CLIMATE CHANGE

Scientific Assessment and Policy Analysis

WAB 500102 027

Peatlands and carbon flows

Outlook and importance for the Netherlands

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Report
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Wetenschappelijke Assessment en Beleidsanalyse (WAB) Klimaatverandering

Het programma Wetenschappelijke Assessment en Beleidsanalyse Klimaatverandering in opdracht van het ministerie van VROM heeft tot doel:

- Het bijeenbrengen en evalueren van relevante wetenschappelijke informatie ten behoeve van beleidsontwikkeling en besluitvorming op het terrein van klimaatverandering;
- Het analyseren van voornemens en besluiten in het kader van de internationale klimaatonderhandelingen op hun consequenties.

De analyses en assessments beogen een gebalanceerde beoordeling te geven van de stand van de kennis ten behoeve van de onderbouwing van beleidsmatige keuzes. De activiteiten hebben een looptijd van enkele maanden tot maximaal ca. een jaar, afhankelijk van de complexiteit en de urgentie van de beleidsvraag. Per onderwerp wordt een assessment team samengesteld bestaande uit de beste Nederlandse en zonodig buitenlandse experts. Het gaat om incidenteel en additioneel gefinancierde werkzaamheden, te onderscheiden van de reguliere, structureel gefinancierde activiteiten van de deelnemers van het consortium op het gebied van klimaatonderzoek. Er dient steeds te worden uitgegaan van de actuele stand der wetenschap. Doelgroepen zijn de NMP-departementen, met VROM in een coördinerende rol, maar tevens maatschappelijke groeperingen die een belangrijke rol spelen bij de besluitvorming over en uitvoering van het klimaatbeleid. De verantwoordelijkheid voor de uitvoering berust bij een consortium bestaande uit PBL, KNMI, CCB Wageningen-UR, ECN, Vrije Universiteit/CCVUA, UM/ICIS en UU/Copernicus Instituut. Het PBL is hoofdaannemer en fungeert als voorzitter van de Stuurgroep.

Scientific Assessment and Policy Analysis (WAB) Climate Change

The Netherlands Programme on Scientific Assessment and Policy Analysis Climate Change (WAB) has the following objectives:

- Collection and evaluation of relevant scientific information for policy development and decision–making in the field of climate change;
- Analysis of resolutions and decisions in the framework of international climate negotiations and their implications.

WAB conducts analyses and assessments intended for a balanced evaluation of the state-of-the-art for underpinning policy choices. These analyses and assessment activities are carried out in periods of several months to a maximum of one year, depending on the complexity and the urgency of the policy issue. Assessment teams organised to handle the various topics consist of the best Dutch experts in their fields. Teams work on incidental and additionally financed activities, as opposed to the regular, structurally financed activities of the climate research consortium. The work should reflect the current state of science on the relevant topic.

The main commissioning bodies are the National Environmental Policy Plan departments, with the Ministry of Housing, Spatial Planning and the Environment assuming a coordinating role. Work is also commissioned by organisations in society playing an important role in the decision-making process concerned with and the implementation of the climate policy. A consortium consisting of the Netherlands Environmental Assessment Agency (PBL), the Royal Dutch Meteorological Institute, the Climate Change and Biosphere Research Centre (CCB) of Wageningen University and Research Centre (WUR), the Energy research Centre of the Netherlands (ECN), the Netherlands Research Programme on Climate Change Centre at the VU University of Amsterdam (CCVUA), the International Centre for Integrative Studies of the University of Maastricht (UM/ICIS) and the Copernicus Institute at Utrecht University (UU) is responsible for the implementation. The Netherlands Environmental Assessment Agency (PBL), as the main contracting body, is chairing the Steering Committee.

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Preface

Peatlands constitute a major carbon stock in the terrestrial biosphere and a large source of human-induced greenhouse gas emissions. A growing international awareness of their vulnerability is leading to an increased pressure to minimize human impacts on peatlands. Most attention is given to tropical peatlands as areas with high biodiversity value that are currently under threat of being logged and drained. Several studies have addressed the emissions from deforested and degraded tropical peatlands.
In this report we explore the link of the Netherlands with the use of peatlands worldwide and try to quantify the associated emissions. Where possible, alternative options with lower emissions are presented. With this report we wish to provide a clearer picture of the relation between the Netherlands and peatlands in the hope that this will lead to a wiser use of peatland.

We thank all that have assisted in preparing this document, including the WAB secretariat. Their support is highly appreciated.

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Samenvatting

Van de terrestrische ecosystemen zijn de veengebieden wat ruimtebeslag betreft de meest efficiënte koolstofputten. De onzekerheden over de exacte omvang en locaties van deze koolstofputten zijn echter groot.

In Nederland is de tuinbouw een belangrijke gebruiker van veen als basis-materiaal voor potgrond. De jaarlijkse CO_2-emissie samenhangend met de import van veen voor de tuinbouw in Nederland is 0,2-0,3 Mton. Dit is ongeveer 0,15% van de nationaal gerapporteerde CO_2-emissies. Ontginning, transport en verpakking van veen zorgt voor nog eens 0,1 Mton per jaar. Meer dan de helft van het geïmporteerde veen wordt echter weer geëxporteerd en is niet opgenomen in de Nederlandse rapportage. In vergelijking hiermee liggen de emissies als gevolg van de verwarming van kassen in Nederland met ongeveer 4% van de nationaal gerapporteerde CO_2-emissies aanzienlijk hoger.

Er is een aantal opties om met het gebruik van veen samenhangende emissies te reduceren:
- verwerking van lokale organische materialen tot potgrond van hoge kwaliteit,
- vermijden van transport door bv. de ontwikkeling van lokale alternatieven voor veen,
- verbranding van gebruikt veen voor de productie van energie.

Bijna 10% van Nederland bestaat uit veen; hiervan is het overgrote deel (ongeveer 80%) in gebruik als grasland voor de melkveehouderij. De CO_2 die uit deze gebieden vrijkomt als gevolg van mineralisatie van veen bedraagt ongeveer 2-3% van de totale gerapporteerde CO_2-emissies in Nederland.

Verhoging van het slootwaterpeil is een relatief eenvoudige manier om deze emissies te verminderen. Dit is echter nadelig voor de melkveehouderij. Door gebruik van een combinatie van onderwaterdrains en een hoger slootwaterpeil is een reductie van 50% mogelijk zonder nadelige effecten voor de melkveehouderij. De exacte effectiviteit en duurzaamheid van deze optie is echter nog niet goed onderzocht. Het bedekken van de veengronden met een laag minerale grond van enkele decimeters is een andere – dure - optie om de CO_2-emissies te verminderen.

Bij voortzetting van het huidige beheer zullen de problemen van bodemdaling en CO_2-uitstoot niet verminderen. Het peilbeheer gericht op de melkveehouderij resulteert onvermijdelijk in bodemdaling en een toename van kwel van eutroof of brak water. Ook het verhogen van sloten en het slootwaterpeil om het grondwater in bebouwde gebieden en natuurgebieden hoog te houden zal op termijn minder effectief zijn. Op den duur zullen er hogere dijken nodig zijn om het water buiten te houden.

Ook zal de totale oppervlakte veengebieden blijven afnemen, en daarmee ook de emissies uit deze gebieden. In de afgelopen decennia is al een belangrijk deel van de ondiepe venen in Nederland verdwenen. Hierbij moet wel worden opgemerkt dat gebieden met een veenpakket van minder dan 40 cm niet als veengrond worden geclassificeerd maar nog wel decennia lang CO_2 kunnen blijven uitstoten.

Door klimaatverandering zullen ook problemen met mineralisatie, verdroging en ontwatering van de veengebieden toenemen. Met een toename van het aantal droge jaren zullen bodemdaling en CO_2-emissies dus toenemen.

'Paliducultuur' of natte landbouw kan bijdragen tot het vasthouden en eventueel versterken van de koolstoffunctie van veengebieden. Met het duurzaam gebruik van veengebieden via 'paliducultuur' is echter nog weinig ervaring.

Bepaling van de relatie tussen de Nederlandse economie en veen in de tropen is lastig. Productketens zijn over het algemeen slecht gedocumenteerd en voor bulkproducten die gemengd worden is het nagenoeg onmogelijk de exacte oorsprong te achterhalen. Er worden

zeker op veen geteelde producten uit de tropen ingevoerd; hiervan zijn ananas en palmolie de bekendste.

Uitbreiding van het oliepalmareaal wordt gezien als een bedreiging van tropische bossen. Het verband tussen deze expansie en ontbossing is echter niet erg sterk. Palmolie is een belangrijke inkomstenbron is voor landen, boeren en bedrijven. Het sociaal-economisch belang van palmolie wordt vaak vergeten in de duurzaamheidsdiscussie maar is een cruciaal element om uit de huidige impasse te komen.

Er wordt verwacht dat de vraag naar palmolie zal toenemen met de bevolkingsgroei in onder andere China en India. De uitdaging is om te voldoen aan deze toenemende vraag en daarbij bossen, venen en andere koolstofputten te beschermen en niet verder te exploiteren. Verhoging van de productie op de al aanwezige oliepalmplantages lijkt de meest voor de hand liggende oplossing.

Productieverhoging kan de behoefte aan land verlagen. Daarnaast kan via certificering en een transparante keten meer duidelijkheid verkregen worden over de oorsprong en impact van productiesystemen en -methoden. Helaas worden bij het opzetten van certificeringschema's kleine boeren niet als volwaardige partner beschouwd, waardoor de kans bestaat dat deze negatief worden getroffen. In Indonesië, waar de productie van palmolie voor een belangrijk deel in handen is van kleine boeren, is een systeem gericht op deze kleine producenten gewenst.

Executive Summary

Peatlands are the most space-effective carbon stocks of all terrestrial ecosystems. Peatlands are found on all continents, the uncertainties regarding their size and exact locations, however, are very high.

Horticulture is the main user of peat in the Netherlands. The annual emission of carbon dioxide from peat import for horticulture in the Netherlands is 0.2-0.3 Mton. This is about 0.15% of the overall national carbon dioxide (CO_2) emissions. An additional 0.1 Mton is emitted by peat extraction, transport, and packaging. More than half of the imported peat is re-exported and thus not included in the Dutch emission reports. In comparison heating glasshouses is responsible for about 4% of the total CO_2 emissions.

Effective measures to reduce peat-related carbon dioxide emissions in horticulture include:
- Reworking local agricultural materials into high quality potting soil constituents.
- Avoiding emissions by reducing transport, e.g., via local development of renewable alternatives for peat.
- Burning used peat for energy production.

Almost 10% of the Netherlands is classified as peatsoils, of these soils about 80% is in use as permanent grassland for dairy farming. The CO_2 emission caused by peat oxidation from these areas is responsible for about 2 – 3% of the national CO_2 emissions.

A relatively simple way to reduce these emission is by raising ditch water levels. This, however, has a negative affect on the dairy farming sector. The use of submerged drains combined with raising ditch water levels may reduce CO_2 emissions by 50% and allow for a viable dairy sector. This option, however, requires further study into effectiveness and sustainability. Covering peatsoils with a few decimetres of mineral soil is another (but expensive) option to diminish CO_2 emissions.

It is unlikely that under current management the problems with peatsoils in the Netherlands will decrease. The ongoing subsidence and adjustment of ditchwater levels to the lowered surface will cause increasing upward seepage of,in some areas, brackish or nutrient-rich water. “High water ditches” to keep groundwater levels of built-up and natural areas high sooner or later become less effective or even useless. Due to ongoing subsidence the polders need higher and higher dikes to keep the water out.

As the total peatland area in the Netherlands will continue to diminish, CO_2 emissions from peatlands will also decrease. In fact already a large part of shallow peatsoils have disappeared during the last decades. Areas with an organic layer less than 40 cm are not classified as peatlands but continue to emit large amounts of CO_2 from the remaining peat for several decades.

Climate change will considerably increase most problems associated with peatsoils in the Netherlands. According to most climate change scenarios, the number of extremely dry years will increase by at least 70% in the next 100 years, leading to increasing subsidence and CO_2 emission rates.

Paludiculture, i.e. agriculture on wet peatlands, has the potential to allow for sustainable exploitation of peatland while reducing emissions or even inducing carbon sequestration in newly formed peat. So far experience with the implementation and exploitation of paludiculture, however, is limited.

Establishing a correlation between economic activities in the Netherlands and the exploitation of tropical peatland is difficult. Values chains are poorly documented and for bulk products that are mixed it is virtually impossible to determine the exact origin of product or raw material. But

clearly the Netherlands does import products originating from tropical peat, of these pineapple and palm oil are the best known.

Of the products imported into the Netherlands palm oil is the most threatening to tropical peatlands. The relation between deforestation and expansion of oil palm, however, is weak. Palm oil represent a large development opportunity for countries, farmers and industries, and the socio-economic importance of palm oil in the producing countries is often ignored leading to a stalemate in the discussion.

Given the increasing demand from, e.g., India and China the main challenge is to meet this demand without clearing forests, reclaiming peatland, or exploiting other carbon stocks. A successful strategy could be to increase productivity on already established oil palm plantations.

