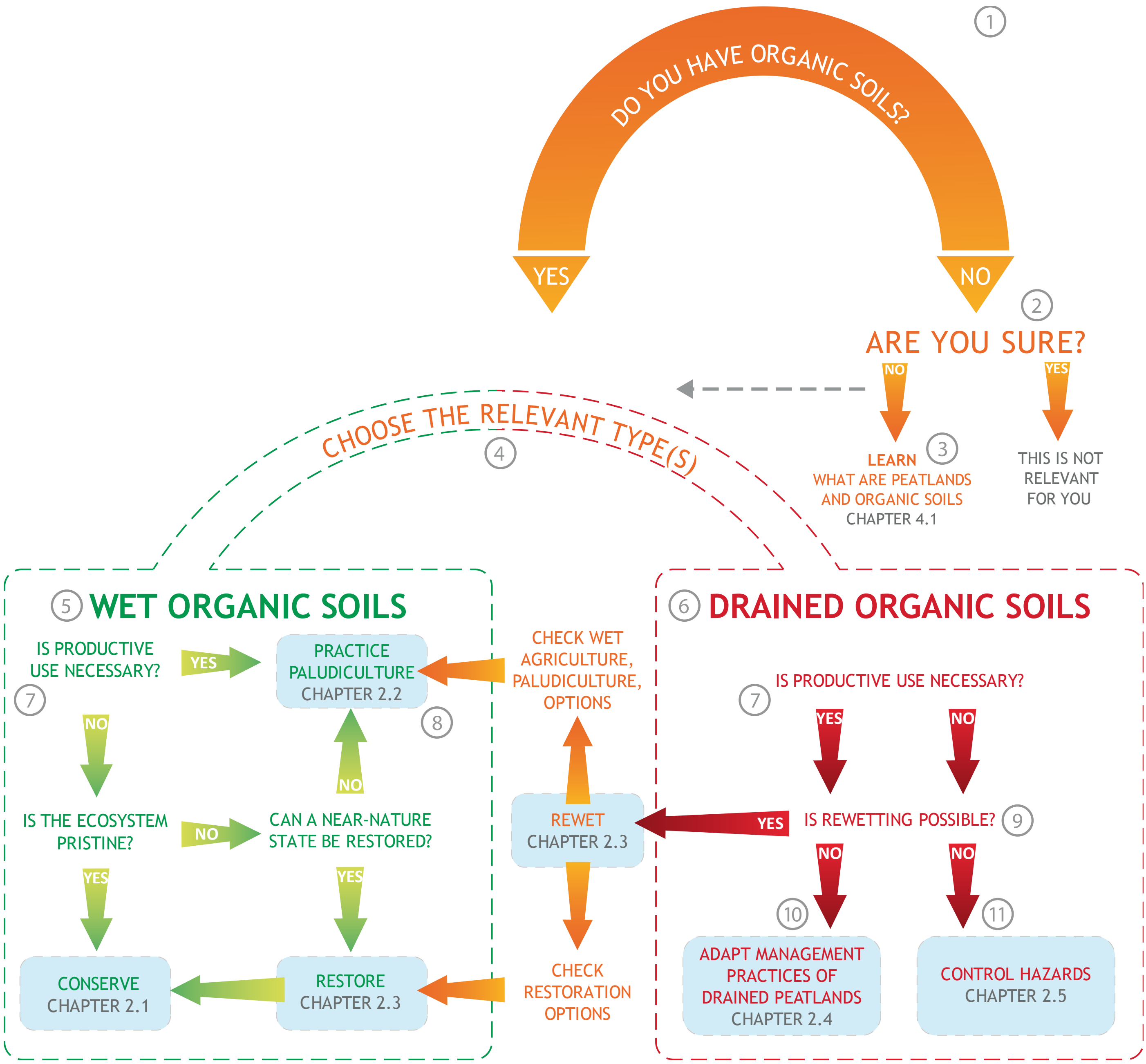


Figure 2. Decision support tree for management of peatlands and organic soils (Numbers in the figure refer to the options enumered on the following page. Download the figure poster from: www.fao.org/climatechange/micca/peat)

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 damaging effects. The key management options (see Decision support tree, Figure 2) both for cultivated and uncultivated peatlands can be summarized as:

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

1) Organic soils (≈ peat soils) are soils with a substantial layer of organic matter at or near the surface.
2) Almost all the world's countries have organic soils. If you are not completely sure, choose "NO".
3) Chapter 4.1. suggests data sources and data suppliers with respect to organic soils in your country.
4) The drainage condition of organic soils is strongly associated with the ecosystem services provided and the environmental problems encountered (see below).
5) 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 point 7).
6) Drained organic soils are organic soils that are not wet (see point 6). They are subject to inherent degradation (see Figure 2 and Box 2), lose carbon and emit CO_2 (and often N_20). Most organic soils that are used for agriculture, grazing or forestry are drained.
7) On land under productive use, management (for obtaining food, feed, fiber or fuel) determines the composition and volume of the standing biomass.
8) Organic soils can be used productively without drainage by adopting what is known as 'paludiculture'. Rewetting of drained degraded soils may revive productivity and address environmental problems.
9) Continuation of productive use on drained organic soils inevitably leads to productivity losses in the long run. Land use practices that require drainage should, whenever possible, be relocated to areas with mineral soils.
10) If this relocation is not feasible, land management practices must be adapted to mitigate environmental problems and extend land productivity as long as possible.
11) Drained and abandoned organic soils that are not properly managed are prone to uncontrolled fires and soil erosion. Hazard monitoring and mitigation schemes are recommended.

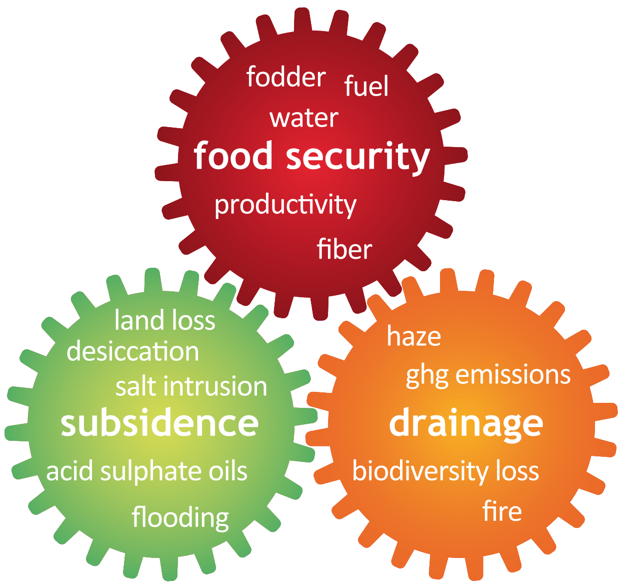

Figure 3. The unworkable gears of drained peatland utilization

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 per year, depending on the drainage level and the type and depth of the peat. After a few years, oxidation becomes the main factor, causing up to 90 percent of the subsidence (Stephens *et al.*, 1984; Hooijer *et al.*, 2012).

Most coastal peatlands originated thousands of years ago when the sea level was much lower than at present and have risen with the rising sea 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 found in various parts of the world.

In Southeast Asia, the deep drainage required for common land uses, such as oil palm plantations and Acacia cultivation for wood pulp, (Miettinen *et al.*, 2012b) with consequent high peat oxidation rates (Hooijer *et al.* 2012, Jauhiainen *et al.*, 2012) is expected to result in serious flooding within a few decades due to subsidence. In tropical climates with over 2 000 mm of annual precipitation, pump-operated drainage will not be feasible. This is true for example for coastal peatlands under cultivation in Sumatra and Borneo, which currently cover 3.1 million ha and are projected to increase to 6 to 9 million ha by 2020 (Miettinen *et al.*, 2012b). In Sarawak, where most coastal peat swamps have been allocated for oil palm plantation development, subsidence may lead to the loss of over 10 percent of the entire land area. In addition, reductions in the steady supply of freshwater from deforested and drained inland peat swamps makes coastal areas with mineral soil more vulnerable to drought and salt water intrusion. This reduces the feasibility of agriculture in these areas, which often have acid sulphate soils (Silvius *et al.*, 2000). Rising sea levels will amplify the risk of flooding (Cruz *et al.*, 2007).

While the use of drained peatland may lead to significant short-term economic profits, its inherent unsustainability may have severe long-term socio-economic consequences, not only in relation to its disproportionately large contribution to climate change. Policy makers must make 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 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

In their natural condition, peatlands have soil that is (almost) permanently wet. 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 the conserved peatlands have no value or purpose. Indeed, undrained peatlands provide many valuable ecosystem services both to individual consumers and to society (Joosten and Clarke, 2002). The conservation of undrained peatlands keeps ecosystems intact and avoids expensive investments needed for (often unsuccessful) repair. Conservation is often a very cost-effective management option.

Effective conservation is hampered when there is insufficient knowledge of the value of peatland environmental services (carbon storage being an important one) and of peatland occurrence and distribution in the country. Mapping peatlands is especially urgent in the tropics and subtropics to avoid uncontrolled and damaging development. Successful peatland conservation 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 tropics can rapidly (within one year) and cheaply (less than US$ 1 million) be accomplished by combining modern remote sensing techniques with a review of the 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 of the damage done to peatlands is irreversible. For this reason, the conservation of the remaining peatlands in their natural state is the best mitigation option to avoid globally significant emissions through peat oxidation and peat fires.

However, funding conservation only through climate financing mechanisms is problematic. For example, the short-term gains from the conversion of peatlands to oil palm cultivation cannot be matched by carbon credits. The long-term costs to society from the loss of land and land degradation, as well as the costs of high emissions, are, however, good reasons for conserving the remaining undrained peatlands. Countries will have to cover the short-term opportunity costs themselves by banning such plantations and ensuring the long-term benefit of the ecosystem services. Additional funding mechanisms, such as those provide through development initiatives or the private sector, have the potential to create attractive win-win situations by linking climate change mitigation with securing livelihoods and providing new and sustainable income options for local people.

2.2. Keep wet peatlands wet: paludiculture

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

Keeping or making peatlands wet prevents and reduces these environmental impacts, but this means 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, as most conventional cultivated plants require low water tables and heavy farm machinery is not adapted to waterlogged conditions. However, land management and crop processing technologies have been developed that remove these obstacles.

Paludicultures (Latin 'palus' = swamp) are land management techniques that cultivate biomass from wet and rewetted peatlands under conditions that maintain the peat body, facilitate peat accumulation and sustain the ecosystem services associated with natural peatlands. Paludicultures help stop peat oxidation and simultaneously provide sustainable harvests from peatlands. Paludicultures use only that part of net primary production that is not essential 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 below-ground roots and rhizomes. Peatlands by nature support vegetation whose above-ground plant material can be (selectively) harvested without substantially harming peat formation (Wichtmann and Joosten, 2007).

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

Paludicultures make use of any biomass from wet and rewetted peatlands, from spontaneous vegetation on natural sites to artificially-established crops on rewetted sites (Joosten *et al.*, 2013). For this reason, paludicultures may have a double role to play in climate change mitigation; they avoid greenhouse gas emissions (by preventing peatlands from being drained or by rewetting drained peatlands) and the biomass produced may replace fossil raw materials and fossil fuels (Wichtmann and Joosten, 2007). Besides being used for food, feed, fiber and direct combustion, the biomass from paludicultures 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.*, 2013).

An obvious paludiculture practice is the collection of food for direct consumption. In the boreal zone of Eurasia, a wide variety of wild edible berries (*Vaccinium, Empetrum, Rubus* and *Ribes*) and mushrooms are gathered for food and vitamins (Joosten and Clarke, 2002). In the Russian Federation and Belarus, these provision services justify the protection and restoration of mires. In other parts of the world, local communities collect from wet peatlands a variety of plants for human nutrition or medical use. Examples include wild (so-called 'floating') rice (*Zizania aquatica*) in North America; bog bean (*Menyanthes trifoliata*), calamus (*Acorus calamus*) and buffalo grass (*Hierochloe odorata*) in Europe; and sago palm (*Metroxylon sagu*) in Indonesia and Malaysia (Joosten and Clarke, 2002; Joosten *et al.*, 2013). Other traditional low-intensity or soft uses include hunting and fishing (Wichtmann, 2011). Especially in tropical peat swamp forests, fisheries are a major economic activity. Aquaculture of indigenous fish species can be an attractive land-use option and offer economic incentives for local communities in areas where many drainage canals must be blocked for hydrological restoration.

Recently, 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 these options revitalize traditional forms of land use through new utilization schemes (e.g. reed cutting for construction materials, such as insulation panels). Other options, 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 costruction 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)

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

When biomass production is cost-effective, the use of wet peatlands for cultivation causes lower GHG mitigation costs than many other bioenergy 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. On sites that were abandoned or where subsidy-oriented, environmentally damaging land use took place, such as in Europe, paludicultures can also provide sustainable income to rural livelihoods from primary production. In temperate zones, autumn and winter harvests lead to more consistent employment throughout the year, and biomass processing may create net added value and generate additional jobs. Paludicultures can also contribute to energy autonomy and help regional economies by improving perspectives for (eco)tourism (Joosten *et al.*, 2013).

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 peat's hydraulic properties 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. As a result, drained peatlands lose a few millimeters or up to several centimeters of peat per year, depending on the climate. These losses are accelerated by the addition of lime, fertilizers and sand or clay, as well as 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 and further lowers the peatland surface (see Figure 3). This creates "the vicious circle of peatland utilization".

Peat oxidation leads to increased emissions of GHGs (CO_2 and N_2O) and nitrates (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 the activity of soil organisms, drained peat soils become loosened and fine-grained and may eventually become totally water repellent.

All these processes negatively affect:

- 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.

Box 3: Paludiculture in Indonesia

So far no true paludicultures have been established in Southeast Asia. However, during the past ten years numerous reforestation trials on degraded peatlands 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 2 000 ha and started tapping *Dyera latex* (Muub 1996). Unfortunately, the plantation burned down due to escalating fires from adjacent areas (Giesen & van der Meer 2009). The 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 timber tree species have the potential to be commercially planted on rewetted peatlands. Moreover, pioneer species, such as *Alstonia pneumatophora*, *Combretocarpus rotundatus* and *Macaranga pruinosa*, that dominate after disturbances are possible surrogates to exotic Acacia species in the production of pulp. Gemor (*Alseodaphne coriacea*) is a well-known peat swamp tree that is harvested in the wild and is in fact often locally overexploited. 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 on rewetted peatlands.

Food production is extremely important in rural areas of Indonesia. In the inhabited peatlands of Sumatra and Kalimantan, trials with food plants that do not require drainage need to be developed, especially with permanent crops that reduce the 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 developing smallholder paludicultures that 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 engage in agroforestry on areas up to 10 000 ha.

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 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 cannot be colonized easily 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 surface drainage, surface runoff, sub-surface seepage, groundwater extraction, and evapotranspiration, and by, where relevant, increasing the 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:** This covers land 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 the water supply for rewetting requires a reorganization of land use within the hydrological catchment, it is necessary to check feasibility and costs and 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 near 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 microclimate (by reducing wind velocity and increasing shade). 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 most important factors determining rewetability. These factors may have changed to such an extent that optimal rewetting may become impossible. Partial rewetting will still reduce 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, a strong interrelationship exists between plants, water, and peat. When one of these components is affected, eventually the other components will also change. The components are, however, not equally vulnerable, nor do they react simultaneously. Generally, organisms are more easily affected than hydrology, which is more sensitive than the hydraulic and morphologic properties of the peat body. As the latter components exercise the strongest long-term influence on the development of the peatland, activities must focus on restoring hydraulic and morphologic properties first. Again, it bears repeating: there is no universal strategy to restore degraded peatlands, as conditions differ widely.

In addition to the criteria for rewetting listed above, the **most important technical components** determining **the peatland's restoration potential** are:

- **Peat hydraulic conditions:** If the upper peat layer is very decomposed, strongly compacted or degraded, the potential for restoring mire types that require non- or little humidified peats to regulate their hydrology is severely limited. In such peatlands, restoration can initially only focus on preserving residual floral and faunal communities and redeveloping pioneer mire types (Schumann and Joosten, 2008).
- **Relief:** In degraded peatlands, drainage, peat extraction or fire often change the peatland relief substantially. This change will affect the peatland's water balance, particularly the proportion of water that is transported through and over the peat body. The consequences cannot easily be predicted because a change in relief triggers a 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. The peatland will then regenerate spontaneously, provided that sufficient diaspores of the key plant species are available. If they are not available, the introduction of diaspores must be considered. If 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, the peatland may also regenerate spontaneously after the disturbing factor has been removed.

