WISE USE
OF MIRES AND PEATLANDS -

Background and Principles
including
a Framework for Decision-making

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Cover: Haapasuo, a 2,500 ha large mire complex in the municipality of Leivonmäki, Central Finland. Photo: Raimo Sopo.

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STATEMENT ON THE WISE USE OF PEATLANDS

Adopted by the International Peat Society and the International Mire Conservation Group March 2002[1]

INTRODUCTION

This document highlights the nature and importance of peatlands and identifies problems resulting from their use. The International Peat Society (IPS) and International Mire Conservation Group (IMCG) provide suggestions on how these problems may be resolved through application of the "wise use" approach. The challenge is to develop mechanisms that can balance the conflicting demands on the global peatland heritage to ensure its continued wise use to meet the needs of humankind. It is understood in this Statement that the term "peatlands"[2] is inclusive of "mires".

WHAT ARE PEATLANDS?

Peatlands are the most widespread of all wetland types in the world, representing 50 to 70% of global wetlands. They cover over four million km^2 or 3% of the land and freshwater surface of the planet. In these ecosystems are found one third of the world's soil carbon and 10% of global freshwater resources. These ecosystems are characterized by the unique ability to accumulate and store dead organic matter from *Sphagnum* and many other non-moss species, as peat, under conditions of almost permanent water saturation. Peatlands are adapted to the extreme conditions of high water and low oxygen content, of toxic elements and low availability of plant nutrients. Their water chemistry varies from alkaline to acidic. Peatlands occur on all continents, from the tropical to boreal and Arctic zones from sea level to high alpine conditions.

WHY PAY ATTENTION TO PEATLANDS?

Wise use of peatlands is essential in order to ensure that sufficient areas of peatlands remain on this planet to carry out their vital natural resource functions while satisfying the essential requirements of present and future human generations. This involves evaluation of their functions, uses, impacts and constraints. Through such assessment and reasoning, we must highlight the priorities for their management and use, including mitigation of damage done to them to date.

They are important ecosystems for a wide range of wildlife habitats supporting important biological diversity and species at risk, freshwater quality and hydrological integrity, carbon storage and sequestration, and geochemical and palaeo archives. In addition, they are inextricably linked to social, economic and cultural values important to human communities worldwide. Their total carbon pool exceeds that of the world's forests and equals that of the atmosphere.

Peatlands are natural systems performing local, regional and often global functions but they mean different things to different people. They can be considered as land, wetland, geological deposit, water body, natural habitat or forest stand. In many cases, they may be all of these at one time. They are analogous to living organisms because they grow, mature and may even die. Peatlands are used by many stakeholders for agriculture, forestry, fuel production, industry, pollution control, recreation, tourism, nature conservation and scientific research, while also supplying for the needs and life support of local communities and many indigenous peoples. As a consequence, any human influence on peatlands, or their surrounding landscape, can affect their form and function. This necessitates an integrated environmental impact assessment approach prior to approval of any development affecting peatlands.

The global area of peatlands has been reduced significantly (estimated to be at least 10 to 20%) since 1800 through climate change and human activities, particularly by drainage for agriculture and forestry. The latter continue to be the most important factors affecting change in peatlands, both globally and locally, particularly in the Tropics. Human pressures on peatlands are both direct through drainage, land conversion, excavation, inundation and visitor pressure, and indirect, as a result of air pollution, water contamination, contraction through water removal, and infrastructure development. The range and importance of the diverse functions, services and resources provided by peatlands are changing dramatically with the increases in human demand for use of these ecosystems and their natural resources.

PEATLANDS - A VITAL LOCAL, REGIONAL AND GLOBAL RESOURCE

Peatlands satisfy many essential human needs for food, freshwater, shelter, warmth and employment. With the growing understanding of their ecological importance to the planet, conflicting uses of peatlands arise. There are many examples of such conflicting and important demands and needs, several of which are outlined below.

- In Europe, agriculture has been the principal sector use of peatlands for several centuries, occupying 125 000 km^2. Well-managed peatland soils are among the most productive agricultural lands available, facilitating the efficient production of essential food crops. Drainage and conversion of peatland to agriculture has been going on for many centuries and continues to this day.
- In the tropics, peatland utilization mainly commenced after 1900; peatland conversion speeded up after the Second World War. The main impacts on peatlands in the tropics are through agriculture and human settlement by forest removal, fires and land drainage.
- Extensive commercial forestry operations have been established on peatlands in many nations. It is estimated that nearly 150 000 km^2 of the world's peatlands have been drained for commercial forestry.
- In several countries, peat is extracted and burned for its energy value, providing an important local and national source of heat and power. In total, some 21 million tonnes of peat generate about five to six million tonnes of oil equivalent per year.
- Peat offers an ideal substrate for horticultural plant production. Peat forms the basis of growing media that are readily available, easily processed, uniform, high performance and cost-effective, a business that is worth around $US 300 million annually. In 1999, nearly 40 million m^3 of peat were used across the world in horticulture.

- The global area of peatland used for energy generation and production of plant growing media is around 2000 km^2. Peat is also used as a critical growth medium for greenhouse seedlings used in many North American forestry replanting operations.
- There are many other uses of peatlands and peat, including building and insulation systems, animal stable litter, alcoholic drinks, environmental improvement and purification systems, balneology, therapy, medicine and textiles.
- All these uses of peatlands underpin downstream businesses that support the livelihoods of many thousands of people and generating billions of dollars annually.

PEATLAND CONFLICTS

Peatlands have been depleted or degraded in many countries around the world owing to short-term or single sector development strategies, leading to conflicts between different user groups. For example:

- the drainage of peatlands may affect their flood control functions leading to damage of downstream valley farmlands, bridges and buildings;
- drainage of peatlands for agriculture may lead to loss of carbon storage and climate change mitigation functions;
- drainage of peatlands and planting them with forests impacts on biodiversity and constrains their use for recreation, berry picking and hunting;
- strict nature conservation may impact upon the local socio-economic situation, especially in developing countries.

These conflicts often relate to trade-offs between different stakeholder groups and result in “win-lose” situations with the more influential or powerful stakeholders “winning” and the less powerful “losing”. An example is peat extraction for energy or horticulture that does not take into account peatland conservation issues or after-use. There can also be “lose-lose” situations in which all stakeholders lose, for example, the Indonesian Mega Rice Project that commenced in 1996. This project was abandoned in 1998 after drainage of 1.2 million ha of wetlands, mostly peatlands, destruction of approximately 0.5 million ha of tropical peat swamp forest and the investment of $US 500 million. The project was cancelled without producing any economically viable agricultural crops.

“Win-lose” situations can sometimes be turned into “win-win” situations by appropriate rehabilitation and after-use in which, for example, formerly drained and cutover peatlands are re-wetted, conditions for peat formation restored, essential functions revitalized, and biodiversity increased.

A key issue in the management of peatlands is the lack of human and financial resources. This includes appropriate understanding of these complex ecosystems, implementation techniques, and the human capacity to manage peatlands appropriately. There are those who wish to use peatlands for their production functions, and others who wish to preserve and regulate these ecosystems for their life-support functions. Conflicts arise between these competing views of protection and production.

Clearly, criteria are needed to assist in land use decision-making surrounding peatlands. Several examples illustrate criteria that could assist in governing the wise use of peatlands:

use of the peatland resource ensures the availability of the same quantity and quality of that resource, there is - except for side effects – no reason to refrain from using the resource.
2. Even when the supply is decreasing, a particular peatland use can be continued as long as the resource is abundant.
3. If the peatland resource is not abundant and getting rare, it is wise not to use the resource to the point of exhaustion, as the resource might be needed for more urgent purposes in the future.
4. The use of a peatland for a specific purpose may have considerable side effects. All other functions must be taken into account in the full assessment of the suitability of an intervention.
5. With respect to side effects, an intervention could be considered permissible when:
   - no negative side effects occur, or
   - the affected resources and services remain sufficiently abundant, or
   - the affected resources and services can be readily substituted, or
   - the impact is easily reversible.
6. In all other cases, an integrated cost-benefit analysis should be carried out involving thorough consideration of all aspects of the intervention

IMPLEMENTING WISE USE

The International Peat Society and International Mire Conservation Group believe that wise management of peatland ecosystems requires a change in approach. This must involve change from that of single sector priorities to an integrated, holistic planning strategy, involving all stakeholders, such that consideration is given to potential impacts on the ecosystem as a whole. The design of peatland resource management projects involving a wide group of stakeholders is a major challenge, in which stakeholders should be prepared to ensure benefits for future generations. Wise use of peatlands will be enhanced by initiatives such as:

1. Adoption and promotion of the Ramsar Convention's *Guidelines for Global Action on Peatlands* (GGAP) and implementation of its wise use themes.
2. Publication and distribution of the joint IPS/IMCG Report *The Wise Use of Mires and Peatlands - Background and Principles*.
3. Implementation of the *Global Peatland Initiative* (GPI) being facilitated by Wetlands International and its partner organizations.
4. Publication of a handbook of *Wise Use Guidelines* by the Ramsar Convention and its partner agencies as a means of delivering key aspects of the GGAP.
5. Refinement of global criteria for identifying and protecting key peatland sites for conservation purposes.
6. Refinement and standardization of peatland classification systems and terminology.

[1] See note on page 181.
[2] A "peatland" is an "area with a naturally accumulated peat layer at the surface. A "mire" is a peatland where peat is being formed and accumulating. All mires are peatlands. Sites no longer accumulating peat would not be considered mires anymore.

GUIDE TO THE USE OF THE DOCUMENT

Since 1999 the International Peat Society and the International Mire Conservation Group have been working on a project to prepare a comprehensive document on the Wise Use of mires and peatlands. This background document is the result of that work. The document is intended to be read as a whole, providing a logical sequence – what are peatlands, why are they valued, what conflicts arise between values and how these conflicts can be resolved. Chapter 5 sets out a framework of procedures which should make it possible to reach a conclusion where conflicting claims arise. These decision support procedures are essentially a sequence of questions the answers to which should provide decision-makers with a rational basis for decisions and should provide those on different sides of a dispute with an understanding of the reasoning behind a particular decision. Because this is a background document it can be further developed and applied to particular circumstances.

This summary Guide is in two parts. The first is an outline of the contents, chapter by chapter. The second is a guide to the framework for decision-making.

1. OUTLINE OF CHAPTER CONTENTS

Chapter 1

Chapter 1 outlines the background to the term ‘Wise Use’, describes why and how the document was prepared, and sets out the purpose and concept of the document and its intended use.

Chapter 2

Chapter 2 defines the principal terms used in the document, describes the process of peat formation, the different types of mires and peatlands[1], the extent and location of peatlands, rates of peat and carbon accumulation, and the characteristics of mires and peatlands. The principal characteristics highlighted are:

- peat formation requires high water levels in the peatland;
- drainage causes oxidation resulting in fundamental changes to the mire;
- there is an intimate relationship between the vegetation type, the type of peat in a mire and its water quality and fluctuations;
- a peatland is closely linked to its surrounding catchment area through water flow.

The chapter concludes with an account of the importance of mires as habitats and ecosystems.

Chapter 3

Chapter 3 outlines different approaches to what values are: why different people value the same entity[2] differently. Two categories of values are identified:

– instrumental value: the value an entity has as a means to an end: and
– intrinsic value: the value an entity has in itself, irrespective of its importance to others.

This document is based on the human-centred (anthropocentric) approach that only human beings have intrinsic value. However, many people have a non-anthropocentric approach and believe that other entities also have intrinsic value.

Instrumental values are divided between *material life-support values* (those which contribute to the maintenance of physical health) and *non-material life support values* (those that contribute to the health of spirit and mind).

Within these categories of instrumental values, a number of functions of mires and peatlands are described:

Material life-support values

These include:

- **production functions:** the role of peatlands in the production of peat for such uses as energy and horticulture, in the production of plants as food and raw materials, in the provision of drinking water, in supporting animals which provide food, and in supporting forestry.

- **carrier functions:** the role of peatlands in providing space and/or a base for such purposes as water reservoirs, fish ponds and waste deposits.

- **regulation functions:** the role of peatlands in regulating climate, and the hydrology, hydrochemistry and soil chemistry in their catchment areas.

Non-material life-support values

- **informational functions:** the role of peatlands in such areas as social identity, providing recreation, the appreciation of beauty, the perception of the spirit, and the development of knowledge.

- **transformation and option functions:** the role of peatlands in helping develop new tastes, and in creating reassurance that their biological and regulation functions will be there for future generations.

Finally, conservation and economic values derive from different instrumental values but can also reflect different approaches to intrinsic values.

Chapter 4

Where different functions and values come in conflict with one another there has to be a way to make sensible judgements between them. As a starting point it is established that the fulfilment of absolute human needs takes precedence over the fulfilment of wishes or 'wants'.

Conflicts can be divided into those dealing with facts and those dealing with choices. The first kind can be dealt with by communication and the exchange of information. Conflicts dealing with choices can be divided into those arising from having:

- **different preferences** as between different instrumental values
- **different** beliefs as to which values take **precedence** over others
- **different priorities** as between different values, and
- **different positions** as to which entities have intrinsic moral value.

In resolving conflicts between *different preferences* a unit of measurement (e.g. monetary value) can sometimes be used. More usually exploring different perspectives may lead to a more comprehensive solution. In general, solutions should tend towards equality and the preferring of needs over wants.

Conflicts between *different precedences* deal with conflicting rights. Conflicts between equal rights can not be solved by balancing pros and cons. A series of principles can be applied which will help in resolving conflicts. In general the lesser interests of individuals are to be sacrificed for the sake of greater benefits to the greatest number.

Conflicts dealing with *priorities* are most significant in relation to intergenerational justice - the obligation of the present generation not to so exploit natural resources as to damage future generations. To take the future into account we must distinguish between what is vital and what is normal (non-essential). A number of vital issues in relation to mires and peatlands are identified. In balancing the present and future the techniques of discounting and of *monetarisation*[3] can be helpful.

Conflicts between *different positions* on which entities have intrinsic value cannot be solved by compromise, as they involve peoples' fundamental value systems. These conflicts can only be approached by each acknowledging and respecting the others' position. While not easy to use in practice, a pluralist approach offers the best prospect of making progress.

Non-anthropocentric positions do not exclude human beings but treat them as part of the elements under consideration. Such a holistic ethos puts in question a system of ethics based only on relationships between human beings. The right to live according to one's own value system implies that such positions have to be considered in conflicts, even by those who do not consider them 'rational' or 'objective'. Such respect implies that environmental conflicts should be evaluated on the basis of seeking to cause the least possible harm rather than in black and white terms.

Chapter 5

Chapter 5 sets out a framework for the Wise Use of Mires and Peatlands, which is defined as that use for which reasonable people now and in the future will not attribute blame. The framework involves two stages of decision-making:

Decision in principle: any proposed intervention in a mire or peatland can first be judged against a series of questions (a '*decision tree*') which establish the effects of the proposed intervention (a) on the function which the intervention is intended to provide, and (b) on other functions of the mire or peatland. The proposed intervention is then subjected to some *general considerations* - for example does it relate to needs or wants, will it be egalitarian in its effects, is it the best means to achieve the intended end.

Implementation decisions: if after these considerations the reaction to the proposed intervention remains positive the proposal can then be considered against a set of *guidance principles*. These fourteen principles include checking, for example, whether

- the proposal is subject to public access to information,
- the proposal will be made on the basis of the best available information,
- any intervention will be the minimum necessary, and so on.

The guidance principles are subject to *modification* depending on the time and place of the proposed intervention.

The next filter is to examine whether a number of *instruments* are in use or will be used in relation to the proposed intervention. These instruments would operate at a variety of levels. For example at **national level** it should be checked whether the proposed intervention will be subject to such instruments as relevant national policies, legislation, land-use planning and environmental licensing.

Instruments to be checked on at the **level of the enterprise** include good corporate governance, the use of cost-benefit analysis in the appraisal of projects, the existence of an environmental management system, and policies on the rehabilitation of peatlands after use.

All of the filters to be used in coming to a decision on a proposed intervention are summarised in checklists, which in turn can be used as a basis for codes of conduct.

In considering the sequence of filters outlined in the framework it is again recalled that participants in any conflict will include persons who do not accept an anthropocentric point of view, who believe that entities other than human beings have intrinsic value.

In conclusion, the importance of dialogue and of seeking to understand the other person's point of view is paramount. Imbued with such a frame of mind the proposed framework will provide decision-makers with a basis for deciding between different options.

2. GUIDE TO THE FRAMEWORK FOR DECISION-MAKING

By talking of 'Wise Use' we implicitly accept that there are conflicts between what is wise and unwise. Conflicts can relate to different appreciation of facts or to different choices.

Conflicts dealing with facts

These conflicts can be divided between those based on *different understandings* or those based on *different judgements*.

Different understandings: The first of these arise from different understandings of terms. Chapter 2 gives definitions of terms used in this document. This does not mean that these definitions are the only possible ones but it does emphasise the need for a clear understanding in all cases of what people mean by particular terms. Conflicts can arise for example, from different understandings of what the word 'peatland' means - some use it to mean wetlands with the potential to accumulate peat, others to describe areas with a minimal thickness of peat.

A second form of conflict between understandings can arise from different levels of knowledge. We have thus included in Chapter 2 and in the second part of Chapter 3 an outline of the relevant state-of-the art knowledge on mires and peatlands, their types, extent, characteristics and functions. For those who want further information a wide range of references is given.

Conflicts arising from ***different judgements*** of which means will best achieve a given end. For example a community in an area with many peatlands might agree that their aim was to maximise financial benefit to the community. Some might believe that the best means was to drain the mires for agriculture and forestry. Others might believe that it would be better to preserve the peatlands and develop scientific, educational and environmental tourism. This sort of difference of opinion as to the best means to an end can best be solved by information. Examples of the elements which could assist in making a decision include

- cost-benefit analysis (as in Chapter 5) of the two options;
- the use of both utility and financial discounting (Chapter 4);
- comparative information based on monetarisation (Chapter 4);
- general considerations such as that benefits accrue widely and not just to a few, and
- guidance principles - such as involving public participation (Chapter 5).

A similar sort of conflict could arise from disagreement on the best management option for a peatland to reduce the greenhouse effect. Faced with a drained peatland some might argue for a carbon sink arising from re-flooding, others for a sink based on planting a forest. Comparative studies can be carried out, as illustrated in Chapter 3 and Appendix 1.

Conflicts dealing with choices

The resolution of conflicts dealing with choices requires an understanding of values - a value is that which causes a person to attribute worth to another person, living being, idea or thing. Chapter 3 contains a brief study of what values are and the types of values. The two principal categories of value are *instrumental values* (valuing something as a means to an end, for example valuing mires for their beauty) and intrinsic value (valuing something in itself - everyone except murderers accepts the intrinsic value of human life).

The different types of conflicts dealing with choices are discussed in what follows.

Different preferences as between different instrumental values. One person might prefer a cultivated flower in a vase which had been grown in extracted peat. Another might prefer an orchid growing wild on an undisturbed mire. These are different preferences between two expressions of the same aesthetic function. One person might prefer to extract peat from a mire to heat their home; another might prefer to leave the mire intact and harvest the berries growing wild on it. These are different preferences between two production functions. In solving conflicts between preferences, those preferences more related to needs should prevail over those more related to wants. As between equal wants, cost-benefit analysis and monetarisation may give a minimum comparative value. Respect for the choices of others and the acceptance of different perspectives may also assist in conflict resolution.

Another choice may arise for example between production functions (one person wants the heat from extracted peat) and cognition functions (another wants to preserve the mire for scientific research). But such a choice is not only between two preferences. It also involves an assessment of other functions - would drainage for peat extraction improve agricultural production on surrounding mineral soils; would drainage adversely affect important regulation functions; if the mire is neither unique nor rare is it worth preserving for research; what eventual effect on biodiversity would drainage or preservation have; are alternative fuels available. The decision-making framework set out in Chapter 5 is intended to deal with the complexity of apparently simple choices.

Attaching different precedence to different values: These are essentially conflicts between different rights: the question of rights and duties is outlined early in Chapter 4. Examples would be the right of a group of landowners to drain and develop 'their' mire against the right of humanity to the carbon store in that mire: the right of a farmer to drain 'his' land against the right of a province to the integrated management of the water in a catchment: the right of humanity to preserve a globally threatened species inhabiting a mire against the right of a local community to drain the mire to get rid of disease-carrying insects: the right of a local community to cut turf from a bog against the right of a government to preserve a rare and important mire.

In such conflicts each person or group has the right to prefer its interest over that of others; but may not violently harm others, nor interfere with their universal rights, nor deprive them of essential needs. Within those constraints one should look to the greatest good of the greatest number. In dealing with such conflicts some of the instruments outlined in Chapter 5 can be used - property rights and compensation can ensure that if the common good prevails over the individual, the latter is compensated; legislation and land-use planning can provide a context within which to make decisions. Education and awareness programmes can ensure that people taking decisions, or benefiting or suffering from decisions, are well informed.

Different priorities with respect to values: These conflicts are essentially those between the wants and needs of the present and those of the future. The present generation has duties to future generations, but there are different opinions as to the extent of these duties. Certain approaches can be helpful in such conflicts, including: utility or financial discounting of future benefits to give them a present value; distinguishing between what are normal or non-essential functions and what are vital; having a balanced approach to risk and uncertainty; and the use in certain circumstances of monetarisation (attribution of monetary value to non-material functions). An example of such a conflict would be the need for agricultural land to feed landless peasants in Indonesia versus the long-term environmental and climatic benefits of tropical peatland forests. In such cases it is possible to establish a discount 'value' for both intervening and not intervening; both the need for food and the environmental and climate functions of the peatland are vital; the risk of the intervention failing and the risk to the future peatland functions even if the intervention succeeds can be estimated. These sorts of cases also lend themselves to cost-benefit analysis; there is general experience (see Chapter 3) that agriculture on peatlands can be marginal, and cost-benefit analysis would estimate the total real costs against the total real expected gains.

Different positions on which entities have intrinsic moral value: This document is based on the premise that only human beings have intrinsic moral value (an anthropocentric view). However, some people attribute intrinsic value to some other beings (for example, sentient beings) while others attribute intrinsic value also to species, ecosystems, even the biosphere (different non-anthropocentric views). The right of people to live according to their own value systems means that all such points of view should be respected, and should be approached through moral pluralism. Anthropocentrists attribute worth to mires and peatlands for their instrumental values (what they can do for mankind). Non-anthropocentrists often value them for themselves.

This can be a fundamental issue in peatland conflicts. If the reason why people disagree in a peatland conflict arises from fundamentally different world-views it is important to establish this fact and deal with it. What many appear to be a conflict between precedents (one considers conservation more important than exploitation) may in reality be a conflict between one who attributes intrinsic value to a mire or a species and one who does not.

Framework

In general in dealing with peatland conflicts an approach based on moral pluralism is relevant - different considerations apply in different cases.

The framework in this document can be summarised in a series of questions which could be posed in relation to any proposed intervention in a peatland (an 'intervention' would include e.g., a proposal to preserve). While the word 'conflict' is used it is not always intended in the sense of disagreement or controversy - it may also refer to different options or choices available in a particular circumstance.

- Are all decision makers and participants in the conflict or choice ("those concerned") using terms with the same meaning, and have they a basic knowledge of mires and peatlands and their characteristics, extent and functions.

- Do those concerned understand the nature and categories of values and why people have different positions with respect to values.

- Do those concerned understand the different types of conflicts or choices which arise and have they identified the type of 'conflict' which arises in this particular case?

- Is the proposed intervention positive for human beings and is the function to be provided essential and non-substitutable.

- Will the proposed intervention ensure a continuous supply of the function (for example, peat for energy) and are the peatlands affected abundant.

- Will the proposed intervention negatively affect other functions, and if so are the negatively affected functions essential, are they abundant or are they substitutable.

- Does the proposed intervention interfere with fundamental human rights, is it intended to satisfy needs or wants, will the benefits be evenly distributed, and is it the best available means to achieve the desired end.

- Is the proposal clear and publicly communicated; will it produce greater advantage then not intervening; will a decision be based on the best available information, take into account effects on other entities, be limited to the minimum necessary, be adapted to the characteristics of the peatland, and respect ecological processes and habitats.

- Are the answers to the last set of questions relevant to the specific time and place of the proposed intervention.

- Is the proposed intervention affected by international law or international co-operative instruments.

- Is the proposed intervention regulated by public policy, national legislation, land-use planning and environmental licensing. Are property rights protected and is there provision for rehabilitation of the peatland after use. Does the country have a policy to protect areas of environmental importance, and are there programmes of education and awareness.

- Does the enterprise which will be responsible for the proposed intervention base its activities on commercial strategy, has it a good record of corporate governance, does it employ cost-benefit analysis in assessing proposals, has it in place an environmental management system, does it use the best available technology to minimise environmental impact, and does it exploit product diversification and alternatives which would reduce intervention in peatlands.

- Do those concerned appreciate the importance of dialogue; that there is no single set of concepts or principles which can govern every situation; and it is not possible to reduce all complexities to simple principles or single measures.

This framework should result in conflicts being resolved or options chosen with:

- a knowledge of the relevant information on mires and peatlands and their functions;
- an understanding of relevant values;
- a knowledge of the type of conflict or choice being faced;
- respect for the different points of view involved;
- a knowledge of the effect of the intervention on the proposed function and on other functions;
- an awareness of the guidance principles which will govern the intervention; and
- a knowledge of the legal, regulatory and business framework within which the intervention will be carried out.

While such a framework cannot remove vested interest or emotion from choices, it can provide a rational and inclusive basis for deciding between different options.

[1] The term ‘peatland’ includes mires. Where ‘peatland’ is used on its own in this document it is understood to include ‘mire’.
[2] ‘Entity’ is used in this document as meaning anything which exists whether physically or conceptually (cf. Latin “ens”).
[3] The attribution of monetary value to entities or services which are not normally seen to have a financial or commercial value.

CHAPTER 1.

INTRODUCTION

The first chapter sets out the context in which this document was prepared, the background to the terms ‘Wise Use’ and ‘sustainable’, and outlines the purpose of the document.

1.1 PREFACE

All human beings have a stake in the peatlands that enrich the planet. From northwest Canada to southeast Asia and southernmost America, from tropical Africa to above the Arctic Circle, everybody wants something from peatlands. Farmers, foresters, oil and mining companies, hydro-electricity plant operators and urban developers want the land beneath peatlands. Horticulturists, farmers and hobby gardeners, energy and building companies, households, chemical and environmental industries want the peat itself. Hunters, fishermen, berry and mushroom pickers want the natural harvest of the plants and animals of the peatlands. Paper industries, building companies, and furniture manufacturers want the timber on peatlands. Nature lovers yearn for primeval peatlands to nurture their spirits; hikers, campers, and backpackers demand that peatlands be preserved for their enchantment; skiers for their openness; conservationists for their biodiversity; scientists as outdoor laboratories and as sources of information.

The distribution of peatland wealth, and its division between the present and the future, was originally relatively simple: some was used to provide land for crops, some to provide peat for fuel; some peatlands were used for hunting, gathering and for recreation; the remainder were inaccessible. In the second half of the 20th century the growing demands for energy, agriculture, horticulture and forestry led to a rapid increase in the commercial use of mires and peatlands. In the same period an increasing awareness of the environmental, ecological, aesthetic and scientific value of mires and peatlands led to demands for the cessation or reduction of this exploitation[1].

Different stakeholders have widely differing views on what peatlands legacy should be left for future generations. All claim they are entitled to the beneficial air and water regulating capacities and to the natural and cultural heritage of peatlands. Increasingly they are becoming aware of the local and global environmental issues associated with peatland exploitation. In the midst of these interest groups are the millions of people who depend directly on peatlands, who earn their living harvesting, converting, cultivating, extracting, cutting, planting, exploiting, conserving, and studying peatlands. Their interests are served by thousands of organisations. Silent, but more significant, are the great numbers of citizens of Earth, who - largely unconsciously - enjoy the products and services that peatlands provide.

1.2 ‘SUSTAINABLE’ AND ‘WISE’ USE IN KEY CONVENTIONS

A number of international conventions have sought to reconcile the actual and potential conflicts between different uses[2] of natural resources. These help to provide a context for the 'sustainable' or 'wise' use of peatlands.

Ramsar: Under Article 3.1, the Contracting Parties of the Ramsar Convention agree to "formulate and implement their planning so as to promote ... as far as possible the wise use of wetlands in their territory." The Regina Conference 1987 defined *Wise Use* of wetlands as "their sustainable utilisation for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem". The Montreux Conference 1990 adopted "Guidelines for implementation of the *Wise Use* concept of the Convention".

The Ramsar Convention Strategic Plan (1997-2002, Recommendation 6.1) calls on Ramsar Parties to facilitate the conservation and wise use of peatlands at national and regional levels, including the development of regionally based peatland management guidelines.

Biological Diversity: The Convention on Biological Diversity states that '"Sustainable use' means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations."

Climate Change: The United Nations Framework Convention on Climate Change states 'The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities….The Parties have a right to, and should, promote sustainable development. Policies and measures to protect the climate system against human-induced change should be appropriate for the specific conditions of each Party and should be integrated with national development programmes, taking into account that economic development is essential for adopting measures to address climate change… The Parties should co-operate to promote a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties, particularly developing country Parties, thus enabling them better to address the problems of climate change.'

This document is informed by these concepts of 'sustainable and 'wise'. It deals specifically with mires and peatlands, and defines the Wise Use of mires and peatlands as those uses of mires and peatlands for which reasonable people now and in the future will not attribute blame. The word 'use' is employed in its widest meaning, including conservation and non-use.

1.3 PREPARATION OF A WISE USE DOCUMENT

The International Mire Conservation Group (IMCG) and the International Peat Society (IPS) agreed in 1997 to prepare jointly a document on the Wise Use of Mires and Peatlands.

IPS (www.peatsociety.fi) is an international organisation containing representatives of different interests: applied and academic scientists, engineers, and businesspeople. The mission of IPS is to promote international co-operation on all matters concerning peatlands. IPS carries out its main work through seven Commissions dealing with the use of peatlands for conservation, industry, agriculture, medicine, forestry; as well as after-use and characteristics.

IMCG (www.imcg.net) is an international network of specialists having a particular interest in mire and peatland conservation. The network encompasses a wide spectrum of expertise and interests, from research scientists to consultants, government agency specialists to peatland site managers. It operates largely through e-mail and newsletters, and holds regular workshops and symposia.

An IMCG/IPS steering group was appointed consisting of Jack Rieley (University of Nottingham), Donal Clarke (Bord na Móna p.l.c.), Hans Joosten (University of Greifswald), and Richard Lindsay (University of East London). The compilation and drafting of the document was carried out on behalf of the two organisations by Hans Joosten and Donal Clarke. It was agreed that the document should consist of a brief, clear executive summary in layman's language (the "Guide" on pages 10–17) , supported by a more extended and referenced background paper.

Progress in drafting the document was reviewed on a periodic basis at internal meetings of both organisations. In addition, meetings attended by various participating parties took place as follows:

Date	**Place**	**Circumstances**
November 1997	Surwold, Germany	Joint IMCG & IPS meeting
September 1998	Jyväskylä, Finland	IPS 'Spirit of Peatlands Symposium' with IMCG members present
May 1999	San José, Costa Rica	13th Global Biodiversity Forum[3]
November 1999	Freising, Germany	Joint IMCG & IPS meeting
March 2000	Lagow, Poland	IMCG meeting with IPS members present
May 2000	Stockholm, Sweden	IPS meeting with IMCG members present
August 2000	Québec, Canada	Millennium Wetland Event
December 2000	Heathrow, England	Joint IMCG & IPS meeting
March 2001	Wageningen	Joint IMCG & IPS meeting with Wetlands International (WI) members present.

The idea for co-operation on the development of Wise Use principles arose also from a series of other events:

Date	**Event**
1994	*The Trondheim Declaration* from the Sixth IMCG Symposium, Trondheim, Norway[4].
1995	*The Edinburgh Declaration* developed at the International Peatlands Convention, Edinburgh, Scotland[5].
1995	*The Palangka Raya Declaration* adopted by the International Conference on Biodiversity and Sustainability of Tropical Peatlands, Palangka Raya, Indonesia[6].
1996	*A Global Action Plan on Mire and Peatland Conservation* proposed during the International Workshop on Peatlands and Mire Conservation, Brisbane, Australia[7].
1996	*Recommendation VI.9 of COP6 and Strategic Plan 1997-2002*, Ramsar Convention[8].
1998	The IUCN Commission on Ecosystem Management report entitled *Guidelines for Integrated Planning and Management of Tropical Lowland Peatlands with Special Reference to Southeast Asia*[9].

1998 *Peatlands Under Pressure – Arctic to Tropical Peatlands*, International Workshop, IUCN-CEM and Society of Wetland Scientists, Anchorage, Alaska, USA[10].

1999 *Recommendations VII.1* of COP7, Ramsar Convention[11].

1999 *Statement on Tropical Peatlands,* “Safeguarding a Global Natural Resource”, Statement of the International Conference on Tropical Peat Swamps, Penang, Malaysia[12].

In preparing this document the precedents[13] set in relation to hydropower and forestry were useful.

1.4 GUIDELINES FOR GLOBAL ACTION ON PEATLANDS[14]

The preparation of this Wise Use document is part of a wider initiative between the participating organisations, the Guidelines for Global Action on Peatlands (GGAP), which has now become a document within the context of the Ramsar Convention. This Wise Use project is referred to in one of the action points within theme 4 of the GGAP. The overall aim of the GGAP is “to achieve recognition of the importance of peatlands to the maintenance of global biodiversity, storage of water and carbon vital to the world’s climate system, and promote their wise use, conservation and management for the benefit of people and the environment.” The GGAP has seven **themes** as follows:

1: Knowledge of Global Resources
   Development and application of standardised terminology and classification systems
   Establishing a global database of peatlands and mires
   Detecting changes and trends in the quantity and quality of the peatland resource
2: Education, Training and Public Awareness
3: Policy and Legislative Instruments
4: Wise Use and Management Guidelines
5: Research Networks, Regional Centres of Expertise and Institutional Capacity
6: International Co-operation
7. Implementation and Support

Each Theme is supplemented by more detailed ‘Guidelines for Action’.

1.5 PURPOSE OF THE DOCUMENT

This document aims to assist all those who influence mire and peatland management in identifying, analysing, and resolving possible conflicts, in order to plan, design, and implement the best management option for any mire or peatland. The document is intended to be applicable to all forms of management or development, from single-sector developments to multiple use projects. The Wise Use of mires and peatlands requires an integrative approach, one which looks at all their different values and functions in an integrated way.

The achievement of an integrative approach requires
(i) a knowledge of the characteristics and functions of mires and peatlands;
(ii) an understanding of the factual issues[15] involved,
(iii) correct reasoning,
(iv) an understanding of the motives and reasons for one’s own point of view,
(v) a willingness to understand the others’ point of view, and
(vi) fair compromise where there are conflicting preferences.

The purpose of the document is to establish a framework within which
– judgements can be made on choices between different options for mires;
– any permitted exploitation of mires or peatlands can be carried out in a way which causes the least damage;

– judgements can be made on whether particular peatland-based services or products have been produced or derived in accordance with accepted principles.

Not all countries will already have in place the full legal and administrative infrastructure assumed in the document. In countries where the full infrastructure does not already exist it cannot be put in place at once. It would be possible, however, to aspire to it over a period of time.

1.6 CONCEPT AND CONTENT OF THE DOCUMENT

There are no rules or doctrines which are accepted by all human beings. Living conditions, preferences, feelings, and convictions differ strongly between different interest groups, different cultures and countries, and in different time periods. Universally, human beings share only a few attributes. These include

- absolute needs (see §4.2.),
- a hereditary tendency to develop specific preferences (see §3.3), and
- an ability to approach choices rationally.

This Wise Use document is based on rational argument and is built on widely accepted premises. These premises include international Conventions and agreed United Nations statements and resolutions. It is necessary to set out first the philosophical, ethical and factual bases from which a framework for Wise Use may be derived. Chapters 2 and 3 provide factual information on the nature, origin, extent, and functional benefits of mires and peatlands. Chapter 3, in addition, describes the values which inform human preferences. Chapter 4 looks at conflicts, their causes, and approaches to solutions. Chapter 5 sets out a framework, based on widely accepted premises, within which the practice of Wise Use of mires and peatlands can be established.

This document provides

- background information on the extent, types, functions and uses of mires and peatlands,
- an underlying rationale for Wise Use, and
- a proposed framework for the Wise Use of mires and peatlands.

The Appendices contain examples of model codes of conduct which can be derived from the framework

1.7 TARGET ORGANISATIONS

This document is addressed to anyone who has to take decisions regarding appropriate uses of peatlands. It is intended to be of assistance to decision-makers in

- International Trade and Environment Organisations, Conventions, and Commissions;
- Governments and their regulatory bodies, for example, Ministries of Forestry and Agriculture, Environment agencies;
- State and voluntary bodies charged with the conservation of peatlands and mires;
- Development assistance agencies;
- Economic entities which derive commercial income from peatlands and mires, including those using peatlands for agriculture, forestry, and extraction.
- Environmental management divisions of private companies whose activities may influence, and be influenced by, the state of peatlands;
- Scientists who work for companies or in the development of forestry or agriculture on peatlands;
- Environment groups, Non-governmental Organisations (NGOs);
- Scientific and educational institutions.

The following networks and organisations would have a specific interest in the document:

- IUCN Commission on Ecosystem Management (IUCN/CEM);
- Ramsar Convention on Wetlands and its Contracting Parties;

- International Mire Conservation Group (IMCG);
- Wetlands International (WI);
- International Peat Society (IPS);
- International Association of Ecology (INTECOL);
- Society of Wetland Scientists (SWS);
- Global Environment Network;
- Institute for Wetland Policy and Research (USA).

[1] Here and elsewhere in the document, the word “exploitation” is used in the sense of deriving benefit from, without any pejorative intent.
[2] The words ‘use ’ and ‘utilisation’ are employed in this document to mean any type of use including conservation (or non-use).
[3] IUCN 1999.
[4] Moen 1995a.
[5] IPS 1995 p 49.
[6] Rieley & Page 1997.
[7] Rubec 1996a, Lindsay 1996.
[8] Ramsar 1996.
[9] Safford & Maltby 1998
[10] Maltby & MacClean 1999.
[11] Ramsar 1999.
[12] IMCG Newsletter 6 (Nov. 1999): 8-9 (www.imcg.net).
[13] Forestry Stewardship Council 2000, International Energy Agency 2000.
[14] Ramsar 2001. http://www.ramsar.org/cop8_dr_17_e.htm
[15] Including factual uncertainties.

CHAPTER 2.

MIRES AND PEATLANDS

The second chapter

- sets down the basic concepts required in this document and the terms chosen to describe them,
- explains the natural properties of mires and peatlands,
- summarises the latest available information on the extent and location of mires and peatlands, and
- outlines some basic characteristics of mires and peatlands relevant to the functions discussed in the following chapter.

2.1 CONCEPTS AND TERMS[1]

International peatland terminology is acknowledged to be in a state of confusion[2]. In order to communicate concepts are needed and terms are required to define these concepts. In this document, the following terms are used for the following concepts[3]:

A **wetland**[4] is an area[5] that is inundated[6] or saturated by water[7] at a frequency and for a duration sufficient to support[8] a prevalence of vegetation typically adapted for life in saturated soil conditions.

Peat is sedentarily[9] accumulated material consisting of at least 30%[10] (dry mass) of dead[11] organic[12] material.

A **peatland** is an area with or without vegetation with a naturally accumulated peat layer at the surface[13].

A **mire** is a peatland where peat is currently being formed[14].

A **suo**[15] is a wetland with or without a peat layer dominated by a vegetation that may produce peat.

Wetlands and suos can occur both with and without the presence of peat and, therefore, may or may not be peatlands. In our definition, a mire is always a peatland[16]. Figure 2/1 illustrates the relationship between the concepts.

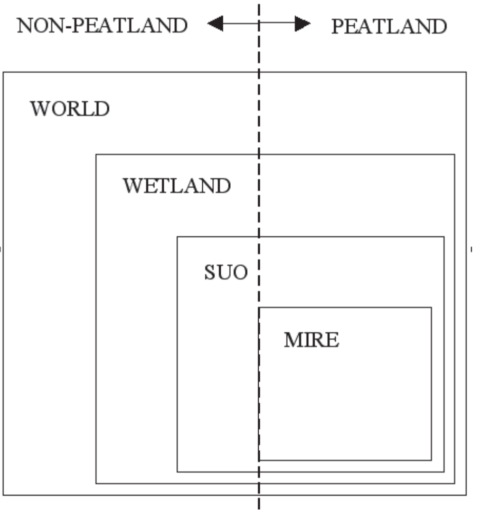


Figure 2/1 Relationship between mire, suo, wetland and peatland

2.2 PEAT FORMATION

The cycling of matter in most ecosystems is relatively fast and complete. In contrast, mires are characterised by an incomplete cycling resulting in a positive carbon balance. Because plant production exceeds decay, a carbon surplus is accumulated as peat. Peat accumulation generally takes place as a result of limited decay (decomposition) of plant material[17]. An important factor for peat accumulation is the chemical and structural composition of the organic material, determining the "ability to decay". The ability to decay varies with species (e.g. *Phragmites* versus Typha), plant parts (e.g. rhizoms versus flowers), and substances (e.g. waxes versus sugars)[18]. This means that some plant species, organs, and substances are more inclined to accumulate peat than others. A large number of plant species that occur in mires can contribute to peat formation, such as sedges, grasses, *Sphagnum* and other mosses, and woody plants. Consequently a wide variety of "botanical" peat types[19] exist.

Water is the most important external factor limiting decay. Because of its large heat capacity water induces lower than ambient temperatures[20]. The limited diffusion rate of gasses in water leads to a low availability of oxygen[21]. Both factors inhibit the activities of decomposing and decomposition-facilitating organisms, leading to a decreased rate of decay of dead organic material and, consequently, to the accumulation of peat[22].

Mires have been developing on Earth since wetland plants first existed. Peat from the tropical mires of the Upper Carboniferous (320 - 290 million years ago) and the sub-tropical mires of the Tertiary (65 - 3 million years ago) is currently found as coal and lignite[23]. The great majority of present-day peatlands originated in the last 15,000 years. Since deglaciation, mires have developed into unique organic landforms with hydrological, biogeochemical, and biological links to upland and aquatic ecosystems. It is estimated that 4 million km^2 on Earth (some 3% of the land area) is covered with peatlands. The largest known concentrations are found in Canada and Alaska, Northern Europe and Western Siberia, Southeast Asia, and parts of the Amazon basin, where more than 10% of the land area is covered with peatlands[24]. Mires store about one third of the soil carbon in the world (see §2.5 below), and contain some 10% of the global liquid fresh water resources[25].