Increasing the per area output can alleviate the pressure on the land. This alone will, however, not be enough, certification and transparency throughout the values chain are needed to gain insight in the origin and impact of production systems and methods and to gain trust of consumers. Unfortunately in many cases certification schemes fail to include smallholders. This is particularly important for Indonesia with a significant percentage of the economic size and area of palm oil linked to smallholder farmers. Understanding decision-making and risk management and how certification and transparency in the values chain will affect farmers is important to avoid market exclusion of smallholders.

1 Introduction

In its last assessment report IPCC (2007) working group III reported that in 2004 energy supply accounted for about 26% of global greenhouse gas (GHG) emissions, industry for 19%, land-use change and forestry for 17%, agriculture for 14%, and transport for 13%, with the remainder originating from residential, commercial and service sectors, and the waste sector. Uncertainties remain high, particularly as regards CH_4 and N_2O emissions (error margin estimated to be in the order of 30-50%) and CO_2 emissions from agriculture and forestry with an even higher error margin (IPCC, 2007). One of the most notable new findings was that carbon emissions from peatland resulting from drainage and fires were estimated to be of the same order of magnitude as deforestation (2-3 Gton CO_2eq annually). But also here uncertainties in estimates are high as reliable emission data are rare.

Peatlands constitute a major carbon stock and a large source of human-induced emissions of greenhouse gases (IPCC, 2007). The increasing awareness of the vulnerability of peatlands leads to international pressure to minimize human activities in these areas. In this discussion most attention is given to tropical peatlands as these still represent areas with high biodiversity value and are currently under threat of being logged and drained. Several studies have tried to quantify emissions from deforested and degraded tropical peatlands (Page et al., 2002, Van der Werf et al., 2008), but also activities to reduce fires and emissions are ongoing (e.g. http://www.ckpp.org/). The underlying causes of peatland degradation are not well studied but market forces, weak implementation of policies, high population densities, and low incomes are most likely important drivers.

Consumers in developed countries are becoming aware of how individual choices can influence markets and market development. Agriculture is in the centre of this discussion with food - e.g. meat - (FAO, 2006) and biofuels production. Agriculture on peatland in most cases leads to peatland degradation with the following outcomes:

- Increase of greenhouse gas emissions, mainly related to drainage and fire.
- Desiccation as water is no longer retained in the landscape.
- Increased runoff of nutrients (e.g. nitrate) to groundwater and surface waters.
- Loss of biodiversity and landscape values.
- Loss of local production capacity.

How the Dutch economy is linked to national and global peatland use and degradation is not clear. Realistic options to manage or reduce emissions and associated costs or benefits have not yet been mapped out. This report provides a first estimate on the importance of peatlands and carbon flows related to the Netherlands. Where possible options to minimize peat oxidation, alternative land uses and products are presented. Also the potentials of payments for environmental services related to low carbon intensive land uses and products are discussed. It is a first step in identifying responsibilities and defining mechanisms to alleviate negative effects resulting from the use and cultivation of peatlands.

Peat is the most suitable substrate for container plants and a variety of related purposes in horticulture. In Dutch horticulture peat has been used for over 100 years and has deeply influenced the design of irrigation and potting equipment. Gradual substitution of peat by other materials is therefore possible but not simple. Horticulture in the Netherlands relies largely on peat imported from the Baltic States.

The Dutch fenmeadow area is a typical culture landscape. The oldest signs of human interference in the area date back to 1500 BC. The peat area of western Netherlands is inhabited by people since ca 1000 AD. Large parts were used for peat extraction since 1400 AD. Arable agriculture followed by dairy farming, peat extraction, fishery, waste disposal and associated soil surface subsidence and water level management have shaped the landscape. Currently the dominant land use is dairy farming. Besides deriving their income from agriculture, dairy farmers play an essential role in maintaining the characteristic cultural-historic landscape and, more in general, in keeping the landscape open. The economic and carbon costs of these activities and possible alternatives are discussed.

The Netherlands is traditionally an important trader of agricultural commodities. This trade is not only important for the Dutch economy but also crucial for the producing countries and regions. The globalizing consumer and producer markets create a stronger link between consumer behavior and production practices. Demands from large developing countries like India and China are rapidly growing and these countries become active players in the globalized world economy. Agricultural activities on peatlands come with a cost in terms of carbon but also with potential economic benefits. The report provides a first overview of products originating from peatlands and imported into the Netherlands.

The aim of this assessment is to identify vulnerabilities of and threats to the Dutch economy resulting from pressure to refrain from cultivation of peatlands and to identify alternative activities and rural development options.

1.1 Layout of the report

This assessment addresses four topics. Starting with a short overview of what peat is and where it can be found, we move to the importance of peat for horticulture in the Netherlands. The following chapter deals with peatlands in the Netherlands and the consequences of current land use for the national greenhouse gas balance, agricultural productivity, landscape, and biodiversity. In the final chapter an inventory of imported products from peatlands outside Europe, notably South East Asia is presented. The report ends with conclusions and recommendations.

2 Peat

Peat consist of partly-decomposed plant material. Normally dead plant material is decomposed to form soil organic matter or is completely lost to the atmosphere. In wetlands with a stable water level, the dead plant material does not fully decompose but accumulates as peat. An area with such an accumulated peat layer at the surface is called a peatland. Where peat accumulation has continued for thousands of years, the land may be covered with layers of peat that are many meters thick. Peats have by the very nature of their parent material a large carbon content.

Peatlands are the most space-effective carbon (C) stocks of all terrestrial ecosystems. In the (sub)polar zone, peatlands contain on average at least 3.5 times, in the boreal zone 7 times, in the tropical zone 10 times more carbon per ha than ecosystems on mineral soils (Joosten & Couwenberg, 2008).

2.1 Global peatland distribution

Because the genesis of peat is typically linked to water-logged, acid and low-nutrient conditions (factors that hamper the decomposition of plant material) most peat areas are found in the (sub)arctic, boreal, and temperate climate zones. Peatlands are found on all continents, from the tropical lowlands to the Siberian tundra. The scarcity of peatlands in the southern hemisphere is due to the absence of land in the relevant ecological zones (Figure 1).

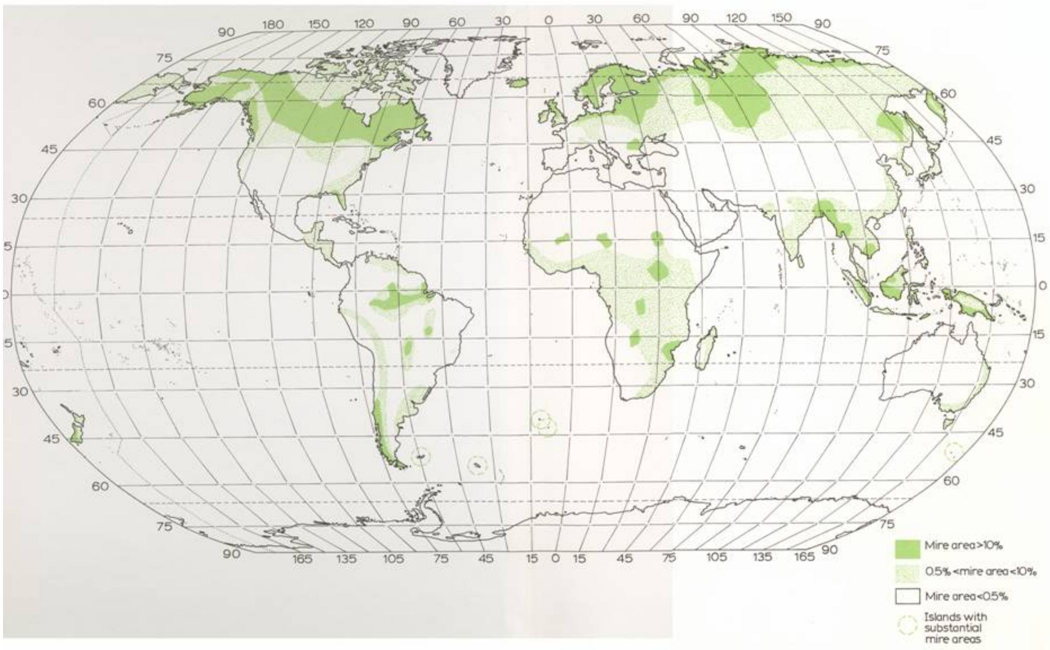

Figure 1 Distribution of peatlands (Gore,1983)

2.2 Europe

The distribution of organic soils in Europe shows a strong northern bias. Outside the former Soviet-Union, almost one-third of the European peatland resource is in Finland, and more than a quarter is located in Sweden. Substantial areas of peatland are also found in Poland, the UK, Norway, Germany, Ireland, Estonia, Latvia, the Netherlands, and France. Small areas of peatland and peat-topped soils are also present in Lithuania, Hungary, Denmark and the Czech Republic (Montanarella et al., 2006; Figure 2).

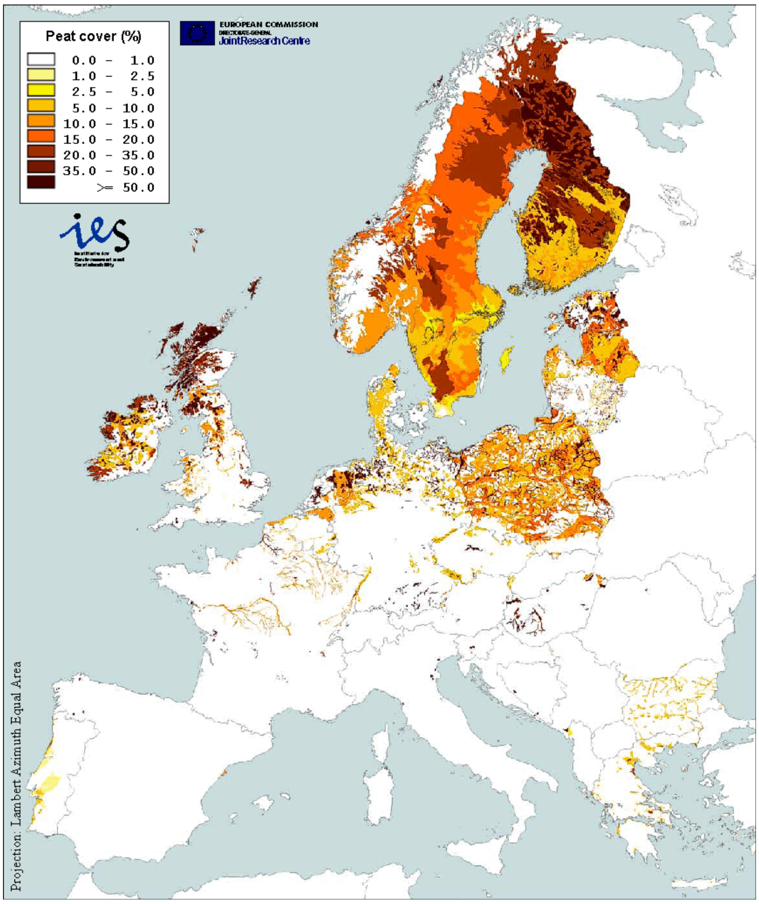

Figure 2 Peatland distribution in Europe (Montanarella et al., 2006)

2.3 Peat and the carbon budget

The most recent reviews estimate that approximately 4–5 10^{12} m^2 (2.5–3.5% of the land area of the world) is covered with a peat layer deeper than 0.3 m (Maltby & Immirzi, 1993; Lappalainen, 1996; Joosten & Clarke, 2002). Rieley et al. (2008) estimate the area of tropical peatland to be 0.3–0.45 10^{12} m^2. Most of it is still under forest cover, but large parts have been selectively logged.

Because of the diversity in land cover (varying from forest, shrubland, to open grassland) peatlands are extremely difficult to map using remote sensing. Assessing peatlands merely on the basis of the vegetation and other surfacial landscape characteristics is error-prone, presented data ranges in literature on global peatland area are merely compilations of different estimates. Assessing the carbon stocks in peatland using remote sensing is impossible. Here the inventory relies fully on field mapping and extrapolation. For most countries no such field data are available. And even the best investigated country in the world, Finland, has only mapped a quarter of its peatland area in detail.

The lack of accurate inventory data results in a range of estimates of the amount of carbon stored in peatlands. According to Gruber et al. (2004) about 450 Pg C of the soil carbon is locked in wetlands and peatlands against 3,150 Pg C in the soil and 650 Pg C in living biomass. Parish & Canadell (2006) estimated a carbon store for tropical peatlands in SE Asia of about 50-90 Pg C, with a carbon store in Indonesian peatlands of up to 70 Pg C. More recently, Jaenicke et al. (2008) presented an estimated carbon store of 55 ±10 Pg for Indonesian peatlands.

Bulk density (dry weight) is perhaps the most important characteristic of peat because it links to other physical and chemical properties. Andriesse (1988) and Boelter (1974) indicate a large range of bulk densities (on a dry weight basis) from around 50 kg m^{-3} for fresh peat to about 200 kg m^{-3} for well-decomposed material, Andriesse reports a maximum of 500 kg m^{-3}. Bulk densities are mainly related to the moisture regime and the proportion of clastic (mineral) material. Drainage of peat results in changes in bulk density and hence changes in the physical and chemical characteristics of the peat.