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

Restoration often requires a complete hydrological system (full peat domes, sub-domes, other integral hydrological units) to be available for rewetting. Land use planning should address land use options from an ecosystem perspective and work toward preserving vital environmental services at the landscape level. In tropical peatlands, in addition to rewetting, reforestation with indigenous tree species, fire prevention and the development of fire control capacities 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 depends strongly 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 reductions.
- Reforest (in the tropics). The hydrology of natural (zero-emission) peat swamp forests is maintained by the forest's above-ground root system and the related differences in surface elevation (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 local people with access to peatlands. By blocking canals, restoration may restrict this access. Consequently, local communities may oppose restoration efforts. For this reason, it is of crucial importance to consult local communities and involve them actively in the planning, designing, and implementation of restoration work.
- Stimulate community development. To enable communities to overcome dependence on unsustainable peatland use, rehabilitation projects, which may result in opportunity costs for local communities, should include community development as an integral component to offset these opportunity costs.

Box 4: Restoration and conservation

Peatland restoration is a good way to reduce the CO_2 emissions from drained peatlands, but it always remains the second best approach after conservation. Restoration of a peatland site can only reduce GHG emissions to zero if the entire area can be adequately rewetted. The experiences in Indonesia have shown that, especially 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 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 restoring degraded peatlands 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

Paludicultures are the only sustainable mode of agricultural production on peatlands. However, 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 (for food, energy or feed) 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 whose shade reduces surface temperatures and thus curbs peat oxidation (Jauhiainen et al., 2012);

- avoiding 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).

Box 5: Towards sustainable grazing on peatlands

Peatlands have long been utilized as grazing land for livestock and game, such as deer. At the right levels, grazing delivers food and fibre while maintaining peat-forming vegetation and the multiple benefits that brings. Unsustainable grazing intensity and associated trampling, on the other hand, can cause physical damage to the peatland system or changes to the typical peatland vegetation with its many rare and threatened species. It also shifts the vegetation community away from species that would typically characterize peatlands towards more common, grazing tolerant species. The result is deterioration in the grazing land itself and loss of other ecosystem services, such as climate and water regulation. (van der Wal *et al.*, 2011.)

Grazing on United Kingdom Atlantic blanket and raised bogs

Atlantic blanket bogs and raised bogs, typical of the United Kingdom, have for several centuries been grazed by cattle and sheep and, in parts of the Scottish Highlands, by red deer. European Union Common Agricultural Policy (CAP) subsidies in the 1970s and 1980s led to significant increases in the density of sheep grazing on bogs. Stocking densities have fallen significantly since the 1990s in response to policy changes, such as the introduction of the Environmentally Sensitive Area scheme in England and Wales (Thompson *et al.*, 1995). High intensity grazing leads to

- a loss of *Sphagnum* moss species and the spread of tussock forming species (including *Festuca ovina*, *Agrostis* spp., *Nardus stricta*, *Molinia caerulea*, *Juncus squarrosus* or *Eriophorum vaginatum*), depending on the soil type, drainage and the species and breed of grazer, Gimingham, 1995; Shaw *et al.*, 1996);
- soil compaction, increasing the likelihood of water running off sheep tracks and increasing the amount of sediment reaching streams (Holden *et al.*, 2007); and
- peatland erosion (Rawes and Hobbs, 1979; Evans, 1998; Evans *et al.*, 2005).

Associated burning activity and drainage, along with inappropriate vehicle use and supplementary feeding, can lead to further peatland deterioration. As a result of these practices, many peat bogs in the United Kingdom are in a damaged state, with lower water tables and a reduced abundance of key peat forming *Sphagnum* species. This leads to erosion, bare peat and deep gullies (Yeloff *et al.*, 2006).

These damaged peatlands present a problem for land managers as grazing quality deteriorates and livestock and game can become trapped and die in the drains and erosion gullies (Holden *et al.*, 2007). Furthermore, these degraded peatlands also lead to carbon loss. They can also exacerbate the risk of flooding and adversely affect water quality in rivers, fisheries and drinking water supplies (Ward *et al.*, 2007; Van der Wal *et al.*, 2011).

By contrast, low intensity grazing (0.25 sheep/ha), such as is traditionally practiced on crofting common grazings, common land and some hill farms, can be important in maintaining the peatland habitat because it controls *Molinia* and shrub invasion on bog habitats (Rowell, 1988) and provides conditions favorable for specialist upland bird species. There have been suggestions that cattle may be preferable to sheep for peatland grazing (Cris *et al.*, 2012). These practices also maintain key skills and economic activity in remote areas with few alternative employment options (Tinch *et al.*, 2011).UNEP-WCMC, Cambridge).

Modelling work has suggested repairing damaged peatlands by blocking drains could reduce peak flows and flooding downstream. There is strong evidence that revegetation and rewetting by gully blocking lead to significant reductions in sediment (and associated heavy metal export) from degraded blanket bogs, which can improve stream biodiversity. There is also increasing evidence that gully blocking reduces dissolved organic carbon.

A range of government funding measures largely delivered through the CAP, the European Union LIFE-Nature programme and national wildlife legislation have helped pay for restoring some of these damaged peatlands. These funding measures include capital payments for fencing, blocking drainage ditches, repairing gullies and revegetating bare peat. These measures were accompanied by prescriptions for reducing stock numbers to sustainable levels, supporting stock removal in winter, managing wild herbivores and controlling burning. In several successful projects across the United Kingdom the work has resulted in improved peatland vegetation, which has helped restore ecosystem service benefits and provided better long term grazing (Cris *et al.*, 2011). Ongoing support given to farmers and other peatland managers for good quality peatland habitat management with sustainable grazing levels will secure the value of peatlands in providing wider ecosystem benefits.

Sheep on blanket bog in the Garron Plateau, Northern Ireland
Photo: Seamus Burns

2.5. Hazard control on abandoned drained peatlands

Millions of hectares of the world's drained peatlands have such low productivity and have become so 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 on partly logged and previously burned forests in the tropics may have accumulated considerable inflammable dead wood litter, and the dry peat beneath is easily ignited in dry seasons.

Peatland fires occur mainly on peatlands with unclear ownership and responsibility. Peat fires are mostly induced by human activities in or around peatlands. A peatland is prone to fire 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.

If peatlands are not rewetted and remain regularly used, fire control must attempt to prevent hazards. Effective fire control includes:

- monitoring by satellite or airborne observation, watchtowers and ground patrols;
- establishing hydrants or ponds to guarantee water availability;
- ensuring sufficient fire brigades are standing by;
- training in fire prevention and suppression and disaster management; and
- maintaining adequate communication structures and coordination.

The high costs of maintaining an operative fire control infrastructure, combined with the abundance of highly inflammable fuel make fire control in drained and abandoned peatlands an unappealing alternative. Furthermore, this does not solve the problem of continuing greenhouse gas emissions from microbial peat oxidation. Although the initial costs of rewetting may be high, rewetting is always preferable in the long term.

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

2.6. Conflicts and synergies

This chapter has provided an overview of various peatland utilization 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 utilization in relation to the aims of production, biodiversity conservation, climate change mitigation and fire hazard reduction. Paludiculture is compatible with all aims, while abandonment conflicts with all of them. Abandoned, drained peatlands are unproductive and do not contribute to human welfare. They are a constant source of greenhouse gases and a perennial fire risk. Fire haze has both 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. This is why rewetting should be an integral part of any peatland management.

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

Aim / Utilization 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

Robert O'Sullivan, Moritz von Unger & Marja-Liisa Tapio-Biström

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 GHG 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 oppurtunity	Climate finance oppurtunities for peatland activities	
	Developing/ non-Annex	Industrialized/Annex II 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.	**For the EU, various policy frameworks such as the EU Water Framework Directive and the EU LIFE-Programme**
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.
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 (see below), 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 (see below), 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 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 JI 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 final challenge is to solve the very limited experience that the practitioners, project developers and the policy makers and regulators often have regarding JI and LULUCF. In particular, the Joint Implementation Supervisory Committee (JISC), which sets the rules for the centrally organized JI track, could benefit from capacity development. In the meantime, practical experience on projects is being gained. At the time of writing (August 2012), a project design document for a (non-peat) LULUCF project (improved forest management) had been published. If this project design document is approved under the JI Track 2, the project would be permitted to generate ERUs for emission reductions through the conservation of the carbon stock. This would invalidate the assumption that JI credits for LULUCF activities could only come from sequestration initiatives. This would have substantial implications for peatland mitigation projects aimed at preserving sinks.

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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.

If project is not approved on the grounds that credits for emission reductions are sought, then regulatory efforts should be made to change the JI Guidelines (along with the accounting and reporting rules) 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.

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. Under the CDM LULUCF activities are currently limited to afforestation and reforestation projects, that means that credits can currently only be 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 thus not (yet) eligible under the CDM. There is, however, scope for future expansion after a recent request at CMP7 in 2011 to the Subsidiary Body for Scientific and Technological Advice to initiate a work programme on inclusion of further LULUCF activities under the CDM, 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 it can apply to forests on peatland. REDD+ activities in peatlands are those activities that reduce or prevent GHG emissions by protecting the forest on undrained peat and by the 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 Brazil, Indonesia, Malaysia, Papua New Guinea, Thailand and Viet Nam, and in other countries rich in peat swamp 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 debate. A number of options exist for interim results-based finance (i.e. payments for achieved emission reductions or increased removals) including the World Bank's Forest Carbon Partnership Facility and bilateral support from the governments of Norway and Germany among others.

More work is also needed on some methodological issues, although 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

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 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.

9 These rules require a type of temporary credit for CDM afforestation and reforestation projects that contain inherent risks and are 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.

reductions and potential finance if the country is able to reduce emissions from peatlands (which may require rewetting drained peatlands). If the area of drained peatland, however, keeps expanding or already drained and emitting peat swamps are not rewetted, 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.

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.

Box 6: Building land use NAMA's: example from Indonesia

In September 2011, Indonesia issued a presidential decree on land-based NAMAs, 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 CH_4 and N_20 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 percent. 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 the national scale.

(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 programme. 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 Viet Nam.

(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 US$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 fully 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 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 (from 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 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 200312[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 Chapter 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". To be sure, if FM, CM and GM would be accounted for, 90 percent of the peatland emissions would be covered and WDR would be largely redundant. 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 not be able to use the huge mitigation potential of organic soils in the land use sector (see Chapter 5) (except in mandatory forestry), unless accounting for WDR is voluntarily chosen. WDR may thus have been created as an option to address the peatland hotspot effectively in case FM, CM and GM would not be accounted for. All in all, 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

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.

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, more likely, after 2020).

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, domestic offsetting 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 domestic offsetting mechanism and several of them have launched national pilots on the matter.

EU Common Agricultural Policy (CAP)
The 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 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 and protect and manage water. Non-compliance should lead to reductions in subsidy and development payments. However, the requirement does not apply 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). 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 percent of the budgetary envelope for direct payments to farmers to support measures beneficial to climate and the environment16. Legislative discussions are ongoing. A final decision by the legislative bodies, Parliament, and Council is 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 US$ 394 million in 2010, this is significantly smaller in value compared to the compliance market which was valued at US$ 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 percent of recorded transactions in 2010, published its new guidance for land use projects that included the new project category: 'Peatland Rewetting and Conservation' (PRC). This 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 associated 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.

Box 7: Emissions reductions from peatlands in Belarus through the voluntary market

Peatlands cover 2.9 million hectares (14 percent) of Belarus. Between 1960 and 1990 half of the country's peatlands – around 1.5 million hectares – were drained, in most cases to make way for agriculture. Today vast areas of this 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.

Through a programme sponsored by UNDP and GEF (2006–2010) as well as the German Ministry of Environment (BMU) and KfW Bankengruppe, a government-owned banking group active in international climate finance (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 programme led to the identification of an additional area of 30 000 hectares that were considered most suitable for carbon project development. According to conservative estimates, a carbon project for rewetting these 30 000 hectares, together with 18 000 hectares that had already been rewetted, would generate around 100 000 tonnes of CO_2 eq. annually over the next ten 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, restoration work, maintenance and the carbon cycle estimated a cost of about € 5 million over ten years, putting the generation costs at around € 5 per credit. The need for ecological (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 five or six. As a result most emission reductions and, hence, credits, will be generated between year five and year ten. This also means that 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. There is a centrally organized institutional structure set within a legislative framework dedicated to voluntary emission reduction projects. However, uncertainties remain, most notably concerning the power for any government entity to confer carbon title to the project entity (the 'initiator' under Belarusian legislation); the responsibilities among government institutions, including the regional and municipal levels; and 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 spin-off 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 considered 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 viewed as 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.

This may be changing, however, and demand of carbon credits increase. Demonstrating high co-benefits such as biodiversity, other environmental services and social benefits may help projects attract other sources of 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.

3.4. Global Environmental Facility (GEF)

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

The Global Environmental Facility (GEF[16]) offers various possibilities to finance the 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 and 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, UNFCCC and UNCCD relevant to peatlands and 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 the new GEF 5 template is 80 percent. 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.

16 GEF web site: www.thegef.org/gef/climate_change

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 contribute to 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:

- Maintain or improve a sustainable flow of agro-ecosystem services to sustaining the livelihoods of local communities.
- Generate sustainable flows of forest ecosystem services in arid, semi-arid, and sub-humid zones, including sustaining livelihoods of forest-dependent people.
- Reduce pressures on natural resources from competing land uses in the wider landscape.
- 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 on how to make progress in this area using existing options and making additional necessary decisions.

Annex I accounting rules for LULUCF
Annex-I countries with significant peat soils are recommended to select WDR to enable projects to reduce emission from peatlands.

Joint Implementation
Where current rules prove to prevent JI from financing WDR projects, they must be widened so that JI projects can reduce emissions in addition to enhancing removals. New rules should also allow AAUs or RMUs to be converted into ERUs.

The Clean Development Mechanism
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 WDR 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 and 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 that 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 GHG 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 guidancein this area and, a supplement to the 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 GHG emissions from organic soils. To address concerns of countries with regard to accounting and MRV, it presents 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. It also discusses important safeguards that need to be taken.

Box 8: 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 include:

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

Surprisingly, considerable information can also be found in the scientific literature, especially with respect to soils, geology, wetlands and palaeoecology. The papers, reports, technical notes or other documents produced and published by the above-mentioned institutions can also be useful.

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 requirements 1 and 2, or 1 and 3 below:

1. The thickness of the 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).
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 percent or more clay; or
   c. an intermediate proportional amount of organic carbon for intermediate amounts of clay.

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 course of 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 GHG 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 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 IPCC also 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, an appendix provides (incomplete) guidance on wetlands, including peatlands used for peat extraction. Emissions from drained organic soils are addressed already in the existing IPCC guidance, which includes emission factors for forest land, cropland and grassland.

In 2010, UNFCCC invited the IPCC to explore the development of supplementary guidance on organic soils, particularly addressing restoration and rewetting of drained peatlands. In response to this invitation, the 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 GHG emissions and removals from peatlands. Chapter 2 will provide cross-cutting guidance

Box 9: 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 under waterlogged conditions without decomposing further. Natural peat forming peatlands are sinks 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 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'. The combined 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 year timescale. In the long run, all natural peatlands sequester carbon from the atmosphere and are climate coolers.

N_2O is formed in peatlands when inorganic nitrogen is made available through peat decomposition (mineralization), through fertilizer application or through nitrogen deposition. N_2O emissions are associated with lowered water tables.. When nitrogen is deficient, 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 GHG. Whereas CH_4 production ceases under the presence of oxygen, lowered water tables result in the loss of soil carbon, which is in 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, a condition known as peat subsidence (see Box 2: 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 where 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 nullified. This is caused by the dying off of non-wetland plants, which produces copious rotting material. These 'transient dynamics' are of limited duration as the availability of easily degradable fresh biomass strongly decreases when wetland plants have been re-established. Over the mid- and long-term, rewetting of peatlands may therefore be expected to lead to a net reduction of climate relevant emissions from the peat body compared with the drained baseline.

on drained organic soils covering all land-use categories, and 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 forest land, cropland, grassland and wetlands. A review of existing IPCC guidance on drained organic soils revealed considerable opportunity for improvement (Couwenberg, 2011). Based on 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

Agriculture on peatlands in Polessie, Ukraine
Photo: Hans Joosten

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).

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. However 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 percent 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 on how projects can comply with the VCS standard. Based on these requirements, methodologies are developed that explain step-by-step how a project can 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).

CUPP deals with activities that avoid drainage in undrained peatland or the expansion or deepening of drainage in partially drained peatland. 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. RDP concerns the establishment of 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 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's 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 in the VCS-PRC can 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. In addition, N_2O emissions 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 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 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's 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, as far as can be judged, and that uncertainties are reduced as far as is practicable" (UNFCCC, 2003).