2.3 MIRE AND PEATLAND TYPES

There are many different ways of classifying[26] wetlands, peatlands and mires that vary according to the purposes of the classification[27]. It is not possible to describe them all in this document. The typologies described here are those appropriate to the discussion in the rest of the document.

Historically peatlands were distinguished on the basis of their situation and the after-use of the remaining land, leading to the identification of:

- **bogs**, raised above the surrounding landscape. After peat extraction, which was normally carried out under dry conditions following drainage, a mineral subsoil suitable for agriculture often remained.
- **fens**, situated in depressions. After peat extraction, which was carried out by dredging, open water remained.

These 'pre-scientific' terms were adopted and adapted (on different conceptual bases) by various scientific disciplines, which has led to much confusion. More recently[28], mires have been classified into two main hydrogenetic types: **ombrogenous** mires that are fed only by precipitation, and **geogenous** mires[29] that are also fed by water which has been in contact with the mineral bedrock or substrate[30].

All water on land ultimately originates from rain and other forms of atmospheric precipitation. Precipitation water is poor in nutrients and somewhat acid. In contact with the geosphere, the quality of the water changes. Depending on the chemical properties of the catchment area (determined by climate, bedrock, soil, vegetation, and land use) and the residence time of the water (determined by the extent, bedrock, and relief of the catchment), the electrolyte and O_2 concentrations, nutrient richness, pH, and temperature of the water change. The resulting differences in water quality lead to mire habitats with differences in nutrient availability (trophic conditions), base saturation (acidity), and characteristic plant species. These differences form the basis of the **ecological mire types** (cf. Table 2/1).

Most mire and peatland typologies are based on water conditions, reflecting the central role of water in peat formation. A distinction is made between **"terrestrialisation"**, when peat develops in open water, and **"paludification"**, when peat accumulation starts directly over a paludifying mineral soil[31]. This distinction has been further developed into a system of seven basic hydrogenetic mire types, which is based on the processes underlying peat formation[32].

Hydrogenetic mire types: Water level fluctuations and water flow play an important role in peat and mire formation. Water level fluctuations influence, through redox-processes, the turn-over rate and solubility of chemical substances (nutrients, poisonous substances), and in that way the vegetation and eventually the composition of the deposited peats. Water level fluctuations furthermore condition the rates of oxidative decomposition, that lead to a change from coarse into fine plant particles and to a decrease in the porosity of the peat. Consequently as the hydraulic properties change the peats become less permeable to water (which decreases water flow) and they can store less water (which increases the water level fluctuations, Figure 2/2). Because of the strong relationship between water, vegetation and peat, hydrologic characteristics constitute one of the appropriate bases for classifying mires.

Hydrogenetic mire types are defined by the role of water in peat formation and by the role of the mire in landscape hydrology. The following hydrogenetic mire types are distinguished:

Terrestrialisation mires (Verlandungsmoore), formed by peat formation in 'open' water, can be divided into **schwingmoor mires** (floating mats, e.g. *Papyrus* swamp islands) and **immersion mires** in which peat accumulates underwater on the bottom after the water body has become shallow enough to allow peat producing plants to settle (e.g. many *Phragmites* stands). The accumulation of terrestrialisation peat ends when the water is completely filled with peat.

Water rise mires (Versumpfungsmoore) result when the water level rises over a drier surface so slowly that no open water (lake, pool) is formed. A rise in the groundwater level may be caused by an increase in water supply (by changes in climate or land use) or a decrease in run-off (by sea level rise, beaver dams, the origin of water stagnating layers in the soil, etc.).

Flood mires (Überflutungsmoore) are located in areas that are periodically flooded by rivers, lakes or seas. Flood mires with a substantial peat thickness only occur under conditions of rising water levels (rising sea water level, rising river beds, etc.). As such they are related to water rise mires. The difference is the mechanical action of periodic lateral water flow and associated sedimentation of allogenic clastic materials such as sand and clay.

Table 2/1: Ecological mire types in Northern Germany and their characteristic plant species (after Succow 1988). This table is included as an example.

ecological mire type → / species ↓	oligo-trophic acid	meso-trophic acid	meso-trophic sub-neutral	meso-trophic calca-reous	eu-trophic	salt influence
Ledum palustre, Vaccinium myrtillus, V. uliginosum, Calluna vulgaris, Empetrum nigrum, Erica tetralix, Melampyrum pratense ssp. paludosum	■					
Calla palustris, Juncus bulbosus, J. filiformis, Ranunculus flammula, Veronica scutellata, Salix aurita, Luzula pilosa, Deschampsia flexuosa		■				
Scheuchzeria palustris, Andromeda polifolia, Drosera intermedia, Lycopodiella inundata, Rhynchospora alba, Eriophorum vaginatum	▓	▓				
Dactylorhiza majalis ssp. Brevifolia, D. incarnata, Liparis loeselii, Carex appropinquata, C. diandra, C. dioica, Juncus acutiflorus			■			
Menyanthes trifoliata, Carex lasiocarpa, C. echinata, C. nigra, C. canescens, Dryopteris cristata, Eriophorum angustifolium, Juncus acutiflorus, Calamagrostis stricta, Potentilla palustris, Viola palustris		▓	▓			
Drosera rotundifolia, Pinus sylvestris	▒	▒	▒			
Tetragonolobus maritimus, Schoenus ferrugineus, Primula farinosa, Dactylorhiza majalis, Cladium mariscus, Utricularia vulgaris, Pinguicula vulgaris, Parnassia palustris, Eriophorum latifolium, Juncus alpinus, Ophrys insectifera, Gymnadenia conopsea, Polygonum bistorta				■		
Polygala amara, Betula humilis, Carex buxbaumii, C. flacca, C. hostiana, C. pulicaris, Laserpitium prutenicum, Juncus subnodulosus, Dianthus superbus, Epipactis palustris, Serratula tinctoria, Briza media, Linum catharticum, Selinum carvifolia, Succisa pratensis, Salix repens			▓	▓		
Hammarbya paludosa, Carex limosa, Drosera longifolia	▒	▒		▒		
Carex panicea, Galium uliginosum, Lychnis flos-cuculi, Potentilla erecta, Cardamine pratensis, Cirsium palustre, Rumex acetosa		▒	▒	▒		
Molinia caerulea	░	░	░	░		
Circaea x intermedia, Senecio paludosus, Cicuta virosa, Carex cespitosa, C. gracilis, C. paniculata, C. vesicaria, Hottonia palustris, Lathyrus palustris, Oenanthe fistulosa, Teucrium scordium, Thalictrum flavum, Lemna minor, Phalaris arundinacea, Typha angustifolia					■	
Alnus glutinosa, Calamagrostis canescens, Juncus effusus		▓			▓	
Ranunculus lingua, Stellaria glauca, Carex disticha, C. acutiformis, Typha latifolia, Caltha palustris, Iris pseudacorus, Myosotis palustris, Ranunculus lingua, Rumex hydrolapathum, Sium latifolium			▓		▓	
Lysimacia thyrsiflora, Thelypteris palustris, Equisetum fluviatile, Salix cinerea, Agrostis stolonifera, Cardamine palustris, Lycopus europeus, Lythrum salicaria, Mentha aquatica, Peucedanum palustre		▒	▒		▒	
Carex elata		░	░	░	░	
Blysmus rufus, Oenanthe lachenali, Plantago maritima, Ruppia maritima, Samolus valerandi, Triglochin maritimum, Aster tripolium, Centaurium littorale, Eleocharis uniglumis, Festuca rubra ssp. littoralis, Juncus gerardii, Salicornia europaea, Bolboschoenus maritimus						■
Eleocharis quinqueflora, Triglochin palustre, Carex viridula, Schoenoplectus tabernaemontani				▓		▓
Pedicularis palustris, Valeriana dioica, Juncus articulatus			▒	▒		▒
Phragmites australis		▒			▒	▒

■ species restricted to one ecological mire type
▓ ecological amplitude of the species comprises two ecological mire types
▒ ecological amplitude of the species comprises three ecological mire types
░ ecological amplitude of the species comprises four ecological mire types

Table 2/1: Ecological mire types in Northern Germany and their characteristic plant species (after Succow 1988). This table is included as an example.

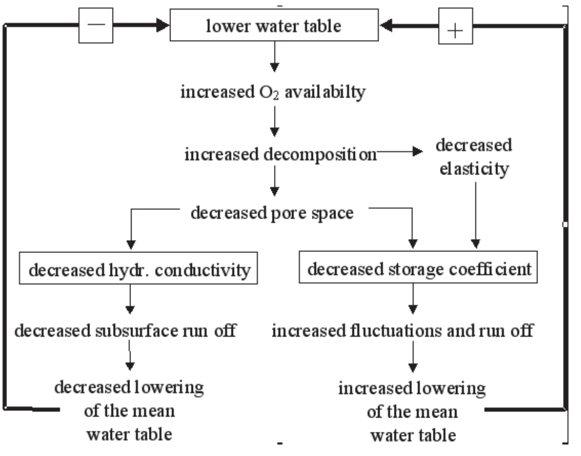


Figure 2/2. Positive and negative feedback between water table and hydraulic characteristics in a system consisting of organic matter and having significant lateral water flow[33].

Mires of all the types listed in the previous paragraph are "passive", that is, they lie **horizontally** in the landscape, their basins fill gradually with peat, but their influence on the hydrology of their catchment areas is limited.

Mires with a substantial water flow (in peat or vegetation) behave differently. The mire surface shows a **slope**[34] and a significant amount of water is lost through lateral flow. This flow is retarded by the vegetation and the peat. Vegetation growth and peat accumulation thus lead to a rise in water table in the mire and often also in the catchment area.

Percolation mires (Durchströmungsmoore) are found in landscapes where water supply is large and evenly distributed over the year. As a result, the water level in the mire is almost constant. Dead plant material reaches the permanently waterlogged zone quickly, is therefore subject to fast aerobic decay for a short time, and the peat mostly remains weakly decomposed and elastic ('schwammsumpfig'[35], Figure 2/3a). Because of the large pores and the related high hydraulic conductivity, a substantial water flow occurs through the whole peat body[36]. The peat's ability to oscillate makes conditions for peat formation at the surface increasingly stable. Whereas at the start percolation mires are susceptible to water level fluctuations[37], with growing peat thickness any fluctuations in water supply and water losses are increasingly compensated by mire oscillation (Mooratmung).

When water supply is periodically exceeded by evapotranspiration and run-off, the water level drops and oxygen penetrates the peat. The resulting strong decomposition (see Figure 2/2) causes the water to increasingly overflow the peat, and surface flow mires (Überrieselungsmoore) result. Also these mires can only endure if oxidative losses are small, i.e. if the water level only rarely drops. Surface flow mires are therefore only found in areas with almost continuous water supply, or hardly any water losses (in particular due to evapotranspiration). Because of the small storage coefficient of the peat the rare water shortages still lead to relatively large drops in water level (Figure 2/3b). Because of their low overall hydraulic conductivity and large water supply, surface flow mires can occur on and with steep slopes. Typical mires belonging to this type are blanket bogs,

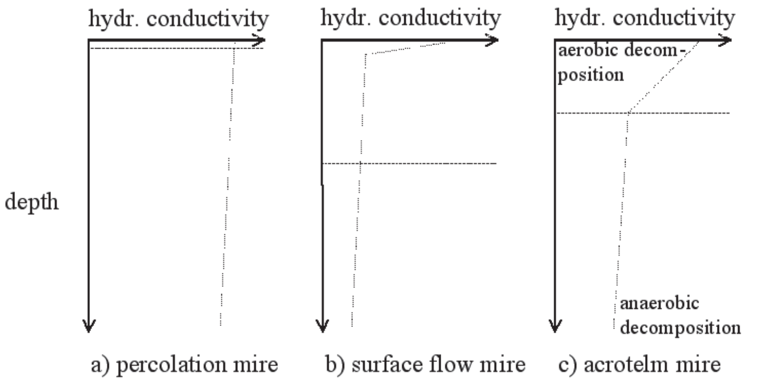


Figure 2/3: Hydraulic characteristics related to depth in different types of mire with substantial water flow. ——— = lowest water level (lasting for short durations only).

sloping mires (sloopy fens, Hangmoore), and most spring mires, which are fed by rainwater, surface run-off, and groundwater respectively.

A third type of water flow mire is the acrotelm mire[38], which accumulates organic material that combines a large storage coefficient (many large pores) with a limited ability to decay. The latter characteristic leads to a slow reduction in the pore size when subject to aerobic decay. As the deeper, older material has been prone to oxidation for longer, a distinct gradient in hydraulic conductivity develops in the upper part of the peat (Figure 2/3c). In times of water shortage, the water level drops into a less permeable range and run off is retarded. Evapotranspiration still leads to water losses, but because of the large storage coefficient of the peat resulting from its relatively large pores, the water level drops only to a small extent. In this way, the deeper peat layers are continuously waterlogged, even under fluctuating water supply. Globally the raised bog is the only acrotelm mire type so far identified. In the raised bogs of the northern hemisphere, a handful of *Sphagnum* species[39] combine a limited ability to decay[40] with favourable external (nutrient-poor and acidic) conditions. The world-wide distribution of raised bogs illustrates the effectiveness of this peat formation strategy.

The peat formation characteristics mentioned above can be combined with a classification based on the origin of water (see Table 2/2). The catchment area to a large extent determines the quantitative and qualitative characteristics of the input water. Under equal climatic, geological and geomorphologic conditions the amount, duration and frequency of water supply increase from

(a) ombrogenous – stemming solely from precipitation water; to
(b) soligenous – stemming from precipitation water and surficial run-off; to
(c) lithogenous – also stemming from deep groundwater.

Nutrient and base richness usually increase similarly. A tight correlation between quantity and quality of water and its origin is, however, not possible over larger areas. A continuous water supply not only occurs under spring-fed conditions: it can also be found in areas with very frequent rainfall. Ombrogenous water may show large differences in chemical composition[41]. When the substrate is inert, lithogenous water can to a large extent have the same qualities as rain water. Thallasogenous water (sea water) shows large differences in salt content (e.g. Baltic, North, and Dead Sea).

At a regional level, a correlation between quantity, quality and origin of water can more easily be made. Within a region, plant species are bound to certain water characteristics and, based on their material composition and hydraulic characteristics, to a large extent determine the peat formation strategy. Regionally therefore, strong correlations between abiotic conditions, vegetation, and hydrogenetic mire type can be found.

Under different bio-geographic conditions, different plant species can form equal hydrogenetic mire types. For instance, in the northern hemisphere ombrogenous surface flow mires (blanket bogs) are largely built from Poaceae (grasses) and Cyperaceae (sedges) whereas in New Zealand and Tasmania they are built from Restionaceae[42].

Percolation mires are normally found as groundwater-fed mires, because only large catchment areas can guarantee a large and continuous water supply in most climates. The raised mires of the Kolchis area in trans-Caucasian Georgia, however, are *Sphagnum*-dominated ombrogenous percolation mires which exist under conditions of over 2000mm rain per year[43]. Also in SE Asia, in areas where the climate is extremely even and wet over the year, forested mires[44] form peats with very high hydraulic conductivity[45] and may also belong to this mire type. Ombrogenous terrestrialisation and water rise mires can be found in larger complexes of ombrogenous acrotelm or overflow mires.

Table 2/2 gives an overview of combinations of the peat formation strategy and origin of water with examples (as far as they are known). Some types thus far remain unidentified (and remain therefore without examples).

As a result of complex interactions of vegetation, water, and peat ("self-organisation"), mires may develop various morphological types, consisting of a characteristic landform (cross-sectional profile, Grossform) combined with characteristic configurations of microtopographic surface-elements (Kleinform)[46].

As well as such internal processes, external mechanisms may also be important in the configuration of peatland macro- and micro-structures. Frost activity may lead to features that also exist in mineral soils but which, in case of peat-covered areas, give rise to specific morphologic peatland types.

Parallel to polygon formation in mineral soils[47], "polygon mires" are formed in areas with continuous permafrost, especially in the Arctic[48], but also in the east Siberian mountains as far as northern Mongolia[49]. The development of the polygon walls restricts water run-off during the short Arctic summer, which provides enough water for peat formation[50]. Eventually such polygons may develop into "high centre polygons"[51]. Parallel to pingo formation in mineral soils[52], a local growth of ice nuclei may give rise to the origin of "palsa" (frost mound) mires and "peat plateau"[53] mires, that often start to develop because of the insulating capacity of *Sphagnum* and that "grow" because of the hygroscopic effect of ice. As this mound formation leads to changes in local hydrological conditions, such ice core mire development leads to a change and often to an end to peat formation on the mound[54].

In mire types with water flow ice development leads to a stronger differentiation between, and a more explicit arrangement of, positive and negative microrelief elements (hummock and hollows, strings and flarks etc.)[55], which results in the development of "ribbed fens" / "aapa" mires and concentric and eccentric bogs[56].

			level water level mires				inclining water level mires		
	peat formation strategy		**Schwingmoor**	**immersion**	**water rise**	**flood**	**surface flow**	**acrotelm**	**percolation**
Water supply			Continuous	mostly continuous	Small	periodic	frequent	frequent	continuous
Mire slope			None	none	None	none / small	small / large	small	small
Internal water storage			Large	mostly large	None	small / large	very small	rather large	large
Effect on landscape water storage			storage <	storage <	storage <	storage < (>?)	storage >	storage >	storage >
Origin of the water	**ombrogenous** *bog*		Ombrogenous schwingmoor mire *Schwingmoor in bog*	ombrogenous immersion mire *terrestrialisation in bog*	ombrogenous water rise mire *water rise in bog complex*	ombrogenous flood mire *flood mire in bog*	ombrogenous surface flow mire *blanket bog*	ombrogenous acrotelm mire *raised bog*	ombrogenous percolation mire *percolation bog*
	geo-genous *fen*	**soli-genous**	soligenous schwingmoor mire *floating mat in moorpool*	soligenous immersion mire *terrestrialisation in moorpool*	soligenous water rise mire *Kesselmoor*	soligenous flood mire *Kessel-standmoor*	soligenous surface flow mires *sloopy fen, Hangmoor*	soligenous acrotelm mire	soligenous percolation mire *some sloping fens*
		litho-genous	lithogenous schwingmoor mire *floating mat on lake*	lithogenous immersion mire *lake terrestrialisation mire*	lithogenous water rise mire *groundwater rise mire*	lithogenous flood mire *river floodplain mire*	lithogenous surface flow mire *most spring mires*	lithogenous acrotelm mire	lithogenous percolation mire *typical percolation mire*
		thalasso-genous	Thalassogenous schwingmoor mire	thalassogenous immersion mire *coastal terrestrialisation mire*	thalassogenous water rise mire *coastal transgression mire, mangrove*	thalassogenous flood mire	thalassogenous surface flow mire	thalassogenous acrotelm mire	thalassogenous percolation mires

See footnote 29 re geogenous mires.

Table 2/2: Hydrogenetic mire types

2.4 EXTENT AND LOCATION OF MIRES AND PEATLANDS[57]

There is a general lack of comprehensive and comparable data on the extent and location of mires and peatlands[58]. Because of different criteria used for definition (footnotes 10 and 13) in different countries and different disciplines the available data do not compare like with like. However, in the absence of better information, the available data have been used here (see Appendix 1).

Subject to these caveats, this section sets out the most recent data on the former and present-day extent and distribution of mires, peatlands, and peat. Although many inventories of peatland resources exist[59], the status of mires has not hitherto been assessed systematically. Data were gathered from a wide variety of published sources and by consulting peatland experts, but a further inventory is certainly required[60].

The peat formation process is strongly influenced by climatic conditions. Mires are predominantly northern ecosystems, especially abundant in continental boreal and sub-arctic regions, but they are also found in the tropics. The occurrence of mires and peatlands is strongly related to topography, with the greatest abundance found on flat land areas, such as western Siberia, the Hudson Bay Lowlands, SE Asian coastal plains, and the Amazon Basin. Figure 2/5 at the end of this Chapter outlines global peatland distribution[61].

The total area of boreal and sub-arctic mires is estimated to be 3,460 -10^3 km^2.[62] The global peatland area is about 4 million km^2 [63], but these estimations remain uncertain owing to different typologies in different countries.

Within the non-tropical world (Table 2/3) less mires have survived in continents with few resources (Africa, South America) than in continents with abundant resources (North America, Asia). Europe has suffered the largest losses, both absolutely and relative to its former mire extent. Approximately 80% of both the original tropical and non-tropical mires are still in a largely pristine condition[64]. In 25% of these pristine mires, both in permafrost and in tropical peatlands, net peat accumulation may have stopped because of natural processes and recent climate change[65]. But even then, peat is still actively accumulating on 60% of the former global mire extent.

	Former extent mires and peatlands	Current extent of of mire losses	
	000 km^2	000 km^2	%
Europe	617	322	52
Asia	1070	90	8
Africa	10	5	50
North America	1415	65	5
South America	25	5	20
Australia	p.m.	p.m.	
Antarctica	p.m.	p.m.	
Total	> 3137	> 487	16

Table 2/3: Former extent of mires in the non-tropical world and losses by human activities[66].

Outside the tropics, human exploitation has altered 500,000 km^2 of mires so severely that peat accumulation has stopped completely. Peat has been and continues to be extracted to be used for the purposes outlined in § 3.4 in Chapter 3. Currently new peat extraction commences each year on some 10 km^2 of mire[67]. The available water, nutrients, organic soils, and space make mires also attractive for agriculture and forestry. 80% of global mire losses are attributable to the latter two types of land use (cf. Table 2/4). Prior to 1992, the global rate of mire destruction for forestry amounted to 4,500 km^2, that for agriculture to 1,000 km^2 per year[68]. These rates are an order of magnitude larger than the mean annual mire expansion rate during the Holocene. As a result, the global mire resource is decreasing by approximately 0.1% net per year[69].

	1000 km^2	%
Agriculture	250	50
Forestry	150	30
Peat extraction	50	10
Urbanisation	20	5
Inundation	15	3
Indirect losses (erosion, other)	5	1
Total	490	100

Table 2/4: Causes of anthropogenic mire losses in the non-tropical world[70].

Its long history, high population pressure, and climatic suitability for agriculture have made Europe the continent with the largest mire losses (Table 2/3). Peat has ceased to accumulate in over 50% of the former mire area. Almost 20% of the original mire area no longer exists as peatland. In many European countries ¶1 % of the original resource remains (Table A1/1). Denmark and the Netherlands succeeded in destroying a dominant landscape type almost completely. Only Latvia, Liechtenstein, Norway, Russia, Sweden, and Ukraine still have more than half of their original mire area left (Table A1/1).

The European experience shows clearly that an abundance of mires is no guarantee of their long-term survival. Finland has lost 60% of its formerly extensive mire area, largely by drainage for forestry since the 1950s[71]. Ireland, where mires originally covered 17% of the country, has lost 93% of its raised bog and 82% of its blanket bog mire resource[72]. The mires of Polesia in Belarus and Ukraine, one of the largest continuous mire areas of the former Soviet Union have largely been drained in the 1970s and 1980s[73].

Tables A1/1 to A1/5 in Appendix 1 give the estimated peatland/mire area where the peat is more than 30 centimetres thick (> 30 cm peat) and contains more than 30% organic material (> 30% organic material). The areas are given in km^2 per country or region grouped by continent. Total area (1998) of each country or region is given according to Encarta.

2.5 RATES OF PEAT AND CARBON ACCUMULATION[74]

Global interest related to rising atmospheric CO_2 content has led to numerous attempts to ascertain the role of peatlands in the global carbon (C) cycle as sinks for organic C[75]. Peat deposits are characterised by a high C content, about 50% of the dry organic matter. A high abundance of peat thus signals a significant net transfer of C to the soil.

In a natural state, mires accumulate C because the rate of biomass production is greater than the rate of decomposition. The accumulation of peat involves an interaction between plant productivity and C losses through the process of decay, leaching, mire fires and deposition of C into the mineral soil beneath peat layers.

Most peat-forming systems consist of two layers: an upper aerobic layer of high hydraulic conductivity, the acrotelm, in which the rate of decay is normally high; and the predominantly anaerobic underlying layer, the catotelm, of low hydraulic conductivity with a lower rate of decay[76]. The boundary between these layers is approximately at the mean depth of the minimum water table in summer, about 10-50 cm below surface[77], depending on the mire type and the micro-sites of the mire area. Carbon is added to the surface of the peat through net primary production, the acrotelm takes in CO_2, converts it to plant material, and finally passes it on to the catotelm. About 5-10% of the biomass produced annually ends up as peat[78]. Most of the C loss occurs relatively quickly and with increasing age, decay slows considerably[79]. Thus, the catotelm is the true site of peat accumulation, where slow anaerobic decomposition results in additional C loss. Generally, as peat accumulates the rate of loss from the whole catotelm increases, because there is more peat to decay.

The recent rate of C accumulation normally refers to young peat layers some hundreds of years old. Depending on the mire type and decay rates, the recent C accumulation can range from 10 to 300 g m^{-2} yr^{-1} in boreal regions[80]. The long-term apparent rate of C accumulation (LORCA) throughout the Holocene is relatively easy to calculate once a profile of dry bulk density from surface to the bottom of the mire and a basal date have been obtained. Analysis of 1302 dated peat cores from Finnish mires gives a LORCA of 18.5 g m^{-2} yr^{-1} for the entire Finnish undrained mire area[81], indicating great C loss compared to the recent average C accumulation rates. Generally, bogs have a higher average LORCA than fens. In Russian Karelia, the LORCA for the whole Holocene can be calculated as 20 g m^{-2} yr^{-1},[82] 19.4 g m^{-2} yr^{-1} in continental western Canada[83], and 17.2 g m^{2} yr^{-1} in West Siberian[84] mires[85]. In Arctic and subarctic regions the LORCA normally range from 1.2 to 16.5 g m^{-2} yr^{-1}.[86]

It is important to emphasise that LORCA can be misleading simply because of the ongoing

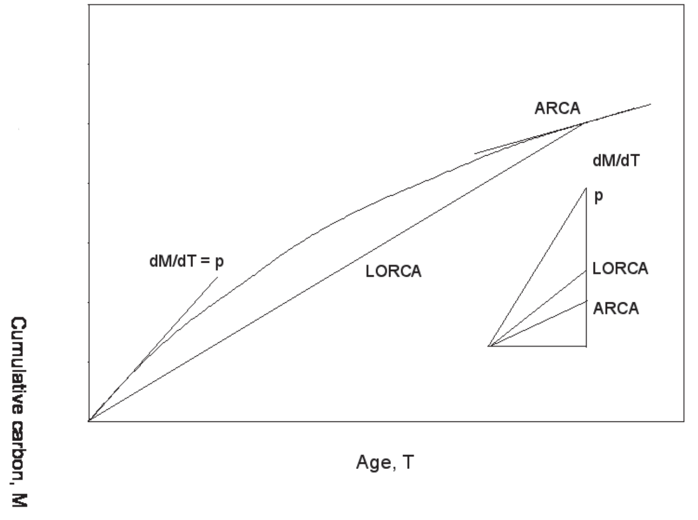


Figure 2/4: Relationship of three different commonly used measures of "peat accumulation rate". The slope at the origin is p, the rate at which dry matter is added to the system; the chord from the origin to the present is LORCA, the long term apparent rate of carbon accumulation.; the slope at the present time is ARCA, the true rate of carbon accumulation. In the inset these three rates are compared. The numerical values are always, for T>0, in the order p>LORCA>ARCA. It is often assumed (wrongly, if there is any decay) that p = LORCA = ARCA[91].

decay in the catotelm. However, LORCA provides insight into the balance between long-term input and decay. The true net rate of C accumulation (ARCA) can be determined by peat accumulation models[87], and has been estimated as 2/3 of LORCA[88]. The relationship of these three different measures of peat accumulation rate is illustrated in Figure 2/4. The differences between these three different measures increase with time.

The mineral subsoil under mires is an additional C sink that may account for approximately 5% of the unaccounted C in the global carbon budget[89].
The present-day sequestering rate of C in global mires is estimated to be 40-70 $\cdot 10^{12}$ g y^{-1} (= 40 – 70 million tonnes C y^{-1}) [90].

270-370$\cdot 10^{15}$ g of carbon (C) is stored in the peats of boreal and sub-boreal peatlands alone[92]. This means that globally peat represents about one third of the total global soil carbon pool (being 1395$\cdot 10^{15}$ g)[93]. It contains an equivalent of approximately 2/3 of all carbon in the atmosphere and the same amount of carbon as all terrestrial biomass on the earth[94].

Peat extraction is presently responsible for oxidative peat losses of approximately 15$\cdot 10^{12}$ g of carbon per year[95], while agriculture and forestry consume 100 – 200 $\cdot 10^{12}$ g C per year[96]. As global peat accumulation is about 40 - 70 $\cdot 10^{12}$ g C per year, the world's peatlands have changed from a carbon sink to a carbon source, with an annual global loss of the peat carbon resource of about 0.5‰[97].

2.6 CHARACTERISTICS OF MIRES AND PEATLANDS

The essential features of mires and peatlands – peat accumulation and peat storage – are associated with a number of other characteristics[98] that distinguish them from most other ecosystem types. As peatlands largely consist of water[99], hydrological characteristics play a central role. There follow four characteristics or processes which lie at the basis of many peatland-specific conflicts. They are therefore especially relevant to the rest of this document. (The characteristics of mires and peatlands that relate directly to "benefits", "resources" and "services" are dealt with in extenso in Chapter 3).

i) *Their principal characteristic is that the water level should - on average in the long-term - be near the surface[100] for a mire to exist, i.e. to make peat accumulation possible.*

Water levels which are too low[101] and too high[102] are detrimental to peat accumulation. This means that activities which substantially lower or raise the water level in peatlands, including their use for many production and carrier functions, negatively affect their peat accumulation capacity and the associated functions.

ii) *Oxidation processes[103] change the physical, chemical, hydraulic, and biological properties of peats and peat soils, and these changes are often irreversible[104].*

Drainage of mires brings about changes in the properties of the peat and hence in the functioning of the peatland ecosystem. Processes induced by drainage include among others[105]:

- subsidence, i.e. the lowering of the surface,
- shrinkage and swelling, and increased soil loosening by soil organisms,
- increased mineralisation (conversion of organic material to mineral substances).

As peat largely consists of water[106], drainage of peatlands leads to subsidence[107] and peat oxidation[108] and compaction. Consequently the hydraulic properties[109] (those which govern water movement) of the peats change. This may decrease the peatland's capacities for water storage and regulation[110]. These processes also take place in deep tropical peats[111]. The shrinkage and swelling of the peat as a result of increased water level fluctuations cause the formation of vertical and horizontal fissures, particularly in drier climates. These impede upward (capillary) water flow and lead to a more frequent and deeper drying out of the soil[112]. Through increased activity of soil organisms, drained peat soils become loosened and fine-grained and may eventually become unrewettable[113].

Aeration leads to oxidation and mineralisation of the uppermost peat layers. It also produces remobilisation of formerly fixed substances, and increased emissions of greenhouse gasses[114] and nutrients[115]. The dry peat following drainage can result in dust storms and fires below the surface[116]. Subsidence and oxidation lower the peatland surface[117], necessitate a continuous deepening of drainage ditches (the "vicious circle of peatland utilisation"[118]), and make drainage increasingly difficult[119].

These processes take place world-wide wherever the protective natural vegetation of peatlands is removed and the peat is drained. They are accelerated by tillage[120]. Most types of peatland agriculture show oxidation rates ranging from some millimetres up to several centimetres of peat per year depending on the microclimate[121]. In general the addition of lime, fertilisers and mineral soil material increases the rate of mineralisation in drained peatlands. In the case of agriculture these processes frequently lead to the abandonment of peatlands[122].

iii) *In mires, very close relationships exist between the vegetation type, the peat type occurring at the surface, and the hydrologic properties of the site (water levels, water level fluctuations, water quality).*

Because of this intimate interaction, changes in one of these components lead to changes in the properties of the other components. A change in mean water level of some centimetres in a mire may lead to a change in the vegetation[123] and consequently to changes in the peat that is formed[124].

iv) *Water flow connects the catchment area with the peatland[125] and various parts of a peatland with each other[126].*

A change in the water flow of the catchment or of part of the peatland may, therefore, influence every part of a peatland[127]. Such interconnections may function over many kilometres[128].

2.7 PEATLANDS AS HABITATS AND ECOSYSTEMS

Mires and peatlands are generally characterised by extreme conditions, which call for special adaptations of the species that live there.

The high water level and the consequent scarcity of oxygen in the root layer[129] requires from mire plants adaptations in

- physiology, to deal with the toxic substances[130] that originate under anaerobic conditions,
- anatomy, such as aerenchyms, plant tissues that lead oxygen from the parts above ground to the root system[131], and/or
- growth form, including aerial roots that protrude above ground or (paradoxically) xeromorphy (morphological adaptation to dry conditions) that reduces water movement in the soil zone around the roots by restricting evapotranspiration losses and so increases the time available for the oxidation of phytotoxins[132], or that enables plants to root solely in the uppermost peat layers.

Peat accumulation in mires results in an immobilisation of nutrients in the newly formed peat and a consequent scarcity of nutrients. Nutrients may further fail because of limited supply (as in ombrogenous mires) or inaccessibility (as in calcareous mires, where all phosphates are bound to calcium[133]). Mire plants therefore generally show various adaptations to nutrient shortage:

- Moss species have cation exchange mechanisms, that enable them to exchange the rare cations in the water for self-produced hydrogen ions. This mechanism is particularly well developed in *Sphagnum*[134];
- Trees often show stunted growth, e.g. conifers and Nothofagus species[135];
- Many species have large rhizome and root systems that function for several years[136];
- Dwarf shrubs are slow-growing and often have perennial or "xeromorphic" (small and thick) leaves, which reduce their need for nutrients, e.g. Ericaceae, Empetraceae, Betulaceae, Salicaceae, Rosaceae, Myrtaceae;
- Monocotyledon[137] herbs often have perennial or thin, blade-like leaves, e.g. Cyperaceae, Poaceae, Juncaceae, Juncaginaceae, Scheuchzeriaceae, Iridaceae, Restionaceae[138];
- Various dicotyledon vascular plants on mires are parasitic and have developed specialized organs to "steal" nutrients from other plants, e.g. Scrophulariaceae, Santalaceae;
- Other herbs are carnivorous[139] and catch insects for food, e.g. Droseraceae, Lentibulariceae, Sarraceniaceae, Cephalotaceae, Nepenthaceae;
- Many higher plants live in symbiosis with fungi or bacteria that help them to retrieve rare nutrients[140] (e.g. Orchidaceae, Ericaceae[141]) or that fix atmospheric nitrogen (e.g. in *Alnus*, *Myrica*, and Fabaceae[142]).

A third complicating factor for plant growth is the continuous cover by accumulating peat and the constantly rising water levels[143]. Perennial plants must be capable of continuous upward growth and must be able to develop new roots every year on a higher level[144]. Few tree species are able to make new roots on the stem[145] leading to a general scarcity or stunted growth of trees in temperate and boreal bogs.
The growth of tall and heavy trees is also hampered because the surface-rooting trees easily fall over or, in mires with a spongy peat structure such as percolation and schwingmoor mires, drown under their own weight.

Peats generally conduct heat poorly, causing a relatively short growing season for vascular plants in boreal areas. The prevalence of water and the limitations to tree growth provide mires with a climate that is generally cooler and more extreme than that of its surroundings[146], which leads to ecosystem features which are not typical of the climate zone. In forested boreal and temperate areas, open mires represent tundra-like conditions and often harbour "ice-age relicts" and disjunct[147] species and communities[148].

The acidity caused by cation exchange and organic acids, especially in the case of *Sphagnum*-dominated mires[149] and the production of toxic organic substances[150] form additional handicaps to organisms.

As a result of these extreme conditions, mires in general are relatively poor in species as compared with mineral soils in the same biographic region. This is true for temperate, boreal and tropical mires[151]. Many peatland species are, however, strongly specialised and not found in other habitat types.

The fauna of mires is also generally influenced by the scarcity of water nutrients and ions, the acidity of the water, the relative coolness, and (in the case of non-forested mires) the strong temperature fluctuations. *Sphagnum*-dominated mires in particular are characterised by poor nutrient availability because "almost nothing eats *Sphagnum*"[152].

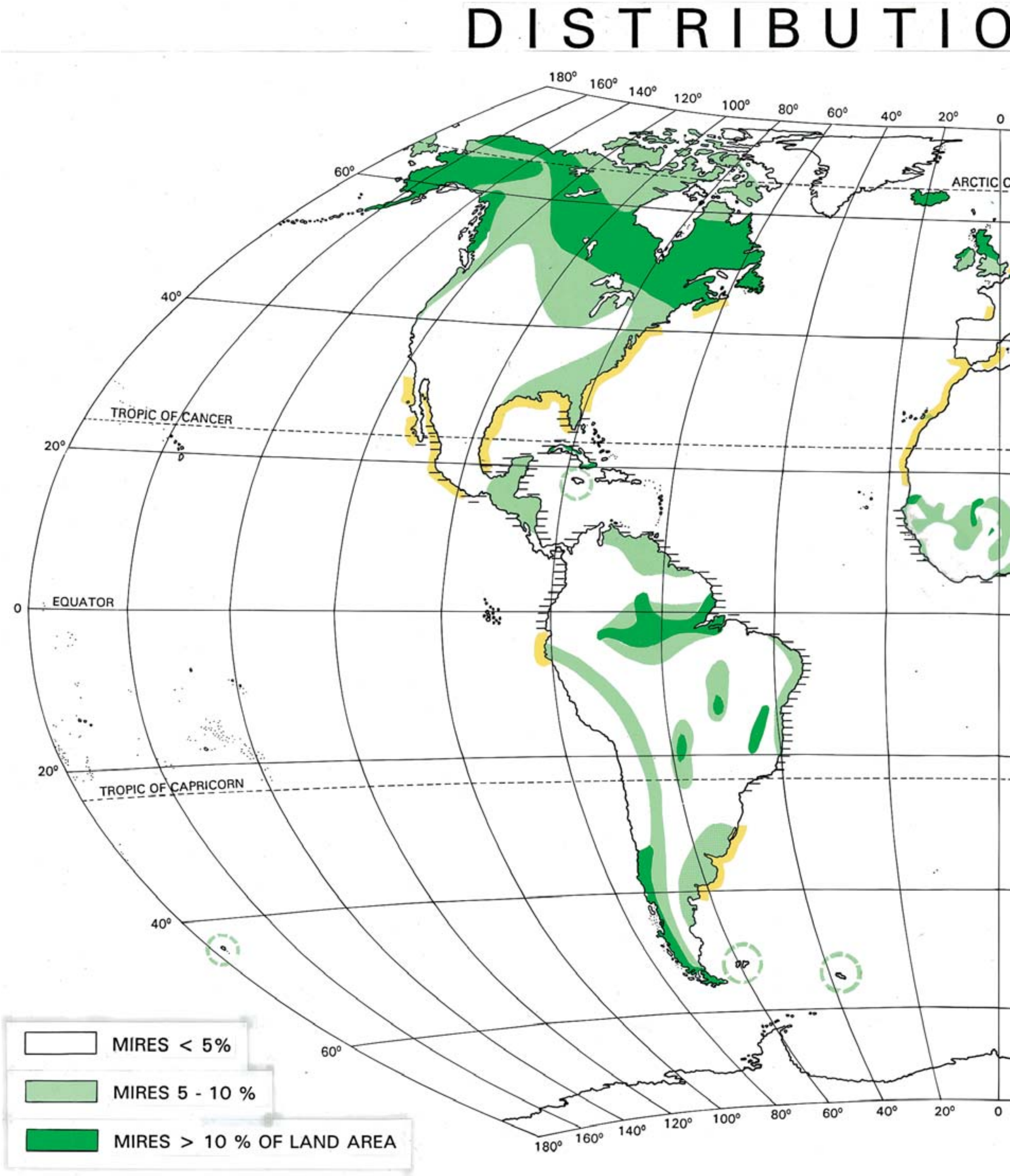
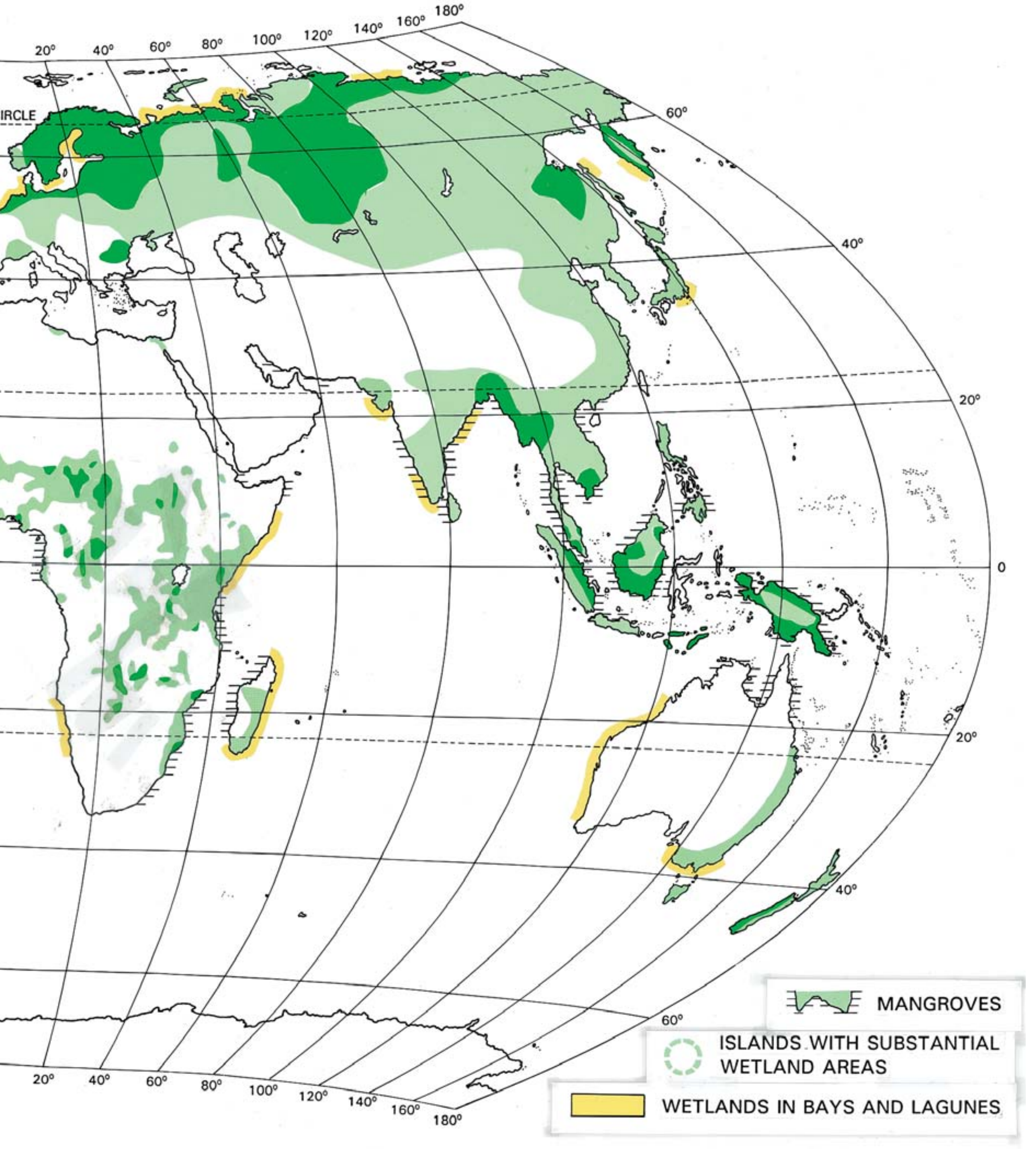


Figure 2/5. Extent and location of global mires and peatlands. From Lappalainen 1996.