The organic carbon content of peat may range from 12 to 60% (Andriesse 1988). This value is of particular importance when determining CO_2 emission based on the loss of peat material, as has been the case in tropical peatlands. Melling (2005) reports a value range of 45–48% C for peats in Sarawak, Kool et al. (2006) used a C content of 50%. Hooijer et al. (2006), referring to Page et al. (2002), took a C content of 60%. Watson et al. (2000) suggest as default for IPCC guidelines a 50% C content for woody species; for plant material values in the range of 45 – 50% are common.

The soil organic carbon pool to 1-m depth ranges from 30 10^3 kg ha^{-1} in arid climates to 800 10^3 kg ha^{-1} in organic soils in cold regions with as predominant range of 50 10^3 to 150 10^3 kg ha^{-1} (Lal, 2004). In mineral soils the surface layers normally contain more carbon than the subsoil layers. In peatland carbon contents remain high throughout the peat profile.

The concentrated carbon reservoirs that peatlands represent require special attention as their disturbance may result in large carbon emissions to the atmosphere. Peatland drainage and peat fires are perhaps the best know factors in this but grazing and peat extraction result in carbon emissions as well. As most human interventions in peatlands start with draining the land, human interventions almost always turn peat into significant sources of greenhouse gases. After drainage peat compaction and oxidation result in lowering of the surface with consequences for buildings, infrastructure, agriculture and water management. Conventional agriculture requires an aerated root zone and a dry soil to avoid trampling by cattle and to allow the use of agricultural machinery, so water management is crucial to allow continuation of agricultural production.

The process of peatland degradation after drainage is largely irreversible. Emission of carbon continues until the peat is rewetted. Deep drainage will result in larger losses over shorter periods of time, but even shallow drainage may result in large losses over time (Fokkens,1970; Schothorst,1982; Van den Akker et al., 2008; Hooijer et al., 2006). With increasing temperatures and longer periods of drought oxidation of peat will increase considerably (Hendriks et al., 2007).

Restoring peat formation is difficult, even with a restored hydrology. In most peatlands slowing down or stopping degradation is the best achievable option. This, however, comes at a cost for current land use systems. On the other hand, very destructive types of land management can be replaced by less damaging land use systems to slow down the peatland degradation process (e.g. conversion of arable land into permanent grassland, use of perennial crops, paludiculture or wet reforestation).

The potent greenhouse gas methane is formed under anaerobic conditions as found in wet peatlands. Northern peatlands are large sources of methane with an estimated annual emission of 0.02 and 0.05 Pg C (Mikaloff Fletcher et al., 2004a, b). Methane production by bacteria is strongly temperature-driven, with higher temperatures resulting in higher methane emissions. This will especially be critical for permafrost peatlands (Walter et al., 2006). The net greenhouse gas balance is, however, positive for most natural peatlands. Human and natural disturbance of peatlands (e.g. increased temperatures, draining, burning, grazing and mining) will turn these large carbon stocks into carbon sources.
The loss and degradation of peatlands is linked to:

- degradation of biodiversity: loss of many (rare) species
- degradation of hydrological regulation capacity, as drained peatlands loose their buffer, sponge, and storage functions
- degradation of climate, as drained peatlands emit huge amounts of CO_2 (depending on drainage depths 10–50 t ha^{-1} yr^{-1}, worldwide 2 Gigatons a^{-1}) and considerable amounts of N_2O
- loss of height through subsidence, eventually making gravity drainage impossible and necessitating (expensive) polder management
- degradation of water quality, as peat oxidation emits much nitrate, and polder pumping may lead to intrusion of salt water
- soil degradation, as drained peat may dry out irreversibly, making adequate water supply to crops impossible
- social degradation, because these problems lead to loss of rural employment and traditional livelihoods.

3 Glasshouse horticulture

Globally an area of 2 10^9 m^2 is actively being used by the peat industry for peat extraction, with 1.2 10^9 m^2 in the EU alone (www.epagma.org). In 2005 peat extraction in the EU totalled a volume of 65 10^6 m^3. A total of 68 10^6 m^3 peat is used in the EU, meaning an import of about 3 10^6 m^3 from outside the EU. About 50% or 34 10^6 m^3 is used for energy, mainly in Sweden, Finland, and Ireland. Horticulture claims 42% or 29 10^6 m^3 peat. The Netherlands, which has no national peat extraction, is an important importer of peat with 3.6 10^6 m^3.

The growing media industry represents an industry of 1.3 billion euro turnover and accounting for 11,000 jobs across the EU Member States. It is particularly important in Germany, Italy, the Netherlands, France and the UK (www.epagma.org).

Dutch glasshouse horticulture produces a net value of 4-4.5 billion euro annually (PT, 2007). Related products by industrial suppliers may easily boost this amount to 6 billion euro in total. The export value is even higher. For cut flowers the export value is 2.2 billion, for container plants 1.9 billion and for tree crops 0.4 billion (LEI, 2005). The estimated share of exported products ranges from 70 to 80% of the total production (PT, 2007).

Annually Dutch potting soil producers import 4.2 million cubic meters peat from the Baltic states (Estland, Letland and Lituania), Sweden, Finland, Ireland and Russia (Tables 2 and 3). Roughly one third is used in glasshouse horticulture, one third for the outdoor/consumer market and one third is directly exported. The monetary value of the peat import is over 170 million euro.

Peat is the most suitable substrate for container plants and a variety of related purposes such as producing preformed propagation plugs (Schmilewski 2008; Blok & Verhagen, in press). As the transport costs of peat play an important role, various areas in the world do not rely upon peat at all. The Mediterranean countries, Australia, the Southern United States etc. use large amounts of non-peat materials, especially bark, as basis for horticultural substrates (Warren et al., in press). In the Netherlands peat has been used for over 100 years as the main substrate for container plants. Consequently, practice and experience are based on working with peat, also deeply influencing the design of irrigation and potting equipment. Substitution of peat by other materials is therefore possible but not simple (Van Leeuwen et al., 2005).

Over the last decade, the use of other materials has nevertheless increased from 10 to 30% (Van Leeuwen et al., 2005; Blok & Verhagen, in press). The main peat substitutes – or rather peat diluents - are coir products, bark, composts and wood fiber (Blok & Verhagen, in press). All are renewable but some require more transport and processing and thus cause a considerable carbon dioxide production (Van Maanen, 1999).

Table 1 Differences in peat qualities, origins and uses, and densities

Peat quality	*Origin*	*Main uses*	*Dry bulk density kg.m^{-3}*	*Relative quantity in % of m^{-3}*	*In this study in kg.m^{-3}*
Sphagnum peat	Norway, Sweden, Finland, Baltic states, Canada	Container plants, container trees, propagation	85	19	100
Peat litter	Germany, Poland, Ireland	Propagation, container trees, container plants	90	26	100
Transitional peat	Ireland, Germany	Propagation, container trees	115	26	100
Frozen black peat	Germany	Propagation, bedded plants, hobby sector	140	15	140
Black peat not fully frozen	Germany	Press pot propagation	140	14	140

3.1 Approach

3.1.1 Peat qualities

The various peat materials differ in dry bulk density (Bos et al., 2002; Table 2). For this study the dry bulk density is an important criterion as it is proportional with the potential amount of carbon dioxide the materials represent. The natural variation in density within the classes is still considerable and therefore it was decided to use only two groups for this study; light peat of 100 $kg.m^{-3}$ and dark peat of 140 $kg.m^{-3}$.

3.1.2 Peat application/decomposition rate

The most important difference between the various uses is the temperature at which the material is kept. Peat used for outdoor tree crops, annuals and in the hobby sector will thus generally decompose slower than peat used in glasshouses. A further subdivision based on application is not made because in the long term this does not affect the amount of carbon released to the atmosphere.

3.1.3 Directly exported peat

The amount of peat that after processing is directly exported to other countries is subtracted from the amount of peat decomposing in the Netherlands. As the material is not instantly transported abroad but stays in the Netherlands for some time, it could be argued that some decomposition takes place in the Netherlands. The average duration of storage between import and export is highly variable but is on average one month. The carbon dioxide released in that period is not taken into consideration as the peat is mainly stored unfertilized and relatively dry, which slows microbial decomposition.

3.1.4 Indirectly exported peat

The amount of peat exported in the form of container plants is not registered. Based on export data it is assumed that about 70-80% of all container plants are exported (PT, 2007).

A part of this indirectly exported peat will decompose in the Netherlands before leaving the country. The amount that decomposes depends mainly on the length of the period and the temperature during this period. The average production period from peat import up to container plant export varies from less than 3 months for container chrysanthemum to more than 6 months for most green container plants. It was decided to take an average period of 6 months between import and export.

Also the actual decomposition in this period is an uncertain factor. Decomposition in the first months after filling the containers is thought to be considerable because the material is amply fertilized and thoroughly watered at an elevated temperature favoring microbial decomposition. The mass loss of wood fiber under such circumstances in six months can be as much as 50%. The mass loss of wood fiber is 10 times that of an average peat under optimal laboratory circumstances (Veeken, 2003; Weerheijm & Blok, 2008). Correspondingly, peat breakdown in a six-month period is set to 5% of the total mass.

3.1.5 Decomposition ratio

A small part of peat is made up of mineral particles and a small part of the organic material will remain as mineral ash, both remaining after oxidation (incl. burning). Furthermore a small part of the peat may become incorporated in the soil organic matter fraction deemed stable. In this study it is assumed that 85% (DW) of the peat will eventually be oxidized. This estimate is higher than presented in the IPCC guideline (2006). The higher value is thought necessary as the dry bulk densities presented here are based on different drying methods which for most pure peats render carbon contents between 56-58% (Botch et al., 1995).

3.1.6 Peat carbon content

Generally 58% of dry plant mass is carbon. As peat is highly pure plant tissue 58% was thought a fair estimate (energy plants using a broader range of peats report 45-60% in Papaanen et al. (2006)). Carbon from peat is released as carbon dioxide with a conversion factor of 3.67.

3.2 Economic size and importance for the Dutch economy

The amounts of peat materials imported were found in the literature and checked with the RHP, the branch organization and quality institute of the Dutch potting soil producers (Van Maanen 1999; Blok & Verhagen, in press). The gross import quantity estimate is 4 233 000 m^3 per year. The sales value of the products ranges from 20-50 euro per m^3. As figures were slightly differing between sources it was decided to base this document on the overall estimates in Table 3 and adapt the estimates in subsequent tables to fit the overall quantities in Table 3.

Table 2 Annual volumes of potting soil traded as peat and others in various market divisions

The Netherlands 2006 Market division	peat m^3	others m^3	total	% non peat
Floriculture	1630	400	2030	20
Hardy nursery stock	526	169	695	24
Vegetable growing	618	33	651	5
Fruit growing	64	16	80	20
Casing soils	375	125	500	25
Other	180	19	199	10
All hobby/retail use	560	140	700	
Total growing media market	3953	902	4855	19
Soil improvers professional	105	945	1050	90
Soil improvers hobby/retail	175	175	350	50
Total imported	4233	2022	6255	32
direct EU export growing media	859	196	1055	19
direct non-EU export growing media	244	56	300	19

Source: RHP, trade figures 2006.
NB The figures on the exported growing media are included in the figures given for the growing media market divisions above.

Although the price of potting soil is a small fraction of the total costs of the final product, usually about 1%, the added value is considerable. The consequences of even a slightly inferior potting soil are production and quality problems with the plants growing on the material. In liability cases the direct damage alone often amounts to 20-50 times the original price of the potting soil, indicating the importance of reliability and quality of potting soils. The substitution of peat is therefore not without consequences (Van Maanen, 1999; Schmilewski, 2008; Blok & Verhagen, in press).

3.3 Importance of peat for the sector

Slightly more than one third is used in glasshouse horticulture, slightly less than one third for the retail or consumer market, and one third is directly exported (Table 3). The main uses are container plants, container trees, propagation and hobby market. The hobby market is much smaller in terms of money than the more expensive potting soils that are used in the glasshouse industry.

Container plants are subdivided into flowering container plants, green plants and bedded plants. Flowering and green plants are used as indoor ornamentals. Bedded plants like garden plants, are sown in small pressed cups and are sold as such or after transplanting. They are sold to consumers and for landscaping. The container trees are also sold to consumers, fruit growers and for landscaping (outdoor ornamentals). Propagation in pressed pots is the basis for a lot of container plants. In the statistics there is sometimes overlap between tree crops and glasshouse crops (some tree crops are grown under plastic or glass roofs) and between bedded plants and propagation. Casing soil is used as a growing medium for mushrooms.

3.4 GHG emissions

Table 3 brings together all information. The result is an estimate of the annual carbon dioxide release caused by peat import into the Netherlands. The 0.2-0.3 Mton of carbon dioxide is about 0.15% of the overall national release and 4% of the release as a result of glasshouse heating. The total Dutch carbon dioxide emission in 2005 was 220 Mton carbon dioxide (CBS, 2005). The emission for horticulture was 6.5 Mton of which almost 1 Mton was for public electricity generation (Van Staalduinen, 2008).

