Appendices

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Appendix 1

Mires and peatlands and the global climate[1]

This appendix is a longer version of the "Regulation of the global climate" material in Section 3.4.3 with tables and text supporting the statements in §3.4.3. It discusses how peatlands and peatland use may influence the global climate.

A1.1 Introduction

The peat formation process is strongly influenced by climatic conditions, but mire ecosystems themselves also affect the global climate. This occurs via the so-called greenhouse gases they absorb and emit and the carbon they store.

Like a window pane in a greenhouse, a number of gases in the atmosphere let solar radiation (visible light) pass to the surface of the earth while trapping infrared (heat) radiation that is re-emitted by the surface of the earth. This trapping of heat radiation, that would otherwise escape to space, is referred to as the greenhouse effect. Gases that influence the radiation balance are called radiatively active or greenhouse gases (GHG)[2].

Greenhouse gases fall into three categories:

- radiatively active gases such as water vapour (H_20), carbon dioxide (CO_2), ozone (0_3), methane (CH_4), nitrous oxide (N_20), and the chlorofluorocarbons (CFCs) which exert direct climatic effects,
- chemically/photochemically active gases such as carbon monoxide (CO), nitrogen oxides (NO_x), and sulphur dioxide (SO_2) which exert indirect climatic effects through their influence on the atmospheric concentrations of hydroxyl radicals (OH), CH_4 and 0_3, and
- aerosols: 10^{-6} - 10^{-2} mm large fluid or solid particles dispersed in the air.

Even without human interference, the natural greenhouse effect keeps the Earth's surface ca. 30^0 C warmer than it would be, if all solar radiation was transferred back to space[3]. Water vapour (H_2O), carbon dioxide (CO_2), and clouds contribute roughly 90 percent to the natural greenhouse effect, whereas naturally occurring ozone (0_3) methane (CH_4) and other gases account for the remainder. The emission of greenhouse gases by human activities causes a change in the radiation balance of the Earth (radiative forcing).

The *type* of gases that mires and peatlands exchange with the atmosphere is not always the same. Different mire types emit different amounts and proportions of gases. In the course of their long-term development, some mire types become spontaneously wetter[45] and the proportion of emitted methane consequently increases.

[1] Based on information supplied by Heinrich Höper.
[2] Because the concentrations of natural and anthropogenic greenhouse gases are small compared to the principal atmospheric constituents of oxygen and nitrogen, these gases are also called trace gases.
[3] Crill et al. 2000.
[4]

Peatland drainage generally enlarges the share of emitted carbon dioxide and decreases that of methane, whereas peatland agriculture additionally leads to a larger emission of nitrous oxide[6]. As all these gases have a different radiative forcing[7], the effect on the radiation balance of the atmosphere differs with mire/peatland type and type of exploitation[8].

The other important aspect is the *store* of carbon, i.e. the carbon that is excluded from short-term (e.g. annual) carbon cycling. Stores are only important when their volumes change. The increase of atmospheric CO_2 in the recent past is especially caused by burning the long-term carbon stores called "fossil fuels" (like coal, lignite, gas, and oil). The felling and burning of the tropical rainforest increases carbon dioxide concentrations in the atmosphere because of the mobilisation of the carbon stored in forest biomass, not because plant productivity decreases. The peatland carbon store can be subdivided into three compartments, which may all behave differently under different management options[9]:

- the carbon store in the biomass,
- the carbon store in the litter, and
- the carbon store in the peat.

To understand the integrated effects of peatlands on climate and the consequences of human impact, it is therefore necessary to consider both

- the types, volumes, and proportions of greenhouse gases exchanged, and
- the carbon stores in peatlands.

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[5] Ivanov 1981, Couwenberg & Joosten 1999.
[6] See § A1.3.
[7] See § A1.2.
[8] Cf. § A1.3.
[9] See § A1.3, A1.4, A1.5, A1.6, A1.7.

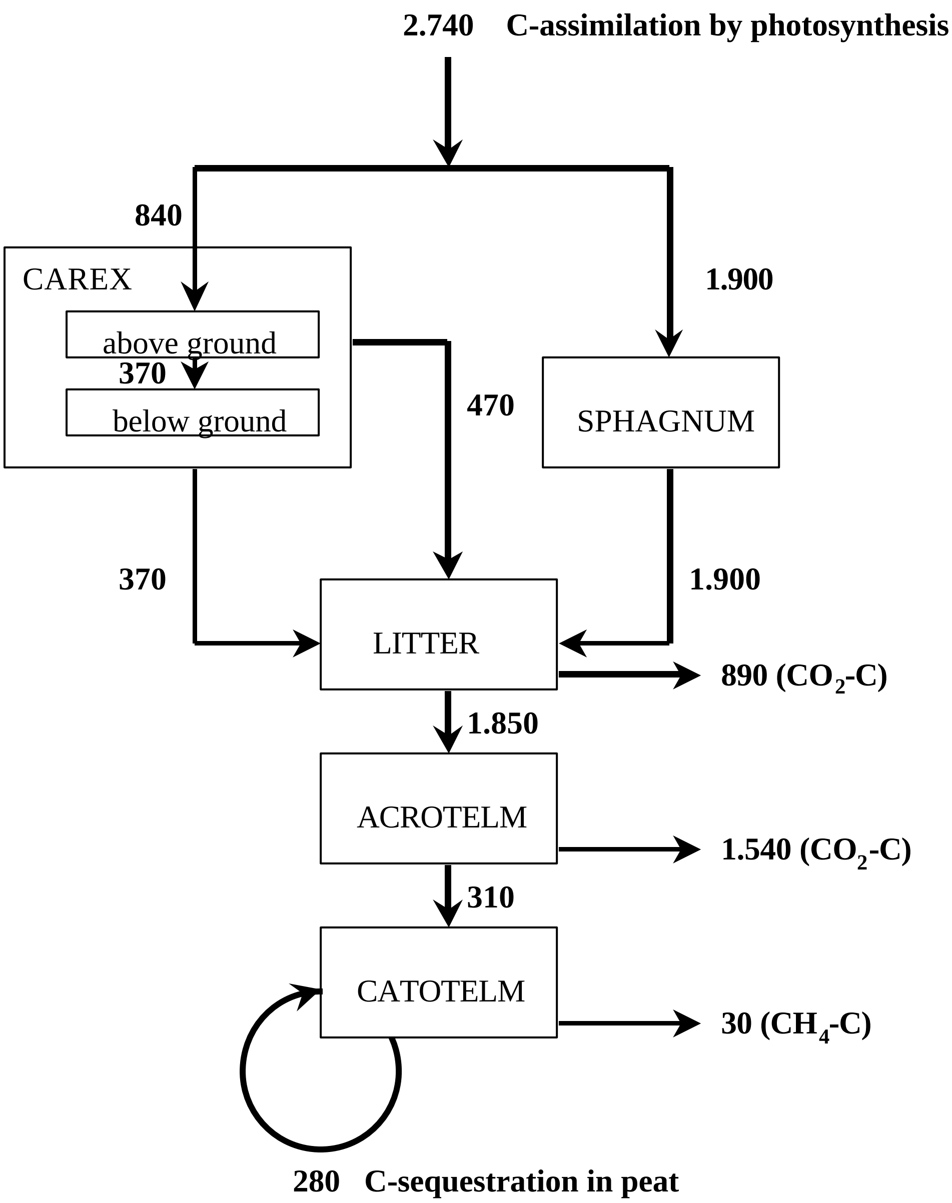

Figure A1/1 Carbon fluxes and carbon sequestration (10^3 g C ha^{-1} $year^{-1}$) in a pristine bog (Pradeaux, French Central Massif, 1250 m over sea level NN)[10]

[10] [10] Francez & Vasander 1985.