Whereas the capacity for monitoring GHG fluxes from peatlands is rapidly increasing (see above), in some countries and situations (e.g. CH_4 emissions from recent rewetting or 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 Kyoto Protocol 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 percent of total GHG emissions in the EU-27, is accounted even with an uncertainty of around 100 percent (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' (WDR) activity.

If a party chooses to elect to account for WDR 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 WDR, 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 GHG 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 data on the extent and location of drained peatlands are easily available in Annex 1 countries from 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 the 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 percent of the total land surface in the EU, 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, the necessary data is often not readily available and collecting the information requires significant efforts, such asare currently being undertaken in Indonesia with the support of bilateral and institutional investments. The African and American tropics, where peatlands occur, are a 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 back to 1990. However, the quality of these data varies. 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, incorrectly, “not applicable” (See examples on forest land, cropland and grassland accounting on UNFCCC Synthesis and assessment report on the greenhouse gas inventories submitted in 2011, FCCC/WEB/SAI/2011 pp.5, 140, 141, 145, 148, 149, 152, 153, 156, 161[1]).

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 for 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. On project sites, all GHG fluxes (emissions and removals) that occur before, during, and after the intervention should be measured. 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 GHG 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 GHG 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 and intensification of drainage structures (canals or ditches) in peatlands.

1 in unfccc.int/resource/webdocs/sai/2011.pdf

A simple yet meaningful system of monitoring peatlands at the national level can be based on 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, for example 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 local context.

Safeguard 1: Policy coherence and consistency with international agreements
Most parts of the world lack coherent policies for peatlands. This, reflects 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.
In most countries, the idea that natural peatlands are wastelands that should be improved 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

Boy running from peat fire, Central Kalimantan, Indonesia
Photo: Alue Dohong

reduction, notwithstanding the serious negative environmental and ensuing socio-economic impacts which are generally not recognized or acknowledged. For instance, current agricultural and forestry policies in Indonesia and Malaysia ignore the long-term impacts of drainage related subsidence that will affect large stretches of coastal areas of Sumatra and Borneo.

REDD+ programmes 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+ programmes may offer the opportunity to address some of the current weaknesses and inconsistencies in policy and legislation of various development sectors that have an impact on the carbon storage and other functions of peatlands.

A useful example of effective governance within REDD+ 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 between Indonesia and Norway for cooperation on REDD+. It provides an 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 EU, 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, supply of potable water and water for irrigation), there are also examples where traditional use has developed into 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 really is. For example, in the Netherlands peatland drainage has caused one-third of the country to lie several meters under sea level, necessitating billions of Euros in investments for dikes and pump-operated drainage systems. How traditional is the Irish custom whereby 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 creates considerable risks of uncontrollable peat fires that generate huge GHG emissions, have an adverse effect on public health and lead to the loss of natural 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 ordue to economic transitions. To what extent should local and traditional rights be acknowledged if this results in serious impacts on the valuable ecosystem services provided by peatlands, including biodiversity conservation, water supply and carbon storage functions? To what extent is this acceptable if it destroys the resource base to which the rights apply?

REDD+ programmes offer a new opportunity to review such uses to reduce the unsustainable use of peatlands and strengthen, enhance and expand community rights for developing and maintaining sustainable uses of peatlands, such as paludicultures. REDD+ also opens up options for communities to actively participate in peat swamp forest management, rehabilitation, and conservation to maintain and restore the below and above-ground carbon stores. This may involve reducing emissions by replacing unsustainable traditionalland uses with practices for sustainable peatland use and by carbon sequestration through peatland conservation and paludiculture. Carbon financing may help to trigger such shifts in livelihoods. Recently, some 30 000 ha of farmland on peat in northeast Germany were subjected to a land swap that move the farms to mineral soil areas. This was largely financed with biodiversity conservation subsidies. The REDD+ programmes should optimize such opportunities to enable equitable sharing of benefits.

Safeguard 4: Full and effective stakeholder participation
Community engagement and community safeguards are essential for land-based carbon projects to enhance effectiveprogramme implementation, guarantee the sustainability of results and reduce business risks. This engagement is required by the UNFCCC and various verification standards, and is included in most corporate social responsibility programmes. Moreover, with natural resources becoming a 'scarce global property good' local communities and the poor tend to suffer. REDD+ programmes offer the opportunity to safeguard local communities from such losses.

In most cases, successful REDD+ projects, whetherdriven by the government or the private sector, 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 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 and 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 an 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 provide easier access to the remaining natural resource base. Effective hydrological rehabilitation will thus require the consent of the official owners and the regular users to gain their cooperation and prevent sabotage.

Peatland rehabilitation requires a substantial amount of labour, which can only be provided by local people. Integrating peatland rehabilitation with needs for socio-economic development of local communities can benefit all stakeholders. Blocking large peatland drainage systems, for instance, may provide an opportunity for aquaculture development. Communities on Russian peatlands have prevented peatland drainage to safeguard their berry and mushroom collection areas.

Given the appropriate consultations with local stakeholders and the right community-based approaches, these benefits can be explored, projects piloted and upscaled as part of REDD+ programmes. 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 for community participation in biodiversity conservation and environmental rehabilitation.

Safeguard 5: Biodiversity
REDD+ programmes in peatland areas must recognize the need for an ecosystem-based approach. The eco-hydrological vulnerability of peatlands requires the entire functional ecosystem to be safeguarded. Although it would be preferable to focus on entire catchments, in many countries this may be difficult to do in the short- to medium-term due to mosaic-patterned land ownerships.

The rapid conversion of tropical peat swamp forest areas in south-east Asia for agriculture development, and the recent land grab by the palm oil and Acacia pulp wood sectors make it difficult to secure entire peat domes. Over 95 percent of all peatlands in Indonesia and Malaysia have been affected by some level of logging or conversion. 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 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. The most options for achieving significant biodiversity conservation co-benefits are in areas where rehabilitation projects of severely degraded areas are situated next or close to remaining peat swamp forests and other high biodiversity pockets. Rehabilitation projects can provide a corridor function between high conservation value areas. Indigenous peat swamp forest tree species should be used in 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 full acknowledgement of traditional land ownership and natural resource use rights, and the development of long-term or permanent ecosystem rehabilitation and carbon management plans and regulatory frameworks, such as long-term carbon concessions. Options that benefit all stakeholders will enhance community and other stakeholder support.

Private sector involvement in investment in peatland rehabilitation, conservation and sustainable management can help provide the necessary long-term financing commitment. However, this should not reduce the pressure on industry and transport sectors to reduce their own emissions. Offsets should be additional to credible GHG emission reduction programmes and be limited to compensating only for unavoidable emissions.

Safeguard 7: Actions to reduce displacement of emissions

A major difference between 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 instantaneous. The emissions 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. This means that emissions may continue for decades, or even centuries, after clearing and draining. Drainage of additional areas adds 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 emissions 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 the ongoing long-term degradation processes and their related GHG emissions.

If a particular drainage-dependent use of peatland is stopped, there is a chance that this land-use activity will move to another not yet degraded peatland or peat swamp forest, 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 western-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 or fire). A displaced activity could, however, still increase 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, all peatlands outside of protected areas will (under current land conversion policies) be deforested and drained within ten 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, such as 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-wide overview of opportunities

René 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 applies to peatlands. Some countries have hardly any peatlands in productive use whereas others have drained almost their entire peatland resources. 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, through examples from the following countries and regions:

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

5.1. Southeast Asia: Indonesia and Malaysia

Southeast Asia is by far the world's most important peatland hotspot. Half of the global peatland emissions originate from this region where peat swamp deforestation and drainage are increasing extremely fast.

Tropical peat swamp forests represent a unique ecosystem, comprised of interdependent biotic and abiotic components (see Box 10). Any change to the natural balance between water, soil and vegetation will result in GHG emissions. Peat swamp forests hold an enormous pool of soil carbon in their peat (on average ten times larger than the carbon stock of tropical forest on mineral soil per hectare). This makes peat swamp forests fundamentally different from 'normal' forests in their emissions behavior (Wibisono *et al.*, 2011).

The distribution and use of peatlands in Southeast Asia is rather well-documented. Large areas of peat swamp forests have been reclaimed for agriculture and plantations or lay temporarily abandoned after deforestation or fire. When drained, deforested or degraded, peat swamp forests release peat carbon much faster than it was 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 GHG emissions. In Indonesia, drained peatlands are responsible for over 60 percent of the country's total emissions (DNPI, 2010). The rapid deforestation and drainage of peat swamps for conversion to oil palm and pulpwood plantations have a significant negative effect on long-term emission patterns and are a threat to biodiversity. Substantial emission reductions are possible, but only if firstly, the remaining good-quality peat swamps are fully protected, secondly, vast areas of deeply drained peatland are rewetted, and thirdly, 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 areas has the highest prospects of improving biodiversity conservation and restoring ecosystem services, such as water retention. Indigenous peat swamp forest tree species should be used for reforestation.

Box 10: 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 forests, peat swamp forests are a unique ecosystem with very close interactions between vegetation, peat and water. These interactions operate as self-regulation mechanisms and they have enabled these ecosystems to survive under varying climatic conditions for thousands of years (Dommain *et al.*, 2010 and 2011). In natural peat swamp forests, the forest provides the plant materials and facilitates the wet conditions for peat formation, carbon sequestration, and carbon storage.

Peat swamp forests are the habitats for many endemic plant and animal species. In Southeast Asia, endemic fauna recorded only in this habitat include: false gharial (*Tomistoma schlegelii*); storm's stork (*Ciconia stormi*); white-winged wood duck (*Cairina scutulata*); hairy-nosed otter (*Lutra sumatrana*); black partridge (*Melanoperdix niger*); proboscis monkey (*Nasalis larvatus*); and flat-headed cat (*Prionailurus planiceps*). Many species of birds, fish and dragonflies are also 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 percent of all fish species are found only in peat swamps. Unpublished data show that this figure is even higher in Borneo.

Peat swamp forests are also home to many endemic tree species including: ramin (*Gonystylus bancanus*); jongkong (*Dactylocladus stenostachys*); sepetir rawa (*Copaifera palustris*); belangeran (*Shorea belangeran*); meranti rawa (*Shorea pauciflora*); jelutung rawa (*Dyera polyphylla*); pulai rawa (*Alstonia pneumatophora*); perapat (*Combretocarpus rotundatus*); and gemor (*Alseodaphne coriacea*). Of the forty-five dipterocarps tree species found in peat swamp forests in Sumatra, Kalimantan, Sarawak and Sabah, twenty are classified by the IUCN as critically endangered, eight as endangered, three as vulnerable and one as least concern (Paoli *et al.*, 2010).

Ramin or white wood (*Gonystylus bancanus*) is a peat swamp forest endemic species with a high economic value. Because of high international demand, timber companies and illegal loggers have heavily exploited ramin. CITES listed this species in Appendix 3 in 2001. In Indonesia, the Minister of Forestry Decree No.127/ 2011 placed a moratorium on the logging and trade of ramin tree. In 2004, CITES raised the status to Appendix 2. These measures have succeeded in bringing about a significant drop in ramin exploitation. This example proves that policy intervention can be effective in conserving and protecting selected species.

Indonesia

Peatland distribution
Indonesia has the largest area of tropical peatland. Of the total 440 000 km^2 tropical peatlands (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 area of 209 000 km^2, only 100 000 km^2 of the peat swamp forests remained in 2010 (Table 4).

Most peat swamp forests in Indonesia have been and still are being destroyed by four main drivers. The first driver is the expansion of smallholder agriculture under the transmigration programme.

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).

The second driver is the industrial plantations of oil palm (*Elaeis guineensis*) and pulpwood (*Acacia* spp.). The third driver is the overexploitation of the timber resources through concession-based and illegal logging. The fourth driver is destructive peat fires. Western Indonesia (i.e. Kalimantan and Sumatra) will lose all of its peat swamp forests by 2030 if the current annual deforestation rate of 3.4 percent is not reduced (Miettinen *et al.*, 2012a). The recent land cover distribution for Kalimantan and Sumatra has been quantified by Miettinen and Liew (2010) and is shown in Table 4. Similar data for Papua are not available.

IIn 2007, 31 percent or around 41 000 km^2 of the peatlands of Sumatra and Kalimantan were already under agricultural use by either smallholder farmers or industrial plantations (oil palm or pulpwood). The extent of the remaining, largely degraded forested peatlands covered 53 500 km^2 or 41 percent (Table 5). The extent of pristine peat swamp forest in western Indonesia has become negligible.

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

Land cover type*	Sumatra		Kalimantan		Western Indonesia	
	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).*

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

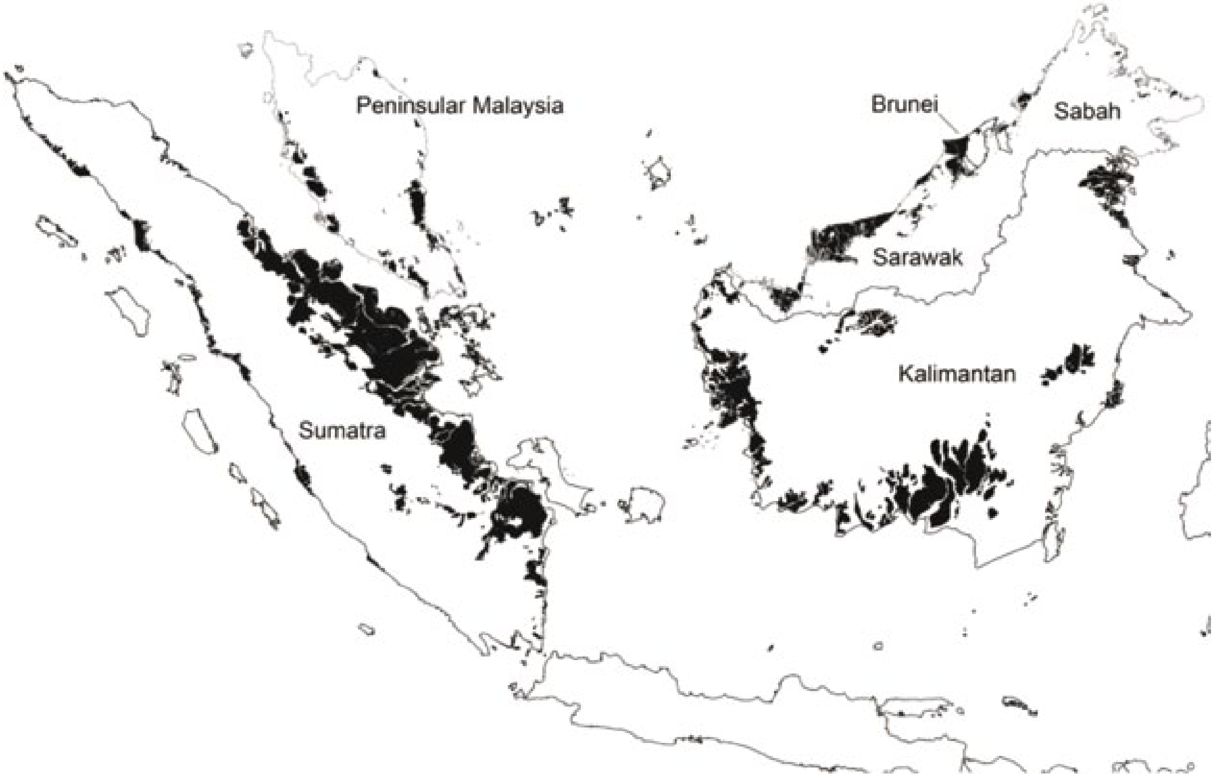


Figure 4. Extent of peatland in Peninsular Malaysia, Sumatra, and Borneo (from Posa *et al.*, 2011)

Carbon stock and greenhouse gas emissions

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

Table 6 shows that the peatlands of Kalimantan and Sumatra emitted about 446 megatonnes of CO_2 in 2007. The vast majority of these emissions come from agriculturally used land due to dense and deep drainage. The negative carbon balance of over 60 percent of the area shows that Indonesian peatlands have switched from an effective carbon sink to a substantial carbon source. If the emissions from peat fires are included, the carbon losses from peat degradation will double (van der Werf *et al.*, 2008).

Opportunities for emissions reductions and enhancement of other ecosystem services

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

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 CO_2 emissions (tonnes)	Total annual C 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**					
Sum drained area (%)			**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 per ha per year for each 10 cm of drainage (see Couwenberg et al. 2010 Hooijer et al. 2012). Peat carbon sequestration in pristine PSF is assumed to be 0.7 tonnes carbon per ha[1] per year (Dommain et al. 2011). * PSF = peat swamp forest*

Malaysia

Peatland distribution

Among the Southeast Asian countries, Malaysia has the second largest peatland areas. 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 areas (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	8 453	3 797	45	2 808	33	2 299	27
Sarawak	16 576	9 656	58	7 180	43	3 075	19
Whole country	25 889	14 482	56	10 484	40	5 726	22

[1] Original peat swam forest (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).