Table 3 Overview of peat imports, exports and their contribution to carbon dioxide emissions in the Netherlands

Row	Description	Unit	Factor	Light peats	Dark peats	Total
1	Amount	m^3 x 1000		2,983	1,250	4,233
2	Costs	euro/m^3		25	35	
3	Value	Mio euro		75	44	118
4	Directly exported	m^3 x 1000		953	150	1,103
5	Indirectly exported	%	0.7			
6	Remains	Months	6			
7	Lost	%	0.05			
8	Indirectly exported	m^3 x 1000		1,350	732	2,081
9	Remaining	m^3 x 1000		680	369	1,049
10	Degradation ratio	%	0.85			
11	Degrading	m^3 x 1000		578	313	891
12	Dry bulk density	$kg.m^{-3}$		100	140	
13	Conversion to carbon	$kg.kg^{-1}$	0.58			
14	Carbon	kg x 1000		33,526	25,434	58,960
15	Conversion to CO_2	kg	3.67			
16	Carbon dioxide	kg x 1000		122 930	93 258	216 188
17	CO_2 emission	Mton/yr		0.12	0.09	0.22

Row 1: the amount of cubic meters in 2006 (RHP, Blok & Verhagen, in press).
Row 2: the cost price per cubic meter in euro (estimated, 2006).
Row 3; the economic value of the import in 2006 (R3 = R1 * R2).
Row 4: The amount of material imported but sold off to customers in other (European) countries before growing plants. This amount is subtracted from the totals before the emissions are calculated.
Row 5: The estimated percentage of material with plants on them, sold off to consumers in other (European) countries. This amount is partly subtracted from the totals before calculating the emissions.
Row 6: The estimated average stay in the Netherlands of indirectly exported peat (in container plants).
Row 7: The estimated % of mass of peat material lost during the period in row 6.
Row 8: The amount of cubic meters indirectly exported (R8 = (R1 - R4) * R5 * (1 - R7).
Row 9: The amount of material remaining in Holland (R1 - R4 - R8).
Row 10: Estimated degradation ratio, giving the percentage of peat eventually turned into carbon dioxide. The mass not included here is mineral mass and peat eventually burned for energy production.
Row 11: Amount of peat degrading in Holland.

Row 12: Dry bulk density of the materials. As usually over 95% of the material is organic in nature, the total is taken as the amount of dry organic material (Row 10 compensates for mineral impurities).
Row 13: The conversion to carbon. The basic conversion of peat to carbon is based on the assumption that 58% of the dry weight is carbon.
Row 14: The amount of the element carbon (R14 = R11 * R12 * R13).
Row 15: The conversion factor of carbon to the amount of carbon dioxide released. The molecular weight of carbon dioxide is 3.67 times that of carbon.
Row 16: The calculation of the amount of carbon dioxide released (R16 = R14 * R15).
Row 17: The amount of carbon dioxide released in Mton (R17 = R16 / 1000).

Most of the transport is done via bulk shipping. Sods for fractioning (a special product) and black peats from Germany are transported predominantly by truck; white peat is transported for over 70% of the distance by ship. Truck transport is 10-15 times less efficient in terms of energy and carbon dioxide release than shipping (Van Maanen, 1999). An average shipload ranges from 10,000 to 20,000 m^3. About 500 shiploads are imported each year, making 1400 kilometers for a single trip. The number of trucks per year is about 10,000 with an average of 400-1700 km per truck depending on whether the transport is black peat from Germany or sod peat from Scandinavia or the Baltic states. The related energy use is taken from Van Maanen (1999) as 420 $MJ.m^{-3}$ for dark peat and 552 $MJ.m^{-3}$ for light peat. The data of Van Maanen are summarized in Table 4.

Table 4 Energy and carbon dioxide stored in peat and used for transport, production and packaging (after Van Maanen 1999)

	Energy in $GJ.m^{-3}$	%	kg $CO_2.m^{-3}$	%
Peat mass (intrinsic)	2.1	62	180	72
Transport	1.1	32	59	23
Production and packaging	0.2	6	11	4
Total	3.4	100	251	100

3.5 Alternatives and their consequences

The alternative materials which currently are used to (partly) substitute peat in potting soil mixtures are listed in Table 5. Imported materials from agricultural waste products are coir products (India, Sri Lanka), rice husks (Italy), and bark (France, Germany). Imported or locally produced non-agricultural products are pumice (Germany, Iceland), expanded clay (Germany), rockwool (NL), perlite (NL), vermiculite (Saudi Arabia), and synthetics (Benelux). Locally produced and composted organic waste materials are: green compost, household compost, spent mushroom substrate, composted agricultural waste, manures, digestates. Locally improved organic waste materials other than composts include torrefacted reed, bound flax or hemp stem waste.

Table 5 Volumes of potting soil constituents traded in cubic meters

Potting soil constituent	m^3 (2001)	m^3 (2006)	Value.m^{-3} euro.m^{-3}	Value million euros
Coir products	150,000	250,000	40	10.0
Bark	100,000	200,000	30	6.0
Perlite	85,000	100,000	50	5.0
Composts	10	65,000	15	1.0
Rockwool granulate	50,000	50,000	40	2.0
Clay (fresh)	25,000	30,000	30	0.9
Expanded clay	15,000	15,000	50	0.8
Pumice	15,000	15,000	20	0.3
Sand	15,000	15,000	15	0.2
Wood fiber	1000	14,000	25	0.4
Rice hulls	10,000	10,000	30	0.3
Others	10,000	10,000	30	0.3
Vermiculite	3,000	8,000	50	0.4
Sphagnum	1,000	5,000	50	0.3
Total				27.8

3.5.1 Economic size of alternatives

A lot of common sense and research has gone into the formulation of potting soil mixtures which match the productive capacity of the traditional peat based mixtures (Van Leeuwen et al., 2005). It is now accepted that the amount of peat in mixtures can be reduced from over 70% at present to an average of 30% without loss of production or quality. To do so growers need to invest in new irrigation systems.

3.5.2 Emissions from alternatives

The paramount factor is whether the material is renewable (agricultural) or non-renewable (fossil). For non-renewable organic materials carbon dioxide release is equivalent to dry weight and organic matter content. But another factor of importance is the amount of transport involved. Remarks on the use of coir (cocos) products and, e.g., palm fibers may be in place as these involve long-distance transport. Most local organic materials will only contribute through processing and transport as they are renewable and may be regarded as carbon dioxide neutral. The mineral materials will partly require energy for quarrying and transport or require substantial amounts of energy for production. Synthetic materials are based on oil products and will contribute to carbon dioxide emission when decomposing. For rockwool a life cycle analysis has been performed which may serve as a bench mark for all substrates in the market (Van Maanen, 1999; Verhagen & Boon, 2008).

3.6 Importance for the Baltic states

Based on a value of about 20 euro m^{-3} peat the total export value of 6 million m^3 peat (2 million ton) is 120 million euro. The import of Baltic peat to Holland is 1 million m^3, equivalent to 20 million euro. The importance of peat for the horticultural multibillion business in the Netherlands has already been indicated. In order to assess the importance of peat for the national economies in the Baltic countries its importance should be indicated in terms of contribution of the peat sector to, e.g., the gross domestic product. The GDP in the Baltic countries is in between 14 and 17 billion euro (2007). In terms of GDP the peat sector is a minor activity. The contribution of peat in terms of income generated by the agricultural sector may also be relevant. Total agricultural production in the three Baltic countries is in the range of 630 to 1596 million euro, again indicating that the peat sector is a small sector (Eurostat data base, 2007).

3.7 Carbon emissions at the source

The harvesting of peat requires draining, thus increasing its mineralization. These mineralization losses are highly variable but are reportedly very large, ranging from 10-100% of the mass sold. Peat (sphagnum) harvesting is done by extracting the top layer of living peat. A level surface that facilitates mechanical removal of the top layer is preferred but not always feasible. Prior to mechanical harvesting surface vegetation is removed and the peat is drained. The area is then harrowed to expose the top layer to sun and wind. After drying, the peat is vacuumed with harvesting machinery.

After harvesting the peat is stored in large piles or stacks until it is transported to the processing facility. Typically, the more valuable professional-grade peat is found near the surface (Quinty & Rochefort 2003). Harvested areas rarely return to functional peatland because the biophysical and hydrological conditions are unfavourable for sphagnum re-growth (Heathwaite, 1994; Price, 1996).

4 Dutch peatlands

The major part of Dutch peatlands is in agricultural use, mainly as grassland for dairy farming. The continuing decomposition (oxidation) of organic matter causes a continuing subsidence of these peatsoils. The water level of the ditches are regularly adjusted to the lowered soil surface, so that the processes of oxidation and shrinkage continue until virtually all peat has been decomposed. In this way oxidation is the main factor responsible for subsidence over the long term. Typical peatland subsidence rates in the Netherlands range from a few millimetres to as much as 5 centimetres per year depending on drainage and temperature. Subsidence of one centimetre per year equates to an emission of about 22.6 t CO_2 per hectare per year (Kuikman et al., 2005; Van den Akker et al., 2008). Subsidence and the associated lowering of ditchwater and groundwater levels may also damage infrastructure and buildings while water management becomes more complex and expensive.

The oxidation of peat soils depends strongly on the groundwater level in summer when evapotranspiration exceeds precipitation. This results in a lowering of the groundwater level because the infiltration capacity of water from the ditches into the peatsoil is low. The peat above groundwater level is aerated which leads to accelerated biological degradation of the organic matter in peat. The low groundwater levels in summer and the fact that biological degradation strongly depends on temperature, causes that more than 80% of the total peat oxidation occurs during the summer half year (Hendriks et al., 2008).

4.1 Peatland conservation

Many wetlands in the Netherlands are difficult to preserve as “natural” wetland because subsidence of adjacent drained agricultural land results in 'islands of peatland' surrounded by lower agricultural lands. The net effect is a constant drainage of the wetlands. As a result semi-natural and natural peatlands have become rare. On the other hand, some peatlands have been in agricultural use for centuries and are part of European cultural heritage and represent highly valued landscapes and meadow bird regions. This is especially true for the Western peat areas of the Netherlands. Peatlands also act as natural stores and filters affecting water quantity and quality. Thus, peatlands are a significant issue in the Ramsar Convention, the Framework Convention on Climate Change, the Convention on Biological Diversity, and other international instruments and agreements.

The Guidelines for Global Action Plan on Peatlands (GAPP)[1] of the Ramsar Convention state that the wise use, conservation and management of the World’s peatlands assets are constrained by limited scientific and technical information and by the effects of economic, socio-cultural and environmental factors. The Ramsar Bureau plays an active role in the implementation of the Pan-European Biological and Landscape Diversity Strategy and in the implementation of the Convention on Biological Diversity.

4.1.1 Current situation

Increased drainage of peatland areas started around 1960 when the economic situation of dairy farming in the peat areas became worse because the high groundwater levels made modern agriculture with heavy machinery and many cows per hectare impossible. Therefore, in 1960–1970 ditch water levels were lowered from a mean of 20–30 cm minus surface prior to 1960 to 60 cm minus surface in the Western peat areas and up to 120–150 cm minus surface in the Northern peat areas. A rule of thumb states that every 10 cm lowering of ditch water level results in an extra subsidence of 1–2 mm per year. This means that in the Western peat areas the subsidence rate was doubled and in the Northern peat areas it quadrupled.

1 Ramsar Scientific and Technical Review Panel, 2001. 10th meeting of the Scientific and Technical Review Panel, Gland, Switserland, 27-29 June 2001. www.ramsar.org/strp_10minutes.htm

Generally, there are significant spatial differences in subsidence within a polder because water levels vary as ditches are not equally spaced, some fields may have a protective clay layer and some parts of the polder have seepage. With time, differences in subsidence and subsequent adjustments (fine-tuning) of water levels in ditches result in a very complicated hydrological situation which makes water management increasingly difficult and expensive. The subsidence of drained agricultural peat areas and subsequent lowering of water levels in ditches may also cause drainage of surrounding non-agricultural areas, which then may lead to increases in the incidence of drought and to damage of buildings and infrastructure.

Drainage of peat soils also contributes to eutrophication of surface waters. Upon drainage and the mineralization of peat, large amounts of nitrogen (100-300 kg N ha^{-1} yr^{-1}) and also phosphorus are released. Part of these nutrients may leach to the surrounding surface waters in autumn and winter. The mean N and P concentrations in peat land polders in the Netherlands are on average high, which reflects the eutrophic nature of the peat and the influence of nutrient-rich seepage. In peat soils nutrient-rich seepage can contribute up to more than 50% of the nitrogen and phosphate load (Hendriks et al., 2002) of surface waters. This will increase considerably when lowering of ditch water levels continues.

Current problems in the peat areas are highly complex. A gradual subsidence and a gradual adaptation of ditchwater levels to a lowering of the surface level have been common features for many centuries. However, the increased subsidence rates during the last 4 decades are unprecedented and aggravated the problems. The low groundwater levels in summer and the fact that biological degradation strongly depends on temperature causes that more than 80% of the total peat oxidation occurs in the summer half year (Hendriks et al., 2008).

Solutions are mainly sought in raising ditchwater levels. The National Spatial Strategy (Nota Ruimte, 2005) states that special attention should be paid to agriculture in peat areas. Land-based agriculture is important to these man-made landscapes, so unique internationally. The policy for the peat areas is generally aimed at maintaining or raising the groundwater levels. Suggested is a ditchwater level of 40 cm below the soil surface to reduce subsidence in vulnerable peat areas. This is a typical compromise because subsidence will still be 4-8 mm per year and it will affect the economic viability of viable dairy farming on these wet soils.