A1.2 The role of pristine mires

A major characteristic of mires is that they sequester carbon dioxide from the atmosphere and transform it into plant biomass that is eventually stored as peat. Peat accumulation in mires is the result of various processes (Figure A1/1) including: carbon sequestration by plant photosynthesis (primary production), direct carbon losses during litter decomposition[11], decomposition in the acrotelm, and decomposition losses in the catotelm. Only about 10 % of the primarily assimilated carbon is sequestered in the peat in the long term. Long-term carbon accumulation rates of the world's mires are estimated to be 40 – $70 \cdot 10^{12}$ g C per year[12]. This is approximately 1% of the 6,000 $\cdot 10^{12}$ g C emitted by global fossil fuel consumption in 1990[13], or 10 % of the 660 $\cdot 10^{12}$ g C emitted by USA electric utilities in 1998[14].

In the long run, mires may in this way withdraw enormous amounts of carbon dioxide from the atmosphere and store it as peat deposits. At present approximately the same amount of carbon is stored in the world's peatlands as in the whole atmosphere[15]. The decreasing atmospheric concentrations of carbon dioxide during interglacials as a result of peat formation and the consequent steadily reducing greenhouse effect is seen by some scientists as a major cause for the origin of ice ages[16].

The effect of pristine mires on the global climate depends not only on the sequestration of carbon dioxide (CO_2) from the atmosphere, but also on the emission of other gases, especially methane (CH_4) and nitrous oxide (N_2O).

Methane is the second most important greenhouse gas after CO_2 and is expected to contribute 18% of the total expected global warming over the next 50 years, as opposed to 50% attributable to CO_2. Furthermore methane participates in tropospheric ozone formation[17]. Global methane production is dominated by natural wetlands, rice paddies, and animal livestock (Table A1/1).

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[11] Francez & Vasander 1985.
[12] See § 2.5.
[13] Committee on Global Change Research 1999.
[14] The Global Climate Change Task Force Of The Council On Engineering and Council On Public Affairs, 1998.
[15] Houghton et al. 1990.
[16] Franzén 1994, Franzén et al. 1996. See also Rodhe & Malmer 1997, Franzén 1997.
[17] Scholes et al. 2000.

Table A1/1: Net sources of global atmospheric emissions of methane (in 10^{12} g CH_4 $year^{-1}$)[18]

Wetlands[19]	115
bogs/tundra (boreal)	35
swamps/alluvial	80
Rice production[20]	100
Animals (mainly livestock)	80
Biomass burning	55
Landfills	40
Gas production	40
Coal production	35
Termites	20
Oceans, freshwaters	10
Hydrates	5?
Total sources	500

Methane emissions in mires are highly variable, but generally higher in pristine fens than in pristine bogs (Table A1/2).

Table A1/2: Methane emissions (in 10^3 g C ha^{-1} $year^{-1}$) from pristine and rewetted mires

Region	Methane emission	
	bogs	**Fens**
Globally[21]	20	101
USA, temperate zone[22]	7 - 1132	0,8 - 1820*
Sweden[23]	11	228
Finland[24]	20 - 220	135 - 480
England[25]	10 - 40	
Germany[26]		293
Germany (rewetted)[27]	81	529 - 980*
Median (lower – upper quartile)	**53** (20 – 84)	**297 (**190 – 480)

[18] Reeburgh & Crill 1996.
[19] The most recent estimates indicate that $109 \cdot 10^{12}$ g yr^{-1} of methane is released by wetlands globally. Tropical regions (20°N to 30°S) are calculated to release 66 $\cdot 10^{12}$ g yr^{-1} (60.5% of the total), emissions from subtropical and temperate wetlands (20-45°N and 30-50ºS) are only 5 $\cdot 10^{12}$ g yr^{-1} (4.5% of the total) but there have been relatively few measurements in the tropics and subtropics, and this figure is therefore currently uncertain. Northern wetlands (north of 45ºN) are calculated to release a total of 38 $\cdot 10^{12}$ g yr^{-1} (35% of the total) with 34 $\cdot 10^{12}$ g yr^{-1} from wet soils and 4 $\cdot 10^{12}$ g yr^{-1} from relatively dry tundra (Milich 1999, Scholes et al. 2000).
[20] More recent estimates of the total CH_4 emission from rice paddies amount to 50 ± 20 $\cdot 10^{12}$ g y^{-1} (Neue 1997).
[21] Aselmann & Crutzen 1990.
[22] Harriss et al. 1985, Bridgeham et al. 1995.
[23] Svensson 1976.
[24] Silvola et al. 1994b, Martikainen et al. 1992, 1994, 1995.
[25] Clymo & Reddaway 1971.
[26] Augustin et al. 1996.
[27] Pfeiffer 1993; Meyer 1999.

Nitrous oxide is a greenhouse gas and also causes destruction of stratospheric ozone[28]. Nitrous oxide emissions from pristine mires are very low (Table A1/3). Occasionally, even a consumption of nitrous oxide may take place due to the reduction of nitrous oxide to dinitrogen (N_2) under anoxic conditions.

Table A1/3: Nitrous oxide emissions (in kg N ha^{-1} $year^{-1}$) from pristine or rewetted mires

Region	Nitrous oxide emission	
	bogs	**fens**
Finland[29]	0,04	0,04
Sweden, Finland[30]	0,0 to 0,2	
USA, temperate zone (flooded)[31]		0,1 - 0,5
Germany[32]		0,6 - 1,2
Germany (flooded)[33]		- 0,7 to - 0,2
Median	**0,04**	**0,10**

Because all gases have a different lifetime in the atmosphere and a different "global warming potential" (see Table A1/4), the combined effects of all three gases together depend on the time horizon chosen. On the 100 year horizon, for example, Finnish undisturbed mires have a positive radiative forcing of + 8.40 ± 0.15 $\cdot 10^{12}$ g CO_2 equivalents (i.e. they increase the greenhouse effect), whereas on the 500 year horizon, the effect becomes negative with - 0.54 ± 0.15 $\cdot 10^{12}$ g CO_2 equivalents (i.e. they decrease the greenhouse effect[34]). This is due to the changing impact of CH_4 emissions.

Table A1/4: The atmospheric lifetime and the IPCC (1996) accepted global warming potentials over different time horizons of radiatively important gases[35].

Chemical species	**Atmospheric lifetime (years)**	**Global warming potential (mass basis) (time)**		
		20-year horizon	100-year horizon	500- year horizon
CO_2	variable	1	1	1
CH_4	12 ± 3	56	21	6.5
N_2O	120	280	310	170

Other reviews arrive at similar conclusions. Martikainen (1996) concludes that northern peatlands have a negative radiative forcing effect on climate (i.e. they "cool the atmosphere") because the CO_2 uptake (by peat accumulation and biomass production) compensates for the warming effect of the CH_4 emissions. Höper (cf. Table A1/5) deduces that over a short time-scale pristine mires contribute to the greenhouse effect with respect to their CO_2, CH_4 and N_2O balances. Over a 500-year

[28] Crutzen, 1979.
[29] Martikainen et al. 1993.
[30] Hillebrand 1993.
[31] Goodroad & Keeney 1984.
[32] Augustin et al. 1996.
[33] Meyer 1999.
[34] Crill et al. 2000.
[35] Crill et al. 2000.

time-scale pristine bogs have a negative global warming potential and fens a small positive potential.