The peatlands of Malaysia are dominantly dome-shaped and rainwater-fed, similar to European raised bogs. The peat domes are of Holocene origin, typically younger than 8 000 years (Dommain *et al.*, 2011). On Peninsular 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 is certainly true for the dominating peat domes. The peat swamp deforestation rate in Malaysia is shown in Table 7. Already in 1990 large areas of peatlands were deforested, most notably on Peninsular Malaysia where cultivation of pineapple, 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 (approximately 3 percent per year). However, since 2000, deforestation in Sarawak (8.1 percent per year) has accelerated rapidly while it has slowed down on Peninsular Malaysia (to 2 percent per year) (Miettinen *et al.*, 2012a). A little more than half a million hectares of peat swamp forests remain in Malaysia. Proportionally, this is much less than what remains of Indonesia's peat swamp forests.

The rapid deforestation of remaining peat swamp forests can largely be attributed to the expansion of oil palm plantations (SarVision, 2011). Today one-third (almost 8 000 km^2) of Malaysia's peatlands are under oil palm plantations. The bulk of Malaysia's oil palm plantations on peatlands are located in Sarawak where, in 2010, almost half a million hectares were cultivated (Table 8). SarVision (2011) reports that as much as 41 percent of Sarawak's peatlands have been converted to oil palm plantations. Even deep peat areas or rare peat swamp forest types are drained for oil palm plantations (Wetlands International, 2010). So far, there are no pulp plantations in Malaysia.

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)]	
	km^2	km^2	%	km^2	%	km^2	%
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 peat swam forest (PSF) cover assumed to be equal to peatland area of Mutalib et al. (1992).*

[2] *Data for 2010 taken from Miettinen et al. (2012b).*

Carbon stock and greenhouse gas emissions

Page *et al.* (2011) estimate the peat carbon stock of Malaysia at 9.1 gigatonnes based on the extent of the area given in Mutalib *et al.* (1992). Multiplying the extent of industrial plantations with the typical plantation emission factor of 70 tonnes CO_2 per ha per year (Hooijer *et al.*, 2012) results in an annual CO_2 loss of 58.7 megatonnes from Malaysian peatland plantations in 2010. This carbon loss is very likely to increase since most remaining peat swamp forests outside conservation areas are already allocated to oil palm concessions. An end to the ongoing land use, which includes deforestation and drainage, is not in sight (Figure 4, SarVision, 2011).

Opportunities for emissions reductions and enhancement of other ecosystem services

Similarly to Indonesia, restoration should be a priority action in Malaysia's REDD+ strategy. Substantial emission reductions are only possible if vast areas of deeply drained peatland are rewetted. Continuous expansion of plantations would further increase carbon losses substantially. Priority for conservation and rewetting should be given to the peat swamps along the Brunei - Sarawak border, where cross-boundary drainage effects threaten Borneo's last pristine peatlands.

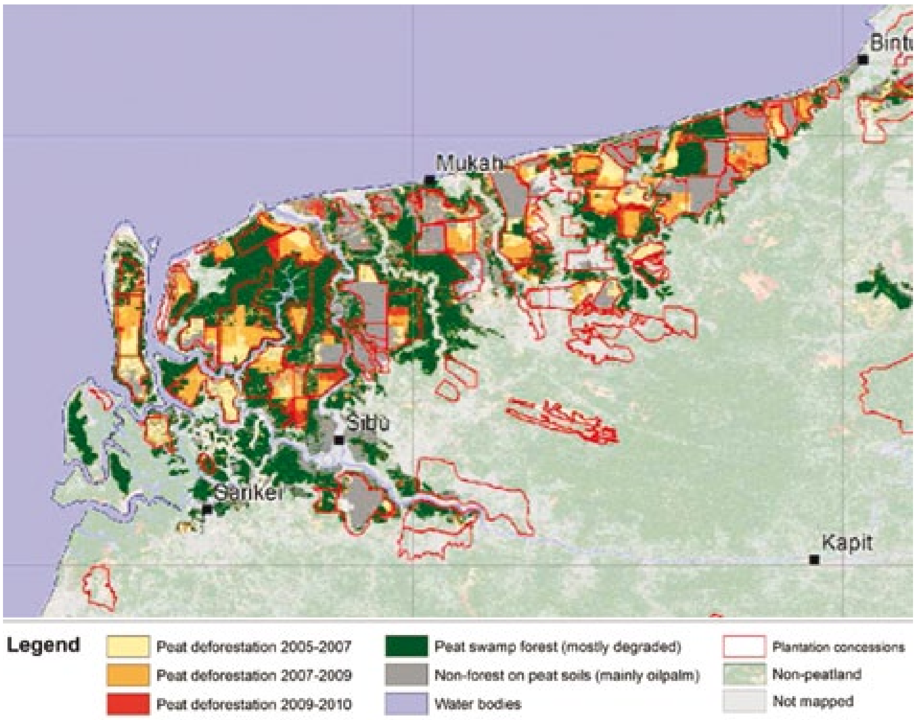


Figure 5: Distribution and status of peat swamp forest in Sibu Division, Sarawak (Malaysia) (after SarVision, 2011)

5.2. European Union: Poland and the 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 (EU) is, after Indonesia and before the Russian Federation, the world's second largest peatland emission hotspot (Joosten, 2009 and 2012).

In the 27 countries of the EU, cropland on organic soils is responsible for 77 percent of the CO_2 emissions from all cropland, and grazing land on organic soils accounts for 79 percent of the emissions from all grazing land (Table 9). It is evident that organic soils are a mitigation hotspot as they occupy only a small percentage 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 forests are generally low because the emission factors are low, but also because several countries claim, incorrectly, 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 EU. Recently the European Commission (EC) has proposed to its Member States the obligatory accounting for emissions and removals from cropland management and grazing land management, which together with the already obligatory forest management cause 90 percent of the emissions from organic soils in the EU. In addition, Member States can opt to account for emissions and removals from "wetland drainage and rewetting" (WDR) (see Chapter 3.2.).

Until now LULUCF activities do not yet count towards the EU's emission reduction target for 2020. The EC acknowledged, though, that the LULUCF activities have a substantial impact on the overall emissions across the Union. As the sector has a substantial potential for emission reductions, LULUCF should be formally included in commitments once the EU decides to increase its level of ambition. The Commission proposal report indicates that mitigation 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 in 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 km^2) has a total peatland area of 12 547.58 km^2. The northern zone on the Baltic coast comprises 74 percent of all Polish peatlands (8 268 km^2), the midland zone 24 percent (4 247 km^2), and the southern zone along the Sudety and Karpaty mountains 1.5 percent (268 km^2) (Ilnicki *et al.*, 2002). Fens occupy 92 percent, transitional bogs 3 percent and raised bogs 4 percent of the total peatland area (Ilnicki *et al.*, 2002). In 77 percent of the 49 500 peatland sites, the peat layer does not exceed 2 metres in depth (Ilnicki and Zurek, 1996).

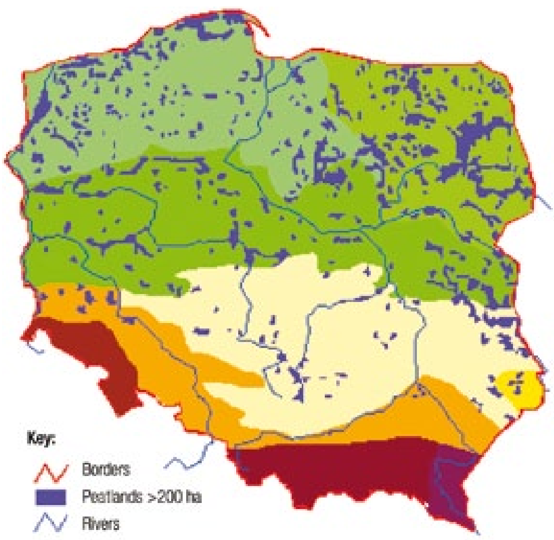


Figure 6: Biogeographical regions in Poland and distribution of peatlands larger than 2 km^2 (from Bragg and Lindsay, 2003)

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

Carbon stock and greenhouse gas emissions
Poland's estimated peat carbon stock is 875 megatonnes. With respect to peatland emissions, Poland is the 10th most important country in the world (23.5 megatonnes CO_2 per year) (Joosten, 2009).

Box 11: Wet agriculture for conserving a little brown bird

The vast fen peatlands of the Biebrza National Park in northeast Poland are a stronghold of biodiversity, holding almost 20 percent of the world's population of the globally threatened aquatic warbler (*Acrocephalus paludicola*) (Figure 6). After traditional hand-scything ceased around 1970, successional overgrowth became the main threat to this habitat. A project funded by the EU LIFE programme and run by the Polish Society for the Protection of Birds (OTOP) and BirdLife Poland recently implemented landscape-wide restoration and sustainable management of the area. Since 2007, machinery capable of mowing large areas of delicate peatlands was tested. Since 2009, adapted mountain piste-bashers, colloquially called 'ratrak' in Poland, have been 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.

Figure 7: 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

Opportunities for emissions reductions and enhancement of other ecosystem services
Peatland rewetting has been restricted to small-scale activities (mainly on bogs) in western Poland. Poland has little experience with large-scale rewetting. However, the mitigation potential of Polish peatlands is vast. Although most Polish peatlands have been drained to some degree, 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 grasslands. As a result 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 reduces GHG 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 provided by projects on the multi-functional use of peatlands and targeted bird conservation activities (see Box 11). Since 2004, agriculture on wet fens has benefited 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 include:

- restoration of the water regimes of drained peatlands and a 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;
- lobby for The EU Common Agricultural Policy (CAP) incentives for peatland rewetting and paludicultures and against "perverse" incentives (e.g. growing maize on drained peatlands for biogas); and
- updating the national peatland inventory to sharpen the identification of target areas.

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

The United Kingdom

Peatland distribution
In the United Kingdom, deep peaty or organic soils cover around 27 000 km^2 or 11 percent of the total area of the country. Shallow peaty soils cover another 47 000 km^2 or 19 percent (see Table 10), indicating where peatland habitats existed in the past – in total a third of all soils in the United Kingdom (Figure 8).

Table 10. Extent of organic-rich soils and bogs and fens in the UK (from IUCN UK PP2011, adapted with kind permission from JNNC 2011)

	Soil data map		UK Biodiversity Action Plan	
	Shallow peaty or organo-mineral soil (km^2)	Deep peaty or organic soil (km^2)	Bogs (km^2)	Fens[1] (km^2)
England	7 386	6 799	2 727	80
Wales	3 592	706	718	62
Northern Ireland	1 417	2 064	1 069	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,OCW, pers. comm.).

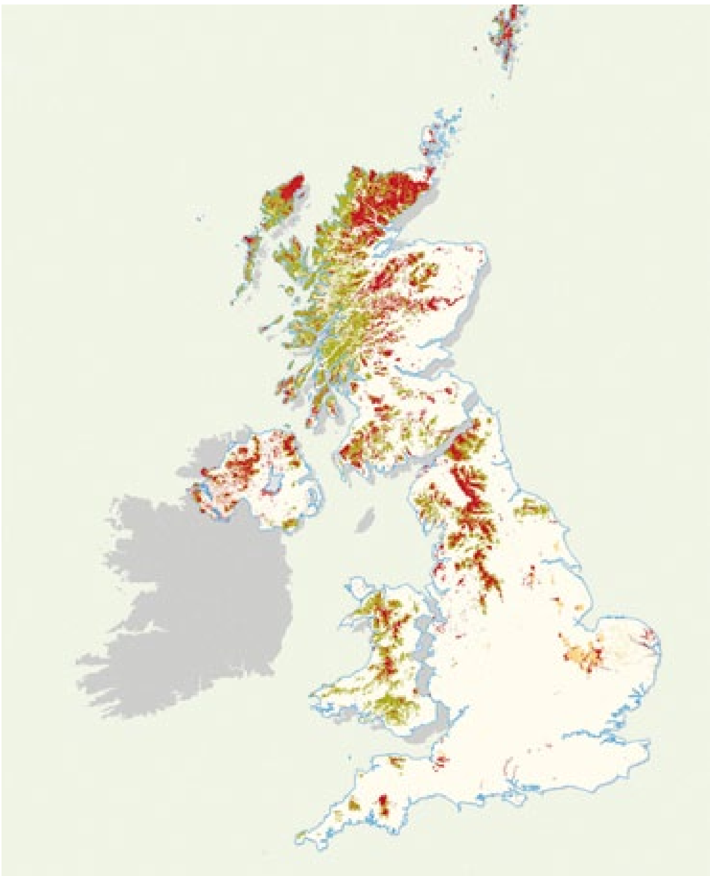


Figure 8. Peat and peaty soils of the United Kingdom (map reproduced from JNCC, 2011): deep peat soils (dark brown), shallow peaty soils (green), wasted deep peat soils (light brown). Peat in southeast England is largely fen peat. Reproduction by permission of OS on behalf of HMSO@ Crown copyright and database Right 2010, MLURI 100019294, AFBI 1:50000 soil digital Data, National soil Maps @ Cranfield University, BGS 1:50000 digital data (license 2006/072)

There are three main types of peatland in the United Kingdom: blanket bogs, raised bogs and fens. All are protected under international and national wildlife law. The United Kingdom Biodiversity Action Plan lists 23 000 km^2 of peatland habitat covering almost 10 percent of the country, with the majority in Scotland. Blanket and raised bogs make up 95 percent of all of the United Kingdom's peatland habitats.

Peatland use and degradation

The state of peatlands and organic soils in the country has recently been compiled in the Joint Nature Conservation Committee (JNCC) report (2011) and the IUCN UK Commission of Inquiry on Peatlands (Bain *et al.*, 2011). Over 80 percent of the United Kingdom's peatlands are in a degraded state due mainly to past drainage, fire and grazing. The majority of these peatlands is not peat forming; 16 percent is severely eroded; 10 percent has been afforested; 11 percent is affected by peat cutting; and 40 percent has been modified or destroyed by conversion to agriculture (Littlewood *et al.*, 2010). The majority of degraded peatlands are blanket bogs that have been drained for grazing. Drainage for use as cropland was more restricted to lowland peat soils. Forestry planting occurred on around 2 000 km^2 of deep peat, mainly in Scotland.

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

Carbon stock and GHG emissions
The Centre for Ecology & Hydrology (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 United Kingdom, peatlands represent the single most important terrestrial carbon store, with deep peat bogs containing over 3 200 megatonnes of carbon (Worrall *et al.*, 2010), approximately twenty times that of the country's 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 peatlands in the country are already releasing almost 3.7 megatonnes CO_2-eq each year (Worrall *et al.*, 2011), which is equivalent to the average emissions of around 660 000 United Kingdom households. These emissions are likely to increase with further peatland deterioration as a result of climate change.

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

Securing 10 000 km^2 of peatlands under rewetting and restoration management would meet the United Kingdom Biodiversity Action Plan targets for blanket and raised bog restoration (8 450 km^2). By conservative estimate, this could mean savings of 2.5 megatonnes CO_2-eq per year (assuming 2.5 tonnes CO_2-eq savings per hectare per year). This equates to 1 percent of the annual GHG reductions that need to be made to reach the country's 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 bogs is easier since land managers agree that it is important. There is also little conflict with food security concerns in the United Kingdom, and most often only low-cost, low-tech management is 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 wetlands, but this concerns only a small proportion of the country's peatlands.

Funding to pay for restoration and ongoing maintenance of peatlands is the key, as most of the peatland area in the United Kingdom is privately owned. The EU CAP can be a major source of current funds for peatland restoration to support more 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 how restoring important peatland sites can provide social and economic benefits.

Peatlands need more coordinated baseline studies and long-term monitoring in relation to vegetation changes and corresponding ecosystem services (e.g. GHG, water quality, flooding) to support further financial investment. Sharing good practice on peatland management and scientific information across peatland countries is an important objective.

The IUCN UK Peatland Programme and partners are working in collaboration with Defra (The United Kingdom 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 United Kingdom, linking with international initiatives such as those of the International Mire Conservation Group and Wetlands International.

The experience of the United Kingdom with blanket bog conservation, restoration, and management may benefit other areas and countries where this peatland type occurs, including Ireland, Norway, New Zealand, Tasmania, Atlantic Canada, Pacific Northwest of North America, southern Chile, Argentina, the Falkland Islands (Malvinas), and Spain.