In the “Voorloper Groene Hart, concept 2008, Gedeputeerde staten van Noord-Holland, Utrecht en Zuid-Holland”,the three western provinces with peat soils present a vision for 2040 and propose measures for the period 2008-2020. This vision for 2040 includes:

- a well preserved and improved cultural historic landscape,
- sustainable water management and minimal subsidence,
- an economically viable agriculture,
- a highly appreciated nature with a high biodiversity,
- an attractive recreational area for the citizens of the nearby cities, and
- an enabling environment for living, working and enterprises.

The spatial planning up to 2020 to concretize this vision is conservation and development of landscape diversity and conservation and development of the valuable and unique peat meadow areas. In the strategy to diminish subsidence three vulnerability classes are distinguished: very vulnerable, vulnerable, and moderate or not vulnerable. Very vulnerable peat areas are designated to become nature-including areas with low-intensity agriculture. Vulnerable peat areas will be conserved as peat meadow areas with a strong and viable dairy farming. Subsidence will be limited with innovative techniques, such as infiltration with submerged drains. Soil tillage (for silage maize growing) will be forbidden. There will be no restrictions for agriculture in moderately vulnerable or non-vulnerable peat areas.

4.1.2 Inventory of peatland area and land use

The peatland area in the Netherlands is about 335,000 ha; this area, however, is decreasing due to oxidation of peat. An inventory in 2001-2003 (De Vries, 2004) on 70% of the shallow peatsoils indicated that about 49,000 ha of the areas classified as peatsoils in the initial soil survey of the Netherlands lost this classification. A peatsoil loses it status if the thickness of the peat layer within 80 cm depth is less than 40 cm. Based on the inventory in 2001–2003 De Vries (2004) estimated that about 18,000 ha of the not investigated 30% of the shallow peatsoils lost its classification. This means that since 1970 a total of about 67,000 ha of the shallow peat soils degraded and moved into another soil class. The area and land use and loss of peatsoils is presented in Figure 3. The area of peatsoils used in official reporting of CO2 emissions of peatsoils in agricultural use in 2003 is 223,000 ha; because the estimated loss of 18,000 ha is not proven, it is not used in the official reporting. A map presenting this official area of peatsoils is presented in Figure 4. The area of peatsoils in 2003 in agricultural use is probably 205,000 ha, mainly as permanent grassland for dairy farming (85–90%).

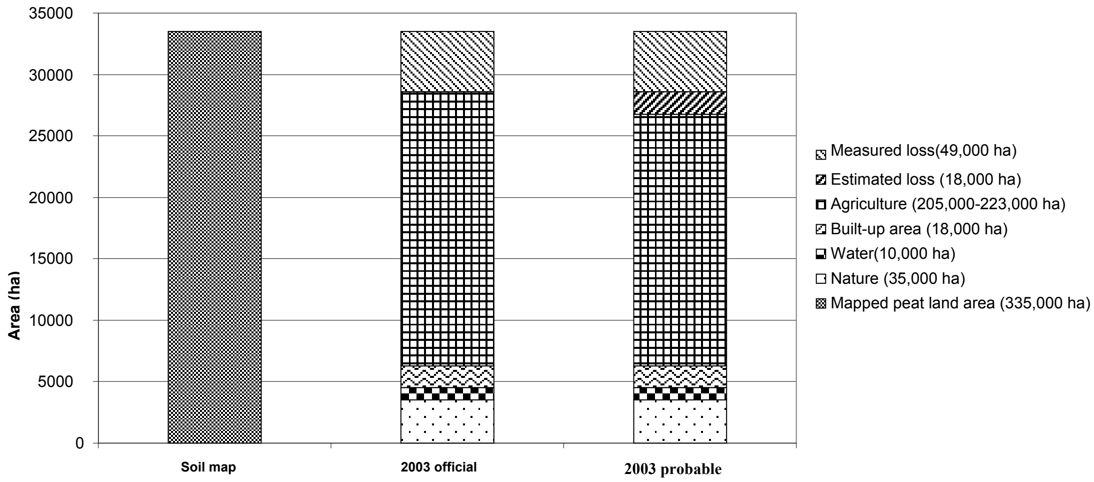

Figure 3 Area according to the Dutch Soil Map 1 : 50 000 and official and estimated land use and loss of peatsoils in 2003

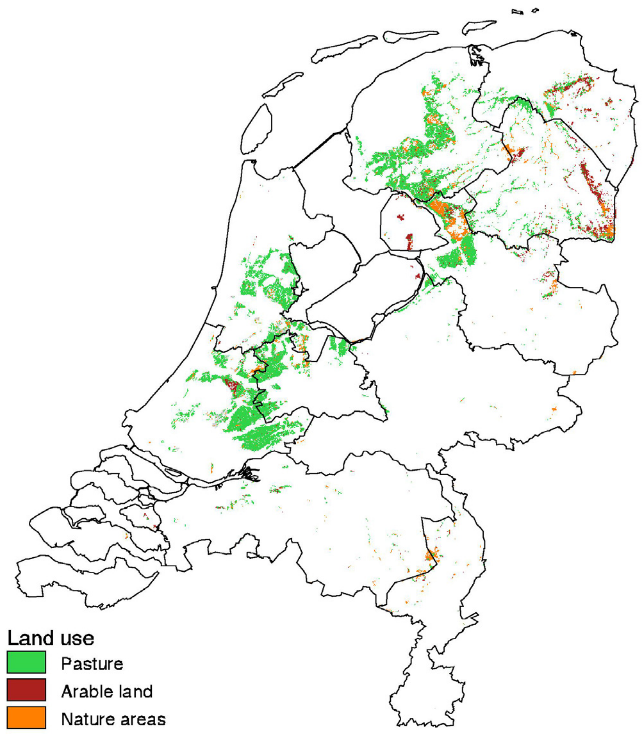

Figure 4 Land use of Dutch peatsoils (Source: Landgebruikskaart Nederland LGN4 (Land use map of the Netherlands, 2001)). (Source: De Vries, 2005).

4.1.3 Economic importance

Dutch peatlands are mainly used for agriculture, especially for dairy farming. And although there are even some important urban centers on peat we will focus on the dairy farming sector in this section. The dairy sector has the largest spatial claim (see pasture in Figure 4) and its economic activities are directly linked to the peatland. In many parts of these areas there are few alternatives to pasture.

The economic importance of the dairy sector in the peatland area for the Dutch economy can be expressed by its value added, or its contribution to the gross domestic product (GDP). The economic size of different sectors within Dutch agriculture is expressed in Dutch size units (dsu), One dsu is equivalent to a certain amount expressed in gross standardized margin (gsm) which comes close to a standardized value of gross value added. A Dutch cow is equivalent to 1710 gsm. In the Netherlands the number of cows that can be kept on a hectare is strongly limited by manure legislation. Because of this regulation most dairy farms do not deviate far from the average of approximately 1.6 dairy cows per ha. At the level of 1.6 cow per ha a value of € 2736 per ha in gsm is realized. Apart from the value added by the young stock (a relatively small part) the contribution of peatland to the Dutch economy can therefore be estimated at 223,000 ha times € 2736 = € 610 million. This is considered the maximum estimation because a large part of the peatland is used with a lower gsm (e.g. most arable land and nature areas). Moreover, research revealed an over-estimation of the gsm for cows in peatland areas of about 10% (Van der Ploeg et al., 2001). More information can be found on the site of the Dutch agricultural economics research institute
(http://www3.lei.wur.nl/bin_asp/?database=LTC&language=1).

Additional economic data:

Production:
During the last years of the past century milk production of dairy farms on peatland was 13% lower than on other Dutch dairy farms (Van Everdingen et al., 2001). At present (figures 2007) an average Dutch dairy farm produces approximately 13,000 kg milk per hectare, with an average production of around 8,000 kg milk per cow on an annual basis.

Capital:
The prices of agricultural land (available on the free market) in the peatland area in the Netherlands over 2007 range from about € 24,000 per ha in the northern parts of the country to € 33,000 per ha in the central and western parts of the country (LEI, 2008).

This is slightly below the average land prices in the Netherlands. Lower land prices result in lower costs for land, the earlier mentioned economic disadvantages are therefore at least partly levelled out by the land prices. The average Dutch dairy farm constitutes a value of around € 2.3 million, roughly 60% of this value is brought in by the members of the family, the rest on loan.

Costs and profits:
The total output of an average Dutch dairy farm in 2007 ads up to € 300,000 per annum, whereas the total costs (including calculated costs of capital and labor input) reach an amount of € 313,000 per annum. An overview of the Dutch dairy farming results is given in Table 6.

Table 6 Economic results of dairy farms

		2005	2006	2007	2008
Total output		220,800	230,700	299,700	286,500
Total payments of costs and depreciation (excluding rent)		141,100	158,700	176,100	199,400
Calculated labour costs		77,300	78,000	78,900	82,900
Of which	Entrepreneurs	72,600	73,200	73,500	
Calculated capital costs		37,300	58,000	58,300	38,500
Of which	Land	5,000	13,900	15,500	
	Other tangible assets	23,800	33,700	29,500	
	Organic assets	4,900	5,800	7,100	
	Monetary assets	3,600	4,600	6,200	
Total farm economic costs		255,800	294,700	313,300	320,800
Net farm result		-34,900	-64,000	-13,700	-34,200
Rate of return (output per 100 euro costs)		86	78	96	89
Family labor income		42,400	14,000	65,200	48,700
Labor income as % of labour costs		55	18	83	59
Income as % of unpaid costs					

Source: http://www3.lei.wur.nl/bin_asp/frm_start_binternet.aspx?database=LTC&language=1

Raising the groundwater level to 35 cm or higher will decrease the rate of subsidence but will at the same time decrease the possibilities for farming. It has been estimated that raising the groundwater level from a mean of 60 to a mean of 35 cm below surface decreases the productivity of the land and lowers farm income by approximately 270 euro per ha per year, which is equivalent to 11,000 euro per farm per year. This loss is considered too high to survive economically, without additional compensation. The nature value of the land increases when groundwater is shallower, and this may become an additional income source in the near future (cross compliances, agri-environmental regulations).

4.1.4 Emissions

The Netherlands periodically reports greenhouse gas emissions to the UNFCCC secretariat in Bonn via a national inventory. Such an inventory should be based on internationally comparable methodologies, be public and transparent, include all sources and removals by sinks of all greenhouse gases. The way how this is done for peatsoils in the Netherlands is presented by Kuikman et al. (2005). This report deals with country-specific methods to calculate nitrous oxide (N_2O) and carbon dioxide (CO_2) emissions related to management of organic soils. The total area of organic soils in agricultural use in 2003 is, based on inventories, estimated at 223,000 ha. This area continues to decrease due to oxidation of shallow peatsoils. The calculated annual emission of CO_2 amounts to 4.246 Mton CO_2 and for N_2O to 0.508 Mton CO_2 equivalents.

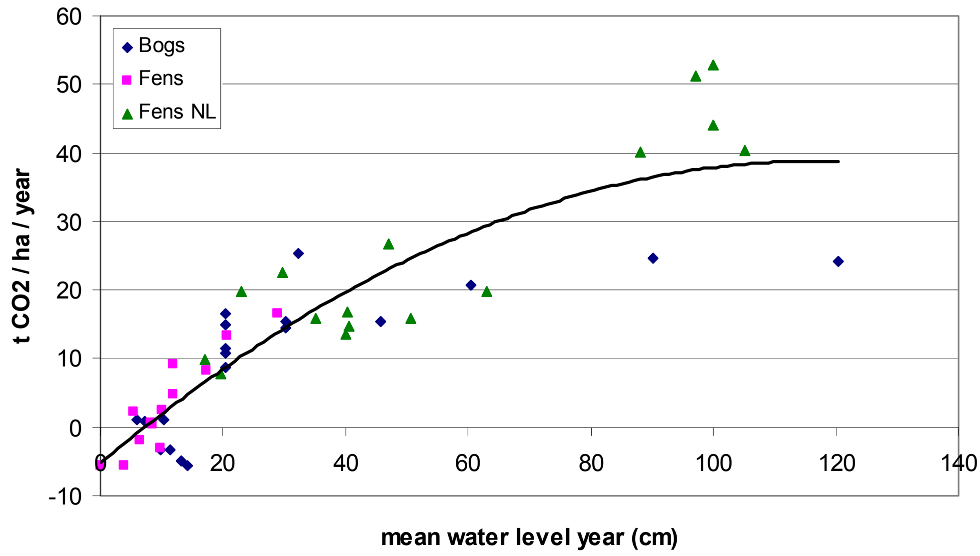

Figure 5 *CO_2 emission of peat soils. Agricultural peatsoils have at least a mean ditch water level of 20 cm minus soil surface. Data collected by Couwenberg et al. (2008) based on direct measurements of CO_2 emissions and emissions calculated from measured mean annual subsidence and Van den Akker (Fens NL, unpublished data) based on CO_2 emissions calculated from measured mean annual subsidence*