N OF MIRES


MANGROVES
ISLANDS WITH SUBSTANTIAL WETLAND AREAS
WETLANDS IN BAYS AND LAGUNES

The scarcity of ions in the mire water requires considerable energy to maintain the chemical concentration in the body water (threatened by osmosis), which probably causes the pigmy forms of many mire organisms. In acid mires, Gastropoda (snails), Bivalvia (molluscs) and Crustaceae (crayfish) are generally absent, because of the scarcity of calcium carbonate. The radiation intensity and temperature fluctuations cause a melanismus (dark colour)[153].

Their inaccessibility and peacefulness have frequently made mires the last refuges of species that have been expelled from intensively-used surroundings[154]. In this manner the peat swamp forests of Borneo and Sumatra are among the last refuges for orang utan (*Pongo pygmaeus pygmaeus*) in the midst of intensively-logged forests on mineral soils[155]. Similar phenomena are also known in Europe and North America[156].

Various mire types develop sophisticated self-regulation mechanisms over time[157] and acquire an exceptional resilience against climatic change[158]. As a result such mires have characteristics similar to a living organism and are thus almost ideal examples of ecosystems. Related features are the inherent tendency of mires to develop complex surface patterning[159] and ecosystem biodiversity[160] (see Table 3/20).

1 This section has benefited from critical comments from John Jeglum and Juhani Päivänen.

2 Cf. Guidelines for Global Action Plan for Peatlands theme 1. Every international approach in peatland science and policy is complicated by the multitude of terms, the inconsistencies in their definition, and the different concepts behind similar terms in different languages and disciplines (Overbeck 1975; Fuchsman 1980, Andrejko et al. 1983; Zoltai & Martikainen 1996). Multilingual lexicons and their precursors (e.g. Früh & Schröter 1904; Mali 1956; Masing 1972; Bick et al. 1973; Overbeck 1975; Gore 1983; International Peat Society 1984) have paid too little attention to this problem. Many concepts have further been confused by uncritical translation of terms, even in translations of important handbooks (Joosten 1995a). Some illustrations: the English "moor", the German "Moor", the Dutch "moer", the Swedish "myr" and the English "mire" do not have the same meaning and cannot be (but too often are) translated one into the other. The same accounts for the German "Torf", the English "turf" and the Dutch "turf", although the meaning of the latter is somewhat similar to that of the Irish "turf". In one and the same language, the meaning of words is ambiguous and may change in time (cf. Wheeler & Proctor 2000) or may differ from discipline to discipline. In some languages the words commonly used for the type of landscapes we want to discuss do not differentiate between areas with and without peat (cf. the English "moor", the French "fagne" and "marais", the Finnish "suo", the Russian "áîëîòî (boloto)", the Georgian "tsjaowbi"), between peat forming or not peat forming (cf. the German "Moor", the Dutch "veen", the English "bog" and "fen"), or only indicate the presence of an economically extractable volume of peat (cf. "tourbière", "torfeira", "turbera" in Romance languages).

3 Communication takes place by means of terms (words, names) that represent concepts (contents, objects, ideas, notions). The concrete form of a term is of minor importance. Communication problems arise out of confusion about or disagreement on connections between terms and concepts (Hofstetter 2000a), as everybody (supported by valid semantic, etymologic, and historical arguments) prefers his or her own way of connecting terms and concepts. In international soil classification, this problem has been solved by introducing artificial terms (FAO-UNESCO 1988). This approach - for scientific purposes - has also been proposed for peatlands (Hofstetter 2000b). In this document, existing terms are used because they make possible an easier association with the subject (even where they also cause some confusion). The terms used are for the purposes of this document and their definitions are not intended to pre-empt further discussion. Definitions are only provided of terms and concepts that are essential for this document. Other than in quotations the document refrains from using confusing words such as "swamp" and "marsh".

4 For an extensive review of definitions of "wetland", cf. Tiner 1999. The definition presented here is based on the Ramsar definition modified with wording derived from the US Amy Corps of Engineers definition.

5 Of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary (cf. Ramsar definition)

6 Up to a depth of six metres at low tide (cf. Ramsar definition).

7 Surface or groundwater, static or flowing, fresh, brackish or salt (cf. Ramsar definition).

8 And that under normal circumstances does support (cf. US Army Corps of Engineers definition).

9 "Sedentary" (cf. Von Post 1922) is used in this document to mean formed on the spot and not transported after its formation and death. Peat

differs in this respect from organic sediments like gyttjas and folisols (Blattmudde, "Waldtorf"), which originate from organic matter "falling" from above (planktonic material, resp. leaves and branches) (cf. Pakarinen 1984). Peat may have a sedimentary component (e.g. derived from algae in hollows, seeds and leaves, or in case of spring and flood mires consisting of mineral material), but a strict sedentary component derived from non-aquatic plants should always be present (cf. Succow & Stegmann 2001a).

[10] Varying with country and scientific discipline, peat has been defined as requiring a minimal content of 5, 15, 30, 50, 65% or more (dry mass) of organic material (cf. Andrejko et al. 1983, Agriculture Canada 1987, Driessen & Dudal 1991, Succow & Stegmann 2001b). The organic matter content is of importance for the use of peats. The different approaches, however, probably do not lead to strongly different global volumes of "peat" (Joosten 1999a). The definition used here is proposed so as to provide this document with a consistent term. The 30% is a value often encountered in definitions of peats and organic soils in international literature.

[11] Peat may contain living organisms and (living and dead) biomass, even in deep layers, including micro-organisms, spores, and living roots (Cf. Belanger et al. 1988), but these do not dominate (Joosten & Couwenberg 1998).

[12] By "organic" is meant that the material results from carbon chemical biosynthesis. Organic materials belong to the larger group "organogenic" materials, which include all substances that have originated from organisms. For example, corals are organogenic, but not organic, sedentates (Joosten & Couwenberg 1998).

[13] Varying with country and scientific discipline, peatlands have been defined as having a minimum thickness of 20, 30, 45, 50 or 70 cm of peat. This question is discussed in detail in work on soil classification – for example in Agriculture Canada 1987. See also Joosten & Couwenberg 1998. The definition used here is proposed so as to provide this document with a consistent definition. It should be noted that – to provide a uniform standard – the inventories in §2.4 and Appendix 1 use a minimum peat depth of 30 cm to which all available data were recalculated.

[14] Cf. Sjörs 1948. It is difficult to test in practice whether or not peat is accumulating. The dominance in the vegetation of species, whose remains are also found in peat, can together with the incidence of almost permanent waterlogged conditions, be taken as good indicators of peat formation.

[15] Some concepts of "mires" (e.g. the Finnish "suo", the Russian "áîëîòî" (boloto), and the mire definition of Löfroth 1994) in fact refer to what we here call "suo".

[16] Mires are wetlands, as peat is largely formed under waterlogged conditions. Approximately half of the world's wetlands are peatlands (Mitsch et al. 1994, Lappalainen 1996). Peatlands where peat accumulation has stopped, e.g. following drainage, are no longer mires. When drainage has been severe, they are no longer wetlands.

[17] Clymo 1983, Koppisch 2001.

[18] Koppisch 2001.

[19] Cf. Succow & Stegmann 2001a. Peat types are furthermore distinguished on the basis of their degree of decomposition (cf. black peat, grey/white peat - Von Post scale), nutrient content, acidity, ash content/content of organic material (cf. Halbtorf, Volltorf, Reintorf), pedogenic alteration (cf. the German Ried, Fen, Mulm), fibre content (fibric, hemic, sapric), and other characteristics (cf. Fuchsman 1980, Andriesse 1988, Succow & Stegmann 2001b).

[20] Ball 2000.

[21] Denny, M.W. 1993.

[22] Moore 1993, Freeman et al. 2001.

[23] Demchuk et al. 1995, Lyons & Alpern 1989, Cobb & Cecil 1993.

[24] Lappalainen 1996

[25] Cf. Turunen et al. 2000a, UNESCO 1978.

[26] Classification comprises the sorting and grouping of things into classes ("classi"-fication) on the basis of their similarities and dissimilarities. The classification procedure results in a typology: a system of categories ("types", cf. "typ"-ology) on the basis of logical principles and functional interests. Classification is the process, typology is the result. Cf. Joosten 1998.

[27] Cf. Overbeck 1975, Gore 1983a, b, Moore 1984a, Eurola & Huttunen 1985, National Wetlands Working Group 1988, Brinson 1993, Finlayson & Van der Valk 1995, Wheeler & Proctor 2000, Succow & Joosten 2001, http://www.imcg.net/docum/greifswa/greifs00.htm.

[28] Dau (1823) was the first to acknowledge that bogs are fed "by merely rain and dew of heaven."

[29] Based on the origin of water, geogenous mires have been further subdivided into topogenous and soligenous mires. According to the original definitions (Von Post 1926) topogenous mires depend on topographic conditions and are relatively independent of climate, because they "develop in terrestrialising lakes or river valleys, or at springs". In soligenous mires, peat formation is not only induced and continued by direct precipitation, but "also by meteoric water running off from the surrounding terrain" (Von Post & Granlund 1926). See Table 2/2 below. In later publications the term "soligenous" has often been used differently to mean "originated under influence of streaming groundwater" (cf. Sjörs 1948) which a.o. leads to a typological switch of spring-fed mires from "topogenous" to "soligenous". To make the confusion even larger (cf. footnote 2), the term "soligenous" has also been used to describe solely spring mires (cf. Masing 1975, Wolejko 2000).

[30] Cf. Sjörs 1948.

[31] Weber 1900, Gams & Ruoff 1929. Kulczyñski 1949 contributed to the development of a hydrological mire typology by pointing out the importance of water movement (Cf. Bellamy 1972, Moore & Bellamy 1974, Ivanov 1981).

[32] Succow 1981, 1983, 1999; Succow & Lange 1984,

Joosten & Succow 2001.

[33] Adapted from Couwenberg & Joosten 1999.

[34] Sjörs 1948.

[35] Cf. Succow 1982.

[36] Cf. Wassen & Joosten 1996, Sirin et al. 1997, 1998a.

[37] Joosten 1997.

[38] Sensu Couwenberg & Joosten 1999.

[39] Joosten 1993.

[40] Johnson & Damman 1991.

[41] Cf. Wolejko & Ito 1986, Damman 1995.

[42] Agnew et al. 1993, Shearer 1997, personal communication from Ton Damman.

[43] Kaffke et al. 2000.

[44] Rieley & Page 1997.

[45] Cf. Driessen & Rochimah 1976; pers. comm. Herbert Diemont 1998.

[46] Examples include plateau bogs, concentric bogs, eccentric bogs, aapa fens etc. The origin and development of these striking patterns is still subject to considerable debate, particularly with regard to the processes that control them (see reviews in Glaser 1999 and Couwenberg & Joosten 1999).

[47] Alexandrova 1988.

[48] Cf. Tarnocai & Zoltai 1988, Glooschenko et al. 1993.

[49] Jeschke et al. 2001.

[50] Polygon mires are therefore a subtype of the water rise mire type.

[51] Tarnocai & Zoltai 1988, Glooschenko et al. 1993.

[52] For a review, see MacKay 1998.

[53] Åhman 1977, Zoltai et al. 1988, Glooschenko et al. 1993.

[54] Blyakharchuk & Sulerzhitsky 1999.

[55] Initial ice formation in surficial peat leads to an initial raising of the surface, because ice has more volume than a similar mass of water. As the more elevated elements get a thinner snow cover they are consequently less insulated in winter, and the ice nuclei thus get colder and expand. The drier surficial moss layer of the elevated element insulates the ice core against thawing in summer (Glooschenko et al. 1993). The formation of ice in the elevated elements also decreases their hydraulic conductivity (Glooschenko et al. 1993) and has a similar effect on pattern formation to that of stronger decomposition (cf. Couwenberg & Joosten 1999).

[56] Glooschenko et al. 1993, Jeschke et al. 2001.

[57] See also Appendix 1. Methodological remarks: See Joosten 2002 for a detailed presentation and discussion of the basic data. For international comparison, existing data have been adjusted to a uniform standard. In this inventory (cf. §2.1) ‘peatlands’ are areas with a minimum peat depth of 30 cm; peat consists of at least 30% (dry weight) organic material; ‘mires’ are peatlands with actual peat accumulation. The first criterion (depth of 30 cm.) excludes many (sub)arctic areas with a shallow peat layer, the second criterion is consistent with common definitions and does not greatly affect the inventory results. Because every peatland is or has been a mire, the former occurrence of mires have largely been reconstructed from the extent of peatlands and peat soils. For the ‘original occurrence’, the maximum mire extent in every region during the Holocene has been used. Applying a fixed time slice would have been complicated, as mires were already being destroyed in some regions, very early and extensively, while still expanding in other places. There are no indications that a substantial area of mires disappeared naturally since the Holocene maximum. Anthropogenic losses (losses due to human activity) also include indirect effects, e.g. consequent hydrological changes outside the mire area itself. Peat subsidence, oxidation, and erosion following human activities have changed many former peatlands into mineral soils according to geological or pedological definitions, excluding them from recent inventories. These sources of error have been corrected for by taking historic land use intensity into account. Human activities have not only led to a destruction of mires, but also to their origin and expansion (Moore 1975, Törnqvist & Joosten 1988). It is difficult to judge to what extent these processes would have taken place without human interference (cf. Moore 1993). For this reason these possible ‘constructive’ activities have not been balanced with those of a ‘destructive’ nature. National borders have been changing considerably in the 20th century, particularly in Central Europe, complicating the use of older inventories. The figures of losses presented here are to a large extent “guesstimates”, as adequate data are not available for the majority of countries. Available data are largely out-of-date, inconsistent, and difficult to compare. This applies to peatlands in general, but especially to mires. Little doubt can, however, exist about the order of magnitude and the trend of the changes. Data for different types of mires are even more difficult to obtain on a global scale, because of non-compatible classification systems and typologies.

[58] “Many of the data on peat resources are published on the basis of undisclosed modes of computation. Field mapping, coring, and analyses are often inadequate or wholly lacking, so that the published values for such cases should be considered as well-intentioned speculations rather than as reliable geological data.” (Fuchsman 1980).

[59] Most recent world-wide overview Lappalainen 1996. See also Rubec 1996, Zoltai & Martikainen 1996.

[60] The absence of reliable data on the actual mire and peatland resource and its recent changes underlines the necessity for further inventory, as recommended by the 6th and 7th Conferences of the Contracting Parties of the Ramsar Convention and the Global Action Plan for Peatlands Theme 1.

[61] The map is taken from Lappalainen 1996.

[62] Gorham 1991.

[63] Lappalainen 1996. Tables A1/1 to A1/5 in Appendix 1.

[64] Joosten, 1999, Safford and Maltby, 1998.

[65] Vitt and Halsey 1994, Oeckel et al. 1993, 1995, Malmer & Wallén 1996, Vompersky et al. 1998,

Sieffermann et al. 1988.

[66] Adapted from Joosten 1999. N.B.: these older data may not be fully compatible with the newer data in Tables A1/1 to A1/5 in Appendix 1.

[67] Guesstimate based on production figures corrected for extraction on already-drained areas.

[68] Immirzi et al. 1992. Additional contemporary information is sought on this figure. It is likely that the order of magnitude of the combined figure remains valid, given recent large projects in South East Asia.

[69] Additional contemporary information is required to verify this figure.

[70] Joosten 1999.

[71] Paavilainen & Päivänen 1995.

[72] Foss 1998.

[73] Bambalov 1996, Belokurov et al 1998.

[74] Based on information from Jukka Turunen.

[75] E.g. Botch et al. 1995; Kauppi et al. 1997; Clymo et al. 1998; Turunen et al. 1999; Vitt et al. 2000; Turunen et al. 2000.

[76] Ingram 1978; Clymo 1984.

[77] Ivanov 1981; Clymo 1984.

[78] Clymo 1984; Gorham 1991; Warner et al. 1993

[79] Tolonen et al. 1992

[80] Tolonen & Turunen 1996.

[81] Turunen et al. 2000a.

[82] Elina et al 1984.

[83] Vitt et al. 2000.

[84] Turunen et al. 2000b. These data concern old watershed ombrotrophic mires in the middle taiga zone. New research gives LORCA values for the south taiga zone of West Siberia of 41.2±12 (SE) (n= 14), with values ranging from 24.9 to 56.4 g m-2 yr-1 (pers. comm. Elena Lapshina, cf. Lapshina et al. 2001).

[85] These new estimates are lower than earlier estimates of 26-30 g m-2 yr-1 for boreal and sub-arctic regions, e.g. Gorham 1991; Botch et al. 1995; Tolonen & Turunen 1996; Clymo et al. 1998. The difference in LORCA estimates is mainly due the fact that shallow mires have been under-represented in previous studies. There has also been great uncertainty in average dry bulk densities of peat layers. The bias of data towards deeper peat deposits is also evident through the classification of mires in northern latitudes based on the minimum thickness of peat deposits, as noted in Note 13 above. For example, the minimum thickness for geological mires in Finland, Canada and Russia is 30, 40 and 70 cm (Lappalainen & Hänninen 1993, Zoltai et al. 1975, Botch and Masing 1979), respectively.

[86] Summarised by Vardy et al. 2000.

[87] Clymo 1984, Clymo et al. 1998.

[88] Tolonen & Turunen 1996.

[89] Turunen et al. 1999.

[90] Gorham 1991, Clymo et al. 1998, Turunen et al. 2000a.

[91] After Clymo et al. 1998.

[92] Turunen et al. 2000a. The large range of these C storage estimates reflects the uncertainty in the depth and dry bulk densities of global peat deposits.

[93] Post et al. 1982.

[94] www.wri.org/climate/carboncy.html, Houghton et al. 1990.

[95] This figure does not include carbon emissions from peat oxidation in peatlands drained for and by extraction.

[96] Immirzi et al. 1992.

[97] See also Armentano & Menges 1986, Botch et al. 1995, Lappalainen 1996, Vompersky et al. 1996, Joosten 1999.

[98] See also §§ 2.2, 2.3, and 2.7. The characteristics outlined in this chapter are principally those relevant to the functions discussed in Chapter 3.

[99] Undrained peatlands contain between 85% and 95% water, making them often "wetter" than unskimmed milk. Undrained peatlands can often be regarded as "mounds of water kept together by some organic material".

[100] = just below, at, or just above the surface, cf. Edom 2001a.

[101] See §2.2, Ivanov 1981, Koppisch 2001.

[102] Because of erosion and the lack of oxygen and carbon dioxide, c.f. Ivanov 1981, Ingram & Bragg 1984 Alexandrov 1988, Sjörs 1990, Lamers et al. 1999.

[103] Resulting from aeration or input of specific ions (e.g. nitrates, iron, sulfates) (Edom 2001a, Koppisch 2001).

[104] Kløve 2000, Edom 2001a, Stegmann & Zeitz 2001, Pozdnyakov et al. 2001. Similar changes also result from the imposition of weight.

[105] Schmidt et al. 1981.

[106] Moisture contents of undrained peats of 90 - 95 % are not uncommon (cf. Segeberg 1960).

[107] Subsidence is the lowering of the peatland surface level as a result of decreased water pressure. A lowering of the moisture content of peat from 95% to 90%, for example, halves the volume of the water in the peat, and affects substantially the height of the mire (Segeberg 1960). Five years after drainage, the height of a bog in Germany had already decreased by more than 2 metres (Baden 1939). Construction of a road through Clara Bog (Ireland) lowered the surface in the centre of the remaining mire by possibly 4 metres (Van der Schaaf 1999).

[108] See Figure 2/2 and §2.3.

[109] Including porosity, storage coefficient, and hydraulic conductivity (Edom 2001a).

[110] Edom 2001b. See also §3.4.3 (o).

[111] Suhardjo & Driessen 1977, Maltby 1986, Stewart 1991.

[112] Cf. Brandyk & Skapski 1988.

[113] Stegmann & Zeitz 2001.

[114] See §3.4.3 (m), Tables A2/7 and A2/8 and Fig. A2/2.

[115] Including nitrates and phosphates, which may cause water eutrophication (Gelbrecht et al. 2000).

[116] Maltby 1986.

[117] Long-term observations show height losses of up to 4 metres in 130 years, c.f. Hutchinson 1980, Eggelsmann 1990.

[118] "Teufelskreis der Moornutzung", c.f. Kuntze 1982.

[119] Gravity drainage becomes increasingly difficult as the water level difference with the main drainage canal (river, sea) becomes smaller. When

water level differences - as in case of many fens - become negative, the instalment of polders - including dike construction and maintenance and continuous pumping - becomes necessary.

[120] See §3.4.1 (ea).

[121] Eggelsmann 1976, 1990; Dradjad et al. 1986, Stegmann & Zeitz 2001.

[122] The rate of surface lowering in Florida peatlands, for example, is 2.5 cm per year, even with careful management. It is estimated that market garden crops can only be grown on an area for about 20 years (Stewart 1991). Oxidation can eventually lead to the loss of the entire peat profile and the exposure of underlying nutrient-poor substrates with waterlogged, potentially toxic (acid sulphate) soils. In sub-coastal situations this may be followed by marine inundation (Page & Rieley 1998). A combination of socio-economic changes, drainage problems, and soil deterioration has recently led to a massive abandonment of agricultural peatland areas in Central Europe (Succow & Joosten 2001).

[123] Ivanov 1981, Davis et al. 2000. Small hydrologic changes may hence induce large losses in biodiversity.

[124] Changes in the vegetation and consequently the peat by century-long mowing of sedge mires in many parts of Europe is possibly, next to shallow drainage of peatland and catchment, one of the prime reasons for scrub encroachment after abandonment of these originally open species-rich fens (cf. Wassen & Joosten 1996).

[125] E.g. Wassen & Joosten 1996, Edom 2001b.

[126] E.g. Glaser et al. 1997, Couwenberg & Joosten 1999, Edom 2001b.

[127] Kulczyñski 1949, Ivanov 1981.

[128] Cf. Schot 1992, Joosten 1994, Van Walsum & Joosten 1994, Glaser et al. 1997, Wetzel 2000.

[129] Cf. Hook & Crawford 1978.

[130] Including possible high concentrations of sulphides and reduced iron and manganese (cf. Sikora & Keeney 1983).

[131] Cf. Grosse et al. 1992.

[132] Armstrong 1975

[133] Boyer & Wheeler 1989.

[134] Clymo 1963, Clymo & Hayward 1982.

[135] Roosaluste 1982.

[136] Bliss 1997

[137] The flowering plants are subdivided into two large groups: the monocotyledons and the dicotyledons. In dicotyledons the embryo sprouts two cotyledons, which are seed leaves that serve to provide food for the new seedling. Monocotyledon embryos only have one such cotyledon. The two groups differ in a number of ways. Dicotyledons have floral organs (sepals, petals, stamens, pistils) in multiples of four or five, monocotyledons generally in multiples of three. The leaves of dicots have a netlike vein pattern, while those of monocots have parallel veining.

[138] Tüxen 1982.

[139] Givnish 1988

[140] Marschner 1995. See also Keddy 2000 who points to the fact that compared to other habitats mycorrhizae are relatively uncommon in wetlands and soil nutrient gradients may therefore be even more important in wetlands than in terrestrial habitats.

[141] Burgeff 1961.

[142] Hall et al. 1979, Chartapaul et al. 1989.

[143] Cf. Van Breemen 1995.

[144] Grosse-Brauckmann 1990, Malmer et al. 1994.

[145] Picea mariana in North America is an important exception.

[146] See also §3.4.3 (n).

[147] Disjunct species are related, through ancestors, to populations found in distant locations from which they have been separated by time and geologic events. Arctic/alpine disjunct species, for example, occur in the Arctic and in various alpine areas outside the Arctic, but not in between. Their distribution was fractured by climatic change.

[148] Peus 1932, 1950, Burmeister 1990, Masing 1997, Schwaar 1981.

[149] Ross 1995, Van Breemen 1995.

[150] Verhoeven & Liefveld 1997, Salampak et al. 2000.

[151] Rieley 1991, Page et al. 1997, Rieley et al 1997.

[152] Clymo & Hayward 1982.

[153] Burmeister 1990.

[154] Burmeister 1990.

[155] Page et al. 1997. See also the long list of endangered mammal, bird, and reptile species that find a refuge in Southeast Asian peat forests in Page & Rieley (1998).

[156] Cf. for example Van Seggelen 1999 and §3.4.1 (d).

[157] Cf. Ivanov 1981, Joosten 1993.

[158] Couwenberg et al. 2000.

[159] Cf. various papers in Standen et al. 1999.

[160] Couwenberg 1998, Couwenberg & Joosten 1999. See also §3.4.4 (u).

CHAPTER 3.

VALUES AND FUNCTIONS OF MIRES AND PEATLANDS

This chapter sets out the types of values that human beings use in making choices between alternative benefits. It sets out the different benefits which are derived from mires and peatlands. A substantial number of experts have contributed material for this chapter.

3.1. WHAT ARE VALUES?[1]

Solving conflicts between different uses of mires and peatlands (for example, between economic utilisation and environmental conservation) in a rational way presupposes an understanding of the various values[2] at stake. There are at least three fundamentally different approaches to what values are[3]:

- In the *idealistic* approach, based on ancient Greek philosophy, values are regarded as ideal and objective, independent of the real world. It is assumed that these values are known through a special "intuitus". Followers of this approach are currently rare[4].
- In the *naturalistic* approach, values are regarded as objective properties of an entity[5], independent of the person making the valuation. Things in the real world are considered to have value, just as they have mass or velocity. Several world religions and contemporary environmental philosophers defend this approach[6].
- In the *preference* approach, values are regarded as properties assigned by a valuer, resulting from the preferences of the person making the valuation. "Absolute" values do not exist. Each person is free to value entities as he or she feels about them. Consequent on the many different resulting preferences, a great variety of value-standards exist. None of these value-standards can be considered "better" or "worse" than the others except when other premises make them so. Most experts in value theory (axiology) currently support this preference approach.

Values are generally divided into two categories:

- ***Instrumental values*** are clear means to an end ("instruments"). Instrumental value is equal to **function**[7]: the beneficial effect of an entity on another entity. Instrumental values can be studied systematically by science and are therefore more objective than intrinsic values.
- Entities that are to be respected as such, i.e. independent from everything else, are said to have ***intrinsic moral value*** (or "moral standing").

The existence of intrinsic moral values is logically included in the idea of a mean-end relationship, when a chain of means (instrumental values) is considered to come to an end at something which has value as such (intrinsic value)[8]. Consequently even the preference approach has ultimately to identify objects with "intrinsic value", i.e. that deserve moral respect for their own sake, independent of whether we prefer it or not.[9]

It is therefore a central question to identify which entities have such intrinsic moral value, to which entities we have moral obligations, and for what reasons.

3.2 POSITIONS WITH RESPECT TO INTRINSIC MORAL VALUES

Anthropocentrism[10] represents the position that human beings, and only human beings, i.e. individuals of the biological species *Homo sapiens*, have intrinsic value. In its first principle "Human beings are at the centre of concerns for sustainable development", the Rio Declaration (UNCED 1992) takes a clear anthropocentric starting-point. The Universal Declaration on Human Rights[11] attaches intrinsic moral value to all human beings, wherever they are[12]. "Sustainable development" in seeking to meet "the needs of the present without compromising the ability of future generations to meet their own needs"[13] also attaches intrinsic moral value to human beings in the future. From the anthropocentric standpoint, all human responsibilities with regard to non-human beings are based solely on the realisation of human happiness.

To justify the anthropocentric position it is necessary to argue which characteristics of human beings are morally relevant. Non-anthropocentrists argue that any set of morally relevant characteristics which are shared by all human beings will not be possessed by human beings only. They furthermore appeal to consistency: if human beings value a state (such as freedom from pain) in themselves, it is arbitrary and "speciesist" (as in racist, sexist) not to value it also in non-human beings. In this way, different people attach intrinsic value to different groups of beings with different justifications (see Table 3/1).

Although intrinsic value is normally attributed to individual persons, intrinsic moral value can also be attached to groupings or systems, a position called *holism*. Such groupings or systems may include institutions (the "party"), nations (patriotism), the "land", forests, species, ecosystems, and

Position	Intrinsic value attached to	Presumed relevant characteristics	Groups or persons who support this position (examples)	Remarks
Noo-centrism	all rational beings	Reason, self-consciousness	Immanuel Kant	Excludes the mentally disabled, the severely mentally ill, and babies[14], but covers some animals (great apes[15], dolphins[16])
Patho-centrism	all sentient beings	The capacity to experience pleasure and pain	the Jewish *sa'ar ba'alê hayyîm*[17], Arthur Schopenhauer, Jeremy Bentham, Peter Singer	Pain is presumed to be bad, since every creature seeks to minimise it. Their capacity for pleasure gives sentient beings the right to pursue whatever pleasures are natural to beings of their kind.
Bio-centrism	all living beings	Being alive	Hinduism, Jainism, Buddhism, Muhammad, Albert Schweitzer, Paul Taylor	Sentiency is considered as a means to another end: life. The position appeals to our intuitions that life is "something special"[18].
Eco-centrism	all beings	Being part of the (natural) whole	Buddhism, John Muir	

Table 3/1: Positions with regard to which beings possess intrinsic value.

Position	Argument	Examples
Theism	All entities are God, in the image of God, or created to glorify God	Many world and native religions
Nature mysticism	The intuitive feeling of humanity's unity with all nature	Pythagoras, Francis of Assisi, Baruch Spinoza, Herman Hesse, Rosa Luxemburg, Guido Gezelle, John Muir, Henry Thoreau
Holistic rationalism	This world is the "best" of all possible worlds, with a maximum economy of premises and fundamental laws, a maximum diversity of resulting phenomena, and its consistency, order, or "harmony"[21]	Plato, Gottfried Wilhelm Leibniz

Table 3/2: Other arguments used to attribute intrinsic moral value to non-human entities.

even the whole biosphere. In some of these holistic approaches, individuals are not valued as such and may be sacrificed for the sake of a whole (e.g. species conservation in nature conservation). The Convention on Biological Diversity (UNCED 1992) explicitly acknowledges "the intrinsic value of biological diversity" and consequently attributes intrinsic value to both species (taxa) and ecosystems. (See also §4.10 below.)

People who cannot draw a boundary between entities with and without moral standing must either attribute intrinsic value to every being (ethical holism)[19], or to no being at all (nihilism).

Apart from the non-anthropocentrist arguments mentioned above, various other arguments with strong metaphysical premises are used to attribute intrinsic moral value to non-human entities (Table 3/2).[20]

Except for nihilists, everyone can agree that intrinsic value exists and that there are morally relevant characteristics, but different groups of people identify different characteristics as morally relevant.

As intrinsic values normally cannot be compromised, the different positions regarding which entities have intrinsic moral value will have an over-riding impact on how conflicts are judged, and may themselves be the main cause of conflict.[22] If some participants in a conflict assume that the integrity of non-human beings is of intrinsic moral value (for example, a sacred cow), they will not accept solutions which other participants, who only look at the instrumental value of these entities (e.g. a cow as a provider of milk and meat), would interpret as fair and well-balanced compromises[23].

In spite of differences on the level of ethical justification, there is some convergence at the level of practical conclusions and political recommendations, as similar conclusions can be reached from different premises[24]. Most people at least agree that all human beings have intrinsic moral value. Enlightened environmentalists and economists will agree that environmental and economic decision-making should take all kinds of values seriously into account.

The following section analyses the instrumental values of mires and peatlands for human beings.

3.3 TYPES OF INSTRUMENTAL VALUES

Instrumental values (functions, services, resources) can be subdivided into ***material*** and ***non-material life support functions*** with various subdivisions (see Table 3/3).

Material life support functions contribute to the maintenance of physical health. They are usually divided into *production*, *carrier*, and *regulation* functions[25]. *Production functions* relate to the capacity to provide (individualisable[26]) resources, ranging from water, food, and raw materials for industrial use to energy resources and genetic materials. *Carrier functions* relate to the capacity to provide space and a suitable subsoil for human habitation, industry, and infrastructure, cultivation (crop growing, animal husbandry, aquaculture), energy conversion, recreation and nature protection. *Regulation functions* relate to the capacity to regulate essential (non-individualisable[27]) ecological processes and life-support systems, contributing to the maintenance of adequate climatic, atmospheric, water, soil, ecological and genetic conditions.

The ***non-material life support functions***[28] cover a large and diverse range of benefits that can be subdivided into two large classes:

> *Proxy functions* include all sensations that are experienced as pleasant, agreeable or beneficial, but whose material advantages are not always immediately obvious. Their real benefits (and genesis) lie deeper[29]. Proxy functions are largely consumed unconsciously. They are shaped and modified by learning, but they do have some genetic, hereditary basis. Behavioural patterns related to these functions may, therefore, long remain the same, even when the conditions have changed and the former benefits have disappeared[30].
>
> *Identity functions* serve to identify one's position in the world. They are limited to self-conscious beings[31] who are able to think abstractly[32]. The capacity to consume (and create) these kinds of functions must also have had an evolutionary advantage, e.g. by consolidating group behaviour and the development of conscious altruism (solidarity).

The significance of these non-material life support functions for human beings is indicated by the large amounts of money that are spent in such areas as team sports, recreation, arts, religion, history, species conservation, and pure science.

All these functions have a future aspect as *option* or *bequest functions*, which refer to what this generation will leave to future generations. *Transformative / educational functions* lead to a change of preferences or value standards. They only make sense, however, for those who believe that one set of preferences or standards is better than another.

3.4 FUNCTIONS OF MIRES AND PEATLANDS FOR HUMAN BEINGS

This section outlines the beneficial functions of peatlands, and their significance in global, regional and local terms. Table 3/4 summarises these functions, and is followed by explanatory text on each function.

3.4.1 Production functions

(a) Overview of peat extraction[33]

Peat is extracted from peatlands and used principally in horticulture, agriculture, domestic heating and energy generation. Peat is either cut from the peatlands as sods, or macerated and formed into sods, or milled on the surface to form crumb. Peat extraction includes the drying of wet peat and the collection, transport and storage of the dried product. The drying process is in two phases:
- a substantial proportion of the water content is taken away by drainage;
- moisture content is then further reduced by solar and wind drying on the surface of a production field.

<table>
<tr><th colspan="4"></th><th>Examples</th></tr>
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[shaded] Restricted to self-conscious beings [unshaded] not restricted to self-conscious beings

Table 3/3: Types of instrumental values

Because of this dependence on meteorological conditions, annual peat production volumes in an enterprise or country may fluctuate considerably.

A mire or peatland is suitable for industrial peat extraction if

- the peat is of sufficient depth.
- its area is sufficiently large and of appropriate shape,
- the quality of peat is adequate for the intended purpose,
- access to the consumer can be achieved at a reasonable price.

Accurate information on the extent of peat extraction is not available. In particular, little is known about the volumes of private, non-industrial peat extraction that remains important for local energy provision in

3.4.1 Production functions:

(a) Peat extracted and used ex situ as/for
- (aa) Humus and organic fertiliser in agriculture
- (ab) Substrate in horticulture
- (ac) Energy generation
- (ad) Raw material for chemistry
- (ae) Bedding material
- (af) Filter and absorbent material
- (ag) Peat textiles
- (ah) Building and insulation material
- (ai) Balneology, therapy, medicine, and body care
- (aj) Flavour enhancer

(b) Drinking water

(c) Wild plants growing on mires and peatlands for/as
- (ca) Food
- (cb) Raw material for industrial products
- (cc) Medicine

(d) Wild animals for food, fur, and medicine

(e) Peat substrate in situ for
- (ea) Agriculture and horticulture
- (eb) Forestry

3.4.2 Carrier functions: space for

(f) Water reservoirs for hydro-electricity, irrigation, drinking and cooling water, and recreation

(g) Fish ponds

(h) Urban, industrial, and infrastructure development

(i) Waste deposits / landfill

(j) Military exercises and defence

(k) Prisons

(l) Transport and herding

3.4.3 Regulation functions:

(m) Regulation of global climate

(n) Regulation of regional and local climates

(o) Regulation of catchment hydrology

(p) Regulation of catchment hydrochemistry

(q) Regulation of soil conditions

3.4.4 Informational functions:

(r) Social-amenity and history functions

(s) Recreation and aesthetic functions

(t) Symbolisation, spirituality, and existence functions

(u) Signalisation and cognition functions

3.4.5 Transformation and option functions

Table 3/4: Overview of functions of mires and peatlands for human beings countries like Ireland, some central Asian republics[34], and China[35]. The latest available information on industrial peat extraction volumes is contained in the Tables in the sections dealing with peat in horticulture (ab) and for energy (ac).

(aa) Peat as humus and organic fertiliser in agriculture[36]

Peat has been used as an organic raw material in the production of organic fertilisers and combined organic-mineral fertilisers and in the improvement of degraded soils by adding humus. Practice in this area differs greatly between different countries.

The most important value of organic or organo-mineral fertilisers produced with peat is in their organic matter containing biologically active substances. Organic substances enrich the soil with trace elements, improve the physical properties of the soil, its pH level, and its productivity.

Peat was used as an organic fertiliser in great quantities in agriculture in the years 1950-1980 (Fig. 3/1). During this period different mixtures, including composted mixtures, were prepared, especially in the Soviet Union. Excavated peat, both raw and dried, was mixed with sandy or loamy soils. This improved the physical properties of the soils but did not change plant nutrition. In the Soviet Union, Ireland, France and Poland considerable research was carried out into the liquid ammonia treatment of peat (15-35 kg NH_4OH/Mg peat), used in agriculture in 10-40 Mg/ha doses. These experiments did not give positive results. Mixtures of peat and different mineral fertilisers had the nutrient value of the fertilisers only. Composts produced using peat with stable manure, sewage sludge, faecal substances, liquid manure and different organic municipal and industrial wastes in 1:1-2:1 ratios were expensive to produce and were not effective. The results obtained from the use of peat preparations have not shown any significant correlation between inputs and either the chemical properties of plants or their yield. Since the political changes in the former Soviet Union, the volume of peat extracted for agricultural purposes has substantially diminished (cf. Fig. 3/1 and Table 3/5).

It is possible that in the future peat could have an economically effective role in the remediation of degraded soils and as topsoil replacement in the regeneration of areas used in open-cast mining.

(ab) Peat as a substrate in horticulture[38]

After its use for energy generation (ac), the most common current use of peat is for horticulture (cf. Tables 3/5 and 3/6). The production of greenhouse and container crops involves the integrated management of water, fertilisers, pesticides and growing media. Of these probably the most important is the type of growing media used. Due to the limited volume of a pot, container or tray module, growing media must provide the appropriate physical, chemical and biological conditions for plant growth. In countries with a modern horticultural industry peat has emerged as the foremost constituent of growing media. The production and processing of peat-based growing media has become a precondition for horticulture. The 'John Innes Composts', the 'Einheitserde' and the 'Torfkultursubstrat' have been milestones in the development of peat-based growing media.

The use of standardised peat-based growing media in horticultural plant production developed for reasons of economics and because of technological advances. Industrially processed peat-based growing media have widely replaced growers' self-made mixes. Continuous research and increasing knowledge of the properties of the constituents of growing media show that growers run considerable risks if they apply

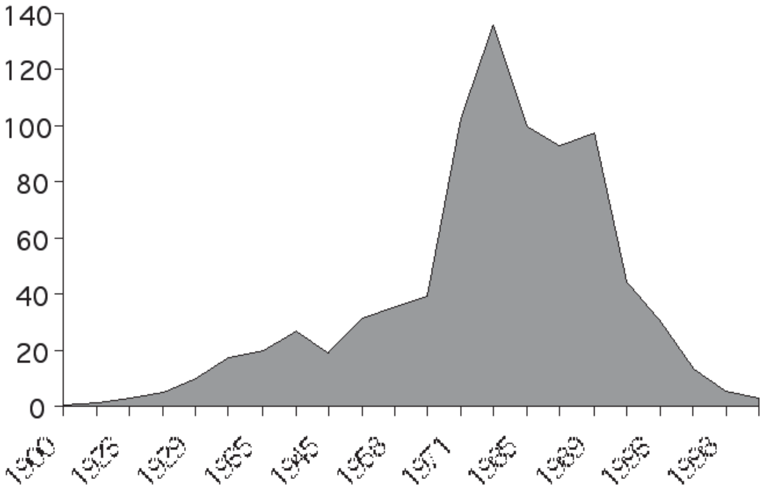


Figure 3/1: Annually extracted volume of peat in the Russian Federation in million tonnes at standardised moisture content[37].