5.3. Eastern Europe: Belarus, the Russian Federation and Ukraine

Drained peatland soils are subject to inherent degradation, which continuously lowers the lands' economic value. The socio-economic changes in Eastern Europe since 1990 coincided with deteriorating peat soil conditions and led to large-scale abandonment. The huge peatland fires of 2010 brought the drained and abandoned peatlands in Russia to the attention of the world and showed that peat fires are not limited to southeast Asia. If not rewetted, peatlands continue to degrade through incessant microbial peat oxidation and, in the case of abandonment, also by periodic uncontrolled peat fires. In Belarus, the European part of the Russian Federation and Ukraine, large-scale peatland rewetting programmes have 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, equal to 14 percent of the country's 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 a large variation in these factors, the amount and types of peatlands are not equally distributed within Belarus. Five peatland districts and three peatland regions have been described (Figure 8, Pidoplichko, 1961; Tanovitskiy, 1980; Bambalov, 2005).

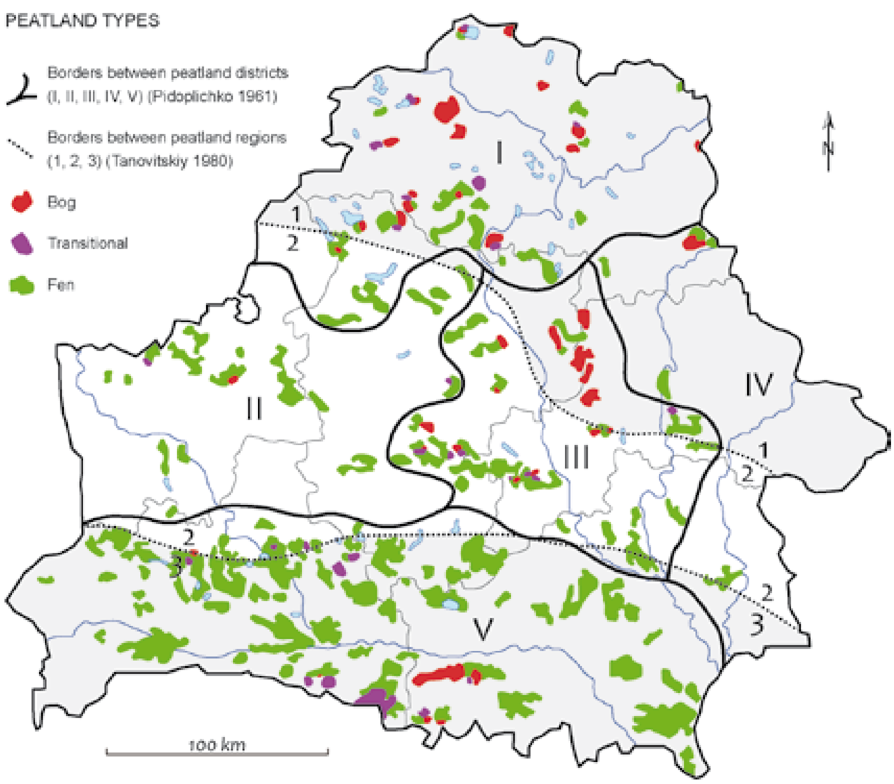


Figure 9: Distribution of peatlands in Belarus (modified after Bambalov and Rakovich, 2005)
Map: Stephan Busse

Peatland use and degradation

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

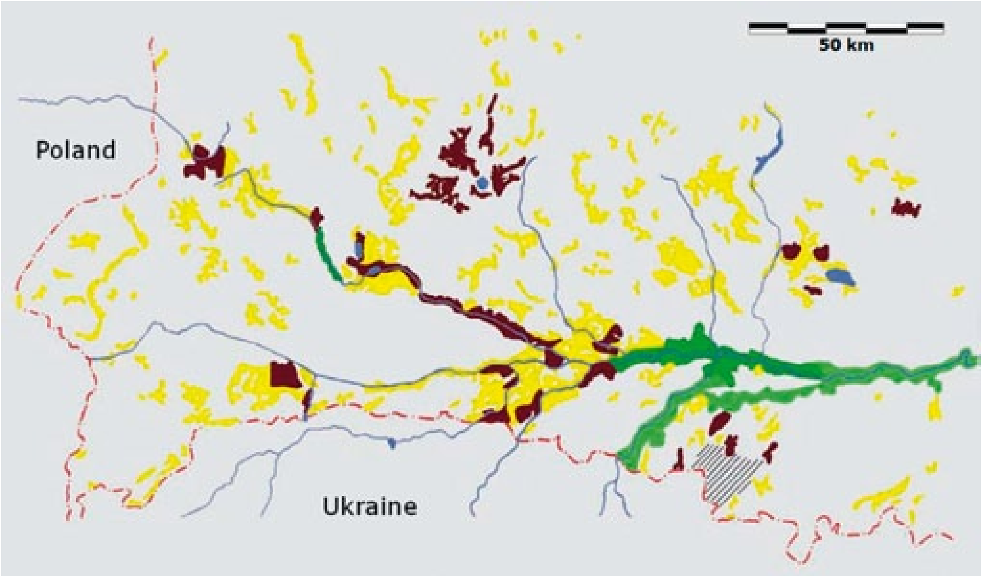


Figure 10: Map of fen mires in southwest Belarus existing in 1977 (yellow) and remaining in 1995 (brown). Dark green indicates the natural Pripyat river floodplain. Light green depicts the Pripyat river floodplain used for low-intensity farming (Kozulin and Flade, 1999).

Carbon stock and greenhouse gas emissions

The estimated peat carbon stock in 2008 of Belarus is 1 305 megatonnes. The Belarusian peatlands emit 41 megatonnes CO_2 per year, making Belarus the world's eighth largest emitter from peatlands. In terms of emissions per unit land area, the country is in third place, 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 for the Environment, Nature Conservation, and Nuclear Safety (BMU) (2008–2011), approximately 360 km^2 of peatlands have been rewetted over the past years (see Box 7). Through monitoring before and after rewetting, the biodiversity benefits of rewetting have been assessed by the UNDP–GEF project. Generally, wetland plant communities on project sites increased in area by 58 to 96 percent and the proportion of wetland bird species of the sites increased by 19 to 48 percent. For example, after rewetting of the cut-over Barcianicha fen, typical 'forest' amphibians declined from 54 percent to 31 percent and previously unrecorded species typical of peatlands were found (e.g. the moor frog (*Rana arvalis*) and common lizard (*Zootoca vivipara*). The effects of rewetting on birds, as well as on amphibians and reptiles, were already pronounced after one year rewetting. Generally, the rate of change in vegetation (and thus habitat) varies with target habitat type, pre-exploitation habitat type, and previous land use. Faster success after extraction has been reported from blocking cut bogs than from milled bogs. Fen vegetation redevelops towards target vegetation more easily after drainage reversal, with the greatest success achieved when rewetting is done slowly, as opposed to rapid, permanent inundation of sites. Transitional stages (e.g. shallow water bodies) can provide valuable habitats for waterfowl. However, these transient ecosystems 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 that benefit biodiversity conservation (see Box 11), paludiculture initiatives have also started in Belarus. At Sporava, another key aquatic warbler breeding site holding around 5 percent of the global population, the habitat is threatened by overgrowing. Vegetation management with conventional agricultural equipment was started in 2006 but seemed to be too dependent on the weather and water level. 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 2011 and facilitates the mowing of 500 ha annually. The biomass briquettes produced will be sold as a substitute for peat briquettes whose use is widespread in rural areas of Belarus. It is hoped this will cover the costs of vegetation management. A follow-up project funded by EuropeAid has initiated cooperation with a peat briquette factory to use sustainably harvested peatland biomass as a substitute for peat. This upscaling will demonstrate the feasibility of this new type of land use for rewetted peatlands and will provide incentives for rewetting and 'wet' land use.

The Russian Federation (European part)

Peatland distribution

The European part of the Russian Federation (3 477 million km²) is said to comprise approximately 200 000 km² of peatlands (Markov and Khoroshev, 1986; Vompersky *et al.*, 1996 and 2005; see Table 11). However, other sources using other inventory methods arrive at double that area (Novikov and Usova, 2000). Most peatlands are located in the Russian Federation's boreal zone, where, in some regions, mires cover over 50 percent of the land surface (Minayeva *et al.*, 2009; Figure 10).

Table 11. Peat-covered wetlands in the European part of the Russian Federation (Vompersky *et al.*, 1996)

Peat thickness	> 0 cm	>0 - 30 cm	≥ 30 cm	> 0.5 m	
				Total	Industrial deposits
Peat area	588 000 km²	375 000 km²	213 000 km²	198 000 km²	105 100 km²

a) b)

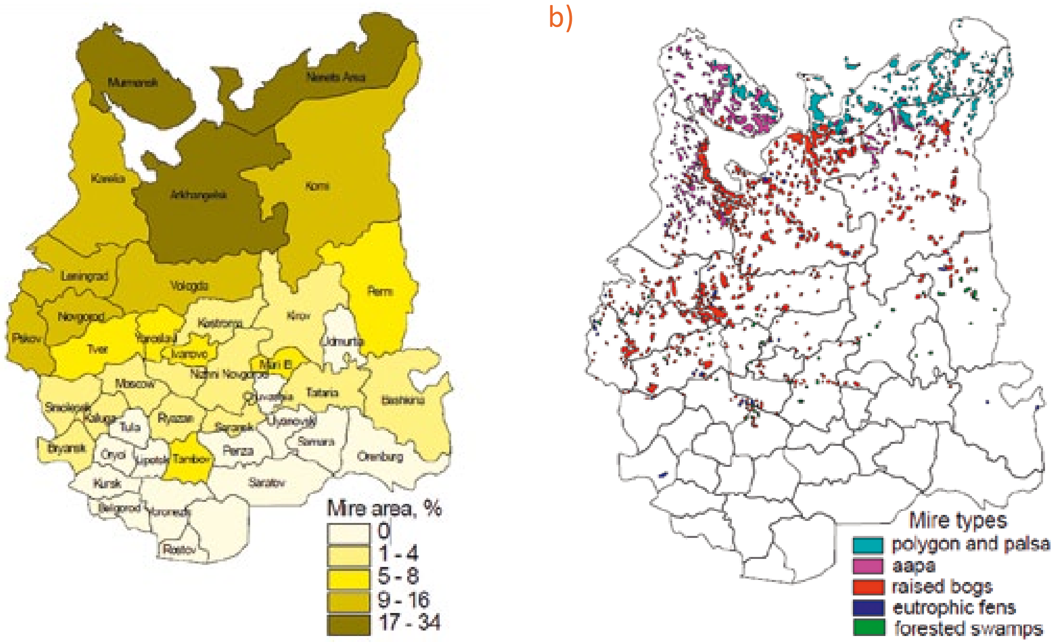


Figure 11: a) Peatland (mire) area within administrative regions of the European part of the Russian Federation. b) Distribution of main peatland (mire) types in the European part of the Russian Federation (from Minayeva *et al.*, 2009).

Peatland use and degradation

The European part of the Russian Federation has a long and intensive history of peatland utilization. This history is reflected in a complex administration of peatlands (Box 12). In the period before 1990, when the Soviet Union was the largest peat extractor in the world, peat extraction was concentrated in regions with significant peat resources. Now peat extraction has decreased considerably and is largely taking place in areas where there are local demands for peat. In 2007, the total area of mined out peatlands in the European part of the Russian Federation was estimated to be 2 309 km², whereas 5 294 km² were under development (Minayeva *et al.*, 2009).

Box 12: Peatland administration in the Russian Federation

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 the 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).

Whereas in 1967 the area of peatland drained for agriculture in the Russian Federation (both the Asian and European part) was estimated at 16 000 km^2, it reached 51 000 km^2 by 1990. According to the latest inventory (1999–2000), about 30 000 km^2 of drained forests on peatland were registered in the European part of the Russian Federation, of which 7 500 km^2 were spontaneously rewetting because of lack of ditch maintenance (Minayeva *et al.*, 2009).

Over recent decades, 30 percent of the agricultural peatlands, 25 percent of the peat extraction areas and more than one-third of the forested peatlands have been abandoned. Many of these abandoned peatlands are GHG sources. Forest stands on peatlands are mainly over-aged and subject to windfall and other degradation processes, which make them vulnerable to fire.

In densely populated regions, there is a high concentration of drained peatlands. For example, in the Moscow oblast where peatlands cover 8 percent of the area, some 75 percent (600 km^2) of peatlands are cut-over, not used and very fire-prone. The peat and forest fires around Moscow in the summer of 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. The economic and health impacts of these peat fires were significant.

Carbon stock and greenhouse gas emissions

The peat carbon stock in European Russia amounts to some 20 gigatonnes. The emissions from drained peatlands in the European part of the Russian Federation may increase to 140 megatonnes of CO_2 annually (Joosten, 2009), making the Russian Federation, after Indonesia and the EU, the third largest global CO_2 emitter from drained peatlands. The Russian peat fires of 2010 alone may have released 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 and the government of Moscow province allocated substantial funds for planning and implementation of rewetting activities. Along with this immediate action, Moscow province decided that the structural

Box 13: Decision Support System for peatland management in Russia

Since the 1990s, millions of hectares of drained peatlands have been abandoned in Russia. Drainage systems, installed 30–50 years ago are, however, still working in many areas. This leads 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.

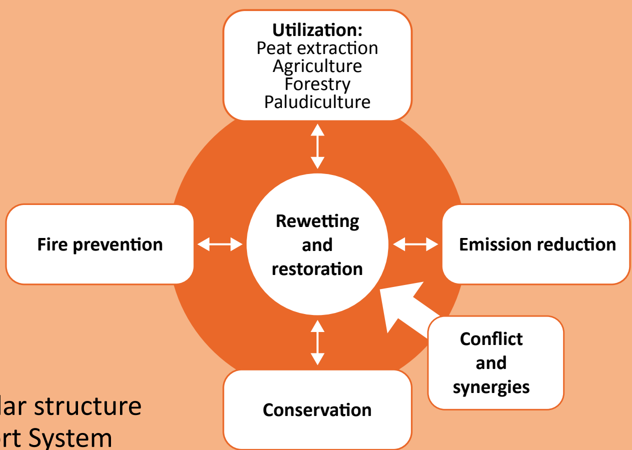
The recurrent, enormous peatland fires in the Russian Federation (2003, 2007, and 2010) stressed the urgency to (re-)install proper management systems. In a project sponsored by the International Climate Initiative (ICI) of the German Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU), a project consortium of Russian, German, and Dutch partners are developing 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[1] (DSS, Abel *et al.*, 2011) has a dichotomous structure as with similar tools for peatlands, such as DSS-WAMOS (Hasch, 2009) and PMDSS (Knieß *et al.*, 2010). The DSS builds on basic principles of peatland ecology (Joosten and Clarke, 2002), peatland restoration (Joosten and Schuman, 2008; Kozulin *et al.*, 2010) and the climate impact of degraded peatlands (Couwenberg *et al.*, 2011). The tool aims to foster sound decision making with respect to the management of degraded and abandoned peatlands and gives special attention to reducing GHG emissions.

The DSS addresses various management (including utilization) options; the advantages and disadvantages of these options; and the conflicts and synergies that exist among these options. It is organized in modules that deal with:

- rewetting to reduce GHG emissions;
- rewetting to reduce fire hazard;
- nature conservation; and
- utilization and 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 module on conflicts and synergies.



Scheme of the modular structure of the Decison Support System

1 Abel *et al.*, 2011. A Decision Support System for degraded abandoned peatlands illustrated by reference to peatlands of the Russian Federation. The bilingual brochure (in English and Russian) can be downloaded from http://www.succow-stiftung.de/tl_files/pdfs_downloads/Buecher%20und%20Broschueren/DSS-Brochure_final_2012_lowres.pdf

problems of drained peatlands require sustainable, long-term strategies to guarantee socio-economic and environmental security and called for technical assistance and international expertise. This led to the development of an innovative Russian–German cooperation project, which developed a standard rewetting procedure and applying the Decision Support System (DSS) for peatland conservation, restoration and utilization in Russia (see Box 13). The project linked project activities to project-based finance sectoral or private sector mechanisms:

- under a post-2012 international climate change regime;
- by applying the VCS-PRC standard (see chapters 3.3. and 4.4.) to enable emission offsetting projects from peatland rewetting; and
- by developing public-private partnerships on paludiculture with emphasis on sphagnum farming.

Another innovation was the 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:

- verifying the GEST model to use vegetation as a quantitative indicator for emissions (Couwenberg *et al.*, 2011) and adapting it to the Russian situation;
- developing a proxy on the basis of peatland water table; and
- applying remote sensing techniques for large scale assessment (Draft Inception Report, 2012).