The oxidation of peat soils in agricultural use results in large CO_2 emissions (see Figure 5). The data of Couwenberg et al. (2008) in Figure 5 have been derived from a literature study. Measurements of CO_2 emissions are difficult because measurements not only include the CO_2 emission of the peat but also the oxidation of fresh organic material and respiration and sequestration of CO_2. Daily and seasonal variations also affect CO_2 emissions. Therefore data collection was restricted to peatlands from temperate Europe and only data on annual emissions were used – based either on year-round measurements or on sound model extrapolations. Only net CO_2 balances (NEE or NEP) from reliable models using light and dark fluxes were used. Also net-emission estimates based on subsidence observations were included by Couwenberg et al. (2008). The data of Van den Akker (unpublished data) are calculated from subsidence. The calculation of CO_2 emissions on the basis of the annual long-term subsidence rate is very robust because it is in fact a mass balance in view of the fact that subsidence is from a long-term perspective mainly caused by the net loss of organic matter by oxidation. Moreover subsidence is usually measured over many years (sometimes decades), so seasonal and yearly variations in CO_2 are averaged over a long period. The main problem is to determine which part of subsidence of drained peat soils is caused by the organic matter oxidation of the peat soil and not by consolidation of the peat layer and permanent shrinkage of the upper part of the peat soil above groundwater level. According to Armentano & Menges (1986), the fraction *Fr* of subsidence due to oxidation of organic matter compared to total subsidence mostly ranges from 0.33 to 0.67. This fraction also depends strongly on the period in which subsidence is measured; directly after drainage subsidence rates are very high due to shrinkage and consolidation. According to Eggelsman (1976) the fraction *Fr* over time is 0.7; Kasimir-Klemedtsson et al. (1997) also used this value in their calculation of CO_2 emissions from subsidence. In their calculation they used the bulk density and carbon content of the upper 20 cm, but these values may vary considerably. For this reason, and to avoid estimation of the fraction *Fr* Kuikman et al. (2005) and Van den Akker et al. (2008) calculate CO_2 emission based on the amount of carbon in the fibric peat layer below the deepest groundwater level and a thickness of the annual subsidence. In this calculation the fraction Fr is 1.0. The results of Van den Akker in Figure 5 are calculated in this way. These calculated emissions show good agreement with Höper (2007) for German peatsoils in agricultural use. Höper (2007) also found that bog peatsoils show more or less similar GHG emissions as fen peatsoils at high ditchwater levels (40–60 cm below soil surface) and much lower GHG emissions at low ditchwater levels (around 90 cm and deeper below soil surface).

The rate of subsidence depends on hydrology, peat type, and the presence of clay layers. It ranges from 2 to 25 mm yr^{-1}, with an average of 8 mm yr^{-1} in The Netherlands (Kuikman et al., 2005). Peat oxidation results in an estimated mean annual CO_2 emission of 19 t CO_2 per hectare. As shown in Figure 5, however, CO_2 emissions of grassland for dairy farming range from less than 10 to more than 50 t CO_2 ha^{-1} yr^{-1}. About 35% of the Netherlands is covered with a thin clay layer (about 25-30 cm thick). This reduces the average subsidence by 4 mm per year (Van den Akker et al., 2007) and the annual CO_2 emission by about 9 t CO_2 per ha. The total contribution of peat soils to CO_2 emission of the Netherlands is estimated at 4.2 Mton CO_2 per year and for N_2O at 0.508 Mton CO_2 equivalents per year (Kuikman et al., 2005).

Results of reviews of Couwenberg et al. (2008), Kaat & Joosten (2008) and Franken & Van den Born (2006) on GHG emissions of eutrofic and mesotrofic peatsoils are collected in Table 7. Couwenberg et al. (2008) considered the measurements of N_2O emissions insufficiently reliable for inclusion in their table. Figure 5 and Table 7 show that only very wet peatland systems have a potential of CO_2 sequestration. According to Kaat & Joosten (2008) the carbon sequestration rate is in the order of magnitude of 0.1–0.4 t C per ha per year in the subarctic, boreal and temperate zone, and may reach 1–2 t C per ha per year in temperate and tropical swamp forest peatlands. In Table 7, row 12, we converted this C sequestration into a CO_2 sequestration of 3.7 - 7.3 t per ha per year. In Table 7, row 13, Franken & Van der Born (2006) suggest an annual CO_2 sequestration of 11 t per ha, which is based on a C sequestration of 3 t C per ha per year, which represents a very optimal situation for C sequestration. On the other hand, they also present values for CH_4 and N_2O emissions expressed in CO_2 equivalents. All this leads us to conclude that swamp forests might have a net annual CO_2 sequestration of 3.7 t per ha.

Table 7 Water management of eutrofic and mesotrofic peatland areas and GHG emission, including net balance (+ = emission, - = sequestration, conversions to CO_2 equivalents consider a 100 year horizon), (modified table Couwenberg et al., 2008 with some additions). N/A = Not Available; DWLw = Ditch Water Level wet season; DWLd = Ditch Water Level dry season

Soil and water management	CO_2 (t CO_2 ha^{-1} yr^{-1})	CH_4 (t CO_2eq ha^{-1} yr^{-1})	N_2O (t CO_2eq ha^{-1} yr^{-1})	Total (t CO_2eq ha^{-1} yr^{-1})
Grazed and mown, dairy farming (1) (business as usual) DWL: -60 cm	18.1 - 27.1	0	2.4 - 3.6	20.4 - 30.7
Moderately moist forbes and meadows DWLw: -35 to -70 cm DWLd: -45 to -85 cm	24	0	N/A	24
Moist forbes and meadows DWLw: -15 to -35 cm DWLd: -20 to -45 cm	15	1.5	N/A	16.5
Very moist meadows DWLw: -5 to -35 cm DWLd: -10 to -45 cm	13	3.5	N/A	16.5
Very moist meadows, forbes and tall reeds DWLw: -5 to -15 cm DWLd: -10 to -20 cm	8	3	N/A	11
Very moist tall sedge marshes DWLw: +10 to -15 cm DWLd: +0 to -20 cm	2.5	2.5	N/A	5
Wet tall sedge marshes DWLw: +10 to -5 cm DWLd: +0 to -10 cm	0	7	N/A	7

Soil and water management	CO_2 (t CO_2 ha^{-1} yr^{-1})	CH_4 (t CO_2eq ha^{-1} yr^{-1})	N_2O (t CO_2eq ha^{-1} yr^{-1})	Total (t CO_2eq ha^{-1} yr^{-1})
Wet moss dominated short sedge marshes DWLw: +10 to -5 cm DWLd: +0 to -10 cm	0	4	N/A	4
Wet short & tall reeds; moss layer DWLw: +10 to -5 cm DWLd: +0 to -10 cm	0	12.5	N/A	12.5
Wet tall reeds DWLw: +10 to -5 cm DWLd: +0 to -10 cm	0	10	N/A	10
Flooded tall and short reeds DWLw: +150 to +10 cm DWLd: +140 to +0 cm	0	1	N/A	1
Swamp forest (2)	-3.7 - -7.3	N/A	N/A	-3.7 - -7.3
Swamp forest (3) DWL: +0 to -20 cm	-11	2.7	0.9	-7.4

(1) National Inventory Report (Klein Goldewijk et al., 2005), as calculated by Kuikman et al. (2005) in compliance with IPCC standards. Range: peatsoil with (lower value) and without (higher value) thin clay cover (< 40 cm).

(2) Kaat & Joosten (2008)

(3) Franken & Van den Born (2006)

N/A: Not Available

4.2 Outlook: alternatives and options

4.2.1 Land use change

A straight-forward solution to reduce GHG emissions from peatlands is land use change, in which water tables are raised and land use activities are adjusted to this new situation (see Table 7). About 35% of the Dutch peatsoils have a thin (< 40 cm) cover of clay on top. This reduces the average subsidence by 4 mm per year (Van den Akker et al., 2007) and CO_2 emission by about 9 t CO_2 per ha per year. The CO_2 emission of peatsoils with a thin clay cover is still about 18 t CO_2 per ha per year. Because peatsoils with a thin clay cover have a reduced CO_2 emission, it is logical to concentrate land use change on peatsoils without clay cover.

Transition to wetter conditions will have to deal with potentially large initial emissions. Flooding highly productive grassland with easily degradable biomass and a nutrient-rich upper peat layer may result in extremely high methane emissions (Couwenberg et al., 2008). Topsoil removal to avoid these extreme methane emissions or to avoid leaching of nutrients may cause CO_2 emissions, depending on the processing of this topsoil (Couwenberg et al., 2008).

4.2.2 Peatlands in agricultural use

About 80% of the Dutch peatsoils is in agricultural use. Current policies aim at preserving the cultural historic agricultural landscape and at stimulating economically viable agriculture. So even when areas would be converted, the major part will most likely remain in use as commercial agricultural land. Solutions are therefore needed to minimize GHG emissions of these peatsoils in agricultural use. Because more than 80% of the subsidence is caused during the summer half year, solutions should focus on reducing emissions during this period (Hendriks et al., 2008). Raising the water level in ditches is only partly effective because the lateral infiltration of water from ditches into the soil is very slow. A technique currently tested is

infiltration via submerged drainage. However, this solution requires further study as regards effectiveness, sustainability, and effect on water management and water quality.
Results of a model study (Van den Akker et al., 2007) into the effect of climate change and water management on subsidence and CO_2 emission are presented in Figure 6. Subsidence and CO_2 emissions are presented as percentage of the subsidence and CO_2 emission of the situation in the period 1971–2000 with a ditch water level of 60 cm below surface. This is a very common ditch water level in the western peatland area in the Netherlands and enables economically viable dairy farming. Raising ditch water levels proves to be an effective measure to diminish CO_2 emission and subsidence. Submerged drains strongly enhance subsurface irrigation resulting in a considerabledecrease in subsidence and CO_2 emission. The effect of submerged drains on calculated subsidence (and CO_2 emission) using empirical relations between groundwater level and subsidence (Van den Akker et al., 2007) are encouraging.

An other advantage of submerged drains is that they also function as drain, lowering groundwater levels during wet periods. For dairy farming this means that a combination of submerged drains with, e.g., ditchwater levels of 40–50 cm below surface could be a good alternative to a peatsoil without submerged drains and a ditchwater level of 60 cm below surface. The results in Figure 6 show that the effects of climate change on subsidence and CO_2 emissions are significant (60–70% increase). Using submerged drains to diminish subsidence and CO_2 emission promises to be very effective in this climate change scenario.

Another solution to reduce oxidation of peatsoils is to cover the peat with mineral soil. The extra weight will cause substantial subsidence by compaction and consolidation; this will, however, become minimal over time, while subsidence due to oxidation is an ongoing process. In fact, covering peatsoil with dredgings and muck and rubbish from nearby cities and villages has been practiced for centuries in the peat areas to improve soil quality and bearing capacity of these peatsoils. Over time this resulted in a - sometimes decimeters thick - manmade cover, a so-called “toemaakdek”. High heavy metal concentrations in this layer are sometimes problematic. Covering peatsoils requires large quantities of suitable mineral soil. Availability and costs might be a problem but this solution might be a profitable long-term investment.

Most studies focus on the peatlands in the western part of the Netherlands; large peat areas, however, are also found in the northern part of the Netherlands (Figure 4). Ditch water levels in these agricultural areas are low, ranging from 100–120 cm below the surface. This means a potential CO_2 emission of 40–50 t CO_2 ha^{-1} yr^{-1} (Figure 5). Raising ditch water levels to, e.g., 60 cm below surface may reduce these CO_2 emissions by 50%. However, in this area distances between ditches are much wider than in the western peat areas, which means that raising ditch water levels will result in very wet fields during wet periods. The currently promoted strategy is raising ditch water levels up to 80 cm below surface in the summer period.

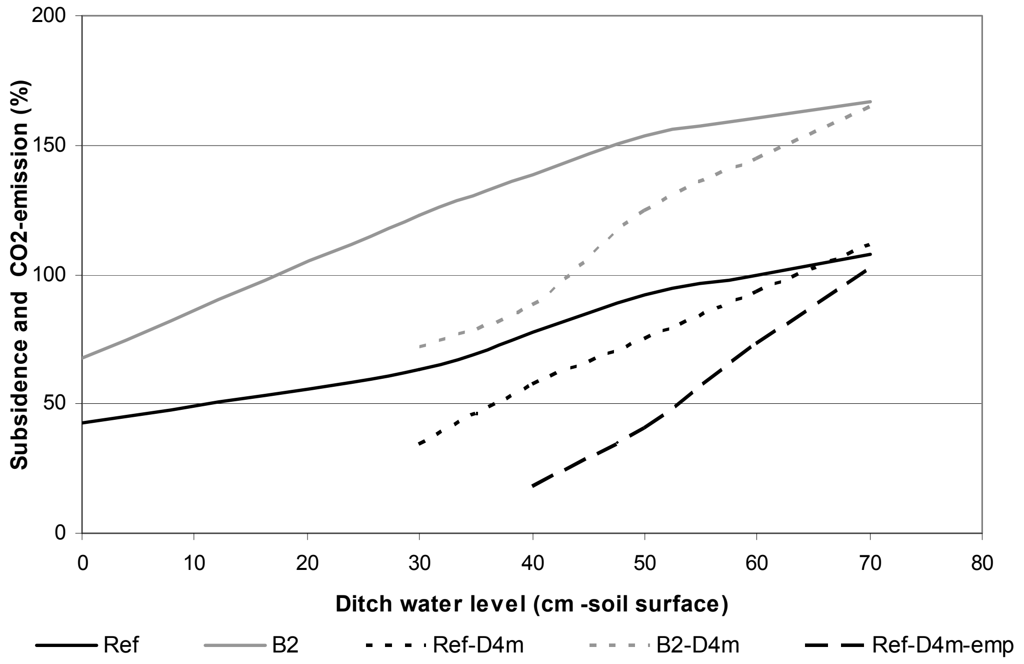

Figure 6 *Effect of water management and climate change on subsidence and CO_2 emission of a representative Dutch peatsoil without a thin (< 40 cm) clay layer and a ditch water level of 60 cm below surface. The climatic reference period is 1971-2000. The chosen climate change period is 2071–2100 under IPCC scenario B2 (moderate change). Ref = Reference; B2 = B2 scenario IPCC; Ref-D4m = Reference with submerged drains at 4 m distance; B2-D4m = B2 scenario with submerged drains at 4 m distance; Ref-D4m-emp = Reference with submerged drains at 4 m distance, however, subsidence calculated with empirical relations between groundwater level and subsidence (Van den Akker et al., 2007)*

5 Paludiculture

Peatland agriculture actually replicates agricultural practices applied on mineral lands (see Chapters 5 & 6), even when draining, tilling and fertilization are the most effective ways to enhance oxidation of peatlands. Generally, peatland drainage and use leads to severe degradation.