Table A1/5: Global Warming Potential (GWP in kg CO_2-C-equivalents ha^{-1} $year^{-1}$) of pristine mires using different time scales

		bogs	fens
CO_2 sequestration (kg C ha^{-1} $year^{-1}$)		-310	-250
CH_4 emission (kg C ha^{-1} $year^{-1}$)		53	297
N_2O emission (kg N ha^{-1} $year^{-1}$)		0,04	0,1
Global Warming Potential	20 years	723	5524
Global Warming Potential	100 years	45	1724
Global Warming Potential	500 years	-233	173

Similarly Roulet (2000b) concludes: "Canadian peatlands are neither a net sink or source of GHGs. … For a time horizon less than 100 years, Canadian peatlands are a source (GWP for CH_4 emissions > sink of CO_2); for a time horizon greater than 100 years, they are a sink."

Although it should be recognised, that there are large uncertainties in these calculations, we may provisionally conclude that

- under the present climatic conditions,
- on a time scale relevant for current civilisation, and
- with respect to the combined effects of CO_2, CH_4 and N_2O exchange,

pristine mires play an insignificant role with respect to global warming.
In this respect, mires do not differ from virgin tropical rainforests and other types of "climax" ecosystems, that are in equilibrium with climate. Like these other ecosystems that have a large carbon store in their biomass, mires and peatlands have a considerable climatic importance as stores of carbon, especially in their peat (see below).

Recently it has been acknowledged, that many more greenhouse gases are emitted by mires including

- Hydrocarbons, that may significantly impact ozone, methane and carbon monoxide in the troposphere. $400\text{-}800 \cdot 10^{12}$ g C yr^{-1}, an amount equivalent to all methane emissions, are emitted by plants, primarily trees. As the emissions are very sensitive to temperature, the emissions from peatlands in North America and Eurasia are expected to significantly increase under global warming[36].
- Dimethyl sulfide (DMS CH_3SCH_3), an "anti-greenhouse gas" that enters the troposphere and is oxidized there to sulfate particles, which - as cloud condensation nuclei - influence cloud droplet concentrations, cloud albedo and consequently climate[37].
- Methyl bromide (CH_3Br) and methyl chloride (CH_3Cl)[38], that have a cooling effect through their ability to destroy stratospheric ozone[39].

36 Scholes et al. 2000.
37 Charlson et al. 1987, DeMello & Hines 1994, Kiene & Hines 1995, Lomans et al. 1997, 1999, Watson & Liss 1998, Lomans 2001.
38 Varner et al. 1999.
39 Daniel et al. 1995.

No quantitative information is available on the global climatic effects of these substances.

A1.3 The role of peatlands drained for agriculture

When virgin peatlands are converted to agriculture, the natural biomass is replaced by crop biomass. This may result in substantial changes in the *biomass* carbon store, e.g. when tropical forested peatlands are converted to vegetable or rice fields. A reclamation of non-forested virgin peatland to grasslands and arable fields will generally not lead to large biomass or litter changes[40].

The dominant effect of peatland drainage for agriculture is, that the peat gets exposed to oxygen which leads to peat mineralisation, i.e. a decrease in the *peat* carbon store, and an increased emission of carbon dioxide, especially in the summer months[41].

Under grassland, drained bogs and fens in the boreal and temperate zones emit about 2,500 and 3,500 kg C ha^{-1} $year^{-1}$ as CO_2 respectively (Table A1/6). Water table depth does not substantially influence the magnitude of these emissions. The highest mineralisation rate is observed with a water table depth of 80 - 90 cm[42], whereas depths of 17 - 60 cm already lead to 80 % of the maximum value[43]. At water levels deeper than 90 cm, drought inhibits peat mineralisation again[44].

Table A1/6: CO_2 emissions from drained peatlands used as grassland.

Region	CO_2 emission in kg C ha^{-1} $y.^{-1}$	
	bogs	**fens**
Finland[45]	1500 - 2500	3140
Canada[46]		1910
North-east Germany[47]		2800 - 6580
North-west Germany[48]	0 – 4840[2]	4119 - 4318
Sweden[49]	3500	
Median	**2350**	**3465**

Under tillage, peat mineralisation is accelerated as compared to grassland due to more intensive aeration. CO_2 emission rates in arable fens are higher than in bogs (Table A1/7).

Table A1/7: CO_2 emissions from drained peatlands used as arable land[50].

[40] Roulet 2000b.
[41] Mundel 1976.
[42] Höper 2000.
[43] Mundel 1976.
[44] Wild & Pfadenhauer 1997.
[45] Silvola 1986, Silvola et al. 1994a.
[46] Glenn et al. 1993.
[47] Mundel 1976.
[48] Segeberg & Schröder 1952, Kuntze 1992, Meyer 1999.
[49] Hillebrand 1993.

Region	CO_2 emission in kg C ha^{-1} $y.^{-1}$	
	bogs	**fens**
North West Germany[51]	4400	13200
South Germany[52]		6600-9900
Poland[53]		11220
Median	**4400**	**10560**

Methane emissions from drained peatlands are generally very low (Table A1/8), though emissions of up to 21 kg CH_4-C ha^{-1} $year^{-1}$ have been observed in bogs. Drained fens emit less methane than bogs and function more frequently as net sinks for atmospheric methane.

Table A1/8: Methane emissions from drained peatlands used as grassland. Negative values correspond to a net uptake and absorption of methane into the soil.

Region	CH_4 emission in kg C ha^{-1} $y.^{-1}$	
	bogs	**fens**
Canada[54]	- 0,8 to + 0,3	- 0,8 to + 0,3
Sweden[55]	0,8	
Finland[56]	2 to 21	- 0,5 to + 5,0
North-east Germany[57]		0,6 to 3,5
North-west Germany[58]		- 1,4 to + 0,3
Median	**2**	**0**

Nitrous oxide emissions from bogs are low (Table A1/9) due to the low pH and low total nitrogen contents. In the more nutrient-rich fens, nitrous oxide emissions of up to 16 kg N ha^{-1} $year^{-1}$ have been observed, with a median of 5.7 kg N ha^{-1} $year^{-1}$. N_2O emissions will depend on the available nitrogen and therefore on nitrogen fertilization. It is assumed that 1% of the nitrogen applied as fertilizer is emitted as N_2O[59].

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[50] The database for tilled peatlands is small and CO_2 emissions have largely to be estimated from subsidence measurements (Höper 2000). In this table the values for fens were calculated using the peat subsidence in cm $year^{-1}$, a bulk density of 150 kg m^{-3}, a C-content of 55 %, and assuming that 80 % of peat subsidence is due to peat mineralisation. For bogs a bulk density of 100 kg m^{-3} was used.

[51] Kuntze 1973, Eggelsmann 1976.

[52] Schuch 1977.

[53] Okruszko 1989.

[54] Glenn et al. 1993.

[55] Svensson 1976.

[56] Lien et al. 1992, Martikainen et al. 1992, 1994, 1995.

[57] Augustin et al. 1996.

[58] Meyer et al. 1997.

[59] Personal communication from Heinrich Höper.

Table A1/9: Nitrous oxide emissions from drained peatlands used as grassland.