Figure 12. Peat fires burning under snow in Russia, November, 2010
Photos: Frank Edom

Ukraine

Peatland distribution
Ukraine (603 700 km^2) has approximately 14 000 km^2 of peatlands (Truskavetskiy, 2010). Most of them are concentrated in the northern part of the country in the huge glacial valley, known as Polesia, which it shares with Belarus (Figure 13). The country's peatlands decrease towards the south, where peat deposits only occur in river valleys and small depressions. Fens are prevalent and constitute up to 90 percent of all peatlands in Ukraine. A few transitional peatlands and bogs occur in the northwestern part of Polesia and in the Carpathian Mountains. In eastern and western Polesia, peat deposits of 2–10 km^2 are prevalent, in central Polesia (Kiev and Zhitomir regions) the deposits are smaller (up to 1 km^2).

Peatland use and degradation
About 80 percent of Ukraine's total peatland area is drained, and 50 percent is severely degraded (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 has declined and large-scale agricultural practices on peat were abandoned after 1990, the exploitation of peatlands continues. Local communities still practice small-scale agriculture on the peatlands of former cooperative farms (kolkhoz). Small-scale private land use of peatlands is currently more common in the northwest (Rivne and Volyn oblasts), while in the Northeast (Chernigov oblast) many sites are abandoned or only subject

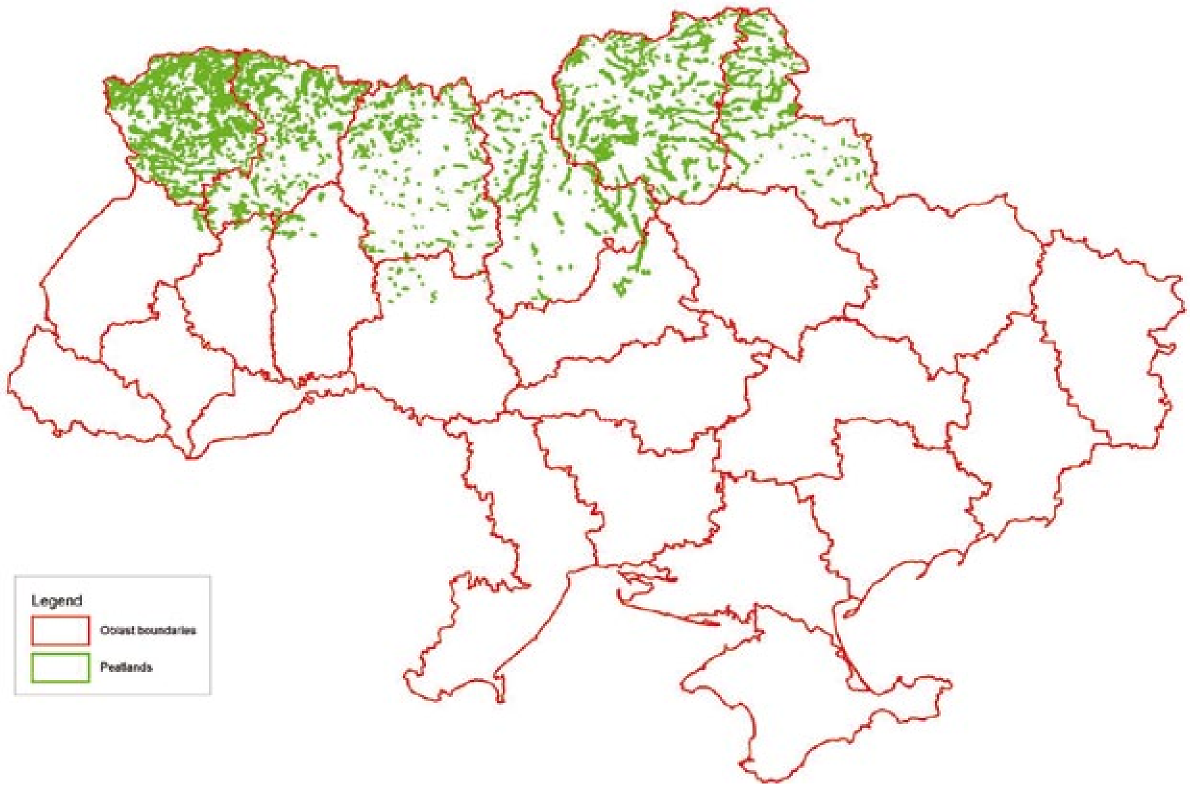


Figure 13: Peatland distribution in Ukraine (from Mikityuk, 2010)

to low-intensity cattle grazing. The Peat Cadastre of Ukraine (as of 2003) mentions the following categories of peatlands:

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

Ukraine has no common policy for peatland use, management or conservation. The agriculture policy guides the use of peatlands used for agricultural purposes. Abandoned peatlands that were formerly used by cooperative farms are unlikely to be rewetted soon since there is a lack of clear and prescriptive legislation addressing them.

The peatlands used for forestry are managed under forest management bodies. Peatlands allocated for peat extraction are extracted down to a depth of 50 cm of peat. After peat extraction these peatlands are administratively transferred to the agriculture or forest cadastral land registries. The extracted peatlands are, however, degraded and not suitable for agriculture or forestry, and often abandoned. Some of the peatlands are rewetting spontaneously, others stay dry. The extraction companies have no legal obligation to rewet these areas after extraction.

Carbon stock and greenhouse gas emissions

The estimated peat carbon stock in 2008 of Ukraine is 750 megatonnes. With respect to peatland emissions, the country ranks 24th in the world, with almost 5 megatonnes CO_2 per year (Joosten, 2009). A methodology for national inventories on peatlands is currently under development within a BMU-ICI project in cooperation with the National Environmental Investment Agency of Ukraine (the central executive body for coordinating compliance with the UNFCCC and Kyoto Protocol obligations in Ukraine).

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 80 percent owned by individuals and local cooperatives. The parcels are small (2–3 ha) and highly fragmented. The 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 are imperative. Rewetting privately owned land also requires officially approved changes in the Land-Use Plans of the oblasts. These plans must define the land management regime of rewetted lands and provide legal restrictions to changing land use of rewetted land in future.

5.4. Central Asia: China and Mongolia

Figure 14. Severely degraded and abandoned peatland in the Chernihiv region (Ukraine)
Photo: Hans Joosten

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 in China (Figure 15). The total peatland area for China is reported to be 34 770 km^2 (Kivinen and Pakarinen, 1980; Chai, 1980). There is an additional area of 6 820 km^2 of 'buried peatlands' (i.e. peat covered by other deposits) (Chai, 1980). The most important 'surface' peatland areas 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 areas, in the northernmost part of China; and
3. the Ruoergai (or Zoige) Plateau on the northeastern margin of the Qinghai – Tibetan Plateau (see Box 1), the largest and most dense area of peatlands in China (State Forestry Administration P.R. China, 2002).

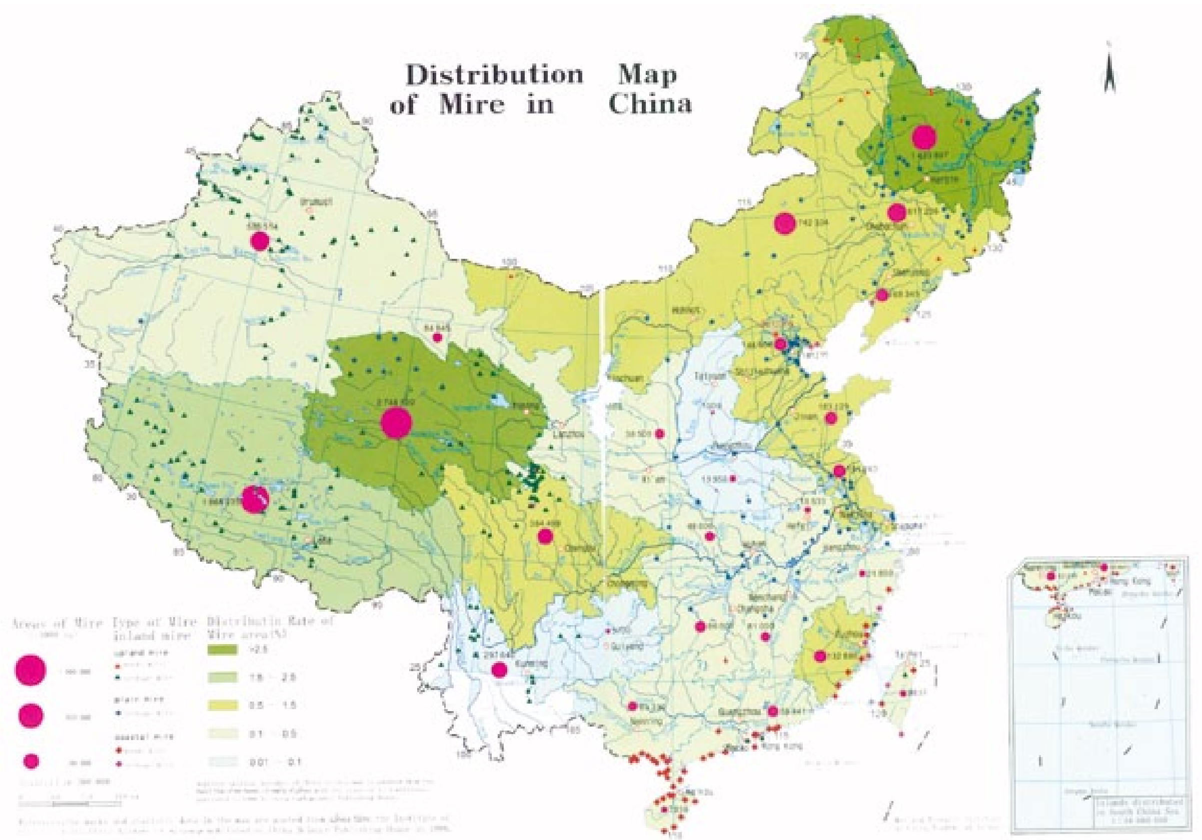


Figure 15: Distribution of “mires” in China (from State Forestry Administration P.R. China, 2002)

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 forestry (Zhang, 2000).

The Sanjiang Plain with a total area of 108 900 km² originally had 24 200 km² of wetland (Kuivi & He, 2000). Huge parts of the plain were converted by local farmers, soldiers and ‘Zhiqing’ (urban educated or ‘rusticated’ youth) between the early 1950s and the 1970s in response to the central government’s call to develop the Great Northern Wilderness (‘Beidahuang’). Currently, the plain is one of China’s most important grain production areas (see Rongfen, 1994). From a biodiversity point of view, it also remains one of the most important wetland sites in northeastern Asia. However, desertification has affected 20 percent of the land area, and only 380 km² of the peatlands have been left in a somewhat natural state (Yang, 2000b).

Since the 1990s, the Sanjiang Plain and northern China have been suffering increasingly from droughts, floods and sandstorms that have been attributed to the shrinking wetlands. Not only do these threaten China’s food and energy security, but the effects stretch into neighbouring countries, such as the Russian Federation.

Figure 16: Distribution of good quality (black) and degraded peatlands (grey) on the Ruoergai Plateau (from Schumann *et al.*, 2008)

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**

On the Ruoergai Plateau, peatlands cover almost 5 000 km^2 (17 percent of the land) of which 60 percent is overgrazed. Over 2 000 km^2 have been drained. Desertification has affected large areas. (Yang, 2000b; Chew, 2003.) Good quality peatlands still cover 1 100 km^2, i.e. 23 percent of the peatland area, but 3 600 km^2 (77 percent) are degraded (Schumann *et al.*, 2008; Figure 15). A comparison of figures from 1977 and 2007 (Table 12) shows that in the last 30 years, the area of degraded peatland has almost doubled. Only 6 percent of the area was in a better state in 2007 than in 1977. Large parts were already degraded in 1977, indicating that grazing had made the peatlands prone to degradation long before recent intensification of peatland use (Joosten *et al.*, 2008; Box 1).

Carbon stock and greenhouse gas emissions

The peatland carbon stock in China is estimated to be 3.2 gigatonnes. With peatland CO_2 emissions of 77 megatonnes per year, China is in the top five of global 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

In recent years, national and provincial governments have recognized the environmental and economic problems associated with peatland drainage. 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. The initial results of these projects 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 areas 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. The government plans to restore 1 500 km^2 of farmland to wetlands and to replant 685 km^2 (Yu, 2009).

In the Sanjiang Plains Wetland Protection Project (2006–2012), which is 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 livelihoods 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).

To maintain and restore the vital ecological functions of peatlands and wetlands in China, the remaining, good quality peatlands must be protected and degraded peatlands must be restored (eg. by implementing paludicultures). There is a need to increase awareness among decision-makers and the

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

public on the important ecological role of peatlands and enhance capacity in integrated landscape and watershed management.

Mongolia

Peatland distribution
Generally considered as a country of vast plains, 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 and cotton grass fens on permafrost; and blanket bogs on mountain

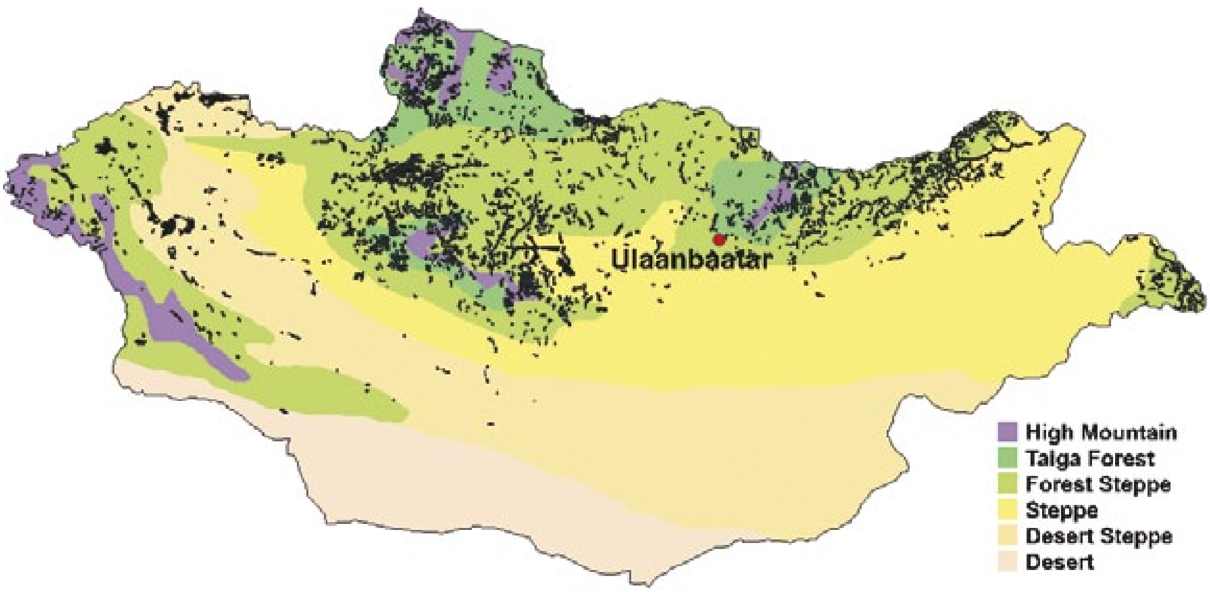


Figure 17: Peatland distribution in Mongolia (from Minayeva *et al.*, 2004)

heights (2 500–3 200 m) with sphagnum and brown mosses and arctic sedges. In the taiga zone of the Khentii Mountains, raised bogs with a peat layer up to 4–5 metres thick occur along with coniferous forests on shallow peat on gentle slopes. In the forest-steppe zone of the Khentii Mountains, fens with birch and dwarf willows, as well as spring mires with very high floristic diversity are found. Minayeva *et al.* (2004) estimated that the total area of peatlands in Mongolia is 272 000 km^2, covering 1.74 percent of the country's total land area (Figure 17).

In Mongolia, peatlands constitute the last wet habitats in a major part of the country. The peatlands 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 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. All sedge fens in river valleys are currently being grazed. The stimulation of private cattle husbandry and the consequent overgrazing in recent years has led to severe losses in productivity. For example, overgrazing and human-induced fires, combined with recent climate change, have led to the loss of thousands of hectares of fens in the Orkhon and Ider valley and the Darkhat intermontane basin. Large flat areas show denuded dry peat without vegetation.

During storm surges, the unprotected peat moves downhill. This causes rapid loss of peatlands and increases desertification. In old maps, native narratives and literature data, these areas (e.g. the Orkhon River valley (Lavrenko, 1956)) are described as covered with vast mires, very wet and impassable. 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 the conversion to arable land (particularly in the piedmont regions of the northern Khentii Mountains). Peatlands are occasionally destroyed by road construction and gold panning in rivers (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

Carbon stock and greenhouse gas emissions
According to the International Mire Conservation Group's (IMCG) Global Peatland Database, the peatlands of Mongolia contain 750 megatonnes of carbon and emit 45 megatonnes of CO_2 per year. This puts Mongolia in the top ten of world's peatland CO_2 emitters (Joosten, 2009).