An innovative alternative to drainage-based peatland use is ‘*paludiculture*’: the sustainable production of biomass on peatlands that are so wet that the peat store is maintained or that peat accumulation is even re-installed. This strategy is especially successful for drained, degraded peatland where rewetting and subsequent paludiculture reduce the above-mentioned problems synergistically. Also some forms of grazing (with Heck cattle, moose and water buffalo) might be compatible with peat conserving wet conditions.

The basic principle of paludiculture is to cultivate plant species adopted to waterlogged conditions. Idealistically only thát part of net primary production (NPP) is harvested that is *not* necessary for peat formation (which is ca. 80-90% of NPP). In the temperate, subtropical and tropical zones, i.e. those zones where high plant production is possible, most peatlands by nature hold a vegetation of which the aboveground parts can be harvested without harming the peat sequestering capability. In these areas natural peatlands are dominated by cyperaceae (e.g. sedges, rushes, sawgrass, papyrus), grasses (e.g. reeds), and trees (e.g. alder, birch, spruce, larch, tropical peat swamp trees), i.e. growth forms that realize peat accumulation by rootlets, roots, and rhizomes (‘replacement peat’).

Paludicultures that have been tested for the European situation include:

- Reed (*Phragmites australis*) as an energy source and as an industrial raw material (incl. roofing material)
- Cattail (*Typha latifolia, T. angustifolia*) for industrial use (insulating materials, lightweight construction boards)
- Sedges (*Carex*) for both energetical and industrial use (incl. second generation biofuels)
- Alder (*Alnus glutinosa*) for veneer, carpentry, and high-quality wood furniture
- Reed canary grass (*Phalaris arundinacea*) for fodder and biofuels
- Peatmoss (*Sphagnum*) as a growing medium replacing fossil peat in horticulture.

In general, the carbon balance of these wetland systems is positive when compared to conventional agriculture.

5.1 Benefits

Paludicultures harbour a variety of species which in conventional agriculture are seldom found. As they restore wetland habitats, paludicultures also include species that have become rare and endangered because of the decline of their natural wet-humid habitats. A nice example is the conservation of the globally threatened Aquatic Warbler (*Acrocephalus paludicola*) in successfully commercially used reedlands in Western-Poland. In *Sphagnum* cultivation plots we can find species like *Drosera* (Sundew), Beak Sedge (*Rhynchospora*) and cranberry (*Oxycoccus*) that elsewhere are protected.

Besides the global climatic and regional biodiversity benefits, paludicultures have several additional advantages including:

- Improvement of regional hydrology because water is kept longer in the landscape
- Mitigation of regional climatic change by providing evapotranspiration cooling
- Reduction of nutrient run-off (e.g. nitrate) into surface waters
- Prevention of peatland fires
- Maintenance of an open cultural landscape
- Increased political autarchy by local production of energy and raw materials.

5.2 Prospects

There are 80 million hectares of drained peatlands worldwide. Rewetting these will substantially reduce global anthropogenic greenhouse gas emissions. Additionally, this rewetting can contribute to avoiding emissions by producing biomass for industrial use and for the generation of energy. Given a continuing rise in prices of biomass it is advisable to rewet as much peatland as possible, wherever the hydrological conditions permit.

Paludicultures are still in their infancy because agriculture, horticulture, and silviculture have traditionally focused on drained sites. Priority is to identify for every climatic zone species and races for optimal cultivation and to further develop the techniques for wet cultivation, harvest, and utilization.

Table 8 Productivity of selected gramineous paludicultures

Dominant species	Productivity t DW ha^{-1} yr^{-1}
Common Reed (Phragmites australis)	3.6 - 43.5
Cattail (Typha latifolia)	4.8 - 22.1
Reed Canary Grass (*Phalaris arundinacea*)	3.5 - 22.5
Sweet Reedgrass (*Glyceria maxima*)	4.0 - 14.9
Lesser Pond-sedge (*Carex acutiformis*)	5.4 - 7.6
Great Pond-sedge (*Carex riparia*)	3.3 - 12.0
High-intensity grassland	8.8 - 10.4

6 Products originating from peatlands outside Europe.

Most products from peatlands outside Europe originate from tropical peatlands. Tropical peatlands cover between 30 and 45 million hectares. Indonesia, Malaysia and Vietnam contain nearly 70% of this resource. About 50% of the total tropical peatland is found in Indonesia, with an estimate of 21 Mha (minimum area 16 Mha, maximum area 27 Mha) (Page & Banks, 2008). For Malaysia the estimated peatland area is 2.5 Mha (minimum 2.2 Mha and maximum 2.7 Mha) (Page & Banks, 2007). Ranges in the areas of peatlands, especially for Indonesia, indicate that there is considerable uncertainty in the estimates, which depends on the methodologies and definitions used to classify peatlands (see also Chapter 1). This uncertainty is also reflected in the regional distribution figures of tropical peatlands (Table 9).

Table 9 Summary Statistics for Tropical Peatlands (based on Immirzi & Maltby, 1992; Rieley et al., 1996; Reiley & Page, 2005)

Region Area (1000 ha)	Mean	Range
Central America	2,437	2,276 - 2,599
South America	4,037	4,037
Africa	2,995	2,995
Asia (mainland)	2,351	1,351 - 3,351
Asia (southeast)	26,435	19,932 - 32,938
The Pacific	40	36 - 45
Total	38,295	30,627 - 45,965

Various products are grown on tropical peat ranging from rice to wood for pulp and paper. Most food crops grown on peat contribute to local food security. Other products are sold on local or international markets. Of the peat-grown products that are exported to Europe oil palm is perhaps best know. But several other commodities exported to Europe, e.g. pineapple and rubber, are grown on tropical peat as well.

Many food crops grown on peat are consumed locally/nationally, thus contributing to local food security. The yields of these crops remain low without proper water and nutrient management. Improving drainage and fertilizer application to enhance yield will also result in enhanced greenhouse gas emissions.

In this chapter we will look at products imported into the EU that could originate from peatland. The main agricultural products are palm oil and pineapple. Palm oil is exported to the Netherlands, most pineapple is shipped to Belgium. This chapter presents a first attempt to get an overview of the relation of the Netherlands with tropical peat with the aim to identify responsibilities and options in the conservation of peatlands.

6.1 Palm oil

FAO (http://faostat.fao.org/default.aspx) reports a total area harvested palm oil of 12.2 million ha in 2004, of which 3,4 million ha is located in Malaysia and 3.3 million ha in Indonesia. For 2006 these numbers already increased to 3.7 million ha for Malaysia and 4.1 million ha for Indonesia on a global total of 13.2 million ha. Clearly, the global increase in harvested area is strongly linked to the increase in Indonesia.

According to the Indonesian Bureau of Statistics (BPS) in 2006, 45% of total palm area is owned by private companies, followed closely at 43% by smallholders, while government-owned estates constitute the remaining 12%. Smallholders are frequently part of a partnership scheme with private companies. The total area of Indonesian palm oil in 2006 is estimated at

6.07 million hectares Indonesia Palm Oil Board (IPOB). Whether the discrepancy between harvested area and planted area is related to administrative errors or to the fact that a large part of the palm oil plantations in Indonesia is unproductive or immature is not clear. The RSPO reports that smallholders in Indonesia alone account of about 35% of the national output.

In 2004 Malaysia exported 12.2 million MT of crude palm oil (CPO) and 0.79 million MT palm kernel oil (PKO). Indonesia exported 8.6 million MT CPO and 0.84 PKO in 2004 (Oil World, 2004). More recent estimates by the USDA indicate that Indonesia equalled the Malaysia production of about 15 million MT of palm oil in 2005-2006. Since Indonesia's production increased more rapidly to about 18 million MT in 2008, about 1 million MT higher than Malaysia in that year. Main export markets are India, the European Union, China, and Pakistan. CPO is commonly used as frying oil. Mixes with PKO are used in various products, e.g., margarine, soaps, shampoos, cosmetics, ice cream, glycerine, and biodiesel. Most of the produced palm oil is processed for edible products.

The oil palm sector is an important contributor to local and national economies by providing jobs and income at production sites but also in the value chain. In 2004, the export value of palm oil amounted to US$ 6.3 billion for Malaysia and $ 4.1 billion for Indonesia, contributing to 5.6% and 1.7% of their gross national incomes respectively (The World Bank, 2006; Lian & Wilcove, 2007).

From FAO data it is clear that the increase in production can best be explained by the expansion of harvested area as production levels stabilised around 20 t fresh fruit bunch per ha in Malaysia and 17 t ha^{-1} in Indonesia.

Claims of deforestation and peatland destruction in relation to palm oil in Indonesia were highlighted by Hooijer et al. (2006). Based on concession data, Hooijer et al. (2006) estimated that in Indonesia some 2.8 Mha oil palm are located on peatlands. In Indonesia oil palm plantation concessions cover some 15% of the total peatland area. In addition, timber concession areas on peatlands cover some 2 Mha peatlands, amounting to 10%. As a result, approximately 25% of the peatlands in Indonesia are under oil palm or timber cultivation. For Malaysia these percentages are much lower; the estimate is around 5% of the peatland area being under oil palm plus timber cultivation.

The exact extent of plantations, however, is difficult to establish as concessions and actually established estates are not the same. Also in 2006 AIDEnvironment reported that "of the 2.5 million hectares of land already allocated to oil palm companies in the border provinces East and West Kalimantan, only 685,000 ha (20%) has been planted up to 2005". In East Kalimantan 2 million hectares are reserved for oil palm but only 303,000 hectares had been planted planted. For West Kalimantan only 354,000 ha were planted of the allocated 1.5 million hectares. These findings highlight the difficulties in using concession data as indication of the actual area of oil palm in Indonesia. More recently, permits for oil palm plantations in Central Kalimantan were reviewed for the Ex Mega Rice Master Planning Project: up to March 2008 22 permits for oil palm covering 350,000 ha were issued. Of these only a few started planting activities but so far no operational plantations are established in the ex-mega rice project area.

But even when numbers are not clear, the increasing demand for palm oil most likely resulted in an increase of oil palm on peatlands. The presented numbers by Friends of the Earth (2005), however, do not match as already indicated by Corley (2006). Friends of the Earth (2004) also stated that 87% of deforestation in Malaysia between 1985 and 2000 can be attributed to oil palm plantations; that may be correct but the palm oil industry expanded by about 2 Mha over that period, equivalent to about 10% of the remaining Dipterocarp forest area; other drivers seem to be important in deforestation.

Part of the expansion of oil palm has taken place in the coastal lowlands. As demand is still increasing, mainly driven by increased palm oil consumption in China and India, even without accounting for the emerging biofuels market, production needs to increase. Most likely this will result in more land converted into oil palm. Although ample scope exists to increase land productivity, many independent growers lack access to the high-yielding plant material or the financial resources to invest in inputs required to achieve annual yields of 10 t FFB ha^{-1}.

Government-supported growers, with equal sized land holding, yield 17 t FFB ha^{-1}, while with proper investments and management annual yields of up to 20 t FFB ha^{-1} are feasible. With an oil content of 22% this is 2.2, 3.7 and 4.4 t oil ha^{-1}. Basiron (2007) reports a national average for Indonesia of 3.7 t oil/ha/yr.
Oil palm is dominated by large-scale plantations, but depending on access to processing mills, smallholders are a crucial factor in the production palm oil; this is especially true for Indonesia. Recently designed sustainability criteria in Western Europe for the emerging biofuels market could prove difficult for smallholders to meet as they are not able to provide the required transparency and mills maybe forced to exclude products from smallholder plots from the production process to provide the required guaranties.