Region	**N_2O emission in kg N ha^{-1} $y.^{-1}$**	
	bogs	**fens**
Finland[60]	0,04	1.2 to 1.5
Sweden, Finland (forest)[61]	0	
USA, temperate zone[62]		5.7 to 13.1
Netherlands[63]		2.2 to 13.3
South Germany[64]		4.2
North-east Germany[65]		0.6 to 14.0
North-west Germany[66]		5.0 to 16.0
Median	**0.02**	**5.7**

Figure A1/2 gives an overview of the global warming potential of drained peatlands under different forms of agricultural use. Carbon dioxide is by far the most relevant gas, contributing between 85 and 98 % of the cumulative global warming potential of all greenhouse gases. Intensively used bog grasslands have similar warming potentials as tilled bogs. Fertilisation and liming of grasslands strongly increases peat mineralisation[67].

[60] Martikainen et al. 1993.
[61] Hillebrand 1993.
[62] Goodroad & Keeney 1984.
[63] Velthof & Oenema 1983.
[64] Flessa & Klemisch 1997.
[65] Augustin et al. 1996.
[66] Tschirsich 1995, Meyer 1999.
[67] As becomes apparent from comparing data from Segeberg & Schröder 1952 and Kuntze 1992.

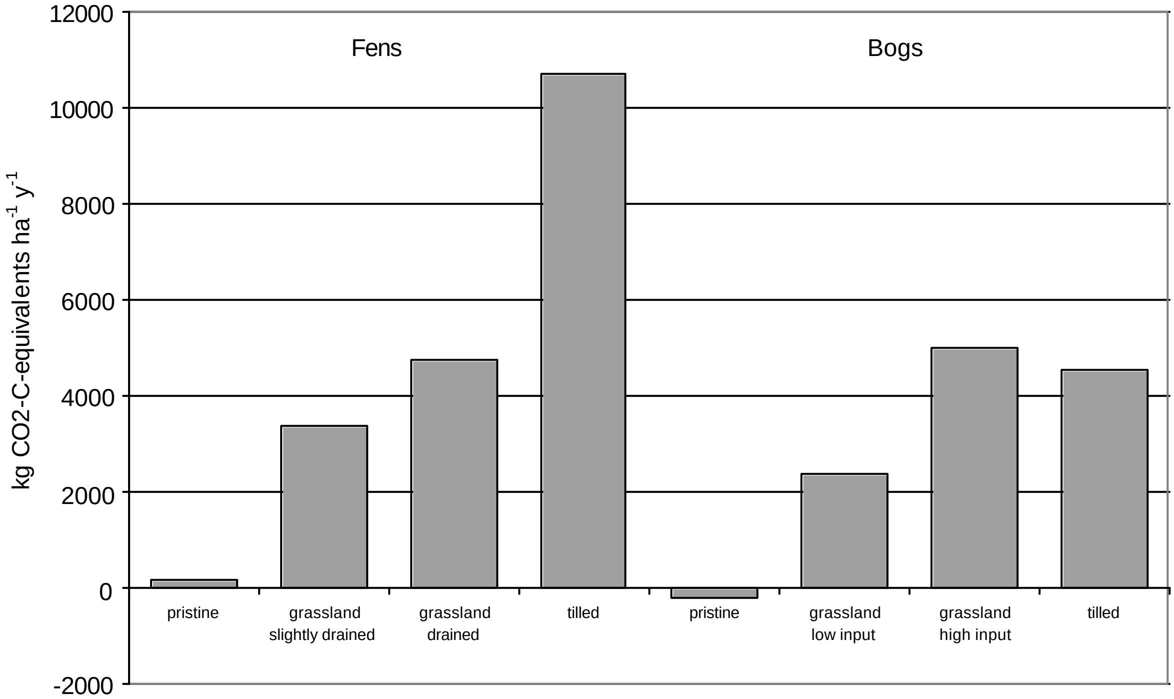

Figure A1/2: Rough estimates of the global warming potential of fens and bogs (in kg CO_2 equivalents ha^{-1} y^{-1}) under different types of land use (compiled by Heinrich Höper 2000).[68]

A1.4 The role of peatlands drained for forestry[69].

The effect of peatland drainage for forestry is more complicated than that of agricultural drainage, as various processes with contrasting effects occur simultaneously and the integrated effects differ considerably over different time-scales.

As in agriculture, increased aeration of the peat after forestry drainage results in faster peat mineralisation and a decrease of the *peat* carbon store. In the boreal zone this aeration may be accompanied by a decrease in peat pH and a lower peat temperature, which may again reduce the increased rate of peat mineralisation to some extent.

As water-logging in mires generally prevents an economic level of wood production[70], peatland drainage aims to increase the wood yield. After drainage, forest vegetation (trees and shrubs etc.) takes the place of the original mire vegetation and the peatland *biomass* carbon store (both above and below ground) increases quickly. This store would eventually reach a new equilibrium that is much higher than that of the former mire vegetation. Before this stage is reached the wood is harvested and the biomass store reduces substantially again.

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[68] Similar results were found by Kasimir-Klemedtsson et al. 1997.
[69] The complexities associated with peatland drainage are excellently reviewed for the boreal zone in Crill et al. 2000, (cf. also Joosten 2000), on which this subsection is largely based.
[70] See also § 3.4.1 (eb).

Peatland drainage for forestry also leads to changes in the *litter* carbon store. The "moist litter"[71] in the mire's acrotelm is generally considered as part of the peat carbon store as it gradually passes into the catotelm peat. The litter in a drained forest[72] is of different quality and can be considered as a separate component. The accumulation of litter leads to an increase in the litter carbon store. As this litter accumulates under aerobic conditions, the litter carbon store eventually reaches an equilibrium and the net accumulation stops. Depending on the peatland type and the cutting regime of the forest, it might take centuries before this equilibrium is reached.

Peatland drainage for forestry therefore leads to

- a steady decrease of the *peat* carbon store,
- a rapid initial increase of the *biomass* store, the harvesting of which leads to a typical saw tooth curve of the carbon biomass store (Fig. A1/3), and
- a slow initial increase of the peatland *litter* store which eventually, after some centuries, reaches an equilibrium.

The *peatland* carbon store, being the combined effect of these processes, varies therefore strongly in time. In the first period after drainage, the increase in biomass and litter stores may strongly exceed the losses from the peat carbon store. As the biomass and litter stores tend to an equilibrium, but the peat carbon losses continue[73], the cumulative carbon losses from peat oxidation prevail on the long run[74] (see Fig. A1/3).

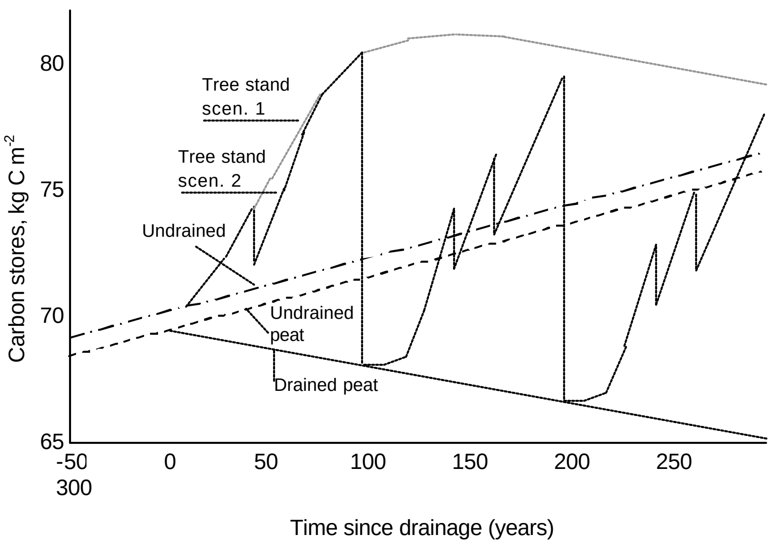

Fig. A1/3[75] Dynamics of the carbon stores of a tall sedge pine fen site (oligotrophic nutrient status) during the 300 years after drainage. Tree stand scen. 1: Total carbon stor of an untreated drained tree stand. Tree stand scen. 2: Total carbon store of a drained production forest. Tree stand stores are shown as a difference between the total (continuous line) and peat store lines (dashed line).