Opportunities for emissions reductions and enhancement of other ecosystem services
Currently, various 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 peatland management (Minayeva *et al.*, 2005).

The Mongolians have lived for thousands of years in harmony with peatlands. However, global changes have thrust people into situations in which traditional knowledge is no longer sufficient. The main threat to peatlands in Mongolia is the absence of detailed knowledge about their diversity, distribution and natural functions. Land use planning should be based on solid knowledge about the role of peatlands in the landscape (Minayeva *et al.*, 2005). Peatland use should apply the principles of wise use that have recently 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

For the regions discussed earlier in this report, there is considerable knowledge about the distribution and status of peatlands. Southeast Asia has recently attracted much scientific attention because of the rapid destruction of the peatlands there and the associated environmental problems. In Europe, peatlands have been used for agriculture, forestry and peat extraction for hundreds of years, and as a result an extensive knowledge base exists. In contrast, there is a serious lack of knowledge about peatlands in central Africa (Figure 18).

In this report, we discuss the Congo Basin, an area where enormous stretches of peatlands exist. These peatlands have remained largely unnoticed until now. Uganda also has large areas of peatlands that are currently under heavy pressure. A substantial part of these peatlands has been drained in recent years, making Uganda the major peatland CO_2 emitter of the African continent (Joosten, 2009).

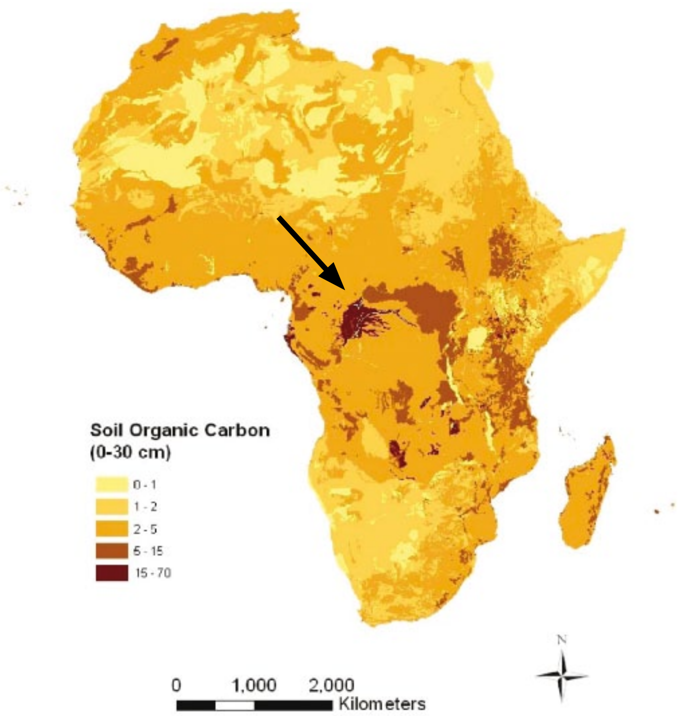


Figure 18: The soil carbon content of Africa (Henry *et al.*, 2009). The black arrow marks the central Congo Basin.

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, known as the 'Cuvette Central Congolaise'. This region covers over 1 176 000 km^2 (Bwangoy *et al.*, 2010), comprising almost 30 percent of the Congo Basin catchment. It 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 per km. The 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). Knowledge about the peatland area of the central Congo Basin is, however, very poor.

Figure 19: 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. The reddish colour of the Likouala aux Herbes floodplain is swamp grassland. (Image taken from Google Earth; Image © 2012 TerraMetrics; © 2012 CNES/Spot Image, © 2012 DigitalGlobe)

Permanently flooded forests reportedly occur in depressions with flooding levels of 4 metres, whereas seasonally flooded forests occur higher on the upper floodplain with water tables reaching between two and four metres above ground (Campbell, 2005; Vancutsem *et al.*, 2009). The partly convex surface between adjacent rivers that 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. They indicate high annual emissions of between 1.6 and 3.2 megatonnes for the entire swamp forests of the Congo Basin (Tathy *et al.*, 1992).

Knowledge of the prevailing vegetation types in the Congo Basin has been greatly advanced recently through 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. Aquatic grasslands cover 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). This project concluded that the overall wetland area was 359 556 km^2 (or approximately 36 million ha) for the central Congo Basin. Most wetlands are located in the Lac Télé–Lac Tumba region (207 467 km^2, 56 percent) and east of Lake Mai Ndombe. The huge area of these wetlands, largely flooded forests, may contain a substantial below-ground carbon stock.

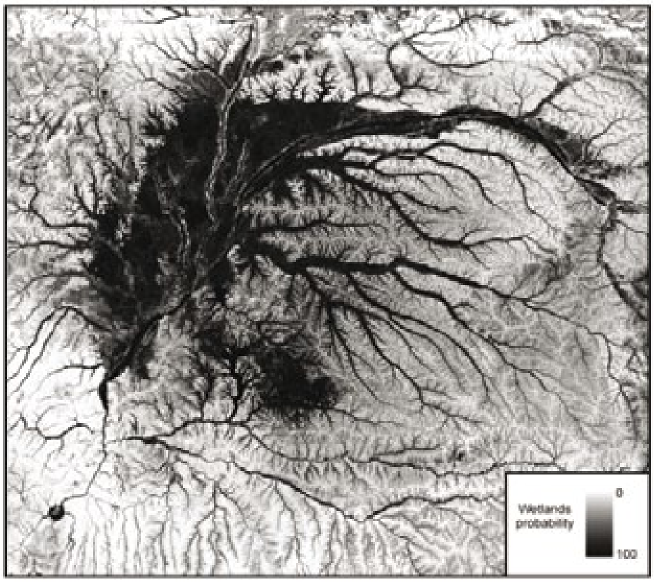


Figure 20. Wetland probability map of the central Congo Basin (from Bwangoy *et al.*, 2010)

Peatland use and degradation

In contrast to the forested peatlands of southeast Asia, logging intensity has been much lower in the Congo Basin wetland forests(Hansen *et al.*, 2008). Commercial-scale logging or agricultural conversion to plantations has not yet taken place in the Cuvette Central Congolaise. Small-scale logging is done by local people for shifting cultivation, but the generally low population density prevents the forests from wider degradation. Catastrophic events such as fires have not occurred in this forest due to the fact that there has been little or no human influence.

Carbon stock and greenhouse gas emissions

The existing estimates on soil or peat carbon are not very high. For the Republic of Congo, Schwartz and Namri (2002) estimate a soil carbon stock in the upper two metres of only 134–160 tonnes per ha for the flooded forests of the Congo Basin and of 276–456 tonnes per ha for the swamp grasslands along the rivers. These authors report a soil carbon stock for the entire country of 3.9 gigatonnes in the upper 2 m.

Page *et al.* (2011) estimate the peat carbon stock of the Republic of Congo at 2.35 gigatonnes and that of DRC at only 0.56 gigatonnes, for a combined 2.9 gigatonnes. Henry *et al.* (2009) report country-based estimates of soil organic carbon for the upper first meter. For the Republic of Congo, the authors estimate 9.3 gigatonnes and for DRC 21.9 gigatonnes. Although not focusing on peat, their soil carbon map for Africa shows the highest soil carbon density in the central Congo Basin (Figure 18).

Assuming that 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}), this would yield a peat carbon stock of 9 gigatonnes. 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 guarantee that major forest degradation or destruction will not happen in the future. Southeast Asia and Amazonia have experienced massive and rapid deforestation within short periods, even though these areas were long seen as impenetrable areas. The search for valuable resources such as metals or oil could cause forest destruction even in deeply flooded wildernesses. Any large-scale impact on the vegetation, soils or hydrology could cause irreversible ecosystem degradation and large quantities of carbon losses.

Incentives are needed quickly to protect these unique forests and do inventories of their natural resources (particularly their carbon stock) before potentially destructive industries 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 percent of total land area) of which 22 809 km^2 or 72 percent is classified as seasonal wetlands (Figure 21). Permanent wetlands cover 7 296 km^2 or 3 percent 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 of Lake Victoria, 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 2–3 metres. On the other hand, Morrison (1968), using findings from numerous coring trials, stated that the papyrus (and grass) swamps below 1 600 m largely do not contain peat

Swamps of papyrus are also common in the Kigezi highlands of southwest Uganda where they reach peat depths of up to 20 m (Taylor, 1990). Grasses typically dominate seasonally inundated swamps.

Figure 21: Distribution of permanent and seasonal wetlands in Uganda in 1996. Retrieved from: http://www.wri.org/map/uganda-distribution-permanent-and-seasonal-wetlands-1996

Figure 22: 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) René Dommain, right: Image NASA; Image © 2012 GeoEye; © 2012 Google

They dry out thoroughly, desiccate during the dry season and do not accumulate peat (Beadle, 1974; Lind and Morrison; 1974; Thompson and Hamilton, 1983).

The Ministry of Energy and Mineral Development estimate the peatland area of Uganda to be 4 000 km^2 (NEMA, 2008). This is much less than what is reported in other sources (Page *et al.*, 2011, Joosten, 2009; Shier, 1985). However, this figure is 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. in the Kisoro and Jinja districts, NEMA, 2008). Studies on draining papyrus peatlands in southwest Uganda had already been conducted in the 1950s (Harrop, 1960). These experiments led to extreme acidification (pH 2.4–2.7) after even a slight drainage of 30 cm and the formation of sterile acid sulphate soils due to the 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 smallholder agriculture with European drainage techniques. Typically, these peatlands are cultivated with sweet potatoes, sorghum and maize, as well as with peas, cereals and legumes (Lind and Morrison, 1974; Thompson and Hamilton, 1983). Small fields have been established between rib-drains resulting in densely drained peatlands.
Another problem in these valley swamps is erosion and the burying of peat from cultivated valley slopes (Pajunen, 1996). Swamp forests have now disappeared from most valley peatlands due to agricultural encroachment (Taylor, 1990). The papyrus swamps around Lake Victoria have often been converted to fields of cocoyam (Colocasia esculenta) leading to CO_2 losses (Saunders *et al.*, 2012), decreased nutrient retention capacity and increased pollution in Lake Victoria (Kansiime *et al.*, 2007).

Figure 23: Densely drained peatlands in southwest Uganda: in the Kisoro District (left) and Ruhuma Fen (Kabale District) (right). Ruhuma Fen has been largely converted to agricultural land since 2003 (Sliva, 2005). Image on the left © 2012 GeoEye and Google; image on the right © 2012 GeoEye, NASA, 2012 DigitalGlobe and Google

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 cm^3 (NEMA 2008) and a carbon content of 50 percent would yield a peat carbon stock of 0.3 gigatonnes. This carbon stock is substantially lower than the reported values of between 1.3 and 1.5 gigatonnes (Joosten, 2009; Page *et al.*, 2011).

There is a need for more rigorous investigation into whether the vast papyrus swamps along Lake Victoria and the Nile basin have substantial peat deposits. 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 per year to 1 600 g m^2 per year. 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 per year, Pajunen, 1996) suggesting substantial peat accumulation under floating papyrus swamps. Perhaps papyrus, as a C_4 carbon fixating species, has already gained benefit from the higher atmospheric CO_2 content. Longer eddy-flux measuring campaigns combined with peat core studies are needed to clarify the current status of undisturbed papyrus swamps as significant carbon sinks.

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

Disturbance or conversion change papyrus swamps and other peatlands into carbon sources (Saunders *et al.*, 2012). In the 1990s, 7.3 percent (about 2 200 km^2) of Uganda's wetlands have been converted to agriculture (NEMA, 2008, see Figure 22). The population of Uganda doubled from 16 to over 32 million people between 1990 and 2011 (UBOS, 2012). Therefore, it is likely that the area of reclaimed wetland has also doubled to about 5 000 km^2 in 2012. Joosten (2009) estimates the annual emissions from drained peatlands in Uganda to be 20 megatonnes, which are the largest peatland 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 by avoiding further reclamation, restoring degraded sites and implementing paludicultures. The highly productive papyrus has long been used for roof thatching, matting and building fishing-floats (Beadle, 1974) and appears to be an ideal plant for sustainable use of undrained peatlands.

5.6. Amazon Basin: Brazil, the Guyanas and Peru

The drainage area of the Amazon Basin, which covers more than one-third of the South American continent, is shared by Bolivia (Plurinational State of), Brazil, Colombia, Ecuador, Guyana, French Guiana, Peru, Suriname and Venezuela. Brazil covers approximately 70 percent 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 24).

No comprehensive surveys on the area of peatlands or organic soils exist for the huge area of the Amazon Basin. Parts of the area, however, have been the subject of case studies combining satellite imagery and ground truthing. The results of these studies were extrapolated to the entire basin. According to Junk *et al.* (2011), 30 percent 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) estimated 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).

Figure 24: The delimitation of Amazonia *sensu stricto* (red line) and four peripheral subregions – Guiana, Andes, Planalto, and Gurupí (from Eva and Huber, 2005)

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).

However, the total area of peatland in the Brazilian Amazon is unclear. Estimates range from 15 000 km² (Bord na Mona, 1985; Andriesse, 1988); 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 estimate (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 25) indicating that the peatland area of the Brazilian Amazon may be conspicuously larger than currently known.

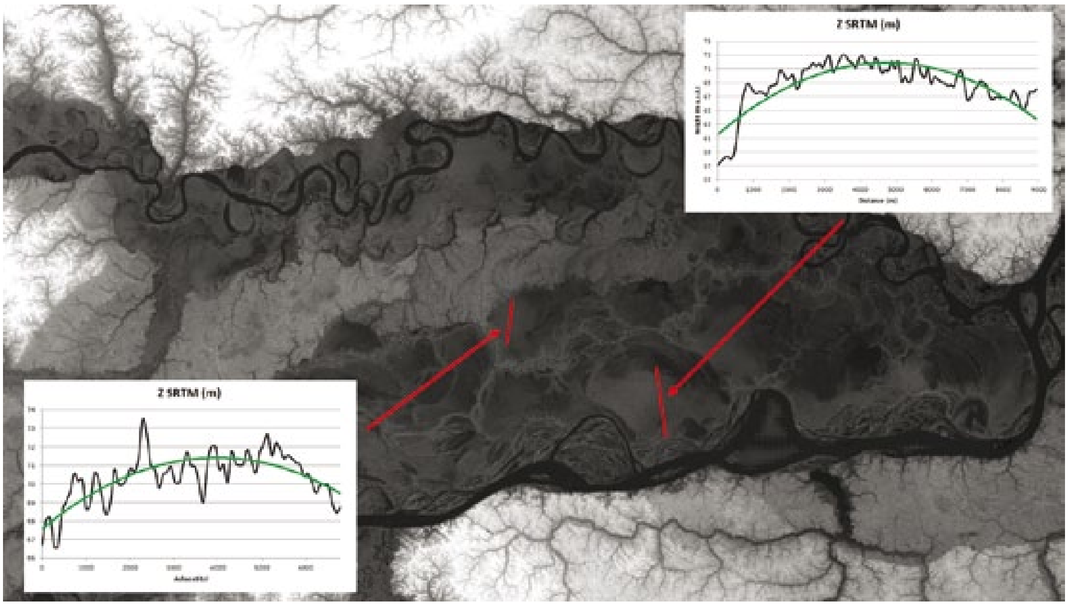


Figure 25: Peat domes of the Central Amazon between the Amazon and the Putumajo River prospected with optical satellite imagery, SRTM (topographic information), and satellite LiDAR data (ICESat/Glas). Graphs show the polynomial regression curve illustrating the convex shape (cf. Jaenicke *et al.*, 2008). 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 to be all drained and used for agriculture or as pasture. According to Markov *et al.* (1988) about 3 140 km^2 of peatlands have been drained, mostly for agriculture (Figure 25).