Country	**1990**	**1997**	**1998**	**1999**
Belarus	10.9	0.3	0.4	0.8
Russia	24.0	2.5	0.8	1.1
Ukraine	9.8	0.1	0.2	0.3
Czech Rep	0.3	0.4	0.1	0.2
Estonia	0.0	3.5	1.0	3.5
Finland	1.5	1.6	0.3	2.4
Germany	6.6	9.0	9.6	9.5
Hungary	0.1		0.1	0.2
Ireland	2.0	2.8	3.2	3.2
Latvia	13.2		0.7	0.0
Lithuania	2.0		0.4	0.8
Poland	0.3	0.7	0.7	0.8
Sweden	0.0	0.6	0.6	1.4
Norway		0.1		0.1
Denmark		0.5		
U.K.	1.4	2.5	1.9	2.5
U.S.A.	1.2	2.2	1.4	1.4
Canada	6.6	7.0	8.8	10.3
N Zealand	0.0		0.1	
TOTAL	79.9	33.8	30.3	38.5

Table 3/5: Production of peat used in horticulture and agriculture (in millions of cubic metres)[39] the wrong materials or the wrong quantities of materials. The major advantages of *Sphagnum* peat as a constituent of growing media include:

- its cellular structure ensures good water holding ability;
- its low pH and nutrient status allow easy adjustment by the addition of crop-specific fertilisation and liming;
- it is free from pathogens, pests and weeds;
- it is easy to handle, process, grade and blend;
- peat products are available on a world-wide basis;
- 'alternative' growing media work best when they contain an element of peat.

Peat substrates are used particularly in glasshouse horticulture for the cultivation of young plants, pot plants and for the growing of crops such as bedding plants and vegetable plants in containers[40]. It is also sold to amateur gardeners as a soil conditioner. In Europe, approximately 90% of all growing media for the professional and amateur markets are peat-based. In countries such as Finland, Germany, Ireland, Sweden and the U.K. domestic peat resources provide horticultural enterprises with peat-based media for growing crops. Countries such as Belgium, France, Italy, the Netherlands and Spain depend on imports of peat and peat-based growing media to support and sustain their horticultural business. The export of peat from the Baltic States to Western Europe is increasing. In North America the same is true of exports from Canada to the U.S.A.[41]

Peat is used as a component of mushroom casing for commercial production of edible mushrooms (*Agaricus bisporus*) and oyster mushrooms (*Pleurotus ostreatus*), and as a carrying medium for rhizobial inoculants for vegetable production (e.g. soybeans)[42].

Although peat has maintained its position as the leading material for growing media, and is the preferred product among amateur gardeners, 'alternative' materials have emerged as substitutes for peat where feasible and safe for use (Table 3/6). These materials include coir[43], wood fibre, composted bark and composted biogenic waste. Environmental awareness, increasing knowledge of the interactions of media properties and product diversification have helped introduce these alternative materials. The peat industry is now participating in research into 'alternative' materials and is introducing products containing these materials. In spite of these developments, there is not at present any alternative material available in large enough quantities and equally risk-free which could replace peat in horticultural crop production.

(ac) Peat for energy generation[45]

Within Europe, peat is an important local or regional energy source in Finland, Ireland and Sweden. It also continues to be important in the Baltic States[46] and in Belarus and Russia (Table 3/7). In Asia, peat is also used for energy purposes in parts of China[47] and Indonesia, but reliable volume estimates are not available. A small amount of sod peat is produced for energy purposes in the mountain regions of Burundi in Africa.

The global use of peat for energy is estimated to be 5 to 6 million tonnes of oil equivalent (Mtoe) (Table 3/8).

In Finland, peat is used mainly in co-generation (combined heat and power, CHP) and in heating facilities. It is an important fuel for district heating in regions where other sources of energy are not readily available. The total installed capacity is over 750 MW_e and 1500 MW_{th}, and includes 60 district heating plants, 34 CHP facilities, 30 industrial plants and one condensing power plant. In Ireland peat is used for power generation in condensing power plants, and also as a fuel for domestic heating. The older generation of pulverised fuel power plants is being

MATERIAL	**GERMANY**		**NETHERLANDS**	
	m³	%	m³	%
Black peat	6,000,000	63	1,500,000	39
White peat	3,000,000	32	1,600,000	42
Wood fibres	190,000	2	5,000	<1
Clay (fresh and dried)	170,000	2	/	/
Composted biogenic waste	90,000	1	/	/
Composted bark / Bark	30,000	<1	40,000	1
Mineral wool	20,000	<1	500,000	13
Perlite	9,000	<1	50,000	1
Sand	8,000	<1	/	/
Coir (fibres and dust)	5,000	<1	100,000	3
Rice hulls	3,000	<1	10,000	<1
Pumice	400	<1	20,000	<1
Expanded clay	400	<1	20,000	<1
Others (lava, vermiculite, synthetic-organic material, etc.)	7,000	<1	5,000	<1
TOTAL	**9,522,800**	**100**	**3,850,000**	**100**

Table 3/6: Estimated amounts of materials used for the production of growing media in Germany and the Netherlands for the professional and hobby market in 1999[44]

Country	**1990**	**1997**	**1998**	**1999**
Belarus	3.4	2.7	2.0	3.1
Russia	6.0	2.9	1.9	3.7
Ukraine	1.3	0.6	0.6	0.5
Estonia	0.0	0.2	0.2	0.6
Finland	5.8	10.1	1.5	7.5
Ireland	7.5	4.0	4.3	4.7
Latvia	0.3		0.1	
Lithuania	0.8	0.1	0.2	0.4
Sweden	0.0	1.4	0.2	1.1
TOTAL	25.1	22.0	11.0	21.6

Table 3/7: Production of peat for energy (in million tonnes)[48] phased out and will be replaced by three fluidised-bed-based plants with a combined capacity of 370 MW_e. In Sweden peat is used in 35 heating plants, the largest of which is located in Uppsala. Small-scale space heating applications and the manufacture of peat briquettes for use in domestic heating are typical in Ireland, the Baltic countries and Belarus, among others.

Country	Energy Peat Use (Mtoe a^{-1})
Finland	1.90
Ireland	1.20
Sweden	0.30
Belarus	0.55
Russian Federation[50]	0.55
Ukraine	0.12
Estonia	0.35
Latvia	0.11
Lithuania	0.03

Table 3/8 Consumption of peat for energy (in million tonnes of oil equivalent per year)[49]

Peat as a source of energy is most beneficial in areas where there is an absence of other fuels, and where energy supply entails transportation of conventional fuels over long distances. As an energy source peat closely resembles wood, and the two are often used together in co-fired applications. Both the calorific value and the carbon content of peat are lower than those found in brown coal (lignite) or in bituminous coal, but the proportion of volatiles in peat is higher. The sulphur content varies with location, but is typically less than 0.3% on a dry mass basis. In the past, grate firing (sod peat) and pulverised firing (milled peat) have been the dominant technologies; but from the 1980s onwards larger scale applications have been based on fluidised-bed combustion which has resulted in higher efficiencies, lower emissions and multi-fuel capabilities.

Overall, energy generation is the most important current use of peat. Looking to the future, peat is expected to remain an important source of energy in rural and isolated regions of countries with abundant peat reserves. On a global scale, it is not anticipated that the use of peat for energy will increase greatly, although there is scope to substitute peat for certain imported fuels in some of the Baltic States. Given its high volatile content peat is suitable for gasification, and the maturation of integrated gasification combined cycle (IGCC) technology may lead to even more efficient peat use for energy in the future.

(ad) Peat as a raw material for chemistry[51]

Peat organic matter is a valuable raw material for chemistry. Chemical peat-processing is carried out by hydrolysis, pyrolysis, extraction and chemical modification. The chemical processing of peat to obtain a specific type of organic compound also produces new substances as a side effect.

Peat wax extraction is one of the indispensable stages in extraction techniques. The wide spectrum of valuable properties of wet peat wax has made it possible to find different applications (such as moulds for precision casting in machine-building, protective and preservative materials for engineering).

Peat dye imparts a uniform nut-brown colour to wood, enhances its texture and, compared to other dyes, raises considerably less nap[52], does not diffuse into finishing materials, is not toxic and is characterised by high light durability. It is easy to mix with synthetic dyes and thus to obtain a range of different hues.

Specific examples of the use of peat in chemical processing include:

1. Water soluble humic preparations have been found to be effective in the purification of metallic surfaces from radioactive substances. They were used successfully in the Chernobyl zone in 1986– 1987 for the purification of technological equipment. It is considered that they may have potential in the purification of technological equipment in active nuclear power stations.
2. Humic preparations which are soluble in acids have been used for the extraction of valuable metals from raw materials, especially in underground extraction.
3. Activated carbon from peat is effective in a number of applications including the purification of soil and water from organic contaminants, for example from pesticides[53].
4. Peat has been found to be an inhibitor of corrosion. Special preparations for the transformation of rust into metal have been widely used in Belarus, for example to remove rust from automobiles.

The total amount of peat used in the chemical industry is not great. For example, in Belarus the amount used is not more than 10,000 tonnes per year. Globally approximately 138,000 tonnes of black peat per year are used to produce some 15,000 tonnes of activated carbon[54].

(ae) Peat as bedding material[55]

Slightly humified sphagnum peat (“white peat”, “peat moss”) was used as a litter in stables in enormous amounts from ca. 1885 until 1919. This use was the basis for the explosive development of the peat moss industry in countries such as Germany, Sweden and the Netherlands.

The main users were armies, transport companies, railways, mining companies and industrial enterprises where horses were employed. For example, the Compagnie Générale d’Omnibus in Paris had 13,500 horses. If the amount of peat used per horse per day is estimated at 4 to 5 kilos, this one customer needed about 22,000 tonnes per year.

Dry peat moss can absorb about ten times its own weight in liquids, reduces unpleasant smells and has a favourable effect on the health of the animals. These were major advantages compared to straw. Another advantage was the after-use of the peat as manure for local vegetable-growers.

Peat moss was later used for the same purpose for poultry and cats. In the Netherlands and Germany it was even recommended for babies, although the cot had to be adjusted to use this uncommon material.

The use of peat as litter continues to-day[56].

(af) Peat as a filter and absorbent material[57]

Peat functions as a filter and absorbent material both in situ (see §3.4.2 (i)) and ex situ. The pollution treatment capabilities of peat materials include:

1. Physical filtration
2. Chemical adsorption/absorption
3. Biological transformation.

Because of the high cation exchange capacity, porosity, surface area and absorption ability of peat, all of the above treatment characteristics occur simultaneously within a peat material whether used for water/wastewater or gaseous treatment.

Firstly, the peat filters out suspended solids and microbiological contaminants. Secondly, chemical components are adsorbed or retained within the peat. Finally biological inactivation occurs as a result of the proliferation of a microbial population indigenous to the peat.

Numerous environmental uses have been identified for peat materials (and by-products)[58] which are currently being scientifically validated. These include the use of peat as a microbial carrier, the use of younger *Sphagnum* peat as an oil spill absorbent, and, finally, the removal of heavy metals from trade effluents.

These pollution treatment qualities of peat have been successfully commercialised by a number of peat extraction companies.

(ag) Peat textiles[59]

Under the long-term influence of humus and humin substances, the basal sheaths of cottongrass (*Eriophorum vaginatum*) in peat undergo a change into brown, 5-20 cm long fibres, which are soft enough to be used for textiles. These fibres are warmer than wool because of their cavity-like, air-filled structure, which makes them also very light. Peat textiles are thus especially suitable for those who need extra warmth, such as infants, the elderly and rheumatism sufferers. The fibres easily absorb and release liquids and have the ability to absorb the secretions of the skin including perspiration and salts, in addition to absorbing smells. They do not acquire an electric charge and burn poorly, like wool.

Early experiments in the 1890s to produce textiles from these fibres failed because the products were too expensive. During the First World War interest in peat textiles was rekindled for a short while, especially in Germany, where they were used for horse blankets, soldiers' clothing and even bandages in hospitals because of the antiseptic and therapeutic properties of peat. After the war this interest ceased.

Since the late l960s peat textiles have been produced in southern Sweden, carded on a 50/50 basis of cottongrass fibres with wool and used for bedclothes or spun into yarn for knitwear or fabrics. Since 1992 some production has also taken place in Finland where small firms produce felt clothes such as hats, coats and loose soles as well as knitwear and woven textiles out of cottongrass fibres and wool. Fibres are bought from Finnish peat mills where they are screened out of the peat as being unsuitable for horticultural use.

Peat has also been used to produce paper. It is thought that the experiments in using peat for paper accelerated the discovery of its potential for peat fibre and as an insulating material[60].

(ah) Peat as building and insulation material[61]

Peat was used in many countries as a building material. In Ireland, the Netherlands and Germany, the very poor also built their homes from sods of turf[62]. Peat has been used in Germany as an insulation material in wooden cottages: in this usage peat is packed in large sheet-form bags and placed along the wall of the building. Sod peat was (and still is) used in constructing the banks of Irish canals. In some parts of Finland sod peat is used as a foundation material on the roads in place of gravel. In Norway compressed peat bales have been used as foundation for rail tracks in areas prone to soil movement from frost[63]. In Russia and Belarus peat has been widely used as an insulation material in the form of dry pressed sheets, for example in industrial refrigerators, or as peat boards in poultry stables[64]. It is understood that sod peat has been used as insulation material for missile silos in the former Soviet Union.

(ai) Peat in balneology, therapy, medicine and body care[65]

In many countries there is a long tradition of using mud for human and veterinary therapeutic purposes. By chance peat was substituted for mud, and from 1802 (first in

Eilsen Spa, near Hanover, Germany and later in Nennodorf and Marienbad - Mariánske Lázné in the Czech Republic) this balneological speciality spread across Central Europe and later to some other European countries including Estonia, the Ukraine and Poland.

The material used is mainly strongly humified sphagnum peat (“black peat”), but younger sphagnum peats as well as lacustrine muds (“Mudde, Gyttja, Sapropel”) are in use in some places.

The fields in which peat is indicated for human medical treatment are:

- gynaecology (illnesses of the female urogenital system)
- illnesses of the locomotion system (the so-called rheumatic field)
- dermatology
- interior illnesses
- ophthalmology

The application is done by peat pulp baths (42-45° C.), poultices, peat kinesitherapy, and peat kneading. In some cases cryo-therapeutic use is to be recommended. Peat preparations are also used.

The effect of peat therapy arises from thermophysical and biochemical mechanisms. Peat baths are, by their heat radiation, able to cause overheating effects, favourable to changes in the digestive system; they act as a relaxing medium because of their buoyancy forces, which are favourable to the spinal system. As peat contains biologically active substances, of which humic acids are the most important, peat influences the immune system positively, and is effective against bacteria, viruses and inflammation.

Peat chemical processing has resulted in the development of a number of preparations with growth-stimulating, fungicidal and bactericidal properties. Hydrolysates of peat contain a wide spectrum of amino, carbonic and uronic acids, humic substances and other compounds which can activate or inhibit various biological processes. Peat oxidate has been found to be helpful in the treatment of skin diseases. Compounds combining volatiles with water steam have been used in the treatment of eye diseases.

Peat has also been successful in veterinary medicine. In Central and Eastern Europe (Belarus, Poland, Russia, Ukraine) peat preparations were used in the large-scale rearing of cattle, pigs and poultry as growth promoters and as medicine, immunological stabiliser, nutrient yeast, carbohydrate fodder additives, and absorbents of harmful substances.

Peat preparations have also been used in plant production as growth promoting, fungicidal and bactericidal substances. Peat oxidates have been used as a treatment for microbiological diseases of agricultural crops, for example with phytophtorose of potato and tomato.

Because of its absorptive properties, peat is also used in nappies (diapers) and in feminine hygiene products[66].

(aj) Peat as a flavour enhancer[67]

The term whisky is derived from the Gaelic *uisge-beatha* meaning water of life, a spirit produced by the distillation of beer. Two distinct types of whisky, malt and grain, are produced in Scotland. Single malts are distilled in simple copper pot-stills from a mash derived entirely from malted barley. Grain whisky is produced by continuous distillation in a patent or ‘Coffey’ still and the raw material contains a proportion of non-malted cereal.

The first stage in malting is to steep screened barley in water for two to three days until the grain becomes soft and swollen. It is then spread on special floors to germinate under controlled conditions for about two weeks. The “green malt” is then dried slowly over a smouldering peat fire. The more prolonged the kilning and the more intensive the peat “reek”, the richer the peaty flavour of the product.

Kilning and curing are arts passed down from generation to generation and each distillery or malting maintains strict security over the processes involved. Thus, little information is available on the importance of peat quality and quantity in the malting process. In general, highly decomposed peat, known locally as blue or black peat, seems to be preferred.

Despite the disadvantages associated with small-scale production units, some distilleries and individual maltings still select, cut and harvest their own peat supplies annually. More recently the use of air-dried peat sods to fuel open fires in the traditional malting process is being superseded by the combustion of peat pellets in special burners resulting in better overall control and efficiency and a significant reduction in the quantity of peat required.

In China the flavour from burning local peat is used for making “weisky wine”[68].

(b) Drinking water[69]

The role of peatlands in the provision of drinking water is important both in areas where catchment areas are largely covered by peatlands, and in drier regions where peatlands indicate a rare but steady availability of water.

Significant areas of the British uplands are secured by the various Water Authorities, that supply water to distant urban centres, e.g. Welsh water to Liverpool and Birmingham, and Lake District water to Manchester. Haworth Moor of “Wuthering Height” fame, for example, was owned by North West Water[70]. In case of Yorkshire Water, some 45% of the water for public supply is obtained from reservoirs draining peatland areas. The water company owns a large area of the catchment and manages it for water quality improvement by preventing pollution, limiting erosion, reinstalling high water tables, and restoring moorland species such as *Sphagnum*[71]. Often this use is associated with the construction of water reservoirs (see also §3.4.2 (f)).

Mires may fulfil an essential role as source areas for rivers; especially in maintaining low flows during dry periods. New techniques using long horizontal rather than vertical wells show that they can provide significant amounts of groundwater without compromising ecosystem quality.

Where or when existing water resources are rare, mires and peatlands can be important as sources of water[72], for examples in KwaZulu-Natal[73] and in Sarawak[74].

The water quality in peatlands is usually very good; the frequently abundant humic acids responsible for deep brown colouring can easily be removed[75].

(ca) Wild plants growing on mires and peatlands for food[76]

One of the oldest and most widespread utilisation of wild plants in peatlands is their use as straw and fodder for domestic animals. In Europe, Asia, and North America, fen peatlands have been intensively cut for hay in the past. In the last decades this type of use has decreased, but it is still important locally in Central Europe. Peatlands are also important as wild pasture for domestic animals in many areas of the world, such as for cattle on Argentinian pampas and Lesotho and Kyrgistan mountain peatlands[77], for sheep and red deer in the Scottish blanket peatlands, and for water buffalo in Georgia and Kalimantan[78].

A second important use - especially in the temperate and boreal zones of Eurasia - is the collection of a wide variety of wild edible berries and mushrooms that are preserved and dried and provide substantial food and vitamins in the winter period. With 100 mg in every 100 g of berries, cloudberry (*Rubus chamaemorus*) has for centuries been an important source of vitamin C for the inhabitants of Fennoscandia and helped to keep them free of scurvy. Other edible berries common on mires and peatlands include cranberries (*Oxycoccus*), a whole range of blueberry (*Vaccinium*) species, crowberries (*Empetrum*), raspberries and brambles (*Rubus*) and currants (*Ribes*). In good berry years, about 12 million kilogrammes of berries are picked from mires in Finland (7.8% of the biological yield). It has been estimated that in a normal year the monetary value of wild berries collected from Finnish peatlands is US$ 13.4 million.

Before the emergence of rice, wild sago (*Metroxylon sagu*) was the main source of sustenance for the inhabitants of the Malay archipelago region. Desiccated products made from sago starch can be stored for exceptionally long periods and enabled the early inhabitants of the Malay archipelago to travel far and to colonise many islands[79].

Wild rice (*Zizania aquatica*) was an important staple crop gathered by native Americans. Currently most production takes place in regular agriculture (see § (ea) below).

In Europe the peatland species *Menyanthes trifoliata*, *Acorus calamus*, and *Hierochloe odorata* are used for flavouring drinks[80]

Utilisation		Vegetation	Harvest	Quality
In agriculture	Mowing, fodder	Wet meadows, reeds	Early summer	+
	Grazing	Wet meadows, reeds	Whole year	+
	Litter	*Carex*-meadows, reeds	Summer	-
	Compost	Wet meadows, reeds	Late summer	-
	Pellets	Wet meadows, reeds	Early summer	+
Industrial	Roofing material	Reeds	Winter	+
	Form-bodies	Wet meadows, reeds	Autumn/winter	0
	Paper (cellulose)	*Phalaris*-reeds, *Phragmites* reeds	Winter	0
	Basket-wares	Willow (*Salix*)	Autumn	+
	Furniture/timber	Alder (*Alnus*) swamps	Frost	+
	Chemicals	Reeds	Early summer	+
Energy	Pyrolysis	Alder swamps, willow	Winter	0
	Direct firing	Alder swamps, reeds	Autumn/winter	-
	Fermentation	Wet meadows, reeds	Early summer	0

Table 3/9: Examples of biomass utilisation from undrained peatlands (demand for quality: + = high. 0 = medium, - = low[87])

(cb) Wild plants as raw material for non-food products[81]

Peatland plants are harvested for human and animal food, and also as raw material for industrial products and energy generation[82] (Table 3/9). For many centuries *Sphagnum* moss has been used as a building and insulation material to fill the chinks between logs and planks in log-cabins and in boats. The Lapps in northern Fennoscandia used peatmoss in children's cots.[83]

Commercial harvesting of live *Sphagnum* moss from peatlands for horticulture, including the cultivation of orchids and bromelias, currently takes place in North America, Australia, and Chile[84].

Harvesting and use of reeds from peatlands takes place all over the world. The use of *Phragmites*[85], *Cladium*, and *Cyperus papyrus*[86] is important for construction purposes, e.g. for thatching and matting, and for making paper.

Biomass with commercial potential can be harvested from both undrained and re-wetted peatlands, which makes possible an economic exploitation combined with the conservation of many natural mire functions[88]. *Phragmites australis* reeds, for example, represent the natural vegetation of eutrophic flood and immersion mires[89]. In such mires thick layers of reed peat can be found. Similar *Phragmites* reeds with peat-forming potential may develop spontaneously or can be established artificially after rewetting of degraded peatlands.

In a number of countries the demand for reed as a roofing material and for the production of mats cannot be satisfied by native reed harvests and imports[90] are needed to meet current demand. In addition to these traditional products, new products made from peatland biomass[91] are becoming economically interesting, e.g. form bodies as packaging material[92] and vegetation- and plaster-porter mats[93], insulation material and construction sheets[94], pulp for paper production[95], the bio-refinement of plant saps for the production of biotechnological raw materials[96].

(cc) Plants for medicine[97]

Mire plants are widely used for medicinal purposes in all parts of the world, principally in areas with large numbers of mires[98]. The number of mire/wetland plants used for medicine on a world-wide scale can be conservatively estimated at some thousand species. The majority is used by local and indigenous peoples, and a few hundred plant species are more widely applied on an industrial scale. This number may increase as more knowledge about mire/wetland plants for medicine in tropical areas becomes available.

Sphagnum plants – as excellent absorbents with antiseptic properties[99] - were used successfully as a substitute for cotton in surgical dressings in the Napoleonic and Franco-Prussian Wars[100], by the Japanese in the 1904 – 1905 war with Russia, and extensively by both sides during World War I[101].

In the former USSR about 40% of medicines were made from medicinal plants, half of them from wild plants. 234 wild species were used on an industrial basis, including 29 mire/wetland species (Table 3/10)[102].

About 230 medicinal preparations are produced world-wide from Sundew (*Drosera*) species[104]. Quantities of various *Drosera* species on the European market are estimated to range from some hundred kg year^{-1} (*Drosera intermedia*, *D. peltata*) to 7-10 tonnes year^{-1} (*Drosera madagascarensis*)[105]. In the period 1981-1994, the quantity of *Drosera rotundifolia* collected annually from

Vascular plant species	**10^3 kg year^{-1}**
Menyanthes trifoliata, Polygonum bistorta, Arnica montana	10 - 100
Acorus calamus, Althea officinalis, Frangula alnus, Nuphar lutea, Ledum palustre, Valeriana officinalis	100 - 1000
Vaccinium myrtillus, Vaccinium vitis-idaea	1000 - 10000

Table 3/10: Order of magnitude of annually collected mire plant material for medicine in the former USSR (in 10^3 kg year^{-1})[103].

natural peatlands in Finland increased from 100 kg to 2100 kg[106].

In Canada Labrador Tea (*Ledum groenlandicum*) is used as a medicinal plant.

In countries where there has been destruction of mires the extent of local collection of mire plants for medical purposes has decreased. This leads to increased imports of mire plant products from countries where large areas of mires remain, which increases the pressure on the resources in those countries.

(d) Wild animals for food, fur and medicine[107]

Many fur-bearers such as coyote, racoon, mink and lynx and game species such as grouse, ducks, geese and moose are often found in peatlands. In North America, black bears, which are used for food and fur, as well as in traditional medicine (bladders), are also frequently found in peatlands. While these species do not depend on peatlands for their survival this habitat may contribute substantially to their continued presence in populated regions where few areas other than peatlands provide safe havens away from direct human disturbance.

Peatlands may also be significant for fisheries. In tropical peatlands, fish provide important proteins to local communities[108]. Many coastal tropical fish are highly dependent on mangroves for nursery, feeding, and spawning grounds.

(e) Peat substrates in situ

Some carrier functions (forestry, agriculture, horticulture) have been included under production functions because in their case it is difficult to separate the production and carrier functions.

(ea) Agriculture and horticulture in situ[109]

The capacity of peatlands for agricultural production depends on a number of natural and socio-economic factors. The natural factors include

- climatic conditions,
- the landscape position of the peatland,
- the type of peat deposit,
- the water and oxygen content of the soil,
- the physico-chemical properties of the soil,
- vegetation.

Climate: Climatic conditions impose the basic limitations on peatland agriculture. Cultivated plants require an adequately long vegetation period and a minimum amount of heat energy. Consequently the temperature conditions that are determined by the macroclimate of the region and modified by the microclimate of the peatland are decisive. The following factors make cultivation difficult or impossible:

– too short a growing period,
– a mean annual temperature which is too low,
– excessive variation between the mean temperatures of the warmest month (July) and the coldest month (January),
– excessive variations in temperature between day and night,

– frequent ground frosts,
– temperatures in the growing period which are on average too low.

Peatlands have a specific microclimate[110]. Compared with the surrounding area, a peatland has a greater variation in temperature, a higher frequency of frost occurrence and higher air humidity. The reason is that peatlands are usually found in terrain depressions (valleys, hollows) into which cooler air flows. As a consequence, the soils of both pristine and reclaimed peatlands are significantly cooler in summer than mineral soils, and the air temperature is also lower. The microclimate of peatlands thus creates significantly more severe climatic conditions for agricultural plants than the microclimate of the surrounding mineral soils. This results in agriculture on peatlands in the northern hemisphere taking place in more southern latitudes than similar agricultural activity on mineral soil. Cooler climatic conditions are more favourable for trees and shrubs and for meadows and pastures.

Landscape position: Depending on the location of the wetland in the surrounding terrain, the excess of water may be removed by gravity drainage or pumping. The drainage network is more intensive in deposits with a greater depth of peat and where there is spring water. Additional difficulties occur in flooded river valleys and in depressions. The more difficult and expensive the maintenance of the required ground water depth and of the moisture in the root layer of cultivated plants, the smaller the possibility of a permanent utilisation of the peatland.

Type of peat deposit: In the majority of European countries the utilisation of peatlands as arable land was thought to be advisable only on shallow (<1.0 m) and very shallow (<0,5 m) deposits, or as sand-cover cultivation. In Belarus, arable land was established on deep peatlands, and shallow areas were designated for use as grassland. Each country developed different methods for the drainage, fertilisation and use of peatlands.

In Europe, east of the Elbe river, agricultural use has been developed on fens which dominate in that area. In countries with a maritime climate, agriculture has been developed both on fens and raised bogs. In the Netherlands and Germany numerous methods of agricultural utilisation of peatlands were developed that involved a partial or total reconstruction of the soil profile (sand cover cultivation, deep ploughing). These methods usually led to an equalising of the air and water conditions throughout the soil profile, to an increased carrying capacity of the surface, to an improvement in the microclimatic conditions, and consequently to a significant increase in the yield of cultivated plants. These methods were used in the Netherlands and in north-west Germany on an area of over 300,000 hectares. As a result, the peatlands ceased to exist and in their place a specific type of organic soil developed.

In parts of Britain the practice of 'warping' transformed estuarine lowland peatlands into agricultural land by allowing sediment-rich water to flood peat-covered areas for extended periods, eventually covering the peat with a mineral soil layer. The result of this process can be observed in the Humberhead Levels of the Humber Estuary in the east of England[111].

Water and oxygen content: The air-water regime of a peatland soil plays a fundamental role in agricultural use. The peat-accumulation process can only be continued by maintaining a groundwater level close to the surface. The use of a peatland for meadow and pasture generally requires a lowering of the groundwater level to a depth of 0.4-0.8 metres below the surface. Its use as arable land requires the water level to be an even deeper 1.0-1.2 metres below the surface.

Physico-chemical properties: The physical and chemical properties of soils are most important in the surface layer of the peatland (to a depth of 0.3 metres) where the majority of roots of cultivated plants are found. These properties depend on:

- peat type,
- degree of peat decomposition,
- ash content,
- peat reaction (pH),
- peat fertility (nutrient content),
- industrial contamination of the soil.

The first three factors determine the physical and water properties, the remaining factors control the conditions of plant growth and the quality of the yield.

Relatively favourable conditions for agricultural production are present in fens with a low or medium ash content and a small or medium degree of decomposition. Neutral and slightly acid reaction (pH 5.5-7.0), higher soil fertility and absence of industrial contamination (heavy metals, persistent organic pollutants) are commonly regarded as beneficial for agricultural production.

Sediments under the peat may contain significant amounts of sulphur (East England, Indonesia), or carbonates (Hungary, Poland). In shallow organic soils the reduction in the depth of the organic layer by mineralisation (see § 2.6[ii]) results in the rapid deterioration of plant growth conditions as the roots of cultivated plants do not usually penetrate to the very acid or alkaline soil layers.

- ***Europe:*** Approximately 14% of European peatlands are currently used for agriculture. Large areas of peatlands used for agriculture are found in Russia , Germany, Belarus, Poland and Ukraine (Table 3/11). In Hungary (98%), Greece (90%), the Netherlands and Germany (85%), Denmark, Poland and Switzerland (70%) the majority of peatlands are used for agricultural purposes. In these countries the high population density required that wetlands be used for food production. Proportional to the total area of peatlands, the use of peatlands for agriculture is small in Fennoscandia, the Baltic countries, Russia and the British Isles. The great majority of peatlands used for agriculture in Europe consist of meadows and pastures. The area of agricultural peatlands has decreased steadily in recent years for economic reasons and due to increasing nature protection.

- ***Tropical agriculture***[113]***:*** While the peat in northern temperate regions is formed largely from grasses, sedges and mosses, tropical peat generally consists of a range of organic debris including trunks, branches and roots of trees.

Indigenous peoples have had long experience in the reclamation and utilisation of peatlands for agriculture, particularly in the cultivation of horticultural crops. In areas which remain under tropical inundation beneficial products can be extracted from sago and other palms.

Approximately 313,600 hectares, or 32% of the peat areas in Peninsular Malaysia, are being utilised for agriculture, largely for estate crops[114]. In Indonesia large areas of peatlands have been cleared for agriculture-based transmigration settlement and for the expansion of estate crops.

Lowland peat soils can be productive for wetland rice[115]. Good levels of productivity can be achieved with horticultural crops with intensive management. On small holdings (which in Indonesia, for example, vary from 0.6 to 2 hectares), an integrated system of animal husbandry (pigs, cattle, poultry) and horticultural crops can provide subsistence. Sago palms grow naturally on peat and are simple to cultivate and need little maintenance[116]. Sarawak is now the world's largest exporter of sago

Country (References)	Total peatland area km²	Peatland area currently used for agriculture (km²)	%
Belarus – (Bambalov)	23 967	9 631	40
Czech Rep.+ Slovakia (Lappalainen)	314	ca 100	ca 30
Denmark (Aaby)	1 420	ca 1 000	ca 70
Estonia (Orru)	10 091	ca 1 300	13
France (Lappalainen)	ca 1 100	ca 660	ca 60
Finland (Vasander 1996)	94 000	ca 2 000	2
Germany (Steffens)	14 200	ca 12 000	85
Great Britain (Burton)	17 549	720	4
Greece (Christianis)	986	ca 900	ca 90
Hungary (Toth1983)	1 000	975	98
Iceland (Virtanen)	10 000	ca 1 300	13
Ireland (Shier)	11 757	896	8
Latvia (Snore)	6 691	ca 1 000	15
Lithuania (Tamosaitis et al)	4 826	1 900	39
Netherlands (Joosten 1994)	2 350	2 000	85
Norway (Johansen)	23 700	1 905	8
Poland (Ilnicki et al.)	10 877	7 620	70
Russia (Kosov et al.)	568 000	70 400	12
Spain (Lappalainen)	383	23	6
Sweden (Fredriksson)	66 680	3 000	5
Switzerland (Küttel)	224	ca 160	ca 70
Ukraine (Żurek)	10 081	ca 5 000	ca 50
Total	880 196	124 490	14

Table 3/11 Peatland used for agriculture in some European countries. [112]

(largely cultivated on mineral soils), exporting annually about 25,000 to 40,000 tonnes of sago products to Peninsular Malaysia, Japan, Taiwan, Singapore and other countries[117]. Palm oil trees, which have a shallow root system and need a higher soil nutrient level than sago[118], are successfully cultivated[119]. Other agricultural activities which can be carried out include buffalo farming and the growing of native species of fruit trees, pineapple, rubber, coconut, coffee and spices.

The greater part of Southeast Asian coastal peats have marginal physical properties for plant growth and, without careful management, crop yields are on average low.

- ***North America***: Extensive areas of peatlands in North America are cultivated for agriculture. In Canada it is estimated that 40 000 hectares of peatland are under cultivation. The principal uses are vegetable production and pastureland. Cranberries are produced in British Columbia, wild rice is grown in Manitoba and peatlands in Newfoundland are used to grow forage crops[120]. Over 230 000 hectares of fen peatlands are cultivated in the Florida Everglades, including large areas of sugar cane and rice. Other crops produced in the U.S.A. include vegetables, grass sods for use in lawns and cranberries[121].

The commercial production of cranberries on peatlands in North America[122] is - with a production of 6 million barrels[123] - a major business enterprise[124]. This form of mono-cropping involving removal of wetland vegetation, re-profiling and periodic flood-harvesting, is very different from the wild berry collection from intact mires described in §3.4.1(ca) above. With the industry's intensive use of water and the application of fertilisers and pesticides in a wet environment, impacts on streams and lakes can be more direct than for other agricultural operations[125]. The consumption of cranberries is promoted for their medicinal values[126]. Expansion of cranberry cultivation on peatlands in other areas of the world[127] is currently being explored.

(eb) Forestry on mires and peatlands[128]

Intensity levels of utilisation: There are three intensity levels of the utilisation of mires for forestry (Table 3/12):

- In some parts of the world wood harvesting is practised on pristine peatlands. This type of utilisation is called 'exploitation'[129] but is referred to here as **transitory collection forestry**. As a consequence the tree growth and regeneration possibilities may be hampered due to a rise in the groundwater level after tree harvesting, leading to decreasing yields. At the same time, however, the functioning of the mire ecosystem may continue.
- **Conserving management forestry** ('sustainable forest management') aims at maintaining the forest resource by applying proper natural regeneration of the tree stands on the sites which have been harvested.
- **Progressive management forestry** aims at increasing the forest resource by ameliorating the growing conditions in the site by drainage and fertilisation and by taking good care of the tree stand by proper silvicultural measures. This man-made disturbance in the peatland ecosystem has to be maintained if the increased levels of wood production on the site are to be maintained[130].

The forms of peatland utilisation for forestry vary from country to country depending on such factors as demand for raw wood, silvicultural management practice and tradition and infrastructure of the countryside. In some countries peatland forestry may still be at the '**transitory collection forestry**' stage although the importance of '**conserving management forestry**' is generally admitted. In countries like Finland the approach to the utilisation of peatlands for forestry has for decades been not only '**conserving**' but '**progressive management forestry**', minimising harmful effects on the site and on stream water.

***Forest on pristine mires*:** On pristine mires several factors (climate, excessive water, deficiency of nutrients) may restrict the productivity of tree species. However, some forested mire sites support commercial-size tree stands. In a typical pristine-mire tree stand the number of stems is high in small diameter classes and decreases abruptly with increasing diameter. The result is that on pristine mires the tree stands have an uneven age structure. There is also some variation in the density of the tree stands.

Forestry type	Industry term	Forest management activities	Wood resource / yield
Nature conservation		None	wood resource not used
Transitory collection forestry	Exploitation	Tree harvesting without adequate care taken of regeneration	continuous wood yield reduced
Conserving management forestry	Sustainable forest management	Tree harvesting with proper natural or artificial regeneration	continuous wood yield maintained
Progressive management forestry	Progressive management forestry	Site amelioration (drainage, fertilisation), (afforestation), thinnings, ditch cleaning etc., final harvest, and regeneration	continuous wood yield increased

Table 3/12 Intensity levels of mire utilisation for forestry[131].

In Fennoscandia nutrient-rich mire sites are usually dominated by Norway spruce (*Picea abies*), although the proportion of hardwoods, mainly pubescent birch (*Betula pubescens*), may be considerable. In nutrient-poor mire sites Scots pine (*Pinus sylvestris*) predominates and in ombrotrophic sites it is the only tree species. In the boreal zone of North America black spruce (*Picea mariana*) is the predominant tree species on mires and occurs alone or mixed with tamarack (*Larix laricina*) or eastern white cedar (*Thuja occidentalis*). In western parts of Canada, lodgepole pine (*Pinus contorta*) is also of economic importance on mires[132].

Forest management on pristine mires: Forest management on pristine mires belongs to the categories of **'transitory collection forestry'** or at its best **'conserving management forestry'** (Table 3/12). To maintain a continuous yield the cuttings should be "light", to prevent the site from becoming wetter due to a rise in the groundwater level. Pristine forested mires may be one of the few cases where management to promote uneven-aged stand structure might be recommended (so-called single-tree selection for continuous cover). Very little commercial tree harvesting is carried out on pristine forested mires in Fennoscandia which are dominated by Norway spruce (*Picea abies*) or Scots pine (*Pinus sylvestris*), because single-tree harvesting is not economic[133]. A private landowner may, however, harvest trees from his wetland property to be used for fuel or construction on his own farm.

In North America harvesting and regeneration of black spruce (*Picea mariana*) is significant, especially in Ontario and Québec, Canada. It forms a major source of fibre for the pulp and paper industry. A large proportion of black spruce comes from forested mires, in which it is important to minimise damage to the soil because of the lack of forest drainage. The preservation of advanced growth[134], mainly black spruce layerings[135], is an essential feature of regeneration of forested mires. On sites without sufficient advanced growth good results have been achieved with both seed-tree groups[136] and clearcut strips[137].

It is typical of the peatland forestry in Ontario that intermediate ("thinning") cuttings and tending of young stands are seldom practised. However, Canadian forestry is gradually changing from '**transitory collection forestry**' towards a planned utilisation of forest resources ('**conserving management forestry**')[138].

Tropical forestry: The natural vegetation of tropical peatlands is mainly forest. In Southeast Asia tropical forest covers extensive tracts of peatlands, mainly between coastal mangroves and the terrestrial rain forest. Most of the tree families of lowland rainforest are found in peatland forests but with fewer species. Peatland forest has a lower and more open tree canopy than terrestrial rainforest. It consists of a connected series of forest types which replace each other from the peatland perimeter to its centre[139]. It includes substantial quantities of commercial tree species and yields some of the most valuable tropical timbers. Ramin (*Gonystylus bancanus*) and agathis (*Agathis dammara*), for example, contribute almost 10% of Indonesia's exports of forest products[140]. Although peat swamp forests produce a smaller number of large trees per hectare compared to other lowland forests, several commercially important timber species, such as ramin and some meranti (*Shorea* spp.), are restricted to this forest type[141]. Peatland forest is exploited in much the same way as terrestrial forest, but allowing for the lower bearing capacity of the soil. There are two types of exploitation – **transitory collection** (even destructive) forestry; and **conserving management forestry**[142]**.**

The most frequent destructive logging operations have been concentrated in peatland forests earmarked for agriculture[143]. In other areas such forest has been damaged by logging concessions issued without detailed environmental assessments conducted in advance, and by illegal logging. A **conserving management forestry** form of selective timber extraction is carried out using minimal mechanisation under assumptions as to the regeneration cycle of commercial species. An example of such cropping is in Sarawak. Oldgrowth peatland forest is worked on a harvesting period of 45 years. Each group of permanent forest areas constitutes a unit managed under a Regional Management Plan. An annual cut is prescribed for each area. Logging is carried out manually. Damage to land is minimised. Silvicultural treatments are carried out after logging. While the felling cycle is set at 45 years the time of subsequent cuts is dependent on the rate of re-growth of the forest[144].

Forest drainage: On a global scale the proportion of the total terrestrial wetland (including peatland) area drained for forestry is about 3%. The area under forest utilisation without drainage has not been estimated. The current practice and extent of drainage ('**progressive management forestry**') in different countries varies considerably depending on the potential wetland area, the structure of land ownership, the demand for raw wood and national economic considerations[145] (Table 3/13).

In maritime climates such as those of the British Isles, drainage and afforestation with lodgepole pine (*Pinus contorta*) and Sitka spruce (*Picea sitchensis*) is a common practice on treeless mires. The long-term prospects for forests on drained peatlands are reported to be good. Yields from the second rotation seem to be even higher than from the first[146]. In Fennoscandia peatland afforestation is nowadays restricted to cut-away peatlands and abandoned farmland on peat soil[147]. Drainage of new areas in Russia has practically stopped[148].

Most of the drainage in Fennoscandia, Russia and the Baltic states has been of naturally tree-covered mires. The profitability of drainage is dependent on the fertility of the site, the volume of the tree stand capable of response at the time of draining, the geographical location of the site, and the price of wood. In general, drainage becomes more profitable with increasing site fertility, with a larger volume of original tree stand, and (in the Northern Hemisphere) the further south the site is located. On over 1 million hectares of the drained area in Russia, the drainage canals no longer function because of neglect, the activities of beavers, or infrastructure (such as roads and pipelines) which disrupt drainage. As a result this land is currently re-paludifying[149].