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[71] Stegmann et al. 2001.
[72] In the boreal zone consisting of remains of conifer needles, branches, rootlets, forest mosses etc.
[73] Provided that the forest management continues and the peatland remains sufficiently drained.
[74] Cannell et al. 1993; Laine & Minkkinen 1996, Minkkinen & Laine 1998, Minkkinen 1999.
[75] From Laine and Minkkinen 1996.

With respect to gas exchange, the drainage of peatlands for forestry generally leads to an increase in CO_2 emissions[76], a substantial decrease in CH_4 emissions and, depending on peatland type and type of land use (fertilisation), to a sometimes drastic increase in N_2O emissions[77].

A1.5 The role of peat extraction

The effect of peat extraction and subsequent oxidation is similar to that of burning fossil fuels. The peat carbon store is largely transformed into CO_2. Per m³ of extracted peat[78] some 50 kg CO_2-C, 11,3 g CH_4-C and 4.3 mg N_2O-N are eventually emitted[79]. Efficient drainage in the extraction areas may maintain high rates of CO_2 emissions[80] while CH_4[81] and N_2O emissions remain fairly low[82].

A1.6 National balances

Detailed national calculations with respect to peat carbon stores and radiative forcing are only available for Finland[83]. Table A1/10 presents the carbon balance data for Finnish peatlands. Both undisturbed and forestry drained peatlands currently have a positive carbon balance, the former because of *peat* accumulation, the latter because of increase in *root biomass* and *litter* carbon.

Table A1/10: Annual carbon balances of Finnish peatlands under different land-use forms (- sequestration; + emission)[84].

	Total C in 10^9 g
Undisturbed peatlands	- 408 ± 28
Peatlands drained for forestry	- 2468 ± 1485
Peatlands drained for agriculture	+ 1485 ± 621
Peat extraction and stockpiles	+ 180 ± n.d.
Peat combustion[85]	+ 2184 ± 178
Totals	**973 ± 2312**

[76] See review in Crill et al. 2000 with respect to boreal peatlands. In boreal peatlands the increased CO_2 emissions from the peat carbon store may – temporarily – be overridden by increased CO_2 sequestration in the biomass and litter stores. In temperate *Alnus* and *Betula* fens, mineralisation rates in flowing drainage may increase substantially (cf. Janiesch et al. 1991, Kazda 1995, Siemens 1996, Münchmeyer 2000).
[77] Cf. Augustin et al. 1998, Augustin 2001.
[78] With a bulk DW density of 100 kg m^{-3} and a C content of 50 %.
[79] Hillebrand, 1993.
[80] According to Sundh et al. (2000) CO_2 emission from the peat extraction site (0.23 to 1.0 kg CO_2 m^{-2} yr^{-1}) is on average ca 6% of the total amount of extracted peat.
[81] In a Swedish study, the CH_4 emission during the growing season was similar to emissions from virgin peatlands (Sundh et al. 2000).
[82] Crill et al. 2000.
[83] See, however, also Roulet 2000b.
[84] After Crill et al. (2000): Tables 6 and 13.
[85] Mean value and S.D. for the years 1994 - 1998.

Table A1/11 presents the integrated effects of various greenhouse gases on radiative forcing. The strongly time-dependent effect of undisturbed mires is striking, because of the decreasing effect of methane[86]. Estimating the effects on the 500-year horizon is even more speculative than that for the 100-year horizon, and does not take into account changes in hydrology and temperature resulting from global change.

Table A1/11: Summary of radiative forcing of Finnish peatlands under different land-use forms using different time horizons[87].

		Radiative forcing (in 10^{12} g CO_2 equivalents)	
Land use	**area in 1000 ha**	**100 year horizon**	**500 year horizon**
Undisturbed peatlands	4000	+ 8.40 ± 0.15	- 0.54 ± 0.15
Forest drained peatlands	5700	- 5.28 ± 5.5	- 7.61 ± 5.5
Agricultural peatlands	250	+ 6.63 ± 2.57	+ 6.12 ± 2.45
Peat extraction and stockpiles	63	+ 0.71 ± n.d	+ 0.69 ± n.d
Peat combustion	77.5 ± 7.3 PJ y^{-1}	+ 8.51 ± 8.97	+ 8.32 ± 0.71
Totals		**+ 18.97 ± 8.97**	**+ 8.06 ± 8.81**

A1.7 The role of peatland fires

In many areas of the world natural fires ignited by lightning strikes were normal phenomena in peatlands[88]. Today fire is most frequently the result of human activities, such as the burning of forested areas for land clearing, of natural grasslands and savannas to sustain nomadic agriculture, of agricultural residues, and of biomass as fuel for cooking and heating[89].

Peatland fires may lead to the ignition of the peat layers, especially after drainage[90]. Such fires are difficult to extinguish and may last for many months despite extensive rains. The depth and extent of such fires depend on the oxygen availability, the moisture content, and the presence of cracks in the peat[91].

Emissions from biomass and peatland burning represent a large perturbation of global atmospheric chemistry[92]. In the 1982-3 drought and fire in East Kalimantan, the area affected by fire included 5500 km^2 of peat-swamp forest[93]. In 1997 and 1998 land clearance activities in Indonesia combined with an extended dry season created several months of forest and peatland fires. Two of the most intensive sources of

[86] The long-term values for forest drained peatland are subject of discussion, because of the contested linear extrapolation of 50 - year litter accumulation data towards the 100 or 500 year time horizon (Joosten 2000).
[87] After Crill et al.(2000): Tables 6, 13, and 15.
[88] Brown 1990, Kangas 1990, Paijmans 1990, Kuhry 1994, Frost 1995, Zoltai et al. 1998, Morrissey et al. 2000, Joosten 2001.
[89] Goldammer 1999a, Nepstad et al. 1999, Scholes et al. 2000.
[90] Maltby 1986.
[91] Ellery et al. 1989, Maltby et al. 1990, Grundling et al. 1998.
[92] Goldhammer 1999a.
[93] Scholes et al. 2000, Lennertz & Panzer 1984.

smoke and particulate matter were fires on the peatlands of Kalimantan and Sumatra. Both the surface vegetation and the underlying peat were ignited. In Kalimantan some 7500 km^2 of peat-swamp forest was destroyed with a loss of surface peat of between 0.2 and 1.5 metres. Total emissions of carbon as a result of the fires are estimated at between 400 10^{12} g C and 900 10^{12} g C [94], being equal to 10 % of the global annual emission from fossil fuel consumption[95].

A1.8 The role of peatland inundation and rewetting

Peatlands are inundated for rice cultivation[96], water reservoirs (especially for hydro-electricity[97]), and mire restoration. Higher water table depths generally lower the carbon mineralisation rate[98]. Nevertheless inundation and rewetting do not necessarily result in lower emission rates.

Rice paddies are among the most important CH_4 emitters in the world[99]. Inundation of peatlands to create water reservoirs leads to significant emissions of both CO_2 and CH_4 [100]. Roulet (2000b) estimates the emission from Canadian wetlands due to flooding to be approximately $1x10^{12}$ g C y^{-1}, representing 5% of Canada's anthropogenic emissions.