Figure 26: 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 International Mire Conservation Group's (IMCG) Global Peatland Database, Brazil's peatlands contain some 5.5 gigatonnes of carbon and emit 12 megatonnes 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 country's peatland distribution, their use, and state of degradation. Such information is crucial for setting 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 lowland Peruvian Amazon (< 500 metres above sea level) consists of alluvial plains. The main rivers in the area are the Amazon (Solimoñes) and the Marañon. Swamps occur in areas with incomplete drainage, such as inactive channels (oxbow and serpentine swamps or lakes) and tributary valleys; poorly drained floodplains depressions or in valleys and depressions in the solid ground 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. Recently the knowledge base has improved. Schulman *et al.* (1999) estimate the area of *Mauritia flexuosa* swamps to be 47 140 km^2 (cf. ONERN, 1986). On the basis of fieldwork, they assume that the peat deposits in these swamps were often more than one metre thick. Ruokolainen *et al.* (2001) estimate the peatland area of the lowland Peruvian Amazon to be 50 000 km². Lähteenoja *et al.* (2009b) found that peat deposits in this area are notably thicker than previously reported from elsewhere in Amazonia (cf. Junk, 1983; Suszczynski, 1984; Shier, 1985; Andriesse 1988). For the Pastaza-Marañon foreland basin (120 000 km²), the total peatland area was assumed to be 43 860 km^2 with a total carbon stock of 6.2 gigatonnes (Lähteenoja *et al.*, 2011).

Figure 27: Mauritia flexuosa peatland in the Peruvian Amazon

The Guyanas

The Guiana subregion is bordered in the north by the Atlantic coast and the Orinoco and Vichada rivers. The southern limit is formed by the watershed of the Amazon River Basin. (Eva and Huber, 2005.) It comprises the Guyana 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 mouth of the Amazon River. 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 metres, the average depth is less than one 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. Peat may also have been deposited in these areas.

The extensive white sand belt of Guyana, Suriname, and French Guiana has a gently rolling aspect and is 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 radial drainage pattern (Brinkman and Pons, 1968).

French Guiana

French Guiana is very humid. About twenty rivers enter the Atlantic Ocean along the 320 km wide lowlands, the width of which varies from 50 km at Pointe Behague to 5 km east of Cayenne (Prost and Loitier, 1989).

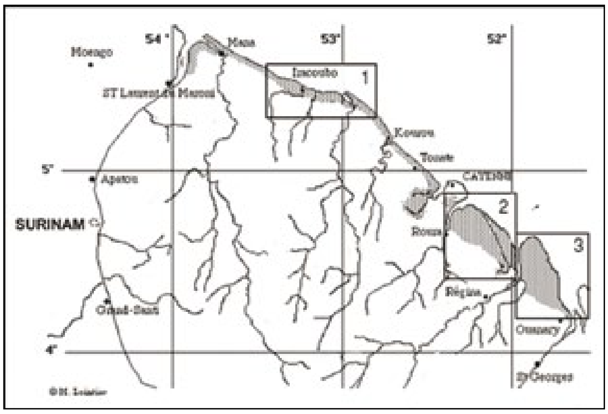


Figure 28: Soil map of part of the Kaw Marshes in French Guiana. Light green areas are covered by shallow peats (Fond Topographique and the Carte géologique de la Guyane Française au 1/100.000, Office de la Recherche Scientifique et Technique Outre-mer ORSTOM, section pédologie de l'Institut Français d'Amérique Tropicale).

Peatland distribution

Important wetlands occur only in this coastal strip and they cover an area of 3 380 km² (Scott and Carbonell, 1986). Vast and 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 from Pointe Behague and the lower Oyapock River (Scott and Carbonell, 1986, Figure 28). These wetlands include large areas covered by freshwater peat, known as 'pegasse', which can be 1–2 metres thick (Boy, 1959). Saline soils and clays prevail close to the Atlantic coast. Farther inland large peat areas occur. Adjacent lateritic soils mark the change towards the non-hydromorphic areas of interior French Guiana (see Figure 29).

On the basis of the FAO/UNESCO 1971–1981 Soil Map of the World, Shrier (1985) estimate the 'mire area' in the coastal swamps of French Guiana to be 1 620 km^2. The interpreted World Soil Map arrives at an almost similar estimate of 1 720 km (Van Engelen and Huting, 2002). Given 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 tracts 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.

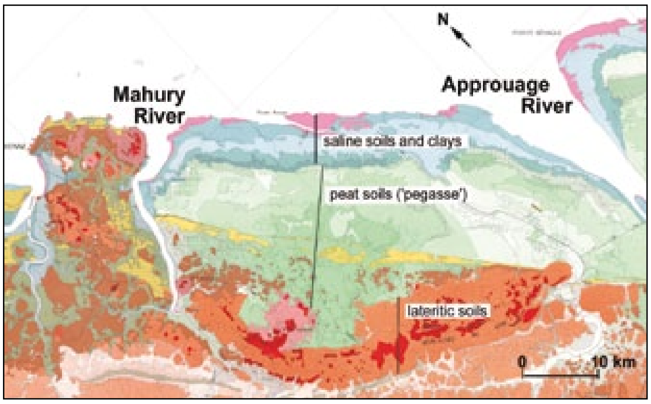


Figure 29: Major wetlands of French Guiana. Rectangles mark wetlands which include larger peatlands: 1: Estuaries of rivers Sinnamary, Iracoubo and numerous smaller rivers; 2: Kaw Marshes: estuaries of the Mahury, Approuage and Kaw rivers; 3: Estuary of river Oyapock on the Brazilian border. (After Lointlier, 1996 and Scott and Carbonell, 1986)

Guyana

Peatland distribution

In the north of the Guyanas, the Guiana Shield includes an area with around 50 isolated table mountains called 'tepuis' that extends into Guyana (Eva and Huber, 2005). These flat topped table mountains of between 1 200 and 3 000 metres high often harbour waterlogged soils that store organic material (Junk *et al.*, 2011).

Peat soils also 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 forests 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 sand belt with its gently rolling aspect and its drainage pattern of blackwater streams.
Figure 30 shows the wetland vegetation types of Guyana. Open swamps, coastal swamp forests and broadleaved upland meadows usually deposit peat (see ter Steege, 1999; Huber, 2006). Combined they cover an area of 12 700 km². How much peatland occurs in the mangroves and the mixed forest/swamp forest complex (Figure 30) remains unclear. All swamp and marsh forests together cover an area of 26 899 km².

Code	Vegetation Types	Map	Area (km²)
1.1	Mixed forest Central/NE Guyana		20,858
1.2	Mixed forest NW Distict		28,393
1.3	Mixed Forest Pakaraimas		3,233
1.4	Mixed Forest South Guyana		47,789
1.5	Mixed Forest on steep hills		7,817
1.6	Mixed Forest on steep hills Pakaraimas		3,339
1.7	Mixed Forest on steep hills South Guyana		6,922
1.8	Mixed Forest/Swamp complex		2,513
2.1	Clump Wallaba Forest		1,016
2.2	Clump Wallaba/Wallaba Forest		2,522
2.3	Wallaba Forest		7,329
2.4	White Sand Forest South Guyana		136
2.5	Dakama Forest		4,234
2.6	Muri scrub/white sand savannah		3,810
3.1	Open Swamp		4,604
3.2	Marsh Forest		9,891
3.3	Coastal Swamp Forest		7,865
3.4	Forested Islands in Rivers		765
4.1	Mangrove Forest		1,262
5.1	Lowland grass/shrub savannah		11,287
6.1	Upland scleromorphic scrub		525
6.2	Upland grass/shrub savannah		1,940
6.3	Broadleaf upland meadow		196
7.1	Submontaine Forest Pakaraimas		23,549
7.2	Montaine Forest Pakaraimas		275
8.1	Submontaine Forest Southern Guyana		3,090
9.0	Clearings, cultivated land, large mines		4,687
	Rivers, lakes, streams		5,123
TOTAL			214,970

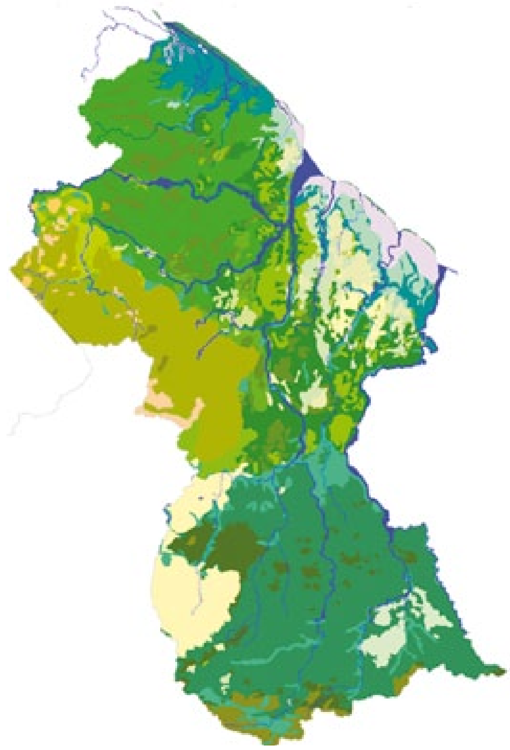


Figure 30: Vegetation map of Guyana showing selected vegetation types (after Alder and van Kuijk, 2009)

Peatland use and degradation
Much of the former seasonally flooded palm marshes 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 to be 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 more than 1 900 tonnes of carbon per ha with each ten centimetres of peat contributing approximately 245 tonnes of carbon per ha (ter Steege *et al.*, 1999). According to ter Steege (2001), the soil organic matter up to one meter depth is 490 tonnes per ha in freshwater peat soils. More conservative figures have also been used. For example, Alder and van Kuijk (2009) use the figure of 167 tonnes per ha for swamps and marshy areas.

Forest degradation and deforestation in Guyana is responsible for the loss of 12.8 million tonnes of carbon per year, or a release of 46.9 megatonnes CO_2-eq (Alder and van Kuijk, 2009). It is not known if the peat soils are adequately included in this figure.

Opportunities for emissions reductions and enhancement of other ecosystem services
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) considered 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). These organic soils should not be drained. Focus should be given to wet agriculture, paludiculture.

Suriname

Peatland distribution
The coastal wetlands of Suriname cover an area of about 18 000 km^2 (Junk, 1993). They include alluvial plains with riverine marshes, freshwater swamps, large areas of swamp forests, rain-fed peat swamps and Mauritia flexuosa palm swamps. The major wetland areas are the Nanni swamps (2 700 km^2), the Coronie Swamps (3 000 km^2), the wetlands along the Coesewijn and the Saramacca River (2 000 km^2) and the Wanekreek wetlands (700 km^2) (Figure 32). In these wetlands, a peatland area of 8 400 km^2 can be expected (see Table 13).

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

National class	Area 1998 km^2	Definition
High Swamp forest	4 833 km^2	- very wet conditions all year round - at least 20 meter high with two storeys and fairly closed - peat soils
Low Swamp Forest	2 392 km^2	- 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	1 146 km^2	closed forests with one storey- undergrowth restricted to ferns
Marsh forest (mostly on alluvial sediments)	4 637 km^2	- insufficient drainage causing seasonal fluctuations in moisture conditions from very dry to very wet - clay soils

Coastal peat soils of northern Suriname are characterized by an organic freshwater peat layer more than 50 cm thick, consisting of more or less decomposed forest litters (van der Eyk, 1957). In the central parts of these swamps, the peat often reaches a thickness of 125 to 250 cm (Figure 32). Large, rain-fed domed peatlands have been described by Brinkman and Pons (1968).

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).

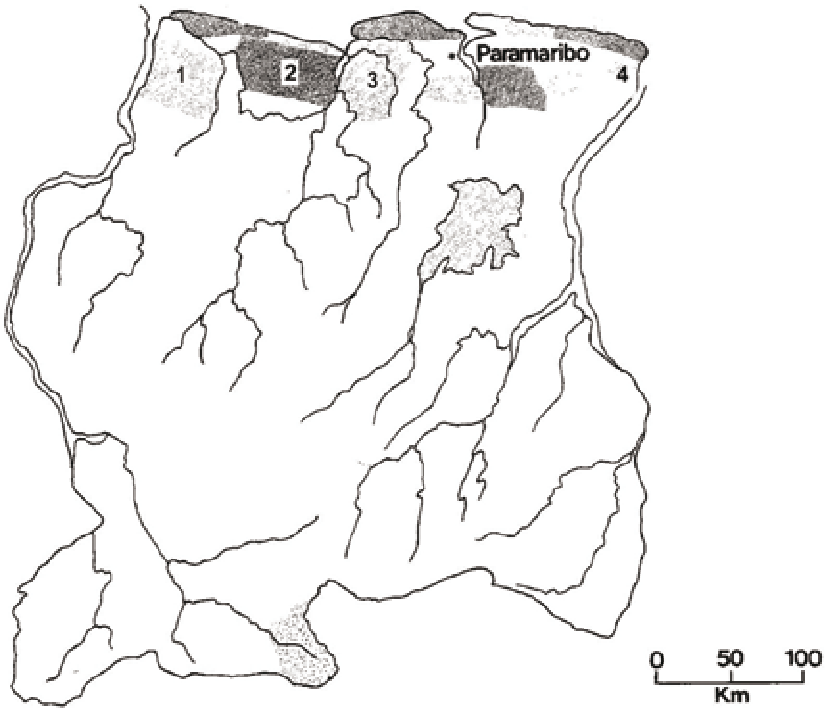


Figure 31: Wetlands of Suriname (after Scott and Carbonell, 1986), which might harbour extensive peatlands. 1: Nanni swamp; 2: Coronie Swamps; 3: wetlands of the the Coesewijn and the Saramacca River; 4: the Wanekreek wetlands.

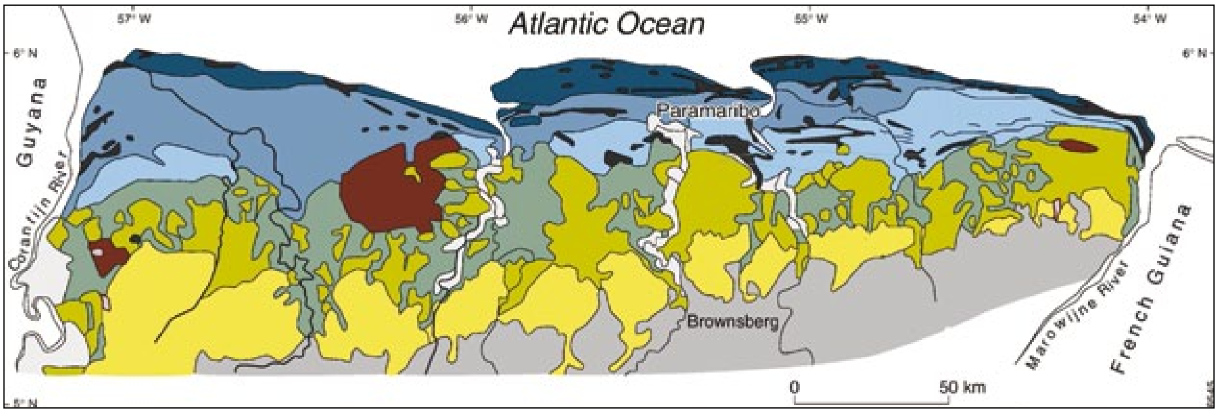


Figure 32: Geological map of the coastal plain of Suriname. Brown: ombrogenous (rain-fed) peat; grey: pyritic clays, peaty clays and peat (Mara formation; after Wong, 2009).

Shrier (1985) mentions for the coastal swamps of Suriname a 'mire area' of 1 130 km^2, whereas according to van Engelen and Huting (2002) 5 932 km^2 of Histosols exist. Taking into account the available information (e.g. Scott and Carbonell, 1986), the latter estimate seems to be more realistic, although more comprehensive and reliable data on the peatlands of Suriname are needed.

Peatland use and degradation

Threats to Suriname'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 percent of the swamp forest areas have been burned and are now covered with secondary swamp woods, swamp scrubs or herbaceous swamps (FAO, Country Report Surinam, 2010).

About 85 percent of the land suitable for agriculture lies in the coastal area. This includes the fertile soil of the young coastal plain and the large freshwater swamps and rivers in the north. Since the arrival of Europeans in the 17th century, about 2 000 km² of this land (mostly wetlands) have been turned into plantations and polders. After 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).

In several places, roads, dams and canals are crossing the swamps, even at places where there is 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 of dam in the south of Nickerie rice area, and the canal and dam in the south of Coronie rice polders) (Tjien Fooh, 2007).

Carbon stock and greenhouse gas emissions
Usually a thin (less than 20 cm) or moderately thick (20–40 cm) peat layer is present in the Surinamese swamp forest areas, although the peat layer may be considerably thicker (Noordam, 2007). Large amounts of CO_2 and other gases are released to the atmosphere through vegetation and peat burning.

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 or aquacultural land if there are no proactive measures taken to prevent this. Because clearing the herbaceous swamps is cheaper, people have preferred to use them instead of (high) swamp forests. However, with the increasing pressure on the land near the capital Paramaribo, these forests are also threatened (Tjien Fooh, 2007). Organic soils should, however, not be drained. If needed, focus should be given to paludiculture.

Surveying a burned peat swamp
Photo: Marcel Silvius