An attempt has also been made to estimate the profitability of forest drainage by calculating the inputs (all cost factors) and outputs (the increase in volume of wood cut multiplied by the price of wood). On this basis the internal rate of return on Finnish forest drainage activity would lie somewhat above 5%[150]. Canadian calculations show that drainage of an existing stand is economical if it can reduce the rotation age by 30 years or more[151]. Forest drainage has been shown to be profitable only if directed towards appropriate sites. This man-made disturbance in the peatland ecosystem has to be maintained if it is wished to maintain increased levels of wood production on the site.

Based on figures for Finland, some 20% of wood harvested on peatlands is used for furniture and construction, the remainder as raw material for pulp and paper mills. A very small proportion goes to energy wood[152].

	km^2
Finland	59,000
Russia	38,000
Sweden	14,100
Norway	4,200
Estonia	4,600
Latvia	5,000
Lithuania	5,900
Belarus	2,800
Poland	1,200
Germany	1,100
United Kingdom	6,000
Ireland	2,100
P.R. of China	700
USA	4,000
Canada	250
Total	148,950

Table 3/13 Estimates of terrestrial wetlands (incl. peatlands) drained for forestry[153]

3.4.2 Carrier functions

The carrier functions of mires and peatlands include all those functions for which they provide space and/or a suitable substrate. Because they lie in basins and are very extensive many mires and peatlands provide suitable locations, or bases, for water reservoirs and pisciculture. Their location and size and the fact that they are largely uninhabited can make them suitable for establishing towns, roads and harbours; as sites for waste disposal; and for military exercises.

(f) Water reservoirs (for recreation, hydro-electricity, drinking water)[154]

Reservoirs created for the production of hydro-electric power now cover extensive areas. Reservoirs cover 1.5 million km^2 globally, of which 0.9 million km^2 occur in temperate, boreal and subarctic regions[155].

Many of these temperate, boreal and subarctic reservoirs have flooded substantial areas of wetlands and peatlands, because they occupy the lower-lying positions in the landscape and because wetlands and peatlands cover a large proportion of the landscape in these regions. Water reservoirs in Belarussian Polesye, for example, cover some 400 km^2 of largely peat-covered areas[156]. It is estimated[157] that the 20,000 km^2 of reservoirs in Canada may have flooded 7,500 km^2 of wetlands and peatlands. In Finland approximately 900km^2 of peatland are covered with reservoirs[158]. Before inundation, these peatlands were generally sinks of carbon dioxide and sources of methane to the atmosphere. There is evidence that flooding converts peatlands from a sink to a source of carbon dioxide and increases the emission of methane to the atmosphere. See §§ 2.5 and 3.4.3(m).

(g) Fish ponds (Pisciculture) [159]

Peatlands have been inundated for commercial fish farming particularly in central Europe and China[160]. In Belarussian Polesye 200 km^2 of fishponds have been created largely on peatlands[161]. In what is now the Czech Republic fish ponds covered an area of 1,600 km^2 at the end of 16th century. Many ponds were later converted into agricultural land. The total area nowadays is 500 km^2, of which 15% is mostly situated on peatland. Fish species like Perch (*Perca fluviatilis*), Powan (*Coregonus lavaretus*), Peled (*Coregonus peled*), Brook Trout (*Salvelinus fontinalis*), and Trout (*Salmo trutta*) tolerate a relatively low pH and are suitable for cultivation in such ponds with a peat bottom. As water which is too acid can kill the fish stock, lime is often applied in places where water from surrounding bogs flows into the pond.

Liming, discharges from agricultural ditches, and sewage can result in a fast decomposition of peat, resulting in a high consumption of oxygen, a release of phosphorus and other nutrients from the decomposing anaerobic peat, and a vigorous growth of algae. When dense stocks of fish are present, the euphotic zone (the upper layer of water that receives sufficient light for the growth of green plants) becomes shallow (0.5 – 0.1 m) and anaerobic conditions in and above the bottom prevail. The oxygen deficits may lead to sudden fish kills. West Lake near Hangzhou (East China) is an example of peat degradation after the discharge of non-treated waste water from the town (1 million inhabitants) into the lake (560 ha), which was known as a national beauty spot. The bottom has become anaerobic, Cyanobacteria ("blue greens") develop, and H_2S and methane are released from a 0.5 – 1 metre layer of decomposing peat on the bottom.

Large stocks of carp combined with liming and organic fertilising change a peat pond ecosystem poor in plant nutrients into a fish pond with excess nutrients, one that is only suitable for carp production.

Fishing lakes have been excavated from cutaway peatland in Ireland and are in active use for recreational fishing[162].

(h) Urban, industrial and infrastructural development[163]

Substantial peatlands and mires are located in coastal areas, where over 50% of the world's population lives. Major cities like Amsterdam and St. Petersburg are largely build on peat. Location near to coastlines makes it tempting to convert mires and peatland to provide infrastructure for towns, roads and harbours so that these areas can become triggers for the development of regions and countries. Mires and peatlands which represent extensive areas of largely uninhabited land

and whose value as real estate is low are obvious targets for land-use planners and developers.

Blanket peatlands in Ireland and Britain[164] are in use for wind farms. Large tracts of peatlands in North America and West-Siberia are used for oil and gas exploitation infrastructure[165]. The Great Vasyugan Mire (Novosibirsk and Tomsk Oblast, Russia) is designated as a drop zone for rocket stages from the Baykonur space launching facility in Kazakstan.

(i) Waste deposits / landfill[166]

The vast quantity of domestic and industrial waste produced daily and its concentration in urban areas creates major disposal problems. Transport is expensive and it is desirable for municipal authorities to dispose of waste close to its source. However land values in urban areas are usually inflated and space is at a premium. Wetlands, especially peatlands, often in estuaries close to urban areas (as is common in the Pacific North West of the USA and Canada), are often the last areas to be developed given the high cost and technical difficulty of building in such wet areas. They also have lower land purchase costs. These factors make them obvious targets for waste disposal. The form of 'landfill' most commonly employed has been to place refuse on top of the mire surface compressing the peat and forcing groundwater to discharge from the water body. This is effectively 'pre-stressing' as practised in most forms of construction on soft or wet land. A direct result is often local flooding, and longer-term results can include contamination of ground and surface water by landfill leachates. Poor understanding of the dynamics of water movement in mires has led in many cases to the conclusion that they are absorbent 'sinks' and that any leachates will be contained within the site - which is not the case. Peat soils have often been proposed as natural barriers for the disposal of sewage sludge, mine tailings leachate etc, because of their high absorption capacity in particular for heavy metals. See also §3.4.3(p).

In terms of more modern forms of waste disposal (including segregation, re-cycling, composting, incineration and landfill in sealed units) peatlands (both pristine and industrial cutaway) have three advantages:

- they often are very extensive in area (and thus can cope with the volumes involved),
- they tend to be in more remote areas, with only sparse human habitation in the vicinity (thus avoiding some of the conflicts with local communities), and
- they often constitute borders between political/administrative areas (being seen, therefore, as nobody's responsibility).

(j) Military exercises and defence[167]

Military training grounds necessarily cover large expanses of land. The potentially dangerous nature of military exercises requires them to take place in remote areas such as peatlands which are away from centres of population. This is especially the case in upland areas where rugged terrain make them ideal locations for military training grounds.

Areas which have been reserved entirely for military exercises often include peatlands of high conservation value. These areas are unlikely to have been drained to improve agricultural potential, overgrazed or utilised for peat removal, so that in various densely populated countries many of the best and most intact mire sites are found within such reserves[168]. The main differences between these sites and surviving mires outside of military zones are severely restricted access; limited development or habitat alteration; and minor disturbance mainly in the form of abandoned ordnance. Restricted access has in many cases protected sensitive sites from disturbance, and damage by vehicles is often limited as wet areas are generally avoided.

The difficulty in accessing peatlands and their impenetrability to heavy equipment have always given them an important role in military defence. The present Groote Peel National Park (the Netherlands) was saved from complete land reclamation in the 1930s because the bog wilderness constituted a part of the Peel-Raam defence line between Belgium and the river Meuse[169]. Similarly in the 1952 Soviet plan for draining the Pripjat marshes, the significance of the area as a factor against possible future invasion from the west was taken into consideration, and contingency provisions for emergency re-flooding of the area were included in the plan[170].

(k) Prisons

Because of their inaccessibility and isolated location, peatlands have often been used to site prisons and labour camps. Examples include Veenhuizen in the Fochtelo peatland (the Netherlands), the Nazi concentration camps Dachau and the Esterweger Dose/ Papenburg complex (Germany), Dartmoor (Britain) and various camps of the Gulag Archipelago (Soviet Union).

(l) Transport and herding[171]

Frozen mires in northern countries are used for the transport of forestry products. They are also used by nomadic peoples to herd reindeer to and from summer grazing grounds. Because of their natural openness, peatlands are also favoured areas for cross-country skiing.

3.4.3 Regulation functions

The term 'regulation function' summarises all the processes in natural and semi-natural ecosystems which contribute to the maintenance of a healthy environment by providing clean air, water and soil[172]. The processes involved can be of biological, biochemical or physical origin. Peatlands have a function in the regulation of essential environmental processes and life support systems; i.e. in the maintenance of adequate climatic, atmospheric, water, soil, ecological and genetic conditions. They may provide clean water, regulate water flow, recycle elements and affect both local and global climates.

(m) Regulation of the global climate[173]

Although carbon dioxide emissions from human activities make up only a small fraction of the carbon that cycles annually among the atmosphere, terrestrial plant and animal life, and oceans, these emissions account for the unwanted build-up of atmospheric CO_2. Reducing the emissions associated with energy production and land use should moderate the rate and reduce the ultimate magnitude of climate change[174].

Mires act as sinks of atmospheric carbon dioxide and peatlands constitute large reservoirs of carbon and nitrogen. Both pristine mires and re-wetted peatlands emit methane and nitrous oxide. Drained peatlands emit carbon dioxide. Because of their extent and the large volumes of carbon stored in their peat, mires and peatlands play a major role in the global carbon balance. This section discusses how peatlands and their use may influence the global climate. It is a summary of material in Appendix 2. The statements in this section are supported by the text, tables, figures, and references in Appendix 2. The section is based on information as it is known at the time of writing of this document. Future research will add to this knowledge.

Introduction: The peat formation process is strongly influenced by climatic conditions, but mire ecosystems themselves also affect the global climate. The natural effect of climate on mires and mires on climate occurs through the so-called greenhouse gases which mires absorb and emit, and the carbon they store.

Like a window pane in a greenhouse, a number of gases in the atmosphere allow solar radiation (visible light) to 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)[175].

Greenhouse gases fall into three categories:

- radiatively active gases such as water vapour (H_2O), carbon dioxide (CO_2), ozone (O_3), methane (CH_4), nitrous oxide (N_2O), 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 O_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 some 30^0 C warmer than it would be if all solar radiation were transferred back to space. Water vapour, carbon dioxide and clouds contribute roughly 90 percent to the natural greenhouse effect; and naturally occurring ozone, methane and other gases account for the remainder. The emission of greenhouse gases resulting from human activities causes a change in the radiation balance of the Earth (radiative forcing).

Carbon exchange: A major characteristic of mires is that they sequester, or capture, carbon dioxide from the atmosphere and transform it into plant biomass and eventually peat. Mires and peatlands also emit greenhouse gases. The type of gases that mires and peatlands thus 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 and the proportion of emitted methane consequently increases. Peatland drainage generally increases carbon dioxide emissions and decreases those of methane, and peatland agriculture additionally increases emissions of nitrous oxide. As all these gases have a different radiative forcing, their effect on the radiation balance of the atmosphere differs with the type of mire or peatland and the type of exploitation[176].

Carbon stores: The other important aspect of mires and peatlands is their function as stores of carbon. This is carbon that is excluded from short-term (e.g. annual) carbon cycling. Stores are only important when their volumes change. The increase of atmospheric carbon dioxide in the recent past has been caused principally by burning long-term carbon stores (fossil fuels such as coal, lignite, gas, and oil). The felling and burning of 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 carbon store in peatlands can be subdivided into three components:

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

Each of these components may behave differently under different management options (such as agriculture, forestry, extraction, in fires, and under re-wetting).

To understand the integrated effects of peatlands on climate, and the consequences for climate 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.

The role[177] of pristine mires: As stated above, mires 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 including carbon sequestration by plant photosynthesis (primary production), direct carbon losses during litter decomposition, 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. Annual long-term carbon accumulation of the world's mires is approximately 1% of the carbon emitted by global fossil fuel consumption in 1990, or 10% of the carbon emitted by USA electricity utilities in 1998.

In the long run, mires 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. The decreasing atmospheric concentrations of carbon dioxide during interglacial periods as a result of peat formation, and the consequent steadily reducing greenhouse effect, is seen by some scientists as a major cause of the origin of ice ages.

Pristine mires affect the global climate both by the sequestration of carbon dioxide from the atmosphere and by the emission of other gases, especially methane and nitrous oxide. Methane is the second most important greenhouse gas after carbon dioxide and is expected to contribute 18% of the total foreseen global warming over the next 50 years, as opposed to 50% attributable to carbon dioxide. Furthermore methane participates in tropospheric ozone formation. Global methane production is dominated by natural wetlands, rice paddies, and animal livestock. Methane emissions in mires are highly variable, but are generally higher in pristine fens than in pristine bogs.

Nitrous oxide is a greenhouse gas and also causes destruction of stratospheric ozone. Nitrous oxide emissions from pristine mires are low. Occasionally such mires may even consume nitrous oxide due to the reduction of nitrous oxide to dinitrogen (N_2) under conditions of severe oxygen deficiency.

Because all gases have a different lifetime in the atmosphere and a different "global warming potential", the combined effects of all three gases together depend on the time horizon chosen. On a 100-year horizon, for example, Finnish undisturbed mires increase the greenhouse effect, whereas on a 500-year horizon they decrease it. This is due to the changing impact of methane emissions (cf. Table 3/14).

Recent general overviews indicate that over a short time-scale (cf. Table 3/15) pristine mires contribute to the greenhouse effect

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

Table 3/14: The atmospheric lifetime and the IPCC (1996) accepted global warming potentials over different time horizons of radiatively important gases[178].

		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

Table 3/15: Global Warming Potential (GWP in kg CO_2-C-equivalents ha^{-1} $year^{-1}$) of pristine mires using different time scales[179].

with respect to their carbon dioxide, methane and nitrous oxide balance. Over a 500-year time-scale pristine bogs have a negative global warming potential and fens a small positive potential.

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 carbon dioxide, methane and nitrous oxide 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. Similar to these other ecosystem types 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.

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

- Hydrocarbons that may significantly impact ozone, methane and carbon monoxide in the troposphere. Plants, primarily trees, emit an amount equivalent to all methane emissions. As the emissions are sensitive to temperature, the emissions from peatlands in North America and Eurasia are expected to significantly increase under global warming.
- Dimethyl sulfide (DMS CH_3SCH_3), an "anti-greenhouse gas" that enters the troposphere and is oxidised there to sulfate particles, which - as cloud condensation nuclei - influence cloud droplet concentrations, cloud albedo and consequently climate.
- Methyl bromide (CH_3Br) and methyl chloride (CH_3Cl) that have a cooling effect through their ability to destroy stratospheric ozone.

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

The role of drainage - 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 change of non-forested virgin peatland to grasslands and arable fields will generally not lead to such large biomass or litter changes.

The dominant effect of peatland drainage for agriculture is that the peat is exposed to oxygen which leads to peat mineralisation. This causes a decrease in the *peat* carbon store and an increased emission of carbon dioxide, especially in summer.

Under tillage, peat mineralisation is accelerated as compared to grassland due to more intensive aeration. Carbon dioxide emissions in arable fens are higher than in bogs.

Methane emissions from drained peatlands are generally very low though some emissions have been observed in bogs. Drained fens emit less methane than bogs and function more frequently as net sinks for atmospheric methane.

Nitrous oxide emissions from bogs are low due to the low pH and low total nitrogen content. In the more nutrient-rich fens somewhat higher nitrous oxide emissions have been observed. Nitrous oxide emissions depend on the available nitrogen and therefore on nitrogen fertilisation. It is assumed that 1% of the nitrogen applied as fertiliser is emitted as nitrous oxide.

Figure 3/2 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 a similar warming potential to that of tilled bogs. Fertilisation and liming of grasslands strongly increases peat mineralisation.

The role of drainage - forestry: The effect of peatland drainage for forestry[180] 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.

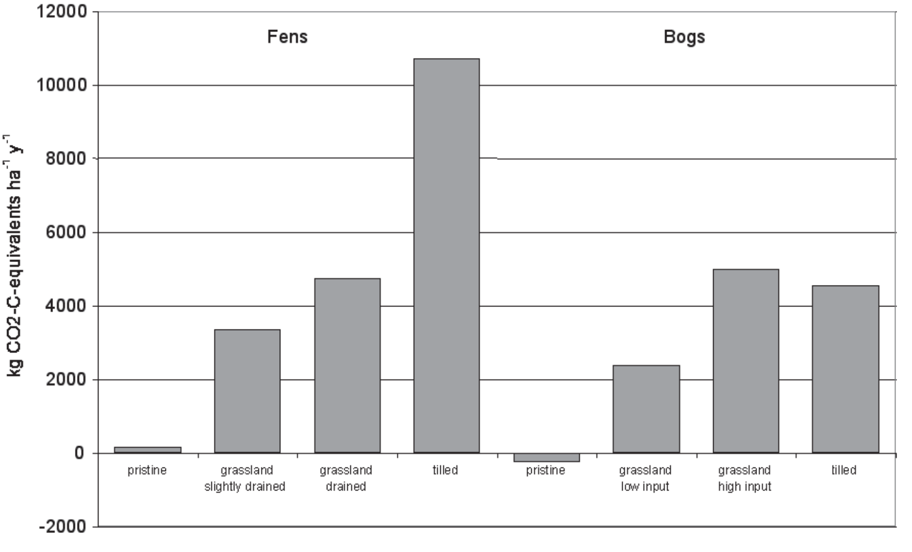


Figure 3/2: Rough estimates of the global warming potential of fens and bogs (in kg CO_2-C-equivalents ha^{-1} y^{-1}) under different types of land use (compiled by Heinrich Höper 2000).

As in agriculture, increased aeration of the peat after forestry drainage results in faster peat mineralisation and a decrease in 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 rate of peat mineralisation.

As water-logging in mires generally prevents an economic level of wood production, peatland drainage aims to increase the wood yield (see § 3.4.1 [eb]). After drainage, forest vegetation (such as trees and shrubs) 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 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.

Peatland drainage for forestry also leads to changes in the *litter* carbon store. The moist litter 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[181] 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* carbon store, the harvesting of which leads to a substantial reduction, and
- a slow initial increase of the peatland *litter* carbon store which eventually, after some centuries, reaches an equilibrium.

Thus, the *peatland* carbon store, being the combined effect of these processes, varies 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[182], the cumulative carbon losses from peat oxidation prevail in the long run.

With respect to gas exchange, the drainage of peatlands for forestry generally leads to an increase in carbon dioxide emissions, a substantial decrease in methane emissions and, depending on peatland type and type of land use (fertilisation), to a sometimes drastic increase in nitrous oxide emissions.

Peat extraction: The effect of peat extraction and subsequent oxidation is similar to that of burning fossil fuels[183]. The peat carbon store is largely transformed into carbon dioxide. Efficient drainage in the extraction areas may maintain high rates of carbon dioxide emissions while methane and nitrous oxide emissions remain fairly low.

Integrated effects: Detailed national balances with respect to peat carbon stores and radiative forcing are available only for Finland. In Finland both undisturbed and forestry drained peatlands currently have a positive carbon balance, the former because of *peat* accumulation, the latter because of an increase in root *biomass* and *litter* carbon. Table 3/16 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. Estimating the effects on a 500-year horizon is even more speculative than doing so on a 100-year horizon, and does not take into account changes in hydrology and temperature resulting from global climate change.

Peatland fires: In many areas of the world natural fires ignited by lightning strikes were normal phenomena in peatlands. Today fire is most frequently the result of human activities. Peatland fires may lead to the ignition of the peat layers, especially after drainage. 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.

Emissions from biomass and peatland burning represent a large perturbation of global atmospheric chemistry. In the 1982-3 drought and fire in East Kalimantan, the area affected by fire included 5500 km^2 of peat-swamp forest. 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 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 to be equal to 10% of the global annual emissions from fossil fuel consumption.

Peatland inundation and re-wetting: Peatlands are inundated for rice cultivation, water reservoirs (especially for hydro-electricity), and mire restoration. Higher water table depths generally lower the carbon mineralisation rate. Nevertheless inundation and re-wetting do not necessarily result in lower emission rates.

Rice paddies are among the most important methane emitters in the world. Inundation of peatlands to create water reservoirs leads to significant emissions of both carbon dioxide and methane. Emissions from Canadian wetlands due to flooding are estimated to represent 5% of Canada's anthropogenic emissions.

The re-wetting of degraded peatlands would also be expected to lead to a decrease in carbon dioxide and nitrous oxide emissions. In practice, however, re-wetting of fen grasslands often leads to increased methane emissions, while carbon dioxide emissions may remain continuously high. 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 major increase in nitrous oxide emissions.

		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 ± 0.75	+ 8.32 ± 0.71
Totals		**+ 18.97 ± 8.97**	**+ 8.06 ± 8.81**

Table 3/16*: Summary of radiative forcing of Finnish peatlands under different land-use forms using different time horizons.*

Re-wetting of drained alder forests leads to increased emissions of methane, but to decreasing nitrous oxide emissions.

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

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.

Some researchers stress the importance of alterations in the water table level, 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 and suggest that a net loss of carbon will take place in northern fens but a net gain in northern bogs.

The behaviour of permafrost peatlands will also be important, as both decomposition and net primary production are accelerated following permafrost melt. In general, methane emissions from peatland ecosystems will decrease with drying. 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.

Conclusion: The atmosphere and the ocean, and the interactions they have with living things constitute a complex dynamic system with many interconnections and feedbacks. This complexity explains the uncertainty and controversy about greenhouse gases and climate change[184]. Most scientists believe that small changes in the "inputs" to the climate system will result in small changes to the resulting climate and that climate change will take place gradually over a period of many decades. If change is gradual, the overall economic impact on wealthy countries will probably be modest. Because of the feedbacks, the response of the climate to an increase in greenhouse gases could, however, also be "nonlinear" meaning that a small change in an input might produce a major change in climate, such as might be brought about by a sudden change in the general pattern of ocean circulation. If that happens, the economic costs to wealthy countries could be very large, as much new investment might be needed in a very short period of time.

Whether it is fast or slow, climate change is likely to have greater economic impacts on poor countries than on rich countries, because poor countries have less capacity to adapt to changes and because traditional life styles depend more directly on a specific climate. In the long run, if sea levels continued to rise, even developed countries might begin to experience serious costs, as many of the world's largest cities are in low-lying coastal locations.

Because of this small but realistic risk of large and negative effects of climate change, a precautionary policy[185] should take into account the climate regulatory function of mires and peatlands, especially their role as major long-term stores of carbon.

(n) Regulation of regional and local climates

Mires have a specific microclimate, which often differs from that of their immediate surroundings. Their microclimate is characterised by a greater variation in temperature, higher air humidity, greater fog frequency and greater risk of night frosts compared with that of mineral soils. There are slight differences between the maximum temperatures and pronounced differences between the minimum temperatures of mires compared with surrounding mineral areas[186].

Peatlands are by nature wet landscapes and are usually situated in terrain depressions into which cooler and heavier air flows ("Kaltluftseen"). This stimulates fog and dew formation[187]. As a consequence, the soils of both pristine and reclaimed peatlands are significantly cooler in summer than mineral soils, and the air temperature is also lower. Forested tropical peatlands have lower mean and maximum temperatures than those that have been deforested[188].

Mires and peatlands strongly depend on the prevailing climate. On the other hand, they also influence the regional and local climate through evapotranspiration and associated alteration of heat and moisture conditions. This influence is larger in warmer or drier climates and smaller when the regional climate is colder or more humid. In areas with extensive peatlands the regional climate is consequently more humid and cool[189]. Drainage of mires in the boreal zone leads to a reduction in the minimum temperatures and a shortening of the yearly frost-free period, a process that is reversed by subsequent afforestation[190].

(o) Regulation of catchment hydrology

Traditionally, peatlands were generally seen as reservoirs or "sponges" storing water during wet periods and releasing it slowly during ensuing dry spells. In this way they were believed to reduce flooding following high precipitation and sustain water flow during times of low precipitation and consequently to have a "buffering" effect on catchment hydrology. This traditional view can, however, no longer be upheld unconditionally[191].

With respect to the hydrologic reservoir or water storage function of peatlands it is necessary to distinguish between a static and a dynamic storage component[192]. The static component is the water in the permanently water-saturated peat layers (the catotelm) and the water that is physically or chemically bound into the uppermost peat layers which are periodically exposed above the water level. Depending on their thickness and extent, peatlands may have a very large static water store as undrained peat consists of 85 - 95% water. In general this water either does not move or moves only slowly and therefore scarcely participates in the annual water cycling and regional water regulation.

The dynamic storage component consists of the rapidly exchangeable water volumes in and over the uppermost peat and vegetation layers (the acrotelm), or, in drained peatlands, the uppermost soil. It is composed of (drainable) soil pore water, water cushions in and under the peat, water in peatland hollows and pools, and inundation water. These different fractions imply that different mire types may have completely different dynamic storage characteristics.

As peat accumulation requires high water levels at the mire surface during most of the year, the dynamic storage capacity of most mire types is limited. In times of abundant water supply the available storage is rapidly filled and the surplus water drains quickly. Peat-covered areas therefore generally show considerable surface run-off, directly consequent on precipitation, and little baseflow[193].

Only mire types of which the peat layer can shrink and swell with changing water supply (such as percolation mires and to a lesser extent schwingmoor mires - see §2.3), or that combine a large storage co-efficient with a limited hydraulic permeability (such as acrotelm mires and patterned surflace flow mires including aapa mires) have a “buffering” effect on catchment hydrology.

Other mire types, such as immersion, water rise, and flood mires and most types of surface flow mires, do not bring about similar effects. The fact that flood mires in river valleys may play an important role in flood mitigation[194], is not related to their peatland or wetland character but to the fact that they lie in or near the valley. Mineral wetlands or dry land with similar topography would function in exactly the same way.

After drainage the water movement and storage characteristics of peatlands change considerably. Generally they start to resemble drier mineral soils: peak discharge is strongly reduced because the peat layer is no longer completely saturated and the dynamic storage capacity is increased[195]. In other cases, open drainage – as associated with afforestation and agriculture – increases peak charge rates, because the increased storage capacity within the peat afforded by the lowering of the water table is of lesser importance than the higher density of open channels in the drained areas[196]. Similar effects result from soil degradation in drained fens, which leads to decreased infiltration of rainwater in the peat body and increased surface run-off[197].

Mires also influence the hydrology of their surroundings because of their evapotranspiration characteristics. In fens (which are also fed by mineral soil water) evapotranspiration often exceeds precipitation, leading to a decrease in run-off[198].

Groundwater charge from peatlands, i.e. the quantity of water flowing downwards through the peat into the groundwater of the underlying bedrock, is generally small[199]. In the long run the accumulation of peat in the lower parts of the catchment may lead to a rise in the regional groundwater level[200]. The reverse may happen in the cases of peatland drainage and peat extraction.

(p) Regulation of catchment hydrochemistry[201]

Ecosystems are linked with their neighbouring systems and continuously exchange matter, energy and information. Ecosystems regulate the flow of an in-flowing substance through transformation, buffering or storage (accumulation) resulting in a change in chemical concentrations in the outflow[202].

Mires accumulate carbon, nitrogen, phosphorus and other nutrients when annual production exceeds annual aerobic and anaerobic microbial decay. First, the vegetation transforms inorganic substances, e.g. CO_2, NO_3 or NH_4, via biochemical processes into organic components (C_{org}; N_{org}). Then the dead plant material undergoes several deformation processes collectively called decomposition, decay or humification resulting in the formation of peat.

The decay of organic matter in mires is determined by many factors including oxygen concentrations in the acrotelm and catotelm, the temperature regime, the chemical composition of the plant material, and pH. An important factor for the rate of peat accumulation is how long litter stays in the acrotelm before the anoxic conditions (lack of oxygen) in the catotelm peat layer reach it. The relation between aerobic conditions in the acrotelm and anaerobic conditions in the catotelm is highly sensitive to changes in the hydrological conditions caused by climatic or human factors. Lowering of the water level increases the oxygen in the soil and fosters fast aerobic decay. Under these conditions, carbon and nutrients are not longer accumulating, but are released from the peat.

Mires and peatlands have diverse effects on the chemical composition of the water in a catchment depending on their position within the catchment, the wetland water balance, the water source, and the related biological, chemical and physical processes[203]. Mires receive water of different quality from different sources. Water pathways include rainwater, surface run-off, lower groundwater, deeper groundwater, or river water inflow due to over-flooding.

Bogs by definition derive their water only from precipitation. Bog mires act as sinks for carbon and nutrients by accumulating carbon, nitrogen and other nutrients in their peats. The water flowing out of bogs is characterised by low pH and high concentrations of humic substances and ammonia[204]. Bogs therefore act as local sources for carbon and nitrogen in a catchment. The concentrations of humic substances, nitrogen and phosphorus in the run-off water can rapidly increase after bog drainage depending on land use practice, e.g. fertilisation, chalking, agriculture, forestry.

Groundwater-fed fens like spring mires or percolation mires have a high potential for the transformation of inflowing substances transported with the groundwater. At the interface between mineral substrate and peat denitrification leads to a decrease in the nitrate concentration of the inflowing groundwater[205]. Additionally, the inflowing nutrients are partly stored through peat accumulation. Groundwater fed fens are able to improve the water quality in a catchment. Drainage and agricultural intensification both in the fen and in the catchment affect this functioning. Due to increased nutrient concentrations in the groundwater following fertiliser application in the catchment, the transformation potential can be over-used, resulting in an increased nutrient availability in the fen and decreased biodiversity. Drainage activities change the water pathways and therefore the mixing of different water sources. As a result, groundwater influence decreases and rainwater influence increase which affects the vegetation composition in the fen.

In flood mires and many terrestrialisation[206] mires, freshwater inflow is the main water source. These mire types foster processes which reduce chemical concentrations, such as denitrification, sedimentation or plant uptake. These wetlands act as sinks for nutrients in the catchment when the outflowing load has decreased compared to the inflowing load[207]. In the nitrogen cycle, denitrification is quantitatively the most important transformation pathway. The efficiency of such fen types in removing chemicals is related to the hydraulic retention time (the length of time the water is retained in the mire) and the inflowing water quality. High ammonia or N_{org} concentration will not be reduced significantly in small wetlands with low detention time. In some wetlands the inflowing nitrate, which is removed by denitrification, is replaced in the outflow by mobilised ammonia concentration. The net quantification of nitrogen and phosphorus retention in wetlands is therefore still a complex task. In addition to assessing the inflow and outflow concentrations of chemical substances it requires an experimental approach for the quantification of internal nutrient transformation rates[208].

Mires and peatlands have diverse effects on the hydrochemistry of a catchment. Mires receive water of different quality from different sources, including rainwater, surface run-off, lower groundwater, deeper groundwater, or river water inflow due to over-flooding. Specific regulation functions of certain mire types include:

- **Bog mires** which derive their water only from precipitation act as sinks for carbon and nutrients by accumulating carbon, nitrogen and other nutrients in their peats. They therefore act as local sources for carbon and nitrogen in a catchment.

- **Groundwater-fed fens** have a high potential for the transformation of in-flowing substances transported with the groundwater. They are able to improve the water quality in a catchment.
- In **flood mires** and many **terrestrialisation mires**, freshwater inflow is the main water source. These mire types foster processes which reduce chemical concentrations such as denitrification, sedimentation or plant uptake. These wetlands act as sinks for nutrients in the catchment.

Because of these properties, peatlands have a capability for the advanced treatment of secondary municipal wastewaters. Results from several systems indicate reduction in B.O.D., suspended solids, nitrogen and to some extent phosphorus.

(q) Regulation of soil conditions

The peat blanket of mires protects the underlying soils from erosion. With respect to adjacent soils[209], undrained peatlands prevent concentrated/preferential water flow which would erode these soils. The insulation capacity of peat retains permafrost far outside the zone of continuous permafrost, e.g. in parts of China and Mongolia.

3.4.4 Informational functions

(r) Social-amenity and history functions

Social-amenity functions include attachment to place and interactions with other people. The attachment to place is "the most important and least-recognised need of the human soul"[210]. Human beings have always been in close contact with wetlands and peatlands. Ancestral hominids and early human beings appear to have lived at and around wetland sites. The 1.5-million-year-old Turkana Boy, the most complete skeleton ever found of *Homo erectus*, was excavated in what had been a lagoon near the edge of a lake or an oxbow of a river[211]. Bog bodies, tools, ornaments, weapons, and other archaeological remains found in abundance in peat testify to the long and intense relationship between people and mires[212].

This relationship was not unambiguous: peatlands were simultaneously seen as life-bringing and life-taking, as repelling and inviting, as "water and fire"[213]. In early 17th century England, fens were described as: "The air nebulous, grosse and full of rotten harres; the water putred and muddy, yea, full of loathsome vermine; the earth spuing, unfast and boggy..." But other voices of that time recognised their value in providing fodder for horses, cattle, and sheep, as store of "osier, reed and sedge", and as "nurseries and seminaries" of fish and fowl, from which thousands of people gained their livelihood[214].

Relatively few people lived or live entirely from and in wetlands and peatlands[215]. For many more people, peatlands were and are part of their home area: the community they share with other human beings, with plants and animals, and with familiar topography[216].

This notion of identity and continuity is expressed in many poems[217], novels[218], myths, fairy tales and fiction[219], songs[220], films[221], and other works of art[222], in a myriad of books and documentaries on local and regional peatland history[223], in language and expressions associated with peatlands[224], in names[225], in museums[226], and on postage stamps[227] and on banknotes[228]. The very remnants of mires and peatlands, anthropogenic peatland patterns, and continued traditional exploitation techniques and folklore are reminders of former socio-economic conditions[229], and reflect some of the *history functions* of mires and peatlands.

Sometimes Johan Clemme would ponder whether he had done right in opening this wilderness for man. He loved the land because of its sadness and its poverty. He loved it because of the secrets of its soil, the sunken world of plants, trees, and animals. He loved the land because of its wide heaven. After them, all generations who lived there, he loved. He knew that among them were many who could only live in the bog and would be unhappy everywhere else. In their silent faces he recognised himself.

Aar van der Werfhorst 1945

Their limited accessibility has often turned mires into political, cultural, and language borders[230].

As part of their *social-amenity functions* peatlands may act as a bringing-together point for social contacts, places where people meet and acquire company, friendship, solidarity, and self-respect[231]. In some areas, these social aspects of employment ("keeping the rural area alive") have constituted decisive reasons for peat extraction, for example in the midlands of Ireland and central Finland.

Data on employment in peatland agriculture, peatland forestry, and mire conservation are not available on a global scale[232]. In direct industrial peat extraction (Tables 3/17 and 3/18), employment has been declining during the last decade, because of decreasing production volumes[233] and the introduction of more labour-efficient production techniques[234]. No data are available on indirect employment but a 1993 report[235] estimated the multiplier effect (the relationship between direct and combined direct/indirect employment) at between 1.15 and 1.25.

(s) Recreation and aesthetic functions

Mires and peatlands have *recreation value* in that they provide opportunities for recreation. The limited accessibility of mires and peatlands ("too wet to drive, too dry to boat") does not make them particularly suited for mass recreation. Where facilities[236] are available, however, large numbers of people may visit these open, often softly undulating landscapes with their endless skies and mirror-like water surfaces, their wealth of extraordinary species, their historical dimension, and their treacherous, mysterious but exciting character[237] (Table 3/19). Many more mires are used for low-intensity recreation by amateur hunters, anglers, gatherers of berries and mushrooms, hikers,

	1990		1998		1999	
	Average	Peak	Average	Peak	Average	Peak
Eastern Europe	89 900	91 200	25 900	26 400	25 600	26 400
Western Europe	8 100	11 000	8 400	15 200	8 300	13 800
North America	2 500	3 600	3 100	3 900	3 200	4 000
Total	100 500	105 800	37 400	44 800	37 120	44 500

(IPS questionnaire 2000, preliminary data, supplemented by estimates)

Table 3/17: Labour force in the global peat industry in man-years

	1990	1998	1999
Belarus	12 000	7 500	7 000
Russia	56 000	12 500	13 500
Ukraine	18 600	4 200	2 700
Estonia		300	1 200
Latvia	4 000	1 100	1 200
Finland	3 000	4 400	3 400
Sweden	1 200	1 200	1 200
Poland	600	800	800
Germany	3 500	2 500	2 600
Ireland	3 900	3 800	3 300
United Kingdom	500	500	500
U.S.A.	1 200	900	900
Canada	2 400	3 000	3 100
Total	105 600	45 000	44 100

(IPS questionnaire 2000, preliminary data, supplemented by estimates)

Table 3/18: Peak labour force in various countries in man-years

skiers, boaters, and by other people looking for wilderness, quietness, and remoteness.

Aesthetic functions attach to the appreciation of beauty. The awesome beauty of mires and peatlands has inspired artists since Albrecht Dürer[250]. The openness, patterns, and symmetry of many peatland landscapes are aesthetically fascinating[251], their blaze of colours varying from pastel and melancholic to deep green and bright red, and the delicate symmetry of specialised groups of micro-organisms[252]. Special conferences have recently been devoted to the aesthetics of mires and peatlands[253]. Some wild peatland organisms are specifically protected (and collected and marketed) for their beauty, such as orchids and ornamental blackwater fish[254].

(t) Symbolisation, spirituality, and existence functions

Symbolisation, spirituality, and existence functions play an important role in the self-identification and group-identification of human beings. *Symbolisation functions* are those attaching to things which act as symbols of other values. Large conspicuous organisms, often mammals or birds[255], more seldom plants[256], and landscapes[257] may have such symbolisation value[258] for individuals, organisations and nations. Examples of the former are hunting trophies[259] (of peatland animals like moose (*Alces alces*), bear (*Ursus sp*.), grouse (*Lagopus lagopus scotticus*, *Lyrurus tetrix*), snipe (*Gallinago gallinago*), crocodiles (*Crocodilia*) and tiger (*Panthera tigris*). Some peatland organisms have a wider symbolisation value, including Eagles[260], Beavers[261], Crocodiles and Alligators[262], Cranes[263], Storks[264], and

Mire/peatland reserve	Number ('000)
Burns Bog (Canada)[238]	50
Everglades NP (USA)[239]	1 141
Kushiro Shitsugen NP (Japan)[240]	740
Exmoor NP (UK)[241]	220
Snowdonia NP (UK)[242]	6 600
North York Moors NP (United Kingdom)[243]	9 500
Peatlands Park (Northern Ireland)[244]	80
Connemara National Park (Ireland)	78
The Broads (United Kingdom)[245]	3 000
Groote Peel NP (Netherlands)[246]	165
Spreewald Biosphere Reserve (Germany)[247]	4 000
Hautes Fagnes (Belgium)[248]	350
Miscou Island (New Brunswick)[249]	6

Table 3/19: Annual number (mostly in visitor days) of recreational visitors in selected mire/ peatland nature reserves

Herons[265], Pelicans[266], Larks[267], the Common Loon (*Gavia immer*)[268], and the Blue Iris (*Iris versicolor*)[269].

Spirituality functions involve an entity's role in religion and spirituality. In former times, mires were seen as mysterious and played an important role in religion and spirituality. This is illustrated by the sacrifices, which took place from the Neolithic age to the middle ages, that are found in peatlands[270]. Many of these were of precious goods or even of human beings.

Nowadays, *existence functions*, providing the notion of ecological and evolutionary connection, that we share this world with other entities with which we are related and for which we have a responsibility, are a considerable motive for nature conservation[271]. The "naturalness" of mires is a major source of interest, as mires often constitute the last terrestrial wildernesses, regionally and also globally[272]. The significance of such existence functions is illustrated by the widespread support for efforts to conserve species and ecosystems in other parts of the world, i.e. which most of those who support their preservation may never see in practice[273].

(u) Signalisation and cognition functions

The *cognition functions* of mires and peatlands are their functions in providing opportunities for the development of knowledge and understanding. One of the characteristic qualities of human beings is their curiosity[274] and the consequent pursuit of knowledge. Identifying, classifying and understanding patterns and processes in nature offers people a challenging and accessible means of developing intellectual capacities, including knowledge, computation, application, analysis, synthesis and evaluation[275]. Mires provide special, even unique, forms of information[276]. They constitute ecosystems with an incomplete

> *"We need the tonic of wildness, - to wade sometimes in marshes where the bittern and the meadow-hen lurk, and hear the booming of the snipe; to smell the whispering sedge where only some wilder and more solitary fowl builds her nest, and the mink crawls with its belly close to the ground."*
>
> *Henry David Thoreau 1854*

cycling of material and a consequent continuous accumulation of organic material[277]. They record their own history and that of their wide surroundings in systematic layers, making them particularly suited to the reconstruction of long-term human and environmental history[278]. The data stored in the peat archives include macro-remains of peat-accumulating plants[279], pollen and spores of plants, including those from the wider surrounding areas[280] and all sorts of materials and substances that one way or another got into the mires. Some recent developments in peatland palaeo-ecology[281] include the detailed reconstruction of human life[282], of volcanic emissions[283], of the atmospheric deposition of heavy metals[284] and nitrogen[285], of atmospheric CO_2 concentrations[286], and of climatic change[287] and the associated role of solar forcing[288]. These recent developments illustrate that the significance of peatlands in this respect will increase in future[289].