The rewetting of degraded peatlands would also generally be expected to lead to a decrease in CO_2- and N_2O emissions [101]. In practice, however, rewetting of fen grasslands often leads to increased CH_4 emissions [102], while CO_2 emissions may remain continuously high[103]. This could be caused by the rapid decomposition of young plant material and is probably a transient phenomenon. Water level fluctuations on such plots may cause a drastic increase of N_2O emissions [104].

Rewetting of drained alder forests leads to increased emissions of CH_4, but to decreasing N_2O- emissions [105].

A1.9 The effects of climate change on mires and peatlands

The distribution of mires and mire types over the globe clearly reflects their dependence on climate[106]. As mires are concentrated in humid or cool regions, a changing climate can be expected to seriously affect their carbon balance and radiative forcing.

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[94] Page et al. 2000.
[95] See § A1.2.
[96] See § 3.4.1 (ea).
[97] See § 3.4.2 (f).
[98] Mundel 1976.
[99] See Table A1/1 (Net sources of global atmospheric emissions of methane).
[100] Rudd et al. 1993, see also Moore 1994, Nykänen et al. 1996.
[101] Cf. Kamp et al. 2000.
[102] Tuittila et al. 2000.
[103] Tuittila et al. 2000.
[104] Flessa et al. 1997. See also Komulainen et al. 1999.
[105] Westermann & Ahring 1987, Grosse et al. 1992, Gonzalez et al. 1995, Augustin et al. 1998.
[106] Schouten et al. 1992.

Most climate models suggest that the northern regions, which contain most of the world's peatlands, will become significantly warmer in the 21st century, - continental areas (though this is less certain) becoming drier and oceanic areas becoming wetter. Since both net primary production and decomposition are closely related to moisture and temperature, significant alterations in the carbon dynamics of peatlands may result[107].

Some researchers stress the importance of alterations in the water table level[108], which might increase carbon accumulation in northern peatlands but might create a greater source of carbon dioxide in the more southern peatlands. Others stress the importance of a rise in temperatures[109] and suggest that a net loss of carbon will take place in northern fens but a net gain in northern bogs[110].

The behaviour of permafrost peatlands will also be important, as both decomposition and net primary production are accelerated following permafrost melt[111]. In general, methane emissions from peatland ecosystems will decrease with drying[112]. Increased temperatures and thaw depth in wet tundra ecosystems could, however, also increase methane fluxes, especially when, as climate models indicate, precipitation at northern latitudes increases.

It may be concluded, that there are still too many uncertainties in the magnitude and the direction of potential changes to arrive at a final conclusion on the reaction of mires and peatlands to global warming[113].

[107] Roulet 2000a, Martikainen et al 2000.
[108] Laine 2000, Martikainen et al 2000.
[109] Pastor et al. 2000, Bridgham et al. 2000.
[110] Laine 2000, Pastor et al. 2000, Bridgham et al. 2000.
[111] Turetsky et al. 2000.
[112] Laine 2000.

[113] Laine 2000; cf. Öquist & Svensson 1996: "Due to site-specific responses by wetlands and the large range of plausible anthropogenic and natural stressors, a quantitative evaluation of them in combination with climatic change is difficult. It is conceivable, however, that within the next decades the main threat to wetlands is likely to be due to anthropogenic activities rather than climate change."

Appendix 2

Convention on Biological Diversity
- Ecosystem Approach –
Principles

The Conference of the Parties to the Convention on Biological Diversity adopted an ecosystem approach for the implementation of the objectives of the Convention. The Fifth Conference of the Parties in Kenya, 2000, recommended the application of the following principles (the "Malawi Principles"):

Principle 1: The objectives of management of land, water and living resources are a matter of societal choices

Principle 2: Management should be decentralised to the lowest appropriate level.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

Principle 4: Recognising potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context.

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Principle 6: Ecosystem must be managed within the limits of their functioning.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

Principle 8: Recognising the varying temporal scales and lag-effects that characterise ecosystem processes, objectives for ecosystem management should be set for the long term.

Principle 9: Management must recognise that change is inevitable.

Principle10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

The full text of the Principles (including the rationale for each) is contained in UNEP 2000.

Appendix 3

Patterns of property ownership of mires and peatlands in some selected countries

The legal basis for ownership, and the pattern of ownership of mires and peatlands, has a major influence on the implementation of Wise Use guidelines in any country. Information on patterns of property ownership in some selected countries is given in the paragraphs which follow:

Ireland[114]: Peat cutting had played a part in the provision of domestic energy since at least the 10th century, sometimes separate from the ownership of the bog, and peat was widely used, even when wood was available.[115] From the end of the 17th century, after effective deforestation, peat became an essential part of domestic economy, not easily substitutable.

The establishment around this time of the great estates does not appear to have consolidated bog ownership, or rights to its use. In the massive report of the Bog Commissioners, presented to the British Parliament in 1814, the obstacle to the drainage and large-scale development for fuel of Irish bogs was considered to be “the indeterminate nature of boundaries between adjoining properties and the rights of turbary and grazing claimed by the tenantry” [116]

When the large estates were divided in the late 19th and early part of the 20th centuries a parcel of peat bog was considered to be a necessary part of an autonomous agricultural unit, so as the land was divided, the bogs were divided. Currently, the present occupier/owner has often not established her title, and undefined turbary rights may be held by a number of former tenants of an estate or their successors. In some cases the right to graze a bog may be held by one party, the peat underlying the grazing by another, the residual cutaway – subsoil or fee simple by yet a third, and sporting or shooting rights by a fourth. It is not impossible that all these rights may be vested in a plot of bog of 0.25 hectares “The break up of the estates accelerated after the establishment of the Irish Free State in 1922 … which divided bogs into individual strips – often very numerous and narrow, the average width being 20-30 yards – and assigned them to individual tenants.”[117]

Finland[118]: The ownership of peatlands in Finland is divided as follows: private individuals 54.5 %; the state 36.5 %; companies 6.0 %; Others (including parishes and other public "associations") 3.0 %.

Peatlands cover about 30 % of Finland’s land area. When the Crown land was divided into private farms, principally in the 19th century, the mire areas were divided between farms in approximately the same proportion as the mineral soil areas. Parcels of peatland are therefore mainly inside farm boundaries. Only occasionally are there

[114] Based on information provided by Katherine Meenan.
[115] Lucas 1970.
[116] Fuel Research Board 1921.
[117] Feehan & O’Donovan 1996 p. 30. See also O’Kelly 1959.
[118] Based on information provided by Timo Nyronen and Veijo Klemetti.

separate all-mire areas. Traditional ways of using peatlands include peat cutting for litter in the animal shelters and for domestic fuel (western Finland) as well as harvesting of naturally growing hay (eastern and northern Finland). New farms had to be established after the Second World War to accommodate the refugees from the Soviet occupied parts of eastern Finland. Many of these farms were established in areas containing large mires, a part of which were drained and cleared for agriculture.

The land owner has the right to decide how to use his peatland areas: he owns the surface, the peat layer and the bottom of the mire as well as the rights to hunt and fish in the area. The land owner can sell or lease his mire to other persons or companies. The State has encouraged private landowners to use their peatlands by granting them long-term low-interest loans for forestry drainage, but these loans are limited to mires which are fertile enough for the growing of trees. Another example of the State's interference in the landowners' rights is the establishment of new mire conservation areas. Most of the new *Natura 2000*[119] areas are in State- owned land, but some private areas have also been protected, especially in southern Finland. In these cases the state buys the land or compensates the owner by other means.