The increasing importance of palm oil for Indonesia and Malaysia is clear. Over recent years the increasing demand for oil palm followed by private sector investments has put Indonesia firmly on the map of palm oil producers. Indonesia moved from a global share in palm oil production of 15% in 1980 to 42% in 2005 in a fast-growing market (Table 10) This also had a clear impact on land use on Sumatra and Kalimantan (for Kalimantan see Table 11). Both islands have large areas of peat and it is likely that part of the expansion took place on peatlands; the exact area expansion on peatlands, however, is not clear.

Table 10 Palm oil production and global market share from 1980 to 2005

	Production (X1000 metric ton)						Share (%)					
	1980	1985	1990	1995	2000	2005	1980	1985	1990	1995	2000	2005
Malaysia	2576	4133	6088	8123	10,842	14,962	56	60	55	40	42	44
Indonesia	691	1243	2413	4220	7050	14,070	15	18	22	21	28	42
Nigeria	433	386	580	660	740	800	9	6	5	3	3	2
Thailand	–	–	232	354	525	685			2	2	2	2
Colombia	–	–	226	388	524	661			2	2	2	2
Papua New Guinea	–	–	145	223	336	310			1	1	1	1
Cote D'Ivoire	–	–	270	285	278	260			2	1	1	1
Brazil	12	29	66	75	108	160	0	0	1	0	0	0
Others	875	1041	1000	5994	5191	1826	19	15	9	29	20	5
World total	4587	6832	11,020	20,322	25,594	33,733	100	100	100	100	100	100

From: Basiron (2007).

Table 11 Oil palm area and change in Kalimantan, 1990 – 2006

	X 1000 ha			Change (%)	
	1990	1996	2006	1990-1996	1996-2006
West Kalimantan	48	211	434	344	106
Central Kalimantan	2	30	467	1762	1470
South Kalimantan	7	54	146	625	171
East Kalimantan	24	41	220	74	432
Kalimantan	80	337	1,268	319	277

From: Vermeulen, S. & Goad, N. (2006). Ages of the crops are assumed equal.

In order to grow oil palm on peat, the peat needs to be drained to approximately 80 cm below soil surface. This drainage causes oxidation of the peat which is estimated to be 0.91 t ha^{-1} yr^{-1} CO_2 emission per cm drainage (Wösten in Hooijer et al., 2006). A drainage of 80 cm thus causes a CO_2 emission of 73 t CO_2 ha^{-1} yr^{-1}. With an area of 2.8 Mha oil palm on peat, the total CO_2 emission due to oxidation of peat is thus approximately 205 Mt CO_2 yr^{-1} for the whole peatland area. If in addition to CO_2 emission caused by drainage for oil palm also emissions caused by drainage for other crops are taken into account, Hooijer at al. (2006) estimated a total CO_2 emission of 632 Mt CO_2 yr^{-1} from all peatlands in Indonesia (minimum estimate 355 Mt CO_2 yr^{-1} and maximum estimate 874 Mt CO_2 yr^{-1}).

With an average yield of 3 t ha^{-1} yr^{-1} every ton of palm oil produced on peatlands thus causes a CO_2 emission of approximately 24 t CO_2 ha^{-1} yr^{-1}. With this average yield the 2.8 Mha peatlands under oil palm cultivation in Indonesia produce approximately 8.4 Mt palm oil. As a whole Indonesia produced in 2006 approximately 15 Mt palm oil (Basiron, 2007); this means that approximately 5 Mha in Indonesia is under oil palm cultivation with 2.8 Mha (55%) on peatlands and 2.2 Mha (45%) on mineral soils. Also in Malaysia, approximately 5 Mha is under oil palm cultivation (Basiron, 2007). Due to an increase in world demand, the area under oil palm cultivation is increases by approximately 12% per year (Basiron, 2007).

Many oil-palm plantations are effectively self-sufficient villages, providing not only employment, but also housing, basic amenities such as water and electricity, and infrastructure including roads, medical care and schools for the families of their employees (Corley, 2006). As such, many communities, particularly those in rural areas, rely on oil palm agriculture for their livelihood. According to the Malaysian Palm Oil Board in Kuala Lumpur, the country's oil-palm plantations provide direct employment for over half a million people from both the local population and neighbouring countries. Any major disruption of the palm oil industry in South East Asia is likely to have widespread and dire socioeconomic consequences throughout the region.

6.2 Pineapple

Pineapple can be grown under acid conditions and is a common crop on peat. First introduced by the Portugese it found its way to the peatlands in Malaysia (Driessen & Sudewo, 1980). Pineapple is grown on deep peats, it has a shallow root system, and a low nutrient requirement. Production levels are best on well-drained peat with water table levels of 60 to 90 cm. It can be planted directly after deforestation. On small-holder plots pineapple is hardly fertilized; on large estates as found in Malaysia fertilizer is applied. In Malaysia about 90% of pineapple is grown on peat, although yields on peat are somewhat lower than on mineral soils (Hanafi & Halimah, 2004).The total area of pineapple on peatland in Malaysia and Indonesia is unknown.

Costa Rica is the main exporter to the EU with a market share of 81% of the 220,000 t fresh pineapple imported in 2006. Other exporting countries from this region are Panama and Ecuador with 11% and 2.2%, respectively. All countries have peat and it cannot be ruled out that pineapple is grown on peat; clear information as to the areas involved, however, is not available.

Of the sustainable, canned pineapple imported into the Netherlands 50% or 28,250 t is imported from Thailand. But imports from Kenya (14%), the Philippines (10%) and Indonesia (8%) represent a substantial market share as well. For all countries it is unclear whether the products originate from peatlands. For Indonesia and Malaysia it is know that pineapple is produced on peat but exact figures are lacking. Malaysia has already been a key producer of pineapples from the sixties and seventies and is ranked as a top producer. Almost all (10,000 ha) pineapple in Malaysia is grown on peatland. The product is exported as canned pineapple to the USA, Japan, Singapore and the Middle East. There is no significant direct export to the Netherlands.

In order to grow pineapple on peat, peat needs to be drained to approximately 80 cm below soil surface. This drainage causes oxidation of the peat, which is estimated to be 0.91 t ha^{-1} yr^{-1} CO_2 emission per cm drainage.

6.3 Rubber

In Southeast Asia (Malaysia, Indonesia and Thailand) rubber is also produced on peat. Imports into the Netherlands in 2007 totalled 48.5 Kt (Eurostat) but the share of peat-based rubber is not known. Some of the rubber imports from Malaysia (26%) and Indonesia (22%) could originate from peat. It is very unlikely that the imports from Ivory Coast (31% of total imports) are linked to peatland.
No clear direct relation between imports to the Netherlands and rubber from peatlands can be established.

6.4 Coconut

Coconut palms are grown on peats in Indonesia and Malaysia, and most likely the system can also be found in Thailand and Papua New Guinea. Coco oil is imported from Indonesia to the Netherlands, the impact on peat, however, is not clear.

6.5 Sugar

The Netherlands imported 95% of its raw cane sugar (19 Kt, 2007) from south America (Brazil, Argentina, the Antilles and Paraguay). In Pantanal in Brazil some sugarcane can be found on peat. The Netherlands also imports from other European countries (Belgium, France, Germany and Italy). From these imports Germany and France import from Swaziland, a country with possibly some sugarcane production on peat.
The impact of sugar imports on peat are most likely low.

6.6 Cranberry

About 48% of the imported cranberries into the Netherlands in 2007 originates from Chile. Most are grown on volcanic ash but about 400 ha is cultivated on peat. Imports from the United States (14%, 430 t in 2007) and Canada (87 t in 2007) are linked to peat (import data Eurostat). The largest exporters, in 2005, are Canada, the United States and Chile with a volume of 40,828, 13,609 and 11,938 t, respectively.
The United states and Canada exploit an area of 19,400 ha of which about 16,000 ha is located on peatlands in Massachusetts, Wisconsin, New Jersey, Oregon and Washington; some 3,300 ha is located on peatlands in Canada (British Columbia and Quebec) (http://www.cranberries.org). Most berries are processed in, e.g., sweetened drinks, only a small part is sold as fresh fruit.

7 Conclusions

Peat is found on all continents and peatlands represent the most space-effective carbon (C) stocks of all terrestrial ecosystems. But uncertainties regarding size and exact location of stocks are very high. Definitions on when a soil can be classified as peat varies, the large spatial and temporal variation of key parameters like bulk density all contribute to this uncertainty. The loss and degradation of peatlands is linked to:

- degradation of biodiversity: loss of many (rare) species
- degradation of hydrological regulation capacity, as drained peatlands loose their buffer, sponge, and storage functions
- emission of greenhouse gasses, notably CO_2
- loss of height through subsidence, eventually making gravity drainage impossible and necessitating (expensive) polder management and leading to structural damage to roads and buildings.
- degradation of water quality, as peat oxidation emits much nitrate and polder pumping may lead to intrusion of salt water
- soil degradation, as drained peat may dry out irreversibly, making adequate water supply to crops impossible
- social degradation, because these problems lead to loss of rural employment and traditional livelihoods.

The annual carbon dioxide release caused by peat import for horticulture in the Netherlands is estimated to be 0.2-0.3 Mton of carbon dioxide. This is about 0.15% of the overall national release and 4% of the release as a result of greenhouse heating. An additional 30% carbon dioxide release is related to transport, production and packaging. More than half of the imported peat is exported and thus not included in the Dutch emissions. Peat substitution will thus not lower the Dutch emissions by 100% of the prevented emission as some 70% of the prevented emission will have to be attributed to other countries. Effective measures to reduce peat-related carbon dioxide emissions in horticulture include:

- A reduction of truck transport for sod peat by developing local alternatives for sod peat (reducing both transport and peat-related carbon dioxide emission).
- Reworking local agricultural materials into high-quality potting soil constituents.
- Burning used peat for energy production.

Almost one tenth of the Netherlands is covered with peatsoils of which about 80% is in use as permanent grassland for dairy farming. The CO_2 emission caused by oxidation from these areas is significant and is responsible for about 2–3% of the national anthropological CO_2 emissions. CO_2 emission of these peatsoils can be reduced by maybe more than 80% by elevating water tables. Changing land use to swamp forest could result in a positive CO_2 balance. However, given the current situation, even with a doubling of the nature area, the major part of the Dutch peatsoils will remain in agricultural use. Rewetting of grasslands will neither be without costs as methane emissions and nutrient leaching will increase.

Raising ditch water levels is perhaps the most carbon-effective measure but will have negative economic repercussions for the dairy sector. The use of submerged drains combined with raising ditch water levels has the potential to reduce CO_2 emissions by 50% and allows for a viable dairy farming sector. However, this solution requires further study on its effectiveness and sustainability. Covering peatsoils with a few decimeters of mineral soil might be another, although expensive, solution to diminish CO_2 emissions.

It is unlikely that under current management the problems with peatsoils will decrease. The ongoing subsidence of peatsoils and the adjustment of ditchwater levels to the lowered surface will cause an increasing upward seepage of nutrient-rich water. Measures such as “high water ditches” to keep groundwater levels of built-up areas and natural areas high will become less effective or even useless with time. Due to this ongoing subsidence the polders are triggering the need for higher of dikes to keep out the water.

The total peatland area in the Netherlands will also continue to decrease which will lead to a reduction of total CO_2 emissions from peatlands. In fact already a large part of shallow peatsoils disappeared during the last decennia; the relatively deep peats are left. In this assessment peat classification is an important factor as degraded peatsoils with an organic layer less than 40 cm are not classified as peat whereas they will continue to emit relatively large amounts of CO_2 for several decades.

Climate change will considerably increase most problems associated with peatsoils in the Netherlands. Subsidence and CO_2 emission rates will increase by at least 70% in 100 years as in most climate change scenarios the number of extremely dry years for the Netherlands increases. The associated lowering of ditch water levels during dry years will increase the oxidation rate of peat.

Paliducultures have the potential to allow for sustainable exploitation of peatland. Emissions can be limited or even turn positive in these wetland systems. These multifunctional systems have several advantages such as:

- improvement of regional hydrology,
- prevention of greenhouse gas emissions,
- increased political autarchy by local production of energy and raw materials,
- enhancing biodiversity values.

So far experience with the construction and exploitation of paludiculture is limited.

The link between the Netherlands and the exploitation of tropical peatland is difficult to establish as sources of origin and material flows are poorly documented. Of the prodcuts imported into the Netherlands palm oil is threatens tropical peatlands most strongly. The correlation between deforestation and expansion of oil palm, however, is weak. Peatland areas represent large development opportunities for developing countries and industries. This socio-economic importance of palm oil in the producing countries is often ignored by NGOs, leading to a stalemate in the discussion.

Given the increasing demand from, e.g., India and China the main challenge is to meet this demand without clearing forests, reclaiming peatland, or exploiting other carbon stocks. A successful strategy could be to increase productivity on already established oil palm plantations.

Increasing the per area output can alleviate the pressure on the remaining land. This alone, however, will not be enough. Certification and transparency throughout the values chain are needed to gain insight in the origin and impact of production systems and methods to improve existing systems and gain trust of consumers. Unfortunately in many cases certification schemes fail to include smallholders.

This is particularly important for Indonesia with a significant percentage of the economic size and area of palm oil linked to smallholder farmers. Understanding decision-making and risk management and how certification and transparency in the value chain will affect farmers is important to avoid market exclusion of smallholders.

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