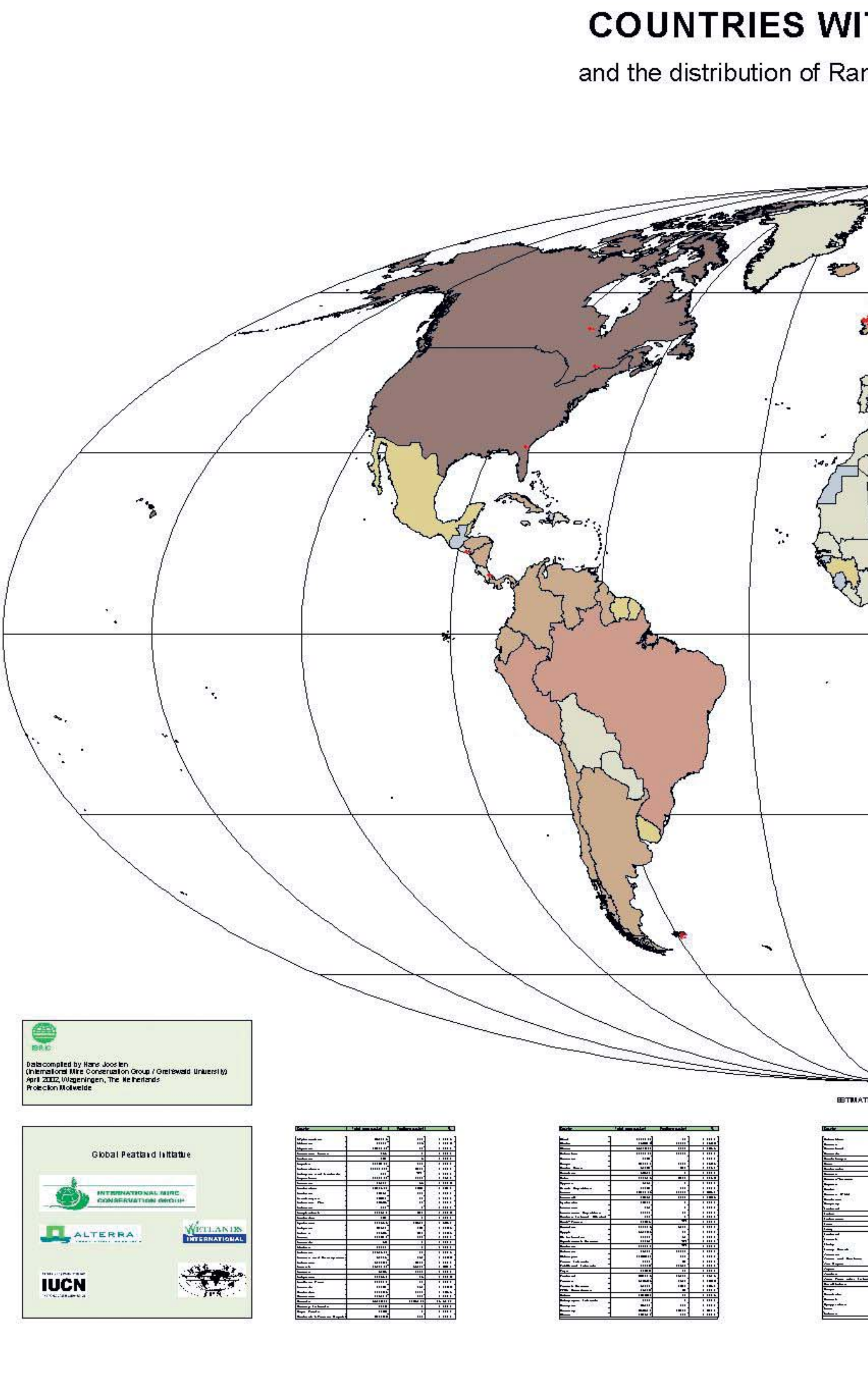
Mires and peatlands are generally characterised by extreme conditions, which require special adaptations of the species which live there. These conditions include the scarcity of oxygen in the root layer, the presence of toxic substances, continuous cover by peat accumulation and rising water levels, the immobilisation and resulting scarcity of nutrients (especially in case of ombrogenous and calcareous mires), and the azonal climatic conditions[290].

Various mire types develop sophisticated self-regulation mechanisms over time[291] and acquire an exceptional resilience against climatic change[292]. This means that such mires are model examples of ecosystems whose long-term development can furthermore be studied with relative ease. Related features are the inherent tendency of mires to develop complex surface patterning[293] and ecosystem biodiversity[294] on various spatial and organisational levels (see Table 3/20). The extent to which biodiversity is influenced by mire size raises questions regarding the management and political level at which decisions on mires are taken: some types of biodiversity require (very) large areas[295].

Signalisation functions include the function of acting as a signal or *indicator*[298]. As accumulating ecosystems, i.e. as "self-registering witnesses", mires have an important signalisation value. The recent environmental impact of human activities can be assessed by comparing the information stored in recent peat deposits with that of deeper, older peat layers, where information on the pre-human situation is stored. As wildernesses that have been spared from direct human activities for a long time, mires may offer the necessary natural "zero" references that historical cultural archives cannot provide[299]. Ombrogenous mires have a particular value in this respect, since they depend solely on precipitation and are therefore well suited to studies of changes in

– atmospheric deposition (e.g. "acid rain")
– climatic conditions,
– conditions in the cosmosphere (e.g. cosmic radiation, sun spot cycli).

Special adaptations of mire plants to acquire the necessary nutrients make these plants useful as environmental indicators, e.g.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(International Mire Conservation Group / Greifswald University)
April 2002, Wageningen, The Netherlands
Projection Mollweide
Global Peatland Initiative
INTERNATIONAL MIRE CONSERVATION GROUP
ALTERRA
WETLANDS INTERNATIONAL
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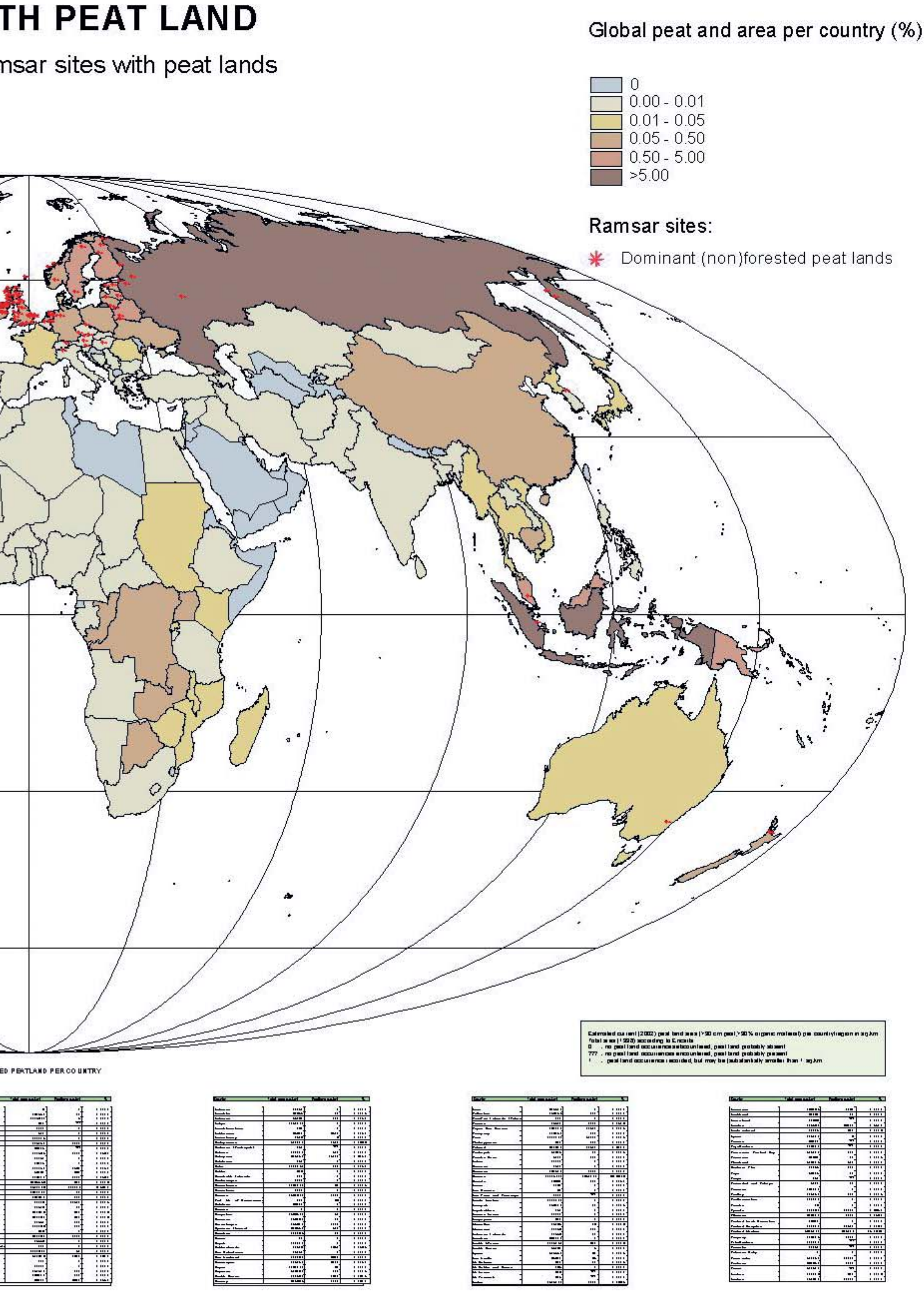

TH PEAT LAND
msar sites with peat lands
Global peat and area per country (%)
0
0.00 - 0.01
0.01 - 0.05
0.05 - 0.50
0.50 - 5.00
>5.00
Ramsar sites:
Dominant (non)forested peat lands
ED PEATLAND PER COUNTRY

Mire organisational level	Name of that level*	Synonyms for that level as used in different literature references	Indication of size (m^2)[297]	Example
0 level	-	-	10^{-8}	Plant tissue, non tissue
1st level	-	Elementary particle, Nanoform	10^{-2}	Single plant, moss clone, open water
2nd level	Nanotope	Mire-microform, feature, element	$10^{-1} – 10^{1}$	Hummock, hollow, pool
3rd level	Microtope	Mire-site, facies, element, segment, mikrolandšaft	$10^{4} – 10^{6}$	Hummock-hollow complex, pool
4th level	Mesotope	Mire-complex, massif, synsite, unit, mesolandšaft	$10^{5} – 10^{7}$	Raised bog (as a whole)
5th level	Macrotope	Mire-system, complex, coalescence, makrolandšaft	$10^{7} – 10^{9}$	Stormosse (Sjörs 1948); Red Lake Peatlands (Glaser 1992).
> 5th level	Supertope	Mire-region, zone, district, province	$> 10^{9}$	Regional zoning of mires (Gams & Ruoff 1929, Ruuhijärvi 1960

*proposed at the IMCG Workshop on Global Mire Classification, Greifswald, March 1998.

Table 3/20: Mire biodiversity on various spatial and organisational levels[296].

Sphagnum species as indicators of atmospheric pollution[300] or as indicators of geological resources[301].

3.4.5 Transformation and option functions

Transformation functions concern the possibility of modifying and changing preferences, e.g. the development of new tastes, the improvement of social skills, and the growing awareness of existence functions[302]. These are important aspects of peatland educational programmes[303]. Outdoor experiences ("survival") in peatlands are increasingly used to develop social and management skills in civil servants, young criminals, and business executives[304].

Experience of wild species and pristine ecosystems is a major advantage in developing a consistent and rational world view, one that fully recognises the place of the human being in the universe as a complex organism whose existence depends upon other living beings and functioning ecosystems. Such experience may inform and challenge existing frames of reference: how to exist in a limited world, how to understand that world, and what value to place on it? It can promote the questioning and rejection of world views that lead to overly materialistic and consumerist preferences. Mires, as economical, stable and self-organising miniature-worlds that provide important historic references, may play an important role in this respect[305].

Option functions relate to the importance people place on a safe future, either within their own lifetime, or for future generations. The prospect of a safe future is a normal human need, and the perception that this prospect might be weakening has a negative effect on welfare. Option functions of mires include the future assurance of their production, carrier, regulation and informational functions, and of the benefits that still have to be discovered[306]. The ability of genetic and other biodiversity to evolve and to adapt to changing conditions is important, as it may provide future humanity with new genetic and ecosystem resources. The adaptations of peatland organisms to excess water and lack of nutrients are significant in this respect; they make possible relatively high productivity under extreme conditions and low intensity management[307]. The future archive function of peatlands is also of special importance: it is guaranteed by continued peat accumulation. Cultural archives only record what contemporary civilisation thinks will be important in future. Future generations will, however, require information from the perspective of that future, not from that of the time when the information is recorded: nobody records what does not change, and when a change has taken place it is difficult to reconstruct the former situation. This implies that required information often cannot be found in cultural archives and that one has to resort to natural archives[308]. Mires are therefore of utmost importance as systematic, unbiased devices recording information on a changing society, one that our successors will want to look at from a different perspective to that of today[309].

3.4.6 The values of conservation and economics

This leads finally to the consideration of "conservation" and "economic" values, which most often feature in environmental conflicts[310]. These values are derivations from and combinations of various instrumental values, and, in the case of conservation, also of different approaches to intrinsic values. They are often expressed as complex concepts. Employment, for example, represents income[311] which makes it possible to fulfil various needs and wants. It also leads to a wide variety of social-amenity benefits, which may be even more important. Similarly "conservation" involves a wide range of motives with respect to instrumental and intrinsic values, as becomes apparent when considering the motives for creating protected areas[312], e.g. for assigning Ramsar Listed Sites (Table 3/21). For a systematic analysis of Wise Uses of mires and peatlands it is necessary to be aware of these complex relationships. Table 3/22 gives an overview of the relationships between value types and conservation and economic values, and illustrates that the same value type may often operate in favour of both conservation and exploitation.

Ramsar Listed Sites	**Number**	**% of sites with peat**	**Ha**	**% of Ramsar Sites Area**
Total Ramsar Sites	1 028	—	78 195 293	100
Sites with peat	268	100	27 213 484	35
Sites with peat with recorded threats (peat extraction, drainage, mining, etc.)	118	29	7 883 161	10

Table 3/21: Ramsar Listed Sites containing peat as at June 2000[313].

	Value types	“Conservation” motives			“Economic” motives		
			D	N		I	E
Anthropocentric instrumental = for the benefit of humanity	Production	Protection of genetic diversity of current production species	+		commercial exploitation of various resources	+	+
	Carrier	Securing space for natural processes and patterns	+	+	securing space for production and habitation and its commercial exploitation[314]	+	+
	Regulation	Protection of regulating capacities	+	+	use and commercial exploitation of regulating capacities	+	
	Social-amenity	Protection of home area, “roots”	+		employment to guarantee company, friendship, and respect		+
	Recreation	Use for recreation, recuperation, stress mitigation	+		use and commercial exploitationof stress mitigation capacities	+	
	Aesthetics	Protection of beauty	+		use and commercial exploitation of this value or position[315]	+	
	Signalisation	Protection of general indicator function	+	+	use and commercial exploitation of indicators (e.g. monetary benefits)	+	
	Symbolisation	Protection of symbols	+		creation, use, and commercial exploitation of symbols	+	
	Spirituality	Protection of reflective and spiritual properties	+	+	use and commercial exploitation of this value or position	+	
	History	Conservation of cultural and natural “monuments”	+		use and commercial exploitation of this value or position	+	
	Existence	Conservation of processes, species, and ecosystems	+	+	use and commercial exploitation of this value or position	+	
	Science	Conservation of sources of cognitive development	+	+	use and commercial exploitation of knowledge	+	
	Transformation	Securing the potential for transformation (education)	+	+	use and commercial exploitation of transformational properties	+	+
	Option	Protection of genetic diversity and evolutionary processes	+	+	protection and saving of non-renewable resources for future use	+	+

	Value types	"Conservation" motives			"Economic" motives		
			D	N		I	E
Intrinsic values	Noocentrism[316]	Protection of all rational beings and their environment[317]	+		use and commercial exploitation of this position	+	
	Pathocentrism	Protection of all sentient beings and their environment	+		use and commercial exploitation of this position	+	
	Biocentrism	Protection of all living beings and their environment	+		use and commercial exploitation of this position	+	
	Ecocentrism / holism	Protection of all beings and systems and their environment	+	+	use and commercial exploitation of this position	+	

[grey box] Does not use/exploit the values as such, but only the people who value these values.

D = diversity, patterns; N = naturalness, wildness, processes; I = Income, monetary profit; E = employment, social benefits.

Table 3/22: Relevance of focal points of "conservation" and "economic" motives of peatland land use with respect to various value types.

[1] This chapter has benefited greatly from information provided by, and discussions with, Konrad Ott, Martin Gorke, and Anne-Jelle Schilstra.

[2] Different people attribute worth to different qualities. Some may value a mire for its beauty, others for its scientific value, yet others for the peat which can be extracted from it. Others again consider the mire to be of value just because it exists. This last view may seem extreme to pragmatic minds but they must understand that such views do exist.

[3] Prior 1998.

[4] But cf. Taoism and Pirsig 1974.

[5] "Entity" is used in this document as meaning anything which exists whether physically or conceptually (cf. Latin "ens").

[6] Cf. also Table 3/1.

[7] In this document the term function is used to express an action of an entity that positively affects the object of that action (i.e. is useful). Function is the complement of use, i.e. the same action (relation, factor) can be seen as a function (from the perspective of the provider) or as a use (from the perspective of the beneficiary).

[8] Outside nihilism, it is illogical to imagine a uni-directional chain of means without any final ends. Mean-end relationships, however, can also be regarded as a network in which the interconnected strands of the web form infinite circular lines without final ends. In such a view a clear distinction between means and ends disappears (see also §4.10).

[9] Cf. the difference between axiological objectivism and meta-ethical objectivism in Birnbacher 1996.

[10] From the Greek ανθρωποσ, οι ανθρωποι, man, mankind.

[11] UN General Assembly 1948.

[12] Cf. Declaration of the UN Conference on the Human Environment, Stockholm, 16 June 1972: "5. ..of all things in the world, people are the most precious."

[13] World Commission on Environment and Development 1987.

[14] Although some of them are "brought back in" again by referring to their potential rationality.

[15] Cavalieri & Singer 1993, Parr 2001.

[16] Reis & Marino 2001, Tschudin et al. 2001.

[17] "Sympathy for life".

[18] Cf. The World Charter for Nature (UN General Assembly Resolution 37/7 and Annex, 28 October 1982): "Every form of life is unique, warranting respect regardless of its worth to man, and, to accord other organisms such recognition, man must be guided by a moral code of action.", and "General principles. 1. Nature shall be respected and its essential processes shall not be impaired.".

[19] This does not necessarily mean that all beings are considered to have equal value. See also §4.10 and §5.8.

[20] Some essentially instrumental positions can come close to attributing intrinsic moral value to non-human beings by:

- assigning them the right not to be unnecessarily

violated, in the interests of decreasing the suffering of human beings who suffer when non-human beings are violated (the sentimental argument);
- acting as though they also have intrinsic value, to avoid the possibility that some people will treat human beings in the same way as non-human beings are sometimes treated - the psychological prudential argument. ("People who delight in the suffering and destruction of inferior creatures, will not ... be very compassionate, or benign, to those of their own kind." John Locke, 1693).
- considering them together with human beings, as interdependent and inseparable parts of ecosystems (the ecological argument) (Watson 1979).

[21] Similar concepts include the "balance of nature", "nature knows best", and "Gaia" in environmentalism, and the free market ideology in political economy.

[22] See also §4.9.

[23] Example: Conferring intrinsic moral value on great apes (the "easiest" non-anthropocentric position, because these animals are self-conscious and able to think abstractly) implies that their natural habitats must be taken into moral consideration, e.g. the orang-utan mires in Southeast Asia. This is not because these rare species have an instrumental (e.g. informational) value for human beings, but because the individual apes have intrinsic value, in the same way as human rights have to be respected, not because *Homo sapiens* is a rare species, but because individual human beings have intrinsic value.

[24] Cf. Norton 1991.

[25] De Groot 1992, Naveh 1994.

[26] Resources which can be divided between individuals.

[27] Resources which are common to all and cannot be divided between individuals.

[28] Jointly called "informational functions" by De Groot 1992. To a large extent, these values include what some philosophers call "eudaimonistic values" (after ευδαιμονια eudaimonia) = Greek "good life") that generally enrich life and that are experienced as "good in themselves" (Seel 1991).

[29] Some examples: We enjoy company (social-amenity values) because during human evolution co-operation (and therewith its direct individual driving force: the pleasure in social contact) has been more effective for survival and propagation than individualism (Callicott 1988, Diamond 1991, Maynard Smith & Szathmáry 1995).
Similarly lying in the sun (recreation values) is enjoyable, as it enables our skin to produce the indispensable vitamin D. We like outdoor experiences because of the resulting stress mitigation (Hartig et al. 1991, Kellert 1993). Aesthetics can be seen as a rapid and integrated ordering and evaluation of a complex set of properties (Berlyne 1971, Kellert 1997). Our predisposition to see beauty in savannah-like landscapes, sunsets, quiet waters, and contained fires goes back to the human past as hunter-gatherers, when these experiences were associated with food and water availability, safety, and security (Ulrich 1993, Heerwagen & Orians 1993, White & Heerwagen 1998). In the same way, human beings are genetically averse to snakes (a fear and fascination we share with African and Asian monkeys and apes), dogs, spiders, enclosed spaces, running water, blood, and heights (Ulrich 1993). We are quick to develop fear and even phobias with very little negative reinforcement (Öhman 1986). Few modern artefacts are as effective - even those most dangerous, such as guns, knives, automobiles, and electric wires (McNally 1987, Wilson 1993, Kellert 1997). Our erotic preferences instinctively focus - via subtle olfactory sensations (smells)- on people with complementary immune systems (Wedekind et al. 1995, Wedekind & Furi 1997, Cutler 1999). We like salt and fat because in our pre-human savannah past it was beneficial to swallow the full supply of these rare goods whenever they were available (Shepard 1998). Bodily symmetry and beauty seems to indicate health (Cf. Manning et al. 1999, Scheib et al. 1999, Thornill & Grammer 1999). Flowers signal future availability of fruits and honey (being the evolutionary background to giving flowers to sick people and hosts, Heerwagen & Orians 1993), animals scanning the countryside or a startled expression on a person's face alert to dangers (Heerwagen & Orians 1993, Darwin 1998) (signalisation values).

[30] An unlimited consumption of sun and fat for example may lead to skin cancer and cardiac diseases.

[31] Symbolisation values might be considered the "self-conscious" offshoots of indicator values; spiritual, existence, and history values as the offshoots of social and amenity values; cognition values as those of aesthetic values.

[32] In contrast to proxy functions, identity functions are not only "consumed" but also to some extent "produced" by human beings themselves ("identi-fication") . Our "world-views" not only rest on "objective" observations, but also on subjective interpretations and projections. This applies for example for history (cf. Walsh 1967, Harmsen 1968, Marwick 1989), science (cf. Popper 1959, Kuhn 1984, Bartels 1987), and spirituality and religion (Midgley 1996, Wilson 1998, cf. Xenophanes 6th century BC in Fairbanks 1898: "But mortals suppose that the gods are born (as they themselves are), and that they wear man's clothing and have human voice and body. But if cattle or lions had hands, so as to paint with their hands and produce works of art as men do, they would paint their gods and give them bodies in form like their own - horses like horses, cattle like cattle.").

[33] Based on information from Timo Nyronen.

[34] Joosten 2001.

[35] Xuehui & Yan 1994.

[36] Based on information from Piotr Ilnicki. Cf. also Lishtvan 1996.

[37] From Sirin & Minaeva 2001. This Figure includes

all extracted peat but is given here to illustrate the dramatic fall in extraction which is due in part to the reduction in the use of peat in agriculture.

[38] Based on information from Gerald Schmilewski. Cf. also Schmilewski 1996.

[39] Source: IPS 2000 Survey. These figures may not be consistent as different moisture contents may be used. However, the purpose of the table is to indicate trends.

[40] Van Schie 2000.

[41] Joosten 1995.

[42] Turner 1993.

[43] Coir fibre dust is a by-product of the coconut processing industry.

[44] Van Schie 2000. The table requires interpretation since a substantial part of the peat reported to be used in Germany is exported to the Netherlands and again included in the figures for the Netherlands.

[45] Based on information from Charles Shier. Cf. also Asplund 1996.

[46] Leinonen et al. 1997.

[47] Cf. Changlin et al. 1994, Xuehui & Yan 1994.

[48] Source: IPS 2000. The figures are not strictly consistent, as different countries estimate tonnes in relation to different moisture contents. In addition, the table combines milled and sod peat at different moisture contents. However, the purpose of the table is to indicate trends. It is clear that production of peat for energy has substantially reduced in the countries of the former Soviet Union and in Ireland.

[49] For 1999 or earlier years, depending on the availability of information. Based on the work of the Energy Peat Working Group of Commission II of the IPS.

[50] First National Communication to the UNFCCC 1995. Interagency Commission of the Russian Federation on Climate Change Problems, Moscow.

[51] Based on information from Nikolai Bambalov. For an extensive overview cf. also Fuchsman 1980, Lishtvan 1996.

[52] A soft surface on fabric or leather.

[53] Zagwijn & Harsveldt 1973.

[54] Gerding 1998. The peak production was in 1975 when 230,000 tonnes of peat were used to produce 25,000 tonnes of activated carbon.

[55] Based on information from Henk van de Griendt.

[56] O'Gorman 2002.

[57] Based on information from Eugene Bolton. Cf. also Mutka 1996.

[58] Viraraghaven 1991, Viraraghaven & Rana 1991. See also many other contributions in Overend & Jeglum 1991.

[59] Based on information from Marjatta Pirtola. Cf. also Pirtola 1996.

[60] Kelleher 1953.

[61] Material compiled by Raimo Sopo and Donal Clarke. Cf. also Fenton 1987.

[62] Feehan & O'Donovan 1996.

[63] Turner 1993.

[64] Moore & Bellamy 1974.

[65] Based on information from Gerd Lüttig and Nikolai Bambalov. Cf. also Korhonen & Lüttig 1996, Lishtvan 1996, Lüttig 2000.

[66] Turner 1993.

[67] Based on information from Allan Robertson. See also Robertson 1975.

[68] Xuehui & Yan 1994.

[69] Cf. Safford & Maltby 1998. Cf. UNESCO 1978.

[70] http://www.gn.apc.org/eco/resguide/2_20.html

[71] Butcher et al. 1995.

[72] Cf. Saeijs & Van Berkel 1997.

[73] Grundling et al. 1998.

[74] Ong & Mailvaganam 1992, Lee & Chai 1996, Page & Rieley 1998.

[75] Personal communication from David Price, Institute of Hydrology, Scotland, 2000.

[76] Cf. Salo 1996.

[77] Joosten 2001.

[78] Dent 1986.

[79] http://www.econ.upm.edu.my/~peta/sago/sago.html; Stanton & Flach 1980.

[80] Personal communication from Lenka Papackova.

[81] Based on information from Wendelin Wichtmann. Cf. also Wichtmann 2000.

[82] Björk & Granéli, 1978, Brenndörfer et al., 1994, Schmitz-Schlang, 1995, Schäffer et al. 1996, Kaltschmidt & Reinhardt, 1997; Michel-Kim, 1998, Schäfer et al., 2000.

[83] Sjörs 1993.

[84] Elling & Knighton 1984, Whinam & Buxton 1997, Whinam et al. 2000, www.losvolcanos.com

[85] Rodewald-Rodescu 1974, Thesinger 1964, Hawke & José 1996, Schäfer 1999, Weijs 1990, Yuqin et al. 1994, Scott 1995.

[86] Denny 1993

[87] Wichtmann et al. 2000.

[88] E.g. Schäfer & Degenhardt 1999.

[89] Succow 1988. For mire types, see §2.3.

[90] E.g. imports from South- and East-European countries and from Turkey into Germany, cf. Schäfer 1999.

[91] Including reed (*Phragmites australis*), cattails (*Typha* spp., Theuerkorn et al. 1993, Wild et al. 2001, sedges (*Carex* spp.) and grasses (e.g. *Phalaris arundinacea*), alder (*Alnus*, Lockow 1997).

[92] Wichtmann et al. 2000.

[93] Wichtmann, 1999b.

[94] Wild et al. 2001

[95] Rodewald-Rodescu 1974, Landström & Olsson 1998, Nilsson et al. 1998

[96] Lange 1997, Soyez et al. 1998.

[97] Based on information collected by Thomas Heinicke. For information on plants in tropical peat swamp forests used for medicinal purposes see Safford & Maltby 1998.

[98] Cf. Van Os 1962, Šimkûsite 1989 Elina 1993, Fuke 1994, Rongfen 1994, Hämet-Ahti et al. 1998, Safford & Maltby 1998.

[99] Williams 1982, Verhoeven & Liefveld 1997.

[100] Varley & Barnett 1987.

[101] Porter 1917, Nichols 1918a, b, Thieret 1956.

[102] Chikov 1980.

[103] After Chikov 1980.

[104] McAlpine & Waarier Limited 1996.

[105] Kirsch 1995.

[106] Galambosi et al. 1998, 2000.
[107] North American information based on material from André Desrocher. European information based on material from Alexandr Mischenko and Tatiana Minaeva.
[108] Page & Rieley 1998, Ali 2000.
[109] Based on information from Piotr Ilnicki. Cf. also Okrusko 1996.
[110] See also §3.4.3 (n): Regulation of regional and local climates.
[111] Based on information provided by Charlotte McAlister.
[112] These original data, compiled by P. Ilnicki, are not fully compatible with those in Table A1/1.
[113] Dent 1986, Radjagukguk 1991, Mutalib et al. 1991, Rieley 1991.
[114] Leong & Lim 1994.
[115] Cf. Shulan et al. 1994.
[116] Stanton & Flach 1980.
[117] http://www.econ.upm.edu.my/~peta/sago/sago.html
[118] Matsumoto et al. 1998.
[119] See for a cost-benefit analysis of sago and oil palm cultivation on peatlands: Kumari 1995 and http://www.econ.upm.edu.my/~peta/sago/sago.html
[120] Rubec & Thibault 1998, Zoltai & Pollett 1983.
[121] Lucas 1982,Stewart 1991.
[122] Based on material from Charlotte McAlister.
[123] www.wiscran.org/whatshta.html
[124] Luthin 2000, Lochner 2000; www.oceanspray.com; www.cranberries.org; www.northlandcran.com; www.wiscran.org; http://omega.cc.umb.edu/~conne/marsha/cranintro.html;
[125] www.library.wisc.edu/guides/agnic/cranberry/dnrpaper.html
[126] www.oceanspray.com/uti_info.htm
[127] E.g. in Estonia (www.loodus.ee/nigula/kuremari/kuremari_e.html) and the Far East of Russia (www.iscmoscow.ru/english/main/rfe_tgp/projects/sg2-03.htm). It has proved to be commercially unsuccessful in Ireland due to the mildness of the climate and lack of sunshine – G McNally).
[128] Based on information from Juhani Päivänen.
[129] Because the words ‘exploitation’ and ‘sustainable’ are used in this document with defined meanings (see Glossary) different terms to those used in the industry have been used in this section.
[130] Päivänen & Paavilainen 1996.
[131] Changed after Päivänen & Paavilainen 1996.
[132] Paavilainen & Päivänen 1995, Päivänen 1997.
[133] Paavilainen & Päivänen 1995.
[134] “Advanced growth” consists of almost mature trees growing beneath the forest’s canopy.
[135] http://www.na.fs.fed.us/spfo/pubs/silvics_manual/Volume_1/picea/mariana.htm.
[136] Areas cleared of trees except for small groups of seed-bearing trees.
[137] Strips cleared of trees. Jeglum & Kennington 1993.
[138] Jeglum & Kennington 1993.
[139] Anderson 1983.
[140] Laurent 1986.
[141] Page & Rieley 1998, 1999.
[142] Rieley 1991, Rieley et al 1997.
[143] Ibrahim & Hall 1991.
[144] Lee 1991.
[145] See also Paavilainen & Päivänen 1995.
[146] Pyatt 1990
[147] Kaunisto 1997, Sundström 1997
[148] Konstantinov et al. 1999
[149] Konstantinov et al. 1999. Vomperskij (1999) even states that half of the ca. 6 million hectares drained for forestry is currently re-paludifying.
[150] Heikurainen 1980.
[151] Payandeh 1988.
[152] Personal communication from V Klemetti; Annual Report of Vapo Oy 1998, p.9. J Päivänen (personal communication) states that there are no statistics dividing cutting removals between mineral soil and peatland. The actual cutting removal from all Finnish forests in 2000 was 61.5 million cubic metres, of which about 47 % was raw material suitable for sawn timber (Finnish Forest Research Institute 2001, p. 153). It has been estimated that the maximum sustainable removal (million m^3 per year) for mineral soil sites is 58.3 and for peatlands 9.7 for the period of 1996-2005. That would mean that 14.3 % of the total removal could be harvested from peatlands. The percentage estimated to come from peatlands is estimated to increase heavily to 24.3 % in the period 2016-2025.(Nuutinen et al. 2000).
[153] After Paavilainen & Päivänen 1995.
[154] Based on information provided by Tim Moore. See also Rubec & Thibault 1998.
[155] St. Louis et al. 2000.
[156] Pikulik et al. 2000.
[157] Roulet 2000.
[158] Virtanen & Hänninen 2000.
[159] Based on information from Jan Pokorny.
[160] Rongfen 1994.
[161] Masyuk 2000, Pikulik et al. 2000.
[162] Information provided by Gerry McNally.
[163] Based, inter alia, on information from Herbert Diemont.
[164] Butcher et al. 1995.
[165] Radforth & Burwash 1977, Meeres 1977.
[166] Based on information from Charlotte McAlister and Gerry McNally.
[167] Based on information from Charlotte McAlister. See also Gorissen 1998, Baaijens et al 1982, Karofeld 1999.
[168] Examples: Within two military training grounds in the North of England (RAF Spadeadam and Otterburn Training Area), ‘notified’ mires include a Ramsar site, Sites of Special Scientific Interest (a UK classification), National Nature Reserves and Special Areas of Conservation (a European Union designation) covering several thousand hectares (personal communication from Charlotte MacAlister). The most extensive remaining largely intact bog area in Central Europe is the Tinner Dose, since 1876 a military terrain (Gorissen 1998). Similarly one of the best bog remnants in the Netherlands, the Witterveld, is situated in a military exercise area (Baaijens et

al. 1982).

[169] Hamm 1955, Joosten & Bakker 1987, Michels 1991.

[170] Kazakov 1953.

[171] Based on information provided by Reidar Pettersson.

[172] De Groot 1992.

[173] Based on information supplied by Heinrich Höper.

[174] http://www.wri.org/climate/sinks.html

[175] Because the concentrations of natural greenhouse gases and those caused by human activity are small compared to the principal atmospheric constituents of oxygen and nitrogen, these gases are also called trace gases.

[176] As defined in the Glossary.

[177] References to 'role' in this and the paragraphs which follow are to role in the regulation of the global climate.

[178] Crill et al. 2000.

[179] Heinrich Höper (see Appendix 2).

[180] 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.

[181] In the boreal zone consisting of remains of conifer needles, branches, rootlets, forest mosses etc.

[182] Provided that the forest management continues and the peatland remains sufficiently drained.

[183] In case of agricultural and horticultural use, the peat is oxidised more slowly.

[184] http://www.gcrio.org/gwcc/toc.html

[185] See also §5.4 (11).

[186] Heathwaite 1993. See also §3.4.1 (ea).

[187] Edom 2001b.

[188] Takahashi & Yonetani 1997.

[189] Edom 2001b.

[190] Yiyong & Zhaoli 1994, Solantie 1999.

[191] See e.g. Goode et al. 1977 for a good review.

[192] Edom 2001b.

[193] Burt 1995, Edom 2001b.

[194] Cf. Mitsch & Gosselink 2000.

[195] Edom 2001b.

[196] Richardson & McCarthy 1994, Burt 1995.

[197] Edom 2001b.

[198] Edom 2001b.

[199] Edom 2001b.

[200] Kulczyñski 1949.

[201] Based on information from Michael Trepel. Hydrochemistry is the chemistry of water.

[202] Mitsch & Gosselink 1993.

[203] Bedford, 1999.

[204] E.g. Heikkinen 1994.

[205] Blicher-Matthiesen & Hoffmann 1999, Haycock et al. 1993.

[206] I.e. immersion and schwingmoor mires, cf. §2.3.

[207] E.g. Devito et al. 1989; Verhoeven & Meuleman 1999. See for a practical regional example Byström et al. 2000.

[208] Cf. Lamers 2001.

[209] Stewart & Lance 1983.

[210] Weil 1971

[211] Coles 1990, Leakey & Lewin 1992.

[212] Glob 1965, Moore 1987, Coles & Coles 1989, Müller-Wille 1999.

[213] Cf. Baaijens 1984, Blankers et al. 1988.

[214] Wheeler 1896, Pursglove 1988.

[215] Examples include the former Fen Slodgers in the English Fenlands (Wheeler 1896), the Marsh Arabs (Ma'dan) of Southern Iraq (Thesinger 1964), and the Kolepom people in Irian Jaya (Serpenti 1977).

[216] An aspect often referred to in nature conservation as representativity.

[217] Poems inspired by peatlands, a.o. from Thomas Moore 1779-1852, Anette von Droste-Hülshoff 1797 - 1848, Nikolaus Lenau 1802–1850, Henry Wadsworth Longfellow 1807–1882, Edgar Allan Poe 1809–1849, E. Pauline Johnson (Tekahionwake) 1861–1913, Hermann Löns 1866 - 1914, Frans Babylon (1924–1968), Victor Westhoff (1916–2001), Irving Feldman (1928–). See also Barlow 1893, Shane 1924, MacCormaic 1934, Cook 1939.

[218] Some examples include novels on daily life in peatlands (e.g. Brontë 1847, Crocket 1895, Maas 1909, Diers n.y., Coolen 1929, 1930, Carroll 1934, Laverty 1943, Van der Werfhorst 1945, Macken 1952, Selbach 1952, Ehrhart 1954, Kortooms 1951, 1959, Kortooms 1949 (after the bible the most sold book in the Netherlands, de Werd 1984), Wohlgemuth 1962, Lepasaar 1997, Seppälä 1999, Vasander et al. 2000, books on the role of peatlands as refugia for fugitive slaves, as Nazi concentration camps, and as centres of anti-Nazi resistance (e.g. Beecher Stowe 1856, Langhoff 1935, Kortooms 1948, Melež 1972, Perk 1970), anthologies (Juhl 1981, Murphy 1987, Sýkora 1987, Ludd 1987, Blankers et al. 1988), peatland biographies (Smits 1987, Veen 1985, Aardema 1981, Van Dieken n.y.),

[219] E.g. Garve 1966, Kluytmans 1975, Stebich 1983, Schlender 1987, Talbot 1986, Conan-Doyle 1902,

[220] E.g. the classic anti-fascist 'Song of the Peatbog Soldiers' (Langhoff 1935), the modern German Rock group *Torfrock*, the Dutch pop group *Rowwen Hèze*.

[221] E.g. the Dutch television series "Het Bruine Goud" ("The Brown Gold"), Irish films "Eat the Peach" and "I went down".

[222] See footnote below under (s) Recreation and aesthetic functions.

[223] E.g. Van der Hoek 1984, Gerding 1995, Müller-Scheesel 1975, Gailey & Fenton 1970, Ahlrichs 1987.

[224] E.g. Crompvoets 1981.

[225] Of places (e.g. Veenendaal, Veendam, Ballynamona, Coolnamona), persons (Thomas Moore, John Muir, Otto Veen, Jean Marais, Gunnar Myrdal, Andres Kuresso), pop groups (the German *Torfrock*, the Chicago band *Peat Moss*), and even a country (*Fin*land / *Suo*mi).

[226] E.g. the peatland museums and visitor centres in Galway (Ireland), Peatlands Park (N. Ireland), Vinkeveen and Bargercompascuum (Netherlands), Hautes Fagnes (Belgium), Oldenburg (Germany), Sooma (Estonia). "Pete Marsh" (Lindow Man) is the second most visited exhibit in the British

Museum London (pers. comm. Richard Lindsay).

[227] E.g. recent issues from Denmark, Estonia, Germany, and Ireland.

[228] E.g. the Estonian EK25 note, the Canadian $5 note.

[229] Cf. Sestroretskoje boloto near St. Petersburg where Lenin hid from the tsarist police; Joosten 1987, Moen 1990.

[230] Cf. Hueck n.y., Weijnen 1947, 1987, Overbeck 1975, Crompvoets 1981. Cf. the border between Tomsk Oblast and Novosibirsk Oblast (W. Siberia) running through Vasyugan, the largest mire complex in the world.

[231] Cf. Etzioni 1998, who stresses that group values, though "pleasant", are not ipso facto "good" and should be judged by external criteria.

[232] Because most agricultural, silvicultural and conservation statistics do not differentiate between peatlands and other types of lands.

[233] E.g. in the former Soviet Union, Cf. §3.2.1 above.

[234] Sopo & Aalto 1996.

[235] Bord na Móna 1993.

[236] E.g. in peatland national parks with visitor centres, boardwalks, and/or specialised vessels.

[237] Masing 1997.

[238] Estimate furnished by Gerry Hood.

[239] http://www.nps.gov/ever/current/ever99.pdf.

[240] 1998 data. Based on information from Hiroe Nakagawara, Kushiro International Wetland Centre 2000.

[241] Based on information from Exmoor NP Tourist Authority 2000.

[242] 1994 data. Based on information from Liz Jenkins Snowdonia National Park 2000.

[243] 1998 data. Based on information from Jo Hearne North York Moors National Park 2000.

[244] Based on information from Michael Morgen Peatlands Park 2000.

[245] http://www.pantm.co.uk/reports/purbeck/CombinedChapters.pdf

[246] 2000 data. Based on information from Staatsbosbeheer Groote Peel.

[247] Based on information from Dana Kühne TVb Spreewald e.V. 2000.

[248] Based on information from Cecile Wastiaux.

[249] Based on information from Randy Milton and Gerry Hood.

[250] "Der Weiher" (1495) of Albrecht Dürer (1471–1528) is the first known painting of a natural mire. Other artists inspired by mires and peatlands include a.o. Jacobus Sibrandi Mancadan (1602–1680), Meindert Hobbema (1638–1709), Jan Luyken (1649–1712), Joseph Mallord, William Turner (1775–1851), John Crome (1768–1821), John Constable (1776–1837), Carl Blechen (1798-1840), Martin Johnson Heade (1819–1904), Frederic Edwin Church, (1826-1900), P.J.C. Gabriëls (1828-1903), Carl Krüger (1834–1880), Vasilij Polenov (1844–1927), Bernhard Willibald von Schulenberg (1847–1934), Victor Vasnetsov (1848–1926), Fiodor Vasil'ev (1850–1873), Elena Polenova (1850–1898), Vincent van Gogh (1853–1890, cf. Schmidt-Barrien 1996), Isaac Levitan (1860–1900), Gerhard Bakenhus (1860–1939), Richard tom Dieck (1862–1943), Alexej von Jawlensky (1864–1941),Valentin Serov (1865–1911); the Worpswede artists Carl Vinnen (1863–1922), Hans am Ende (1864–1918), Otto Modersohn (1865–1943), Fritz Mackensen (1866–1953), Fritz Overbeck (1869–1909), the father of the famous peatland scientist Fritz Overbeck, Overbeck 1975), Heinrich Vogeler (1872–1942), Paula Becker (1876–1907), Walter Bertelsmann (1877–1963), R. Stickelmann, H. Saebens, (cf. Weltge-Wortmann 1979, Busch et al. 1980, Riedel 1988); William Turner (1867–1936), William Hoetger (1874–1949), William Krause (1875–1925), Wilhelm Schieber, (1887–1974), John Bauer (1882–1917), Fryco Latk (1895–1980), Marius Bies (1894–1975), Sepp Mahler (1901–1975, cf. Konold 1998), Gerrit van Bakel (1943 –1984), Bremer 1992), Jerry Marjoram (1936–), Nikolaus Lang (1941), Anne Stahl, Hans van Hoek (1947–), Etta Unland (1959, see also Stadtmuseum Oldenburg 1993, Janssen 1999); bogwood sculptors in Ireland including Michael Casey and the Celtic Roots studio.