Peat producers can either lease or buy their harvesting areas from private or public landowners. In the case of leasing, the peat producer returns the land to the owner after the end of peat extraction. The landowner can then select the land-use method for the area. The most popular uses are afforestation and agriculture. Where the peat producer purchases the mire area he becomes the landowner and has the same rights and duties as the other owners.

Estonia[120]: Estonian legislation provides that land ownership extends only to the bedrock. Because peat is above the bedrock it belongs to the landowner. It is estimated that c.a. 85-90% of the peat deposits belong to the state and rest to individual owners or to local communities. The reason for the concentration of ownership in the State is that the largest part of the peat reserves is located in the centres of the peatlands which belong mainly to the state.

The rules for obtaining an extraction permit are the same whether the peat is owned by the State or privately. The exception to this is that an individual owner has the right to extract peat located within the boundaries of his/her property without an extraction permit and free of charge for his/her personal household.

Sweden[121]: Landowners in Sweden are private individuals such as farmers and foresters, private and state-owned companies. Included in their ownership are peatlands and parts of peatlands. Under Swedish law the exploitation of peatlands requires permission from the authorities but the position is different depending on whether the exploitation is for energy or horticultural purposes.

A special Peat Law allows any company (subject to permission from the authorities) the right to exploit peat for energy purposes. The landowner cannot prevent this, because energy peat is regarded as an "energy mineral" and minerals belong to the state. By expropriation the state gives the company the rights to exploitation for,

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[119] A network of protected areas established by the European Union.
[120] Based on information provided by Rein Raudsep.
[121] Based on information provided by Lars-Eric Larsson.

usually, 25 years. At the end of this period the company must return the area to the landowner. The company should by that time have reclaimed the area into, for example, productive land for forestry.

If the peat is exploited for other purposes, such as for horticulture, litter, or as a soil improver, the peat is owned by the landowner. In these cases a company can purchase the peat area or come to a profit-sharing agreement with the landowner.

Belarus[122]: All peatlands in Belarus belong to the State. Anyone is free to apply for a license from the relevant State authorities to use peatlands for peat excavation or as drained land for agriculture.

Canada[123]: In Canada, all land including peatland, other than land in National Parks, is governed by the provinces, each of which has varying rules for leases on peatlands. Less than 10 percent of peatlands in Canada are privately owned, the great majority being Crown lands (i.e. owned by the State).

Peatlands cover approximately 12 percent of Canada's surface area and comprise 72 percent of the 148 million hectares of wetlands in Canada[124]. Most peatlands occur in the boreal zone of Canada and are generally unaffected by agricultural, urban, ports/harbours, and industrial impacts.

The distribution of peatlands in Canada is 80 % pristine; 15 % in agriculture; 2% in urban and hydro; 0.02% in forestry; and 0.01% used for peat extraction[125].

Germany[126]: In the case of Germany the illustrative information is provided in relation to the Land of Lower Saxony:

Of the area of peatland in Lower Saxony 94% is in private ownership and 6% in State ownership. Some 67% of the total is in agriculture, 12% in peat extraction, 3% is being re-wetted following peat extraction and 2% is relatively untouched. Status unknown, including degraded peatlands grown with natural bushes and trees, comprise 16%.

After the second world war the government of Lower Saxony was interested in leasing peatland for peat extraction and agriculture, as there was substantial demand for energy peat and for new agricultural areas. Since 1990 the Land of Lower Saxony does not lease any new peatland areas for peat extraction or agricultural use, as the emphasis is now on preservation or restoration.

Indonesia[127]: The information provided relates mainly to the island of Kalimantan. Because the usage of land was traditionally decided by use and practice effective ownership of most land lies with the government. In remote areas indigenous peoples

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[122] Based on information provided by Nikolai Bambalov.
[123] Based on information provided by Gerry Hood.
[124] Rubec, 1996.
[125] Rubec 1988.
[126] Based on information provided by Hartmut Falkenberg.
[127] Based on information provided by Adi Jaya and Jack Rieley.

have longstanding rights to use land for hunting, cultivation moving from place to place, fishing and other resources. They do not have any legal title so the government has the power to assume legal ownership. In Kalimantan only a small percentage of the land belongs to private owners. In general, only small areas of peatland are included in the land which local communities such as Bugis, Banjarese and Dayaks cultivate. In the area of Kapuas or Samuda-Sampit, there are extensive wetlands. The areas of shallow peat cultivated vary between 2 and 10 hectares. The largest area of shallow peat cultivated by local people is in South Kalimantan, probably about 1000 hectares. To use this land they did not need a government permit as they already occupied the land before the introduction of the requirement for permits. Private companies, such as those running oil palm plantations, normally obtain government permits. These were originally issued by the central government but in future will probably be issued only by the governor/local government. These permits grant the right to use the land for 25 years. However, few of these plantations are on peatlands. In Kalimantan, particularly in South Kalimantan, most of the peatland which has been developed has been for government migration projects. Such government projects include those in Pangkoh, Basarang and most recently PLG. In the past most the land came under the Department of Forestry. The Department of Migration can only use Conversion Forest for its migration areas. Thus, as far as the use of peatland is concerned, the principal role in deciding the use of land lies with the government.

Appendix 4

Code of conduct which might be applied by a wholesale or retail company to its suppliers of peat-based horticultural products

This is an example of the type of criteria which might be applied, for instance, by a large retail chain or a large wholesaler of growing media to its suppliers of peat or peat-based growing media. ***This suggested draft code is intended to apply no matter where in the value chain the company applying the code is situated***[128].

It is not necessary for every supplier to score 100% on each item. Allowance should also be made for rate of improvement. For example, it might be more relevant to judge a new company in a developing country on the basis of improvement being made rather than on a absolute basis. It is for each wholesale or retail company to draw up its own code of conduct. What follows is no more than an illustration of some of the criteria which might be applied.

1. Characteristics of the countries in which any of the supplier enterprises operate. Are the supplier enterprises all from countries which:
1.1 Have ratified the principal international environmental conventions
1.2 Have in place comprehensive national policies relevant to mires and peatlands.
1.3 Have in place relevant legislation on land use planning and environmental protection
1.4 Have public administration functions adequate to administer this legislation
1.5 Have in place legal frameworks which protect the rights of individuals and communities over land
1.6 Take decisions at a macro-economic level regarding the exploitation of mires or peatlands on the basis of cost-benefit analysis
2. Type of mires from which all the supplying enterprises operate:
2.1 Are any of the mires and peatlands from which the peat is extracted rare, and are any of their inhabiting species rare
2.2 Are similar mires and peatlands to those exploited by the enterprises decreasing in abundance or not
1.3 Are similar mire and/or peatland types sufficiently protected in the countries of origin
2.3 Are there no alternative sustainable resources available
2.4 Do the enterprises operate on any protected sites

[128] In the case of a company manufacturing growing media it should apply to all the companies supplying it with peat; in the case of a trader or wholesaler it should apply to the manufacturer and to the companies supplying the manufacturer. In the case of a retail chain, it should apply to the wholesaler, the manufacturer and the manufacturer's suppliers.