[251] E.g. of excentric, concentric, and radiating bogs, aapa mires, palsas, and polygon mires, cf. Wright et al. 1992, Aaviksoo et al. 1997, Standen et al. 1999.

[252] E.g. Testacea amoebae, Desmidiaceae, Diatoms.

[253] e.g. Hakala 1999.

[254] Ng et al. 1994, Lee & Chai 1996.

[255] E.g. eagles as national symbols, that have triggered the founding of nature conservation movements in many countries (Masing 1997), the Giant Panda in nature conservation (WWF).

[256] E.g. the olive tree as a symbol of peace, the "flower of Scotland", the Maple Leaf.

[257] Mitchell 1994, Schama 1995.

[258] Cf. Lawrence 1993.

[259] Cartmill 1993.

[260] Masing 1997. All around the world, the eagle, the king of birds, is strongly associated with the sun, fire, air, life, sky, sun gods, and Resurrection. The eagle is believed to enjoy staring directly into the sun, which is equated with the ability of the pure in heart to see God and discern divine truths; Cf. http://ww2.netnitco.net/users/legend01/eagle.htm

[261] As a symbol of diligence, chastity, asceticism, and the willingness to sacrifice, cf. http://ww2.netnitco.net/users/legend01/beaver.htm. The Canadian Beaver (*Castor canadensis*) is the official symbol of the sovereignty of Canada, cf. http://www.users.fast.net/~shenning/beaver.html

[262] As a symbol of silence, deceit, and wisdom, cf. http://ww2.netnitco.net/users/legend01/crocodi.htm

[263] As symbols of happiness, justice, diligence, purity, loyalty, piety, filial gratitude, beauty, love, vigilance, contemplation, self-knowledge, wisdom, longevity, immortality, and Resurrection, but also as an evil omen, cf. http://ww2.netnitco.net/users/legend01/crane.htm. The Japanese Crane (*Grus japonensis*) is an important symbol of Japan (Iwakuma 1996).

[264] As fertility symbols and associated with

springtime, birth, and good fortune. It was believed that the souls of unborn children lived in wetlands. Since storks frequented such areas, they were thought to fetch the babies' souls and deliver them to their parents. Because they are rumoured to feed their elderly parents, storks are a symbol of filial piety or gratitude. They are emblems of immortality and longevity.

[265] As symbols of contemplation, vigilance, divine or occult wisdom, and inner quietness.

[266] Exemplifying the sacrificial love of a parent for its offspring.

[267] As symbol of freedom, ardour, joy, youth, happiness, and the desire to be happy.

[268] E.g. in Minnesota and Canada (Cf. the Canadian $20 note).

[269] The national flower of Québec.

[270] Cf. the extensive review in Müller-Wille 1999.

[271] Cf. Gorke 1999. In all cultures and major religions, there is a latent premise of the worth of life, indicating an underlying core of ethical values common to all people (Skolimowski 1990).

[272] Cf. Joosten 1999a. A related concept to "wilderness" is that of "integrity", which a.o. played a role in the resistance against large-scale peatland forestry in the Scottish Flow Country (cf. Stroud et al. 1987, Lindsay et al. 1988).

[273] Note the importance of the efforts of such international NGOs as the Worldwide Fund for Nature (WWF), the International Union for the Conservation of Nature (IUCN), Wetlands International (WI), and the International Mire Conservation Group (IMCG). Note also the efforts of many states, including those made in the framework of international conventions, especially the Wetland (Ramsar) Convention. An interesting example of frontier-crossing commitment is the Dutch Foundation for the Conservation of Irish Bogs.

[274] Illustrating the neotenous character of human beings, in which infantile characteristics are prolonged into maturity. Other characteristics of neoteny include the great size and long-continued growth of the brain, the tendency to play (cf. Huizinga 1938), spontaneity, openness to new impressions, and the capacity for widely extended sympathy (Midgley 1983).

[275] Kellert 1997.

[276] Information is strongly related to the concepts of difference and diversity (Joosten 1998). For a review on biodiversity values in peatlands, see Joosten 1996, 1999b.

[277] See §2.2 in Chapter 2. Mires share this character with lakes, oceans, and corals, i.e. they are the only terrestrial accumulating ecosystems and, together with corals, the only long-term sedentarily accumulating ecosystems.

[278] For an overview of the palaeo-ecological values of peatlands and the importance of long-term studies: Overbeck 1975, Birks & Birks 1980, Godwin 1981, Frenzel 1983, Berglund 1986, Franklin 1989, Barber 1993, Joosten 1995.

[279] The first palaeo-ecologic reconstructions of vegetation and climate based on macro-remains in peat date back to de Chamisso 1824, Dau 1829 and Steenstrup 1842.

[280] Systematic pollen and spore analysis (palynology) of peats started with Von Post (1916). For a recent overview cf. Moore et al. 1991.

[281] The reconstruction of human and environmental past.

[282] Brothwell 1986, Coles & Coles 1989, Fansa 1993, Turner & Scaife 1995.

[283] Pilcher et al. 1995, Dwyer & Mitchell 1997.

[284] Cf. overview in Shotyk et al. 1997.

[285] Cf. Malmer et al. 1997.

[286] Wagner et al. 1996, 1999.

[287] E.g. Mauquoy & Barber 1999, Barber et al. 2000.

[288] By way of analysis of cosmogenic isotopes in peat, cf. Van Geel & Renssen 1998, Van Geel et al. 1998.

[289] By the development and application of new analytic techniques and knowledge a.o. in palaeo-physiology, organic and isotope geo-chemistry, palaeomorph-morphology (incl. phytoliths, fungal and moss spores, algal remains, sponge gemmoscleres, chrysophyte cysts, soot particles, rare pollen types, macrofossils), research in little-known geographical areas, and by an increased temporal and spatial resolution.

[290] Conditions not typical of the surrounding climate zone. Cf. §2.7.

[291] Cf. Ivanov 1981, Joosten 1993.

[292] Couwenberg et al. 2000.

[293] Cf. various papers in Standen et al. 1999.

[294] Couwenberg 1998, Couwenberg & Joosten 1999.

[295] E.g. large mire patterns, large macrotopes, large predators, and migratory birds. See also Joosten 1999b.

[296] After Couwenberg & Joosten 1999.

[297] For lay readers it may be helpful to state by way of illustration that $10^{-2} = 0.01$, $10^4 = 10{,}000$, $10^6 = 1.000.000$.

[298] As, for example, in "economic indicators".

[299] Joosten 1986, 1995, During & Joosten 1992.

[300] Wandtner 1981.

[301] Äikäs et al. 1994.

[302] Norton 1984, 1987.

[303] See §5.6.3 (8) below. Cf. Irish Junior Certificate syllabus (see O'Cinnéide and MacNamara 1990, pp 195 – 199); and IPCC (Irish Peatland Conservation Council) programmes in Ireland.

[304] E.g. Kirsamer 2000.

[305] Joosten 1997, Couwenberg & Joosten 1999.

[306] Cf. the "serendipity value" of De Groot 1992. Cf. the recent discovery of the role of mires in the greenhouse effect, and the discovery of the filtration capacity of peatlands.

[307] Cf. Keddy 2000.

[308] A good example is the current greenhouse effect. Although the effect of greenhouse gases on world temperature has been supposed since Svante Arrhenius 1896, see special issue Ambio 26/1 (1997), continuous cultural records of CO_2 concentrations in the atmosphere only exist since 1953. For the reconstruction of greenhouse gas concentrations before that date, natural records in natural archives, e.g. peatlands (cf. Wagner et al. 1996, 1999), are required.

[309] Joosten 1986.

[310] See also Chapter 4.

[311] Money as such has a signalisation function as an embodiment of human labour or of corn equivalents (classical economics) or as an indication of human gratification (neo-classical economics).

[312] According to IUCN (1994), the main purposes of conservation management are: scientific research, wilderness protection, preservation of species and genetic diversity, maintenance of environmental services, protection of specific natural and cultural features, tourism and recreation, education, sustainable use of resources from natural ecosystems, and maintenance of cultural and traditional attributes. Various management categories are based on combinations of these objectives (cf. EUROPARC & IUCN 1999). See §5.6.3(7) and Appendix 8.

[313] Based on information from Scott Frazier and Doug Taylor (Wetlands International).

[314] In this Table, and elsewhere in the document, the word “exploitation” is used in the sense of deriving benefit from, without any pejorative intent.

[315] E.g. in tourism or in advertisements for other commercial products, cf. De Groot 1992.

[316] Cf. §3.2.

[317] “Their environment” means here: all relevant values (cf. the range of anthropocentric instrumental values) that are instrumental in the wellbeing of these beings.

CHAPTER 4.

VALUES AND CONFLICTS: WHERE DIFFERENT VALUES MEET

This chapter analyses types of conflicts, and how such conflicts arise in relation to mires and peatlands.

4.1 INTRODUCTION

The concept of "Wise Use"[1] incorporates complex environmental, economic and social concerns that require integrated decision-making. Different values may be intertwined in a complicated way. Values may be mutually incompatible, and - when compatible - the distribution of the benefits can be a matter of dispute. To make sound decisions, incompatible values have to be identified, conflicting claims have to be weighed against each other, and norms have to be established for assigning priority to one over another[2].

There are serious limitations to the extent to which values and claims can be compared. Many values can be compared only if we take fairly extreme cases (one value at stake in a small way, another in a big way). Alternatively values may lack attributes that allow addition and subtraction. But in general[3], competing claims can be weighed to such extent ("this is more valuable than that") that sensible judgements can be made or workable solutions can be found, at least between those who share the same "world-view"[4].

Under democratic conditions, accepted norms take the character of "mutual coercion set by mutual agreement"[5]: guidelines, conventions, and laws. This presupposes a setting in which people - in an open debate based on all the information and reasoning available - agree freely to restrictions on the realisation of individual preferences. Such agreements are made from the perspective of citizens who take a moral interest in public affairs while the coercion itself (norms, laws) restricts the behaviour of private persons and interest groups who try to satisfy their preferences and economic interests.

In the rest of this chapter these general statements are analysed in more detail, starting from a position that considers human beings as the prime focus of concern[6].

4.2 NEEDS, WANTS AND RIGHTS

As a preamble to a discussion of conflicts, it is important to discuss the difference between needs and wants.

(i) Needs: According to John Maynard Keynes, absolute needs (necessities/ primary goods/basic interests) are those that can be fully met: there is a physical maximum to what a person can consume of drink, food, sex, company, information, etc.

(ii) Wants: The satisfaction of wants (amenities/commodities/peripheral interests) is a comparative concept[7]: it is largely based on what others in the social surrounding possess[8]. "Keeping up with the Joneses"[9] is to some extent obligatory, as it co-determines social acceptance and respect[10]: a social being cannot behave altogether differently from others[11]. This "mimetical desire"[12], however, has no material upper limits[13]. The distinction between needs and wants is complicated by the fact that the same product may satisfy both needs and wants[14].

		Conflict cause	Examples
Conflicts dealing with facts	1	**Different understanding** of terms and concepts (miscommunication, insufficient information exchange)	* one person using the term "mire" meaning the Finnish "suo" versus another meaning the German "Moor" * agreeing on "sustainability", but attributing different meanings to that concept (cf.§ 4.7)
	2	**Different judgements** as to the means most suited to achieving a particular end.	* disagreeing on the best management option for peatlands to reduce the greenhouse effect * conflicts on how to maximise monetary profits
Conflicts dealing with choices	3	**Different preferences** as between different instrumental values	* preference for cultivated orchids in a vase versus wild orchids in a mire * preference for cloudberry[19] liquor versus a winter living room temperature of 22^{o} C.
	4	**Attaching different precedences**[20] to different instrumental or intrinsic values	* conservation of a medically important globally threatened species versus mire drainage to prevent disease in an adjacent village * vital local versus vital global human interests
	5	**Different priorities**[21] with respect to instrumental or intrinsic values	* reducing malnutrition among contemporary human beings versus long-term environmental impacts on human beings
	6	**Different positions** with respect to which entities have intrinsic moral value	* nature conservation (oriented on species) versus animal protection (oriented on individual organisms) * anthropocentric versus non-anthropocentric position: "But the pine is no more lumber than man is, and to be made into boards and houses is no more its true and highest use than the truest use of a man is to be cut down and made into manure"[22].

Table 4/1: Overview of the causes of conflicts between human beings.

In the Universal Declaration on Human Rights, the global community has identified the needs that human beings can rightfully claim (Table 4/3). These claims are defined as an individual's *rights* and are "boundary conditions" that may not be violated, even if that would result in a greater good of the same category for others[15]. The Universal Declaration implies that needs have to be satisfied. Permissible[16] wants and value systems do not have to be actively satisfied or supported, but their pursuit may not be hindered or violated[17].

As between needs and wants, the satisfaction of needs prevails over that of wants[18].

4.3 DIFFERENT TYPES OF CONFLICTS

Conflicts can be subdivided into **conflicts dealing with "facts"** (true / not true), and **conflicts dealing with "choices"** (agree / not agree) (Table 4/1). Conflicts of the first kind are relatively easy to solve. Conflicts of the second kind are more complicated because they are based on different weightings which different persons place on particular values and they concern options for actions that are mutually exclusive.

4.4 CONFLICTS DEALING WITH FACTS

Conflicts arising from **different understanding** are common, but also the simplest to solve: their solution only requires effective communication[23] and sufficient information exchange to create a common base of knowledge. It will then become clear that there is no real conflict, rather there is misunderstanding and talking at cross-purposes[24].

Conflicts arising from **different judgements** of mean-end relationships (the means most suited to achieving a particular end) should take into account the principles of rational choice (Table 4/2). They can in principle also be solved factually. Which alternative is to be chosen is again a matter of optimal information exchange and best professional judgement. The correctness of the decision can be tested. When more than one "means" are tested, a quantitative solution can be reached: "this means is better than that". When only one alternative is tested, a qualitative answer can be given: "this means does / does not achieve the aim".

4.5 CONFLICTS DEALING WITH PREFERENCES

In this subsection the relationships between different *preferences* are surveyed (Table 4/1). *Preferences* pertain to things that can be replaced by something else[26]. Conflicts between preferences relate to balancing what one party gains against what the other loses. A central question therefore is: is there a way to rank or value different preferences, do some types of *wants* prevail over others?

Both ethics and economics try to address this question by reducing the complexities concerning value to a single measure, for

The principle of effective means:	That alternative should be adopted which achieves the end in the best way.
The principle of the greater likelihood:	Preference should be given to the alternative which is more likely to give the desired outcome.
The principle of inclusiveness:	Preference should be given to the alternative which achieves all of the direct aims and one or more further aims in addition.

Table 4/2: The principles of rational choice[25].

example by trying to extend monetarised cost-benefit analysis to all aspects of impact assessment. By using one weighting factor to express each individual's change in utility, it is intended to reflect the overall benefits for society. In principle[27], *instrumental* values and preferences can indeed be monetarised[28]. The instrumental value of human beings is, for example, expressed in the wages for labour, the price of tickets for a piano concert, or the cost of safety provisions in a truck that guarantee the future productivity of the driver.

This partial monetarisation of instrumental value should, however, not be mistaken for a full determination of total (comparative) value[29]. A gothic cathedral may bring $xxx a year to a city from visitors, but may at the same time have an inestimable artistic value. A wetland can be said to have a value of $yyy for the purification of sewage, because it makes technical provisions with the same effect unnecessary, but its total value can not be estimated. Many issues can not be monetarised completely (see §4.8). Monetarisation is useful to get *a* minimum value, not for getting *the* value. Furthermore, the weighting of preferences does not solve the central question of how such weightings would be allocated[30].

If there is no single set of concepts or principles by which to value every situation, it is sensible to view cases in different ways[31]. Different perspectives can reveal things which are overlooked when only a single perspective is used. As well as comparing the costs and benefits of specific actions, for example, we may also take more explicitly into consideration the costs and the renounced benefits of the status quo[32]. By adopting such a pluralist stance, we not only do justice to the complexity of real situations, but we can also seek ways in which different modes of valuing and ways of responding can be linked together to provide a more comprehensive solution to a situation.

In the absence of other premises, no preference can be considered better or worse than others[33]. In making choices, other premises[34] may give rise to the following considerations:

1. All means of meeting *wants* should be distributed equally unless an unequal distribution of any or all of these goods and services is to the advantage of the least favoured[35].
2. In the grey area between clear *needs* and clear *wants*, those preferences more related to *needs* (i.e. things that are more essential) prevail over those more related to *wants*.

4.6 CONFLICTS DEALING WITH PRECEDENCES

In contrast to conflicts between preferences, conflicts dealing with *precedences* can not be solved by balancing pros and cons. Conflicts between different precedences (Table 4/1) deal with conflicting *rights* (see §4.2) of beings with an intrinsic value, i.e. with beings that fall in the same value category [36]. They involve the precedence to be accorded to one right over another and include conflicts between "me" and "you", "those here" and "them there", and "some few" and "those many"[37]. Even though we accept the equality of all people we continuously hesitate between the extremes of a "charity begins at home" and a St. Martin who showed - by giving half his cloak to a poor stranger - that the stranger's well-being was as important to him as his own[38].

The human character resists altruism which is entirely disinterested[39]. People give more weight to their own interests than to those of others. In doing do they must respect the rights of others, as illustrated in Table 4/3: "the greatest good of the greatest number"[43] furthermore implies that people have a duty to sacrifice their interests for the sake of larger benefits to others[44]. They do not, however, need to accept great losses to secure a small increase in the aggregate good[45].

Right to	Valid **claim**	**Duty** of others
Subsistence	• not to be violently harmed • to the physical **needs** of survival: food, water, shelter, clothing, basic health care • to protection from those who might do physical harm	• not to violently harm • not to actively deprive others of these needs • not to expose others to unacceptable risks
		• to protect against such harm • to provide these needs
Liberty	• to freedom from positive external constraints upon the pursuit of permissible[1] **wants** • to protection against deprivation of this freedom	• not to restrict this freedom
		• to secure this freedom
Autonomy	• to a self-directed life according to one's own **value system** (moral position)[2]	• not to impair (the development of) self-determination
		• to help the development, strengthening, and preservation of this autonomy

Veto duties are stronger than prescription duties [shaded box] veto duty [white box] prescription duty

Table 4/3: Overview of the most important human rights and duties[1].

As a help in resolving conflicts between the rights of different persons or different groups, John Rawls has formulated a set of principles and priority rules[46]:

The principle of liberty: Each person has an equal right to the most extensive system of equal basic liberties[47] compatible with a similar system of liberty for all.

The principle of just inequality: Social and economic inequalities are to be arranged so that they are both:
(a) to the greatest benefit of the least advantaged[48], and
(b) attached to offices and positions open to all under conditions of equality of opportunity.

The priority of liberty: Liberty can be restricted only for the sake of liberty:
(a) a less extensive liberty must strengthen the total system of liberty shared by all;
(b) a less than equal liberty must be acceptable to those with lesser liberty.

The priority of justice over efficiency and welfare:
(a) an inequality of opportunity must enhance the opportunities of those with the lesser opportunity;
(b) an excessive rate of saving must on balance mitigate the burden of those bearing this hardship.

General conception:
All social primary goods - liberty and opportunity, income and wealth, and the bases of self-respect - are to be distributed equally unless an unequal distribution of any or all of these goods is to the advantage of the least favoured.

4.7 CONFLICTS DEALING WITH PRIORITIES[49]

Intergenerational justice: Since the Brundlandt Report[50], intergenerational justice, i.e. a balance between the well-being of present-day and future generations, is a central point of concern to the global community. Sustainability is based on two premises:

- the present generation is morally obliged to abstain from exploiting the Earth's resources to the detriment of future generations. Rather, it must share resources with future human beings so that they are allowed to have a standard of life not substantially lower than that enjoyed today;
- it is possible to define the needs of future generations in order to take practical steps for the achievement of sustainability. Duties towards these future generations must not only be expressed in principle, but also in concrete terms. What are we obliged to do, from what else are we obliged to abstain?[51]

The first point is not seriously contested. Some may believe that it is *unnecessary* to care for future needs, either because the Earth's resources are sufficiently abundant or because science, technology, and the market will automatically provide for future resource availability[52]. But almost nobody will argue that it is morally permitted to seriously damage the prospects of future generations[53]. The second point is more controversial. Agnostics hold that nobody knows the needs of the future[54]. They substantiate this by pointing to the past, where many economic decisions "for the sake of future generations" have been proven wrong. Others argue that the fundamental physical and social needs of the human species will not change. "Of course, we don't know what the precise tastes of our remote descendants will be, but they are unlikely to include a desire for skin cancer, soil erosion, or the inundation of low-lying areas as a result of the melting of the ice-caps"[55]. Again others state that the concerns of the present generation should not be for the physical preconditions[56] for the well-being of future generations, but the well-being itself[57]. Even when some resources are irreversibly lost, cannot the life of future generations be fully satisfactory without them?

Different concepts of sustainability[58]: These deliberations reflect two different concepts of sustainability[59]:

- **weak sustainability** permits the depletion of natural resources if natural or artificial substitutes can be found and if the profits are invested rationally. If, for example, the economic benefits of peat extraction are invested in infrastructure, human knowledge, technologies, and other capital, the well-being of future generations may be greater even if this should include the global extinction of some mire species;
- **strong sustainability** casts doubts on these substitutability premises and argues for keeping the stock of different types of resources intact separately. Natural and artificial capital are seen as complementary.[60]

The position of strong sustainability cannot be held indiscriminately for every type of resource. The present generation cannot take care of every detail that may be relevant to future generations. It is not realistic for the present generation to concern itself with the whole range of problems its descendants may come across during their lifetimes. What can be done is to ensure that options are kept open and that they have available to them opportunities, chances which they can seize. The present generation should also do everything possible to avert serious evil in which its actions might result.

Discounting[61]: In a world with perpetual economic growth in which present-day and future values are weighted equally, the aim of "the greatest good of the greatest number"[62] would force early generations to excessive saving to allow later generations to live a luxurious life. Intergenerational justice favours a more egalitarian development[63] which requires the discounting of future values[64]. This can be done by way of

- *discounting of well-being* (*utility discounting*), in which future well-being is given less weight than present well-being, or
- *financial discounting*, in which not the well-being itself, but the monetary costs and benefits which determine future well-being, are discounted[65].

The discounting of well-being solely because it lies in the future ("myopic behaviour") is a widespread phenomenon: people generally prefer enjoying something now to enjoying it later; we prefer to go to the dentist tomorrow instead of today. Similarly, problems for future generations are considered as less important than problems right now. Our "defective telescopic faculty"[66] makes us believe that even very important things become unimportant once the distance to them in time is long enough. Important things, however, do not become unimportant in time: they remain important for those affected by them. No smoker will consider lung cancer in 20 years equally important to a cold tomorrow. Myopic behaviour is contrary to the concept of sustainable use, because it treats the interests of future generations as being of less value than similar interests of the present generations. If a civilised society is characterised by its respect for the weak, it should respect the interests of future generations even more than those of the present, because - unlike contemporaries - future generations are powerless against the harmful actions of the present[67].

The importance attached to some things does, however, change with time. A boy of eight years, for whom a ditch is too difficult to cross, can be confident that after ten years he will have grown and will be able to jump across it easily. Similarly, economic, technological, scientific, and moral growth can be acceptable justifications for discounting future costs and pains. If future generations are better-off than the present generation, it will be easier for them to cope with the problems being caused by the latter. This approach is not universally applicable: people in the19th century would have been correct in discounting the future pain involved in a visit to the dentist, because the pain involved in dentistry has been reduced substantially since. But they would have been much less justified in discounting the pain caused by cancer, as this disease has lost none of its malignity. Thus, it is essential for any sensible resource planning to develop sound expectations as to what will become easier tasks in the future and what will not. Future generations cannot blame the present generation if it errs in such decisions after due reflection but they can attach blame if the present generation does not reflect to the best of its ability[68].

Normal and vital functions: Taking the future into account therefore requires that we:

- identify *vital functions* (= essential and non-substitutable) which, to the best of present knowledge, will remain equally important and regarding which it cannot be prudently assumed that progress will solve the problems associated with their decrease or disappearance[69]. Their effect in the future must therefore receive the same attention from us as their present effect. For these issues no form of discounting is applicable.
- apply some routine valuation procedure for all other *normal functions* (non-essential or substitutable), allowing for flexibility, adaptation, substitution, progress, and growth. This valuation can imply an element of discounting, based on the expectation (which must be well-founded) that the provision of these concrete services or resources will be of a lower

importance to future generations due to advances in problem-solving capacities. Often, these will be problems that can be handled by "money" and investment (see §4.8).

Uncertainty and risks: Any consideration regarding the future involves uncertainty. The question "what decision to take?" is, however, not only a matter of assessing probabilities but also an ethical question[70]. Imposing risks on others, even future others, has as a direct consequence that they are exposed to a potential danger, i.e. a direct change for the worse[71]. A good reason is required to permit the creation of situations which involve risks to others, and to discount these risks in order to increase our own net present value.

The simplest way to avoid risks would be not to interfere at all. But in practice we prefer to take a small chance of a great disaster in return for the high probability of a modest benefit[72]: e.g. we fly in order to save some time. If an act involves a risk of negative consequences this is a reason to avoid it. If the consequences are extremely negative, even a small risk of producing them is a reason to avoid the act and to accept some costs in doing so.

Vital functions of mires and peatlands: Vital functions are resources and services that are *essential* to human life and reproduction, and that are prudently expected to be *non-substitutable* within any reasonable human timeframe[73].

Essential functions relate to

- the physical needs of survival (food, water, shelter, clothing, basic health care)
- the liberty to pursue permissible wants, and
- the autonomy to live according one's own moral position (see Table 4/1).

With respect to mires and peatlands such vital issues may include:

- the **maintenance of general problem-solving capacities** (cf. conservation of global biodiversity for maintaining production, regulation, existence, indication, and cognition options, see Table 3/22)[74],
- **global climate regulation** (cf. UN Framework Convention on Climate Change) especially with respect to carbon storage (see §3.4.3),
- the **maintenance of food production capacity** (e.g. preventing soil erosion),
- the **availability of drinking water** (related to climate change, large-scale drainage, and pollution),
- the **availability of habitable land** (e.g. preventing climate change and the associated sea level rise),
- **health conditions** (e.g. preventing damage to the ozone layer and spread of diseases resulting from climate change),
- all developments that severely affect peoples' **value systems** (e.g. preventing decrease in biodiversity).

4.8 THE MONETARISATION[75] OF PEATLAND VALUES

Making wise decisions depends on adequately valuing all the aspects involved. The easiest way to resolve conflicts would be to set out what one party gains against what the other loses. As there are many types of values (cf. Chapter 3), such balancing would require a single and one-dimensional measure by which all values could be equally expressed. The measure most used in normal life is the "market price", the amount of money one has to pay for a product or service. The market price makes it possible to compare and exchange such divergent products and assets as sugar, shoes, land, and knowledge.

The market does not assign monetary value to everything[76]. Some experiences and services have no price as a matter of tradition. We do not pay for a friendly greeting on the street (although artificial friendliness is effectively used in commerce). Traditions, however, change with time. In many countries it has become normal to pay for the care of the elderly, a practice unthinkable in former times. Other experiences and phenomena have no price, because they are neither produced nor have a clearly defined ownership. Most of the regulation and non-material-life-support functions (see Tables 3/3 and 3/4) are such "collective goods". The techniques for monetarising these functions are generally underdeveloped[77]. Some ecosystem functions can not be valued, because their precise contribution is not known and indeed unknowable until they cease to function[78]. Other functions cannot be monetarised because there is nothing equivalent to be put at their place: intrinsic values are by definition without price[79]. Consequently, any weighting can only be partial and whole ranges of values, benefits or disadvantages escape monetary evaluation (i.e. they are regarded as "free goods")[80].

Freely functioning markets are based on narrow self-interest. The upstream polluter has no incentive to account for the cost he imposes on a downstream user of the river. The non-consideration of such "externalities" – the third party costs – may lead to decisions that are "wise" for the individual now, but "unwise" for society as a whole[81] (and that may eventually also be harmful to the individual)[82]. This is a *market failure*.

Similarly government interventions in the market, for example to serve some social purpose, may be accompanied by an under-appreciation of environmental benefits. Examples include financial incentives for deforestation or peatland drainage, the underpricing of water resources, and many agricultural subventions[83]. This is an *intervention failure*.

Some regulation and information functions exceed national boundaries, e.g. the maintenance of global biodiversity or the peatland carbon store[84]. But if the country in question receives no financial or other resources to pay for these global external benefits, it will have no incentive to look after these resources[85]. This is a *global appropriation failure*[86].

Correction of these failures is necessary to better reflect the value of ecosystem services and natural capital in national accounting. Various methods have been and are being developed for that purpose[87], including methods applicable to wetlands[88]. Such methods attribute monetary value either by directly asking people to state their strength of preference for a proposed change (e.g. "willingness-to pay" for enjoyment of a nature reserve) or by indirect comparison with actual, observed market-based information (e.g. by assessing the costs of travel to a nature reserve, or the costs of substituting the natural water purification function by sewage treatment plants). In this way, Costanza et al. (1997) estimated the services that nature provides at between $16 and $54 trillion per year[89]. Such attributed monetary values can then be fed into a comprehensive cost-benefit analysis (CBA)[90]. Table 4/4 presents some figures related to wetlands and peatlands that were assessed in this way.
Even though economic value can only relate to preferences, there are several reasons why a complete monetarisation and cost-benefit analysis may be difficult or impossible[126]:

- Every determination of monetary value is marginal, i.e. only refers to small parts of a larger available total[127].
- The order of peoples' preferences is not constant but changes with environmental conditions[128], income levels and budget availability[129], knowledge and technologies, availability of substitutes and alternatives, personal circumstances[130] and public policies[131]. It is subject to hysteresis-effects[132], and dependent on a

	in 1000 US$ km^{-2} yr^{-1}
Production functions	
water supply from a marsh and swamp area in Massachusetts (1978)[92]	3,943
water supply of global swamps and floodplains (1994)[93]	882
water supply of global wetlands (1994)[94]	441
habitat for harvested species of global swamps and floodplains (1994)[95]	51
wood, fish, and animal fodder from Danube floodplains (1994)[96]	10
food production of global swamps and floodplains (1994)[97]	5
renewable raw materials from global swamps and floodplains (1994)[98]	6
Regulation functions	
service value of coastal Louisiana wetlands[99]	2,000 – 3,700
ecological value of mangroves in China[100]	21
gas regulation of global swamps and floodplains (1994)[101]	31
disturbance regulation of global swamps and floodplains (1994)[102]	840
flood control in a marsh and swamp area in Massachusetts (1978)[103]	1305
water regulation of global swamps and floodplains (1994)[104]	3
waste treatment of global swamps and floodplains (1994)[105]	192
nutrient removal in a marsh and swamp area in Massachusetts (1978)[106]	962
nitrogen and phosphorous removal by Danube floodplains (1994)[107]	21
Information functions	
recreational value of coastal wetlands in Louisiana (1983)[108]	1 – 2
recreational value of wetlands in Louisiana (1986)[109]	11
recreational value in the North York Moors National Park U.K.[110]	35
recreational value of Danube floodplains (1994)[111]	18
Recreational value of global swamps and floodplains (1994[112])	57
Recreational value of a marsh and swamp area in Massachusetts (1978)[113]	122 – 2,196
increased privacy for those whose property is bordered by a marsh and swamp area in Massachusetts (1978)[114]	6 – 19
existence and recreational value of a German floodplain forest[115]	52
Informational/cultural value of global swamps and floodplains (1994)[116]	204
Aggregate values	
total value of global swamps and floodplains	2,271
total value of global wetlands (1994)[117]	1,715
total value of global tropical forests (1994)[118]	233
total value of global temperate/boreal forests (1994)[119]	35

Environmental costs of peatland drainage	
N emissions from drained fens to water in Sweden[120]	15 – 1,736
Greenhouse gas emissions from drained fens in NE Germany[121]	1.5 – 26
Restoration costs[122]	
general wetland restoration[123]	120 – 420
replanting mangroves in Thailand[124]	6
restoring shrimp ponds to mangroves[125]	83

Table 4/4: Monetary values (in 1000 US$ km^{-2} yr^{-1}) of some peatland (and related wetland) functions for the year 2000[91].

person's role at a specific moment[133]. Even within a single role a person's order of preferences may rapidly change with their state of mind – for example, a preference for a type of landscape.

- Non-egocentric anthropocentrism[134] requires that the value of specific functions for future generations be taken into account. Such determination might be possible with respect to fundamental needs which are not expected to change[135], but not with respect to the more subtle wants and preferences[136]. The same accounts for long-term effects, such as climate change, that will affect future generations more than the present generation and should therefore - to get a complete view - also be evaluated by those future generations, which is impossible.

"Normal" problems of the future are likely to be soluble through investment. With an economic growth rate of some 1.6% per year, a technical solution that would cost 100 million in 100 years requires an investment of 20 million now, if the rate of technological change remains constant. If technological progress were to increase by a similar rate, the cost of a similar future solution would be only 4 million now.[139] "Normal problems" are those that can be solved by progress. The question is how to measure this progress, i.e. which discount rate[140] should be applied, as nothing influences long-term assessments and cost-benefit analyses more than the discount rate.[141] Discounting can make the non-sustainable use preferable to the sustainable use. If the rate of interest on monetary capital is higher than the rate of reproduction of a renewable resource, this could push the use of that resource to the point of extinction[142].

It is unlikely that the current rate of exponential economic growth can continue indefinitely[143]. In the case that contemporary economic growth is replaced by biophysical equilibrium, the market rate of interest will give fundamentally misleading signals to any current generation.[144] The rate of technical progress, if it can be measured in an unbiased way, would provide a more appropriate discount rate.

Future generations will probably be better off only in some respects, so we are permitted to discount with regard to these respects alone. Complex patterns of increasing scarcity and growing abundance will be more likely to occur than an overwhelming pattern of diminishing scarcity in all respects[145]. It is therefore misleading to treat goods whose scarcity will probably increase irreversibly in the same way as goods whose scarcity will probably diminish[146].

Should we monetarise ecosystem services at all?[137]

The idea that "we should not price the environment" keeps coming up[138]*. While the many sides of this line of reasoning can be appreciated, ultimately the argument denies the reality that we already do, always have, and cannot avoid doing so in the future.*

Even people are constantly monetarised. When the European Union introduced a drinking water norm of a maximum of 50 mg nitrate per litre, it compromised between the increased costs of a lower maximum norm and the extra death of some (anonymous, statistical) bottle-fed babies and elderly people, thereby implicitly pricing human lives.

Similarly, we (both as individuals and as a society) make choices and trade-offs about ecosystems every day. When we preserve a natural area and this limits its economic use, this decision is generally made on the basis of values other than market prices. But the decision will result in a different set of prices for many things, and consequently to an implicit economic value for the natural area. We do not have to know the implied price in advance, but it is still interesting to know what prices are implied by our choices. They may be higher or lower than we would have guessed, and can serve as a cross-check on the reasonableness and consistency of our political decisions.

The exercise of monetary valuation does not preclude or supercede other ways of approaching the problem or other forms of valuation. But one has to communicate with people in the language they understand (while also perhaps teaching them a new language), and utilise the tools at hand (while at the same time developing new, more appropriate tools). If we are to avoid uneconomic growth we must be sure that the value of the natural services sacrificed is not greater than the value of the man-made services gained. Even a crude "total economic value" approach has significant potential to change decisions in nature's favour.

4.9 CONFLICTS DEALING WITH MORAL POSITIONS

Conflicts arising from **different positions** concern which entities have intrinsic moral value and to which moral obligations exist. Any moral obligation can only be over-ridden by another moral obligation of higher importance (for example we may hurt a person in order to save his or her life), not by a non-moral consideration, such as a preference.

Conflicts with respect to intrinsic value cannot be solved through compromise, as they deal with the fundamentals of people's value systems[147]. Whereas other world-views may represent a position fundamentally different from the prevailing anthropocentric view, they are held by many people in the world[148] and may be fully consistent[149]. There are many ways of being objective and rational and it is neither necessary nor possible to have reduced all competing claims to a common measure[150], or to see them as falling under a single hierarchy of principles.

Conflicts between different world-views can only be mitigated by acknowledging and respecting the other's position, - so long as the positions do not fundamentally clash. An atheist or agnostic without any religious conviction can nevertheless accept the sanctity of a church or other place of worship to avoid the suffering of religious believers should the place of worship be violated.

Moral pluralism allows that living decently involves many kinds of principles and various sorts of responsibilities. It recognises that feelings and responses to situations are drawn from many sources and cannot be simplified without distortion. "It remains true that a pluralist perspective will not be easy to use. If many different sets of values are in play when environmental issues are being discussed, the role of the policy-maker becomes much more complicated. But life is complicated, and we will not make progress in tackling the grave difficulties we face unless we learn to avoid shallow thinking and simple solutions[151]."

4.10 NON-ANTHROPOCENTRIC APPROACHES

The non-anthropocentric approaches referred to in the previous section are worth exploring further. They allow the investigation of alternative views in moral philosophy and more extended value systems. These may add additional sophistication to the discussion in this document. The difficulty of motivating people for sustainability, in the light of complex and unknown relations and discounting over time, may favour the use of non-anthropocentric positions, as an easy approach[152]. Furthermore, the right to live according to one's own value system (Table 4/1) implies that such positions have to be considered when brought forward in specific conflicts.

Non-anthropocentric positions do not exclude human beings, but treat them as part of the elements under consideration. As an example we present the moral philosophy of Martin Gorke[153], one of the most extreme and most consistent forms of ecocentrism and holism[154].

Any moral position must be founded on a world-view of certain basic, empirically-derived assumptions, e.g. on our knowledge of the position of human beings in the universe. Astronomy, evolutionary biology, and ecology show that humanity is neither the pivotal point nor the final end of the world. Nature, including inanimate nature, does not exist solely for human beings. If humanity can no longer be seen as the centre of the world, then ethical anthropocentrism must be questioned: ethics can no longer be regarded *a priori* as something that is restricted to relationships between human beings.

While the intrinsic value of non-human entities is usually demonstrated by selecting a particular "decisive" quality (e.g. the condition of having consciousness or that of being alive, cf. Table 3/1), Gorke starts from a different point of view. In his view we are forced, as a fundamental of morality, to make an "original decision" between two basic options: "egoism" and "a moral (i.e. non-egoist) standpoint". If one opts for the latter, any selection of entities not worthy of moral consideration is an act of egoism, because *I* determine whom I will respect, when and under what circumstances. If having a moral standpoint is taken seriously, moral consideration has to be extended to all other entities.

Advocates of more restricted concepts of morality will object that it is by no means egoism to exclude certain entities of nature from the moral community but simply a rational and objective assessment of circumstances. In Gorke's analysis of the concept of morality, however, *they* carry the burden of proof. They must convincingly demonstrate that the lack of certain qualities makes exclusion necessary. Anthropocentrism, pathocentrism, and biocentrism[155] do not achieve that. Wherever a logical relationship between a moral consideration and some empirical quality has been claimed, a naturalistic fallacy[1561] is always involved. And wherever the claim is based solely on plausibility, the evidence appears to be arbitrary. An ecocentric, holistic position appears to be the only logical conclusion.

In practice, the differences with a (non-egoistic) anthropocentric position appear to be not so much in the fundamentally different types of conflicts, but rather in the much larger number of conflicts to which such holistic ethic leads. Regarding the way human beings have to deal with nature in general, Gorke advocates with Albert Schweitzer that harming other entities always involves a smaller or larger quantity of *guilt*, depending on how necessary the intervention is. This means that for evaluating environmental conflicts, an ethical "black/white" approach (allowed/forbidden) should be replaced by a graduated concept (the less harm the better)[157].

1 Cf. §1.2.

2 "The assignment of weights is an essential and not a minor part of a concept of justice. If we cannot explain how these weights are to be determined by reasonable ethical criteria, the means of rational discussion have come to an end. An intuitionist conception of justice is, one might say, but half of a conception. We should do what we can to formulate explicit principles for the priority problem, even though the dependence of intuition cannot be eliminated entirely." Rawls 1971.

3 See Brennan 1992, and below.

4 Cf. Rawls 1971, Taylor 1986, Attfield & Dell 1996. See also §3.2.

5 Hardin 1968.

6 Following the Universal Declaration of Human Rights (UN General Assembly 1948) and the concept of sustainable development (World Commission on Environment and Development 1987), cf. §3.2. While the framework in this document is based on an anthropocentric position, it nontheless recognises (§§ 3.2, 4.10 and 5.8) that many people believe in the moral right of animals, plants, ecosystems and landscapes to exist, i.e. that these entities have intrinsic value.

7 Frank 1985, 1999.

8 Satisfaction of needs is the removal of shortage, satisfaction of wants is the removal of dissatisfaction.

9 Science Action Coalition & Fritsch 1980. Human beings share this characteristic with many other animal species. The display of affluence functions as an indication of good prospects for the successful raising of offspring, and attracts potential reproduction partners. Once this mechanism functions, competition for mating rapidly results in the evolution of exaggerated forms, as is shown by peacock tails, large antlers, fat bellies, even to the extent that the initial advantage changes into a disadvantage (e.g. giant deer).

10 Cf. the "trickle-down-effect" of Simmel 1905. This inclination is actively exploited by commerce by creating trends and ridiculing people who do not follow them (Mishan 1967).

11 At relatively high levels of income, personal happiness depends on one's income or expenditure relative to the mean income or expenditure of some reference group. At really low levels of income happiness is not associated with income (Gupta 1999).