3. Quality of decision-making
3.1 Before they develop peatlands do the supplier enterprises make adequate information publicly available and do they engage in adequate public consultation
3.2 Are the enterprises' decisions regarding the exploitation of mires and peatlands based on the best possible information
3.3 Do the enterprises take into account the implications of their decisions for other parties directly or indirectly affected; and do they take into account the effects on surrounding ecosystems, defined in the widest sense.
3.4 Do the enterprises limit their interventions to the minimum necessary
3.5 Have the enterprises located their extraction where it will cause least impact – could they or should they obtain their supplies from other sites
3.6 Do the enterprises conduct their activities on the basis of sound commercial strategy
3.7 Do the enterprises operate on the basis of accepted principles of good corporate governance
3.8 Are decisions to exploit a mire or peatland taken on the basis of cost-benefit analysis
3.9 Do the enterprises take their decisions in relation to mires and peatlands in accordance with the criteria outlined in Tables 5/3 and 5/4
4. Conditions under which peat is extracted
4.1 Do the supplier enterprises operate in accordance with national land-use planning laws and regulations
4.2 Are the enterprises' activities licensed. Do the enterprises act in accordance with the licence conditions
4.3 Do the enterprises operate environmental management systems
4.4.1 Is every effort made to preserve the ecological processes necessary for the survival of species 4.4.2 Do the enterprises seek to ensure, where possible, that any loss or damage caused by extraction is reversible
4.5 Do the enterprises - Prevent - Control - Reduce - Repair or - Compensate for any damage consequent on peat extraction
4.6 Do they bear the cost of these measures
4.7 Do the enterprises seek to adapt their extraction processes to the natural characteristics and constraints of the mires or peatlands
5. Social and environmental responsibility

5.1 Have the supplier enterprises balanced their peat extraction by compensatory conservation measures such as setting aside and preserving pristine mires
5.2 Do the benefits of the supplier enterprises' activities accrue to a large number of people and not a privileged few. For example, - do the enterprises pay adequate wages, - do they give local employment, - do they adequately compensate those with rights over land, - do the enterprises sell their products at prices affordable by ordinary people
5.3 Do the enterprises have acceptable policies on the after-use of degraded peatlands ensuring that, when production has ceased, they restore the peatland to a peat accumulating ecosystem (mire) or other environmentally appropriate use.
5.4 Do the enterprises promote knowledge and awareness of mires and peatlands
5.5 Do the enterprises conduct research into, and/or use, alternative growing media

Appendix 5

Code of conduct which might be applied to a facility for the conversion of peat to energy and the related peat extraction.

This type of code could be applied to an electricity generating station or to a briquette factory. As with the outline code in Appendix 3 this is given as an example only.

1. Role of the facility in national policy.
1.1 Is the use of peat a necessary part of national energy policy
1.2 Is the use of peat a part of national socio-economic policy
2. Type of mires which supply the facility
2.1 Within the country, are the mires and peatlands from which peat is extracted rare, are any of their inhabiting species rare, and are the functions affected rare
2.2 Are similar mires and peatlands to those used for supply decreasing in abundance or not and are similar mires and/or peatlands in the country sufficiently protected
2.3 Are there any alternative sustainable resources available
2.4 Is any of the peat extracted from protected sites
3. Peatland development
3.1 Before the peatlands were developed was adequate information made publicly available and did the enterprises engage in adequate public consultation
3.2 Were the decisions regarding the exploitation of the peatlands based on the best possible information
3.3 Did the decision to exploit take into account the implications of the decision for other parties directly or indirectly affected; and does it take into account the effects on surrounding ecosystems, defined in the widest sense
3.4 Is the intervention in the peatlands limited to the minimum necessary
3.5 Is the extraction located where it will cause least impact – could or should supplies be obtained from other sites
3.6 Does the operation conform with sound commercial strategy.
3.7 Do both the peatland enterprise and the facility enterprise operate on the basis of accepted principles of corporate governance
3.8 Was the decision to exploit taken on the basis of cost-benefit analysis
4. Conditions under which peat is extracted
4.1 Were both the peatland development and the construction of the facility in accordance with national land-use planning laws and regulations
4.2 Are the peatland operation and the facility operation licensed. Are both operated in accordance with the licence conditions

4.3 Do both enterprises operate environmental management systems
4.4.1 Is every effort made to preserve the ecological processes necessary for the survival of species 4.4.2 Does the enterprise seek to ensure, where possible, that any loss or damage caused by extraction is reversible
4.5 Does the peatland enterprise - Prevent - Control - Reduce - Repair or - Compensate for any damage consequent on peat extraction
4.6 Does it bear the cost of these measures
4.7 Does the peatland enterprise seek to adapt its extraction processes to the natural characteristics and constraints of the mire or peatland
4.8 Does the peatland enterprise have a policy of using the latest available technology to minimise environmental impact
5. Social and environmental responsibility
5.1 Has the peatland enterprise balanced its peat extraction by compensatory conservation measures such as setting aside and preserving pristine mires
5.2 Do the benefits of the operation accrue to a large number of people and not a privileged few. For example - do the enterprises pay adequate wages, - do they give local employment, - were those with rights over land adequately compensated, - is the energy produced available to all
5.3 Does the peatland enterprise have an acceptable policy on the after-use of degraded peatlands ensuring that, when production has ceased, the enterprise restores the peatland to a peat accumulating ecosystem (mire) or other environmentally appropriate use
5.4 Do the enterprises promote knowledge and awareness of mires and peatlands
5.5 Do the enterprises also promote the use of alternative energies
6. Characteristics of the facility
Does the facility use peat as efficiently as possible, using the latest technology and minimising emissions

Appendix 6

International Conventions

- United Nations Framework Convention on Climate Change http://www.unfccc.de/
- Convention to Combat Desertification (UNFCCD) http://www.unccd.int/main.php
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat (RAMSAR)
- Protocol to Amend the Convention on Wetlands of International Importance Especially as Waterfowl Habitat http://ramsar.org/
- Basel Convention on Transboundary Movements of Hazardous Wastes and their Disposal http://www.basel.int/
- Bonn Convention on Migratory Species (CMS) http://www.wcmc.org.uk/cms/
- Convention on Biological Diversity (CBD) http://www.biodiv.org/
- Convention on International Trade in Endangered Species (CITES) http://www.cites.org/
- Vienna Convention for the Protection of the Ozone Layer http://www.unep.ch/ozone
- Montreal Protocol on Substances that Deplete the Ozone Layer http://www.unep.org/ozone/
- Lusaka Agreement on Cooperative Enforcement Operation Directed at Legal Trade in Wild Fauna and Flora
- Regional Seas Conventions http://www.unep.ch/seas/
- Barcelona Convention (Mediterranean Action Plan)
- Convention on Trade in Dangerous Chemicals and Pesticides (PIC) http://irptc.unep.ch/pic/
- Convention on Persistent Organic Pollutants (POPs) http://www.chem.unep.ch/pops
- Aarhus Convention on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters

Appendix 7

The six management categories of IUCN

Category I - Strict Nature Reserve/Wilderness Area:
Protected area managed mainly for science or wilderness protection.

Category II - National Park:
Protected area managed mainly for ecosystem protection and recreation.

Category III - Natural Monument:
Protected area managed mainly for conservation of specific natural features.

Category IV - Habitat/Species Management Area:
Protected area managed mainly for conservation through management intervention.

Category V - Protected Landscape/Seascape:
Protected area managed mainly for landscape/seascape conservation and recreation.

Category VI - Managed Resource Protected Area:
Protected area managed mainly for the sustainable use of natural ecosystems.

These categories were agreed at the 19th Session of the IUCN General Assembly, Buenos Aires, January 1994, slightly amending an earlier, long-standing set of categories. A fuller explanation, with examples of protected areas in each category, is given in IUCN (1994), *Guidelines for Protected Area Management Categories,* prepared by WCMC and WCPA, published by IUCN.