12 Achterhuis 1988.

13 Increased information exchange in the "global village" has on the one hand enormously enlarged the circle of reference for mimetical desire (everyone in the world can know what everyone else possesses). On the other hand it has removed the spatial obstacles for group formation, making possible - more than in the past - the free choice of social surroundings.

14 A villa, for example, satisfies the basic need for shelter, but additionally satisfies many "wants". The same applies to food, drink, clothing, health care, social contacts etc.

15 Rawls 1971. If, for example, the only way to save the life of five patients is to kill an innocent person and divide his/her organs among them by transplantation, the killing is wrong even though, by saving five lives at the expense of one, it has overall "better" consequences. Saving life is not "equivalent" to killing (Harris 1975, Hurka 1993, Prior 1998).

16 I.e. that do not violate the rights of others.

17 It should be noted that the concept of Human Rights is essentially an individualistic approach. In other societies more "holistic" approaches (see §3.2) may prevail, that pay more attention to the societal "whole" and less to the individuals constituting that whole. The caste system in ancient Hindu society, for example, ecologically stabilised society by reducing competition among various people for limited natural resources (Dwivedi 1990).

18 Cf. "Live simply that others may simply live", Salleh 1990.

19 *Rubus chamaemorus*

20 A precedence is a measure of importance in space within the same value category (e.g. finding "me"

more important than "you", finding a person here more important than a person somewhere else, finding two human beings more important than one human being).

[21] A priority is a measure of importance in time (e.g. short-term versus long-term).

[22] Thoreau 1864 (in: Homan 1991).

[23] Being reliant on both sender and receiver.

[24] A consensus can, for example, easily be reached on questions like "peatland forestry leads to increased peat accumulation" (cf. Crill et al. 2000, Joosten 2000) or "peatland biodiversity leads to peatland stability" when
– all parties involved really want to know the right answer,
– agreement exists on the content of the terms ("peat", "biodiversity", "stability", etc.) and the period of time and location and area under consideration, and
– all available information on the subject is exchanged.

[25] Rawls 1971.

[26] I.e. things that have a "price" and can be exchanged for a set of alternatives; Cf. Kant 1785: "In the realm of aims, everything has either a price or a dignity. For what has a price, something can be put as an equivalent at its place; what on the contrary is above all price, and therefore allows no equivalent, has a dignity." The equivalency may be based on the accomplishment of the same aims (e.g. peat or wood for energy generation) or on indifference in utility (e.g. a bottle of whisky versus an orchid in a vase). Preferences apply to both needs and wants The Universal Declaration of Human Rights recognises the right to pursue wants so long as this does not violate the rights of others (see Table 4/3). This means that the wants of one party can never prevail over the needs and basic liberties of others. See §4.6.

[27] Apart from unsolvable practical problems, see below.

[28] For an in-depth discussion on possibilities, methods and restrictions of monetarisation, see Grönemann & Hampicke 1997, on which much of the following is based.

[29] Somebody can be equally happy with the existence of a close relative and without a million dollars as without the existence of that relative and with a million dollars. For that person, the existence of the relative only has an instrumental value and a price, however no intrinsic value, i.e. no "dignity". It is impossible to monetarise intrinsic value.

[30] Attfield & Dell 1996.

[31] Although the fulfilment of an individual's wants is not necessarily beneficial for him or her, the right to liberty (see §4.6) requires that we respect these choices as long as no rights of others are violated. The choices may only be influenced by information and education: these may transform preferences.

[32] including the aspects of reversibility, cf. Joosten 1997.

[33] See §3.1.

[34] See the needs and wants discussion, and the General Conception of the Principles of Justice of Rawls (1971) in §4.6.

[35] In order to provide genuine equality of opportunity, society must give more attention to those with fewer native assets and to those born into less favourable social positions (Rawls 1971). The policy of positively weighing the gains and losses of those at a low level of well-being is consistent with most notions of social justice, and may also be justified in that acting thus makes a greater beneficial difference, and satisfies desires which are more crucial and more pervasive. The weights to be attached to the utility of different parties at different levels of well-being must be settled by politicians; but decision-making can only claim to be rational where it is based on the foreseeable consequences for all affected parties, and where the same weights are used consistently throughout (Attfield & Dell 1996).

[36] Intrinsic value is an absolute concept: something either has (+) or lacks (0) it. Instrumental values are generally comparative, i.e. more or less suited (+1, +2, +3, ...) for a specific purpose.

[37] Possible obligations to future generations are dealt with in §4.7.

[38] Cf.Hampicke 2000. This problem results from the dilemmas of being a rational social being. All animals distinguish between "group members" and "non-group members" and must treat these differently (otherwise all predators would eat their offspring). Social beings have an extended sympathy that includes other beings than the direct offspring, i.e. that exceeds direct egoism. Rational beings are aware of the existence of this boundary between "in" and "outside" the circle, and - driven by the (social) tendency towards extended sympathy - question the rationale of the boundary (Midgley 1983). This has in history led to extending moral circles, as, for example, is apparent in the development of U.S.A. legislation that subsequently extended rights to American colonists (Declaration of Independence 1776), slaves (Emancipation Proclaration 1863), women (Nineteenth Amendment 1920), native Americans (Indian Citizenship Act 1924), Labourers (Fair Labor Standards Act 1938), and blacks (Civil Rights Act 1957), cf. Nash 1989.

[39] "We have no choice but to be especially interested in ourselves and those close to us." (Midgley 1996).

[40] UN General Assembly 1948, modified after Taylor 1986.

[41] I.e. that do not violate the rights of others.

[42] In so far as it does not compromise other people's rights.

[43] Cf. McGee W. J.: "Conservation is the use of natural resources for the greatest good of the greatest number for the longest time." (Herfindahl 1961).

[44] Cf. Crocker 1990, "Live simply that others may simply live", Salleh 1990.

[45] Hurka 1993.

[46] Rawls (1971) argues that the correct principles

of justice are those that would be agreed to by free and rational persons, placed in the "original position" behind a veil of ignorance: not knowing their place in society; their class, race, or sex; their abilities, intelligence, or strengths; or even their conception of good. In contrast to the Universal Declaration on Human Rights, that is largely founded on a western metaphysical concept of rights, Rawls' principles follow the Kantian approach of rationality and universalisation (the "categorical imperative"): Act only on a rule that you wish to see generally followed by everyone. Accordingly, he derives two principles of justice to regulate the distribution of liberties, and of social and economic goods.

[47] Basic liberties include: political liberty (the right to vote and to be eligible for public office) together with freedom of speech and assembly; liberty of conscience and freedom of thought; freedom of the person along with the right to hold (personal) property; and freedom from arbitrary arrest and seizure as defined by the concept of the rule of law (Rawls 1971).

[48] To deal with intergenerational relations, Rawls introduced the concept of "just savings", implying what is reasonable for members of succeeding generations to expect from one another by balancing how much they would be willing to save for their immediate descendants against what they would feel entitled to claim of their immediate predecessors.

[49] This section draws substantially on the ideas of Hampicke (2000).

[50] World Commission on Environment and Development 1987.

[51] Howarth 2000.

[52] Some technological optimists, for example, expect that the science of ecology will eventually provide sufficient understanding of ecological processes and relationships to enable an effective control of ecosystems and natural resources. This belief disregards the fundamental scientific limitations to ecological knowledge: the enormous complexity of ecosystems, the unpredictability of their dynamics due to chaos and contingency, their uniqueness which precludes far-reaching generalisations, and the limited possibilities of quantifying their qualities (Gorke 1999).

[53] Hampicke 2000.

[54] Cf. Alexander Solzhenitsyn (1968): "Happiness is a mirage – as for the so-called "happiness of future generations" it is even more of a mirage. Who knows anything about it? Who has spoken with these future generations? Who knows which idols they will worship? Ideas of what happiness is have changed too much through the ages. No one should have the effrontery to try and plan it in advance."

[55] Barry 1977.

[56] I.e. the material life support functions.

[57] Dasgupta, 1995.

[58] "Almost every article, paper or book on sustainability bemoans the fact that the concept is broad and lacks a broad consensus; this is usually followed by the authors' own preferred definitions which in turn add to the lack of consensus!" (Bell & Morse 1999).

[59] Neumayer 1999.

[60] The distinction between weak and strong sustainability is similar to that of the distinction between the "sustainability of the means to an end" and the "sustainability of the end" (Bell & Morse 1999). E.g. "sustainable peatland forestry" generally refers to the sustainability of forestry on that spot, not to the sustainability of peatland, as the peat may eventually disappear as a result of drainage (cf. Päiväinen 1997, 2000).

[61] See also §5.6.5 (2) below.

[62] I.e. the maximisation of the well-being of all present and future humankind.

[63] This is also expressed in the Ramsar definition of sustainable utilisation: "the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations".

[64] Cf. Dasgupta 1995.

[65] See §5.6.5 (2) below. If, for example, society in 100 years will need a specific sum of money to mitigate the consequences of climatic change, a much lower sum can be invested today and this sum will increase to its final size 100 years from now, according to the laws of compound interest.

[66] Pigou 1978.

[67] Hampicke 2000.

[68] Hampicke 2000.

[69] This does not exclude the possibility that advances towards solving these problems or substituting the concrete services and resources might be made at some time in the future.

[70] Ott 2000.

[71] Rehmann-Sutter 1998.

[72] Sober 1985.

[73] Those who consider their loss acceptable should indicate how they are substitutable. There can also be discussion regarding whether a particular function is essential or substitutable.

[74] In considering which part of biodiversity is vital, it can be asked from the anthropocentric point of view on which this document is based, whether we have to preserve all mires, all mire species and all peat? To what extent is their maintenance necessary for maximising human happiness (or minimising human suffering)? To what extent is their abundance redundant and useless?

The probability of an unknown property of a species being directly useful for humankind in future is low, because it is the product of two low probabilities: (i) that the species indeed is useful, and (ii) that its use will be discovered (Norton 1987). In a world with tens of millions of species, the loss of a currently useless species may therefore be of negligible importance. It is, furthermore, irrational to defer some real and known benefit in favour of a theoretically possible but still unknown use of certain species ("a bird in the hand is worth two in the bush").

Contrary to what ecologists thought in the 1970s, species diversity is no longer regarded as a guarantee for stability. Many species, particularly rare ones, are probably even "useless" for ecosystem functioning (cf. review in Gorke 1999). The loss of others will in general not ruin an ecosystem, because ecosystems are, contrary to what is often suggested, not "wheel-works" but "networks". They do not collapse, they simply adjust (During & Joosten 1992, Hargrove 1987), because they normally contain a complex of mutually substitutable negative-feed-back mechanisms (cf. Ivanov 1981, Joosten 1993). There is, however, insufficient knowledge of interdependence to judge which concrete species are and will be redundant in this respect (Lovejoy1988, cf. Naeem 1998). Furthermore, "useless" species play a role in shaping the evolutionary template of other species (cf. Brown et al. 2001). Therefore it is wise to preserve the whole taxonomic and ecosystem biodiversity pool (see also Naeem 1998).

In terms of the global biosphere, western civilisation and the functioning of regional landscapes some mires were and are inessential. Because there are so many mires, the likelihood that the destruction of the next mire will produce a disaster is low. Each destruction, however, will increase the chance that a positive feed-back mechanism which ultimately disastrous consequences is initiated (cf. Joosten 1993, Couwenberg & Joosten 1999). That this probability is initially low and the effects are initially limited encourages the notion that the absence of disaster so far is evidence that disaster will never come (Norton 1987, cf. Ehrlich & Ehrlich 1981: "The Rivet Poppers"). The limited direct effect may lead to a destruction of the majority of mires and peatlands, especially in areas where a seeming abundance leads to the false conception that an endless resource is available (Joosten 1997, 1999).

If we accept the central assumption that every species and ecosystem may have great but non-quantifiable value, species and ecosystems should be saved as long as the costs of doing so are tolerably low. In the face of high costs society might choose a small risk of serious negative consequences (Norton 1987).

Because there is much we do not know, and much more that we do not understand, we should not irreversibly destroy extensive areas of the world's remaining mires and peatlands. At the same time we can not exclude mankind from all the benefits of developing mires and peatlands.

75 The attribution of monetary value to entities or services which are not normally seen to have a financial or commercial value.

76 Grönemann & Hampicke 1997.

77 This is not only a problem in the valuation of regulation functions of nature, but also in valuing similar indirect "means" such as infrastructure, time-saving in traffic, security against floods etc. (Grönemann & Hampicke 1997).

78 Vatn & Bromley 1993.

79 See footnote 29 and §3.1. Also, transformation values can not be valued because their impact on people's preferences is unpredictable and varies from person to person (Brennan 1992).

80 Brennan 1992.

81 Cf. Goetz 1997, who shows that from a private economic perspective a farmer should use his agricultural peatland intensively, which would lead to rapid and complete loss of the peat soil. See also Van Vuuren & Roy 1993.

82 Hardin 1968.

83 Hanley et al. 1998, Hodge & McNally 2000.

84 A hectare of Malaysian tropical forest may be "worth" US$3000 on the basis of its soil-protecting, gene maintaining, and possible medicinal properties (Pearce 1993). But that cash is "virtual" because these services are not owned by anyone in particular. The same Malaysian hectare is worth US$ 300 – 500 "cash in the bank" when the timber is felled and sold on the Japanese market. The two sets of dollar values are simply not the same (O'Riordan & Voisey 1998).

85 This failure does not arise from the functioning of markets, but from the fact that the markets are not there at all. They are "missing markets" (Pearce & Moran 1994).

86 Note that all these failures can occur simultaneously: they are not mutually exclusive (Pearce & Moran 1994).

87 See for reviews Pearce & Moran 1994, Georgiou et al. 1997, O'Neill 1997, Pimentel et al. 1997, Hampicke 2000b, and http://management.canberra.edu.au/~gkb/benefit.html.

88 Cf. Barbier, 1994, Gren et al. 1995, Söderqvist et al. 2000 and the special issue of Ecological Economics 35 : "The values of wetlands: landscape and institutional perspectives."

89 Cf. the global gross national product being US$18 trillion per year (Costanza et al. 1997).

90 See, however, Pearce 1998.

91 Original data recalculated to year 2000 US$ using the US consumer price index: http://stats.bls.gov/cpihome.htm. Other currencies are recalculated in US$ using the exchange rates of July 2001. Attention: The data may contain double counting in the aggregate values (cf. Turner et al. 1998).

92 Thibodeau & Ostro 1981.

93 Costanza et al. 1997.

94 Costanza et al. 1997.

95 Costanza et al. 1997.

96 Gren et al. 1995.

97 Costanza et al. 1997.

98 Costanza et al. 1997.

99 Farber 1996.

100 Han et al. 2000.

101 Costanza et al. 1997.

102 Costanza et al. 1997.

103 Thibodeau & Ostro 1981.

104 Costanza et al. 1997.

105 Costanza et al. 1997.

106 Thibodeau & Ostro 1981.

107 Gren et al. 1995.

108 Costanza et al. 1989.

109 Bergstrom et al. 1990.

110 77 visitor days ha^{-1} y^{-1} (http://www.pantm.co.uk/reports/purbeck/CombinedChapters.pdf) at $4.50

person^{-1} yr^{-1} (White & Lovett 1999).
[111] Gren et al. 1995.
[112] Costanza et al. 1997.
[113] Thibodeau & Ostro 1981.
[114] Thibodeau & Ostro 1981.
[115] Hampicke & Schäfer 1997.
[116] Costanza et al. 1997.
[117] Costanza et al. 1997.
[118] Costanza et al. 1997.
[119] Costanza et al. 1997.
[120] Using \$2 – 35 kg^{-1} N (Gren 1995, Byström 1998) and emission rates of 7,540 – 49,600 kg N km^{-2} y^{-1} (Gelbrecht et al. 2000).
[121] Using \$5 - 25 t^{-1} C (Tol 1999a) (with ratios between the marginal costs of CO_2 and those of CH_4 and N_2O equal to the global warming potentials of these gases, cf. Tol 1999b) and a cumulative radiative forcing of 2,928 – 10,334 CO_2-C-kg-equivalents ha^{-1} y^{-1} (Augustin 2001).
The aggregated monetarised damage due to climate change has been estimated at 1.5 to 2.0 percent of World GNP; the OECD would lose 1.0 to 1.5 percent of GDP; the developing countries 2.0 to 9.0 percent. These figures are not comprehensive and are highly uncertain. Recent studies increasingly emphasise adaptation, variability, the rate of change, extreme events, other (non-climate change) stress factors, and the need for integrated assessment of damages. As a result, differences in estimated impacts between regions and sectors have increased, the market impacts in developed countries have tended to fall, and non-market impacts have become increasingly important.
Whether it is fast or slow, climate change is likely to have greater economic impacts on poor countries than on rich countries. On the whole, market impacts fall relative to economic growth while non-market impacts rise relative to growth (http://www.gcrio.org/gwcc/toc.html).
[122] Capital investment costs recalculated to annual costs using an interest rate of 6%.
[123] IPCC 1996.
[124] Primavera 2000.
[125] Primavera 2000.
[126] See also discussions in Costanza et al. 1997.
[127] Cf. the exclamation "my kingdom for a horse" in Shakespeare 's King Richard III, V, iv, 7. The answer to the question: "How can you monetarise 'nature', 'biodiversity', or 'the environment' " is simply: "you cannot". The same answer, however, also applies to everyday necessities such as food, drinking water, or shelter. To ask the question how much poorer the world would be without any food or without biodiversity is absurd (cf. Costanza et al 1997). In daily practice, however, a loaf of bread, a litre of water, and a house is replaceable and hence does have a price. Similarly a peatland can have a monetarised value for tourism, for education, for energy generation, etc., a price that is dependent on demand and scarcity (Mitsch & Gosselink 2000).
[128] Cf. the recent discussions of the role of peatlands in climate change (Gorham 1991, Franzén 1994, Crill et al. 2000).
[129] Cf. MacGillivray 1998, who shows that even in depressed areas there is a strong appreciation that there is more to happiness, welfare or quality of life than cash income. This appreciation includes a recognition of the value of such qualities as health, security, standard of living, education, and environment.
[130] For example, one might accept the killing of farmed rabbits for eating while not accepting the killing of a child's pet rabbit. Cf. Brennan 1992.
[131] Norton 1987.
[132] I.e. in general, people dislike losing a benefit more than they like gaining the same benefit.
[133] Brennan 1992. There may, for example be large differences between the perspective of a person as a consumer and of the same person as a citizen, for example in her attitude towards rules and regulations. The decision to have or not to have peat extracted in a country concerns the political question of what limits should be placed on the satisfaction of consumer preferences. The decision to buy a bag of compost containing peat, when it is available on the market, concerns merely the satisfaction of individual preferences within these limits (Cf. Norton 1987).
A person in her role as palaeo-ecologist may prefer the view of a bog while it is being exploited, because the exposure of peat profiles allows optimal access to stratigraphical information (cf. Casparie 1972, Barber 1981). The same person in her role as conservationist may prefer to see pristine bogs.
[134] See §3.2.
[135] Cf. §4.7.
[136] Cf. the large sums currently spent on mire restoration in West and Central European countries which clearly show that present day society values things different from society only 30 years ago.
[137] Based on Costanza et al. 1998 and Hampicke 2000b.
[138] Cf. Rees (1998): "…at this critical stage of world development, we must regard many of nature's services as we would an expensive yacht. If we have to ask the price, we probably can't afford it."
[139] Fear that "intermediate" generations might "hijack" the funds is no reason to refrain from providing them, because
– our duty to mitigate the consequences of our actions exists, independent of what future generations may do. If they abuse the funds, they are responsible for the ensuing suffering. If we do not start to invest, we are;
– instead of in bank accounts, we may as well invest in technical progress. This might improve the capacity to solve problems more efficiently and is less reversible than the stockpiling of money (Hampicke 2000).
[140] cf. Tol 1999b. See §5.6.5 (2).
[141] The decision on the correct method of discounting is independent of whether the present generation is actually going to pay for future damages or not. If it appears after thorough calculation that the present costs are relatively

small compared to the wealth of future generations, we may well feel that they themselves should pay for the problems we have caused, a situation that we face with respect to problems that former generations have left to us. Calculating the results of a hypothetical transfer helps estimate what can be expected from future generations without being unjust (Hampicke 2000).

[142] Cf. Clark 1973.

[143] Cf. Hubbert 1976. Cf. Daly 1990: "When something grows it gets bigger. When something develops it gets different. The earth ecosystem develops (evolves), but does not grow. Its subsystem, the economy, must eventually stop growing, but can continue to develop. The term 'sustainable development' therefore makes sense for the economy, but only if it is understood as "development without growth" – i.e. qualitative improvement of a physical economic base that is maintained in a steady state by a throughput of matter-energy, that is within the regenerative and assimilative capacities of the ecosystem. Currently the term "sustainable development" is used as a synonym for the oxymoronic "sustainable growth". It must be saved from this perdition. … Even "green growth" is not sustainable. There is a limit to the population of trees the earth can support, just as there is a limit to the population of humans and of automobiles. To delude ourselves into believing that growth is still possible and desirable if only we label it "sustainable" or colour it "green" will just delay the inevitable transition and make it more painful."

[144] As long as there is general growth, there are no losers: the investor who borrows money does not become poorer by paying interest if she invests the loan in such a way that, allowing for the interest, she is richer than before. In a society which is not physically growing it is impossible for everyone to gain by saving at compound interest. In those circumstances interest only functions as a mechanism of redistribution: the money-lender is getting richer, but not society at large (Hampicke 2000).

[145] Ott 2000.

[146] Price 1993.

[147] See §3.2.

[148] Even the United Nations General Assembly adopted a non-anthropocentric approach when affirming that "Every form of life is unique, warranting respect regardless of its worth to man" (World Charter on Nature 1982).

[149] Cf. §3.2.

[150] See also §4.5.

[151] Brennan 1992.

[152] Gorke 1999.

[153] Gorke 1999, 2000

[154] See also §3.2.

[155] See Table 3/1 in §3.2.

[156] A "naturalistic fallacy" means deriving a moral conclusion from a factual premise, i.e. deriving an "ought" statement from what is no more than an "is" statement. Naturalistic fallacies are common in environmental argumentation. Some examples:

- "For 5000 years there was much more forest and much less mire. Therefore we have to change mires into forests again." This conclusion would only be valid when combined with a value premise, e.g. "in former times everything was better".
- "This mire contains the only population of Aquatic Warbler in the region and should therefore be protected". This conclusion is only valid when combined with a value premise like "we must protect all species diversity in this region".

[157] Such an approach could be made operational in daily practice by adapting the (originally biocentric) principles of Paul Taylor's *Respect for Nature*. See also §5.8.

CHAPTER 5.

FRAMEWORK FOR WISE USE

Chapter 3 outlined the values and uses of mires and peatlands. Chapter 4 described the origins and types of conflicts. This chapter sets out a Framework within which conflicts between different values and uses of mires and peatlands can be resolved.

5.1 INTRODUCTION

Wise Use of peatlands can be described as the uses of peatlands for which reasonable people now and in the future will not attribute blame. This document sets out to provide a context for, and parameters within which, Wise Use decisions can be taken in relation to mires and peatlands. It proposes a Framework for the Wise Use of Mires and Peatlands.

The development of such a Framework must start from values, as outlined in Chapter 3. This proposed Framework is based on the anthropocentric premise that human beings have intrinsic moral value, the premise on which the Universal Declaration of Human Rights is based. Accepting the definition that "Sustainable development" is seeking to meet "the needs of the present without compromising the ability of future generations to meet their own needs[1]" these Guidelines attach intrinsic moral value to human beings in the future. They are further based on the statement that "Human beings are at the centre of concerns for sustainable development[2]."

Chapter 3 described the values and functions of mires and peatlands. Chapter 4 outlined the types of conflict which can arise. In particular conflicts arise between

- different positions with respect to intrinsic moral values,
- the interests of human beings now and human beings in the future, and
- the different preferences of different people.

The rational resolution of such conflicts involves a structured framework for the examination of all the elements relating to a conflict or a decision concerning mires or peatlands.

The proposed Framework includes two stages:

1. The arrival at a decision in principle through answering the series of questions contained in the decision tree in Tables 5/1 and 5/2 as summarised in Figure 5/2, and by examining the application of a number of general considerations (§5.3) to the situation;
2. The examination of the decision in principle to see if its implementation
   - will be consistent with a series of guidance principles (§5.4);
   - which in turn may be modified by time and place (§5.5); and
   - will involve the use of instruments in arriving at or implementing the decision (§5.6).

This consistency can be evaluated through the use of checklists. These checklists are intended to be taken in the context of the document as a whole. Each checklist only has value as part of the framework illustrated in Figure 5/1. They are not intended to be taken out of context and should not be used as simplistic 'ticking boxes'. The checklists can be used to establish codes of conduct (§5.7). Agreed codes of conduct make it easier to judge if a national or regional authority, or an enterprise, takes decisions in a manner consistent with the Framework.

This Framework is intended to be considered as a whole, and is illustrated in the following diagram (Figure 5/1). If a decision comes through the 'decision in principle' process with a clear 'yes' then it can be examined further under the elements of the 'implementation decision' column. If it comes through with a 'no' it should be established if the 'no' is a genuine stopper or more a reason to be cautious.

It is unlikely that any proposal would achieve 100% 'yes' under the 'implementation

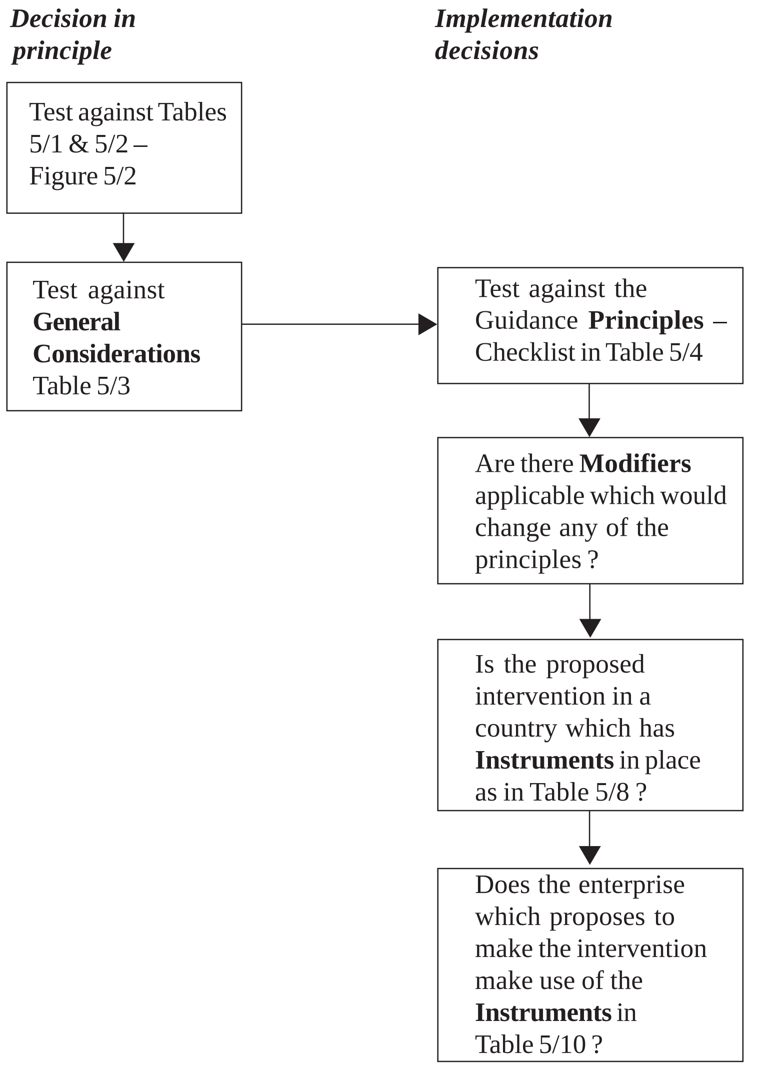


Figure 5/1 Framework for making decisions on interventions in peatlands decisions' process. In most cases a proposal will emerge either preponderantly positive or preponderantly negative. It is to be decided in the circumstances of each case whether the negative elements are 'stoppers' or not. For example, in some cases a record of poor corporate governance would be a stopper. In other cases it might cause the authorities to say 'yes' but to impose a code of conduct.

In applying the Framework it should be recalled that Wise Use is not simple or simplistic and cannot be reduced to formulae.

5.2 DECIDING IN PRINCIPLE IF AN INTERVENTION IS ADMISSIBLE

Overall, the major - anthropocentric - conflicts which arise with respect to peatland use are between those who wish to develop mires and peatlands for their production or carrier functions, and others who wish to preserve them for their regulation and non-material life-support functions.

In dealing with peatland conflicts, the approach of moral pluralism discussed earlier (§4.5 and §4.9) is relevant - different considerations apply in different cases: it is not possible to reduce all complexities to simple principles or single measures.

With respect to conflicts relating to human needs and wants, two aspects have to be considered:

- the effect of the proposed use[3] on the function itself: does the intervention negatively affect the further provision of that function[4]
- the effect of the use on other functions: does the intervention negatively or positively affect other functions.

This section provides some assessment criteria for dealing with these questions.

5.2.1 The effect of a use on the function itself

The effect of the intervention on the function itself[5] has to be judged using the criteria in Table 5/1.

Criterion	Question	Answer	Consequence
1. Advantage	Will the proposed intervention have a positive effect on the satisfaction of human needs and wants?	No	No intervention
		Yes	Go to 2
2. Essentiality	Are the resources or services to be provided essential for the maintenance of human life[6] and non-substitutable?	Yes	Intervention agreed
		No	Go to 3
3. Self-maintenance	If the proposed resource use or service is implemented will the continuous provision of the same quantity and quality of resources or services remain possible?	Yes	Go to Table 5/2
		No	Go to 4
4. Abundance	Are the peatland resources or services to be consumed by the proposed intervention abundant and will they remain abundant?	Yes	Go to Table 5/2
		No	No intervention

Table 5/1: Criteria and decision tree for assessing the admissibility of an intervention with respect to its effects on the function itself.

Some examples may illustrate these criteria:

- If the maintenance of human life is at stake, it is not unwise to use an non-substitutable resource to the point of exhaustion. One cannot be blamed for killing the last bear if it is the only way to stay alive[7].
- If the use of the resource keeps the quantity and quality of that resource intact, there is no reason not to use the resource. Even when the supply is decreasing, the use can be continued as long as the resource is abundant.
- If the resource is not abundant and getting rare, it is wise not to use the resource to the point of exhaustion, in case the resource might be needed for more urgent (and presently unknown) purposes in future (option value).

In all but 2 a positive answer is conditional on the effects the intervention has on other services and resources (see Table 5/2).

5.2.2 The effect of a use on other functions

The use of a peatland for a specific purpose may have considerable side-effects. These effects on all other functions[8] must be taken into account in the full assessment of admissibility of an intervention. To judge the impact of the intervention, the criteria in Table 5/2 can be applied.

With respect to the side-effects, an intervention is considered permissible in principle when:

- no negative side-effects occur, OR
- the affected resources and services remain sufficiently abundant, OR
- the affected resources and services are easily (and completely) substitutable, OR
- the impact is easily reversible.

In all other cases an integrated cost-benefit-analysis has to be carried out that involves a thorough weighing of the pros and cons of the intervention, taking the considerations of Chapter 4 into account.

The two tables 5/1 and 5/2 are combined in the flow chart of Figure 5/2.

In deciding on the preservation or destruction of pristine mires, we have to be aware of our limited knowledge, the possibly high risks arising from development, and the long-term benefits and drawbacks of either preservation or development. Tables 5/1 and 5/2 and the

Criterion	Question	Answer	Consequence
1. Impact	Will the proposed intervention have negative effects on other functions?	Yes	Go to 2
		No	Consider approval
2. Essentiality	Are the negatively affected functions non-substitutable and essential for the maintenance of human life?	Yes	No intervention
		No	Go to 3
3. Abundance	Are the negatively affected functions sufficiently abundant to guarantee their adequate future provision?	Yes	Consider approval
		No	Go to 4
4. Substitut-ability	Are these negatively affected functions easily substitutable or are the negative impacts easily reversible?	Yes	Consider approval
		No	Do an integrated cost-benefit analysis

Table 5/2: Criteria and decision tree for assessing the effect of an intervention with respect to other functions.

flow chart of Figure 5/2, combined with a systematic evaluation of the peatland functions and values as dealt with in Chapter 3, provide a good start for a Wise Use assessment. Other elements to be considered in coming to a decision are provided in the rest of this Chapter. These are the components of the 'implementation decisions' column in Figure 5/1.

5.3 GENERAL CONSIDERATIONS

Some general considerations also form part of the 'decision in principle' process. The following General Considerations are taken from parts of Chapter 4:

1. All human beings have rights, boundary conditions that may not be violated. In resolving value conflicts, and conflicts between rights, the satisfaction of essential needs take priority over the satisfaction of desirable wants. (§§ 4.2, 4.5)

2. In taking decisions an egalitarian principle should apply: a smaller amount of good equally distributed should be preferred to a larger amount of good disproportionately shared (including taking future people into account). Preference in such decisions should be given to those with fewer native assets and less favourable social positions. (§§4.2, 4.6)

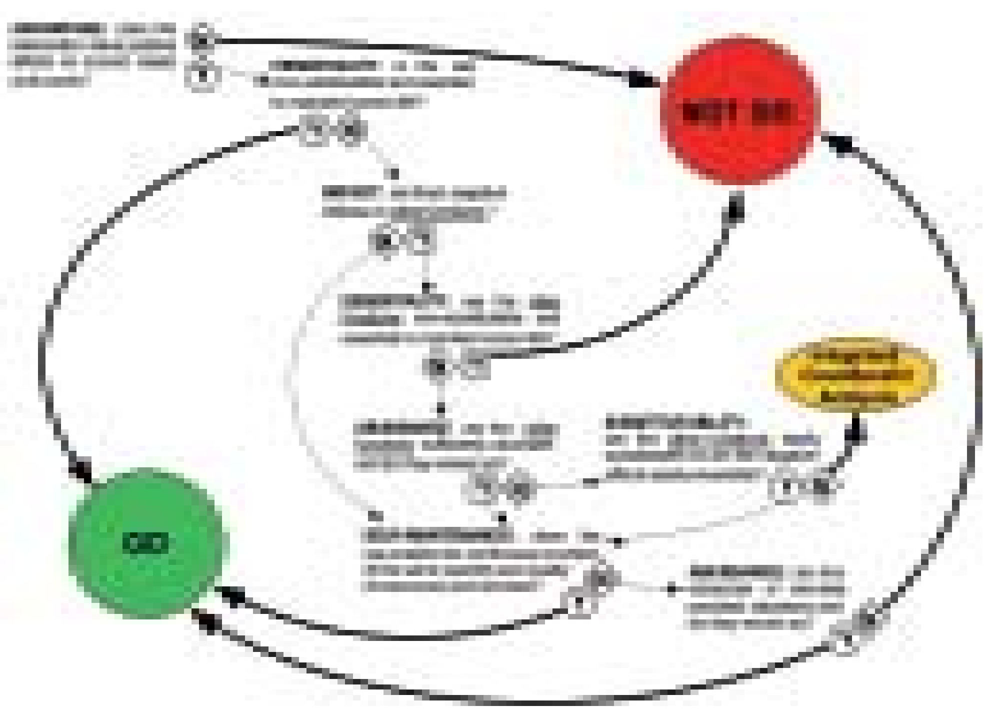


Fig. 5/2: Flow chart for assessing the permissibility of interventions in mires and peatlands.

3. There is no single set of concepts or principles which can govern every situation. Different considerations apply in different cases: it is not possible to reduce all complexities to simple principles or single measures. (§4.5)

4. The first stage in taking any decision is to describe the issue or issues to be resolved. The rules to be then taken into account include:
   - The alternative which achieves the desired end in the best way should be adopted.
   - Preference should be given to the alternative which is most likely to achieve the desired outcome.
   - Preference should be given to the alternative which achieves all of the direct aims and further aims in addition. (Table 4/3)

As an illustration of how such general considerations can be helpful a checklist follows (Table 5/3). A negative answer does not necessarily mean that a use / intervention should be excluded. Not all the general considerations lend themselves to use in a checklist.

5.4 GUIDANCE PRINCIPLES FOR WISE USE

The following guidance principles are set out as an aid to resolving issues which arise in decisions relating to interventions in the fundamental properties of peatlands and mires.

1. The principle of clarity[9]: concepts should have clear content; terms should be clear and consistently applied.

2.The principle of public access to information: the public should have adequate access to information regarding proposed decisions[10]. The information should be transparent and understandable.

3. The principle of public participation: interventions should follow a consultation process in which all stakeholders[11] can actively and effectively participate[12].

4. The principle of motivation: interventions should be motivated by the prospect of greater advantage[13] for society[14].

5. The principle of careful decision-making: decisions should be made on the basis of the best available information[15].

What are the aims of the proposed intervention; will the proposed intervention achieve them; and will it achieve them in the best way.	
Does the proposed intervention interfere with a fundamental human right. Or	
Does the proposed intervention reinforce a fundamental human right.	
Do the aims of the intervention relate to genuine needs, or merely to wants.	
Will the benefits accrue in an egalitarian manner, not just to a privileged few (including taking future people into account).	

Table 5/3. Checklist against the General Considerations - Elements to be considered when decisions arise as to the use of a mire or peatland

Are the relevant concepts clear: is everyone talking the same language.	
Has adequate information been made publicly available.	
Has adequate public consultation taken place.	
Will the proposed intervention produce a greater advantage than not intervening.	
Is the decision based on the best possible information.	
Have the implications for other entities and other parties indirectly affected been taken into account.	
Do all those participating in the decision acknowledge that other valid points of view may exist.	
Will the proposed intervention result in its benefits being distributed equitably unless an unequal distribution would advantage the least favoured.	
Is the intervention located where it will cause least impact - could it or should it be moved elsewhere.	
Is the proposed intervention limited to the minimum necessary.	
Will any damage consequent on the intervention be	
* prevented	
* controlled	
* reduced	
* repaired or	
* compensated for.	
Will the cost of these measures be borne by the responsible party.	
Is the user required to restore the mire/peatland after use to a wetland, a suo or a mire: or is alternative afteruse planned.	
Is the intervention consistent with the precautionary principle.	
Is the intervention adapted to the natural characteristics and constraints of the mire or peatland.	
Is every effort being made to preserve the ecological processes necessary for the survival of species.	

Table 5/4. Checklist against the Guidance Principles - Elements to be considered when decisions arise as to the use of a mire or peatland

6. The principle of responsibility: Any decision should take into account its effects on other individuals and entities. Decisions at one level should reflect the interests of other levels[16].

7. The principle of plurality: Participants in a decision should accept that cases can be looked at from different perspectives and that a pluralist stance can be the best means of dealing with complex situations.

8. The principle of distributive justice: all means of meeting wants should be distributed equally unless an unequal distribution is to the advantage of the least favoured.

9. The principle of minimum intervention: if interventions have to take place, they should be limited to the minimum necessary.[17]

10. The principle of re-location: those activities that are harmful, and cannot be avoided, should be relocated to areas where they will cause least impact.

11. The precautionary principle: where it is anticipated that the effects of an intervention could be seriously damaging, measures to prevent this damage[18] should not be avoided because of lack of full scientific certainty[19].

12. The principle of avoidance: the exploitation of mires and peatlands should be adapted to the natural characteristics and constraints[20] of the mires and peatlands concerned.

13. The principle of species integrity: the ecological processes responsible for the survival of mire and peatland species should be protected and the habitats on which their survival depends maintained.[21]

14. The principle of compensation[22]: when the fundamental properties of mires and peatlands and their hinterlands are violated, other than in accordance with these principles, the cost of measures to prevent, control, reduce, repair, and compensate for any damage should be borne by the responsible party[23].

5.5 MODIFIERS

Guidance principles are general in nature and may be modified in practice[24]. Factors which modify principles are defined here as Modifiers. An example of a modifier taken from law and morality would be:

Principle: Thou shalt not kill.

Modifier: Special circumstances - for example self-defence.

The main modifiers for the guidance principles outlined in §5.4 above are SPACE and TIME (Table 5/5).

Thus, the conditions for Wise Use will differ in different regions, countries and areas. Wise Use in one particular peatland may not be Wise Use in another. Similarly, the conditions for Wise Use will differ at different points and over different periods of time. Wise Use under one particular circumstance may not be Wise Use under other circumstances and changes over time may alter Wise Use to unwise use.

Modifier	**Aspect**	**Explanation**
SPACE	Location	What might be relevant in Africa might not be at all relevant in Australia.
	Spatial scale	What might apply at national level might not apply at village level.
TIME	Point of time	What might be wise in 1980 might not be wise in 2020.
	Period of time	Wise over a decade may not be wise over a year.

Table 5/5 Illustrations of Modifiers of Space and Time

Examples of Principles combined with Modifiers would be :

a. **The principle of re-location**: those activities that are exceptionally harmful to the fundamental properties of mires and peatlands and their hinterlands, and cannot be avoided, should be relocated to areas where they will cause less impact.

Modifier: SPACE

Example of combination: A small operator at local level may have no opportunity to re-locate: she cannot follow the principle without wiping herself out. She cannot be blamed for this if she has no alternative. Thus she has to take the decision to remain in the location. At a national level, a government could intervene and make an alternative location, or compensation, available.

b. **The "polluter pays" principle**: The cost of measures to prevent, control and reduce damage to the fundamental properties of mires and peatlands should be borne by the responsible party.

Modifier: TIME.

Example of combination: In a case where immediate compensation could bankrupt an enterprise, it might be better to wait until the enterprise had sufficient means to compensate adequately.

5.6 INSTRUMENTS

Instruments are mechanisms which facilitate the application of the modifiers of time and place to the guidance principles. There are instruments at a variety of levels, including (but not limited to) at
- international level,
- regional level involving groups of countries,
- national[25] level,
- sub-national level involving provinces or regions,
- the level of the enterprise[26], and
- the level of the individual.

Decisions as to what is and what is not Wise Use have to be taken at all these levels simultaneously.

5.6.1 Instruments at an international level

(1) International law: International law is a body of rules of conduct accepted by participating countries and which regulate relations between them. International law is most frequently embodied in international agreements and conventions such as the Ramsar Convention and the Convention on Biological Diversity. A list of environmental conventions and agreements relevant to mires and peatlands is given in Appendix 7.

In this decision do the General Considerations or Guidance Principles need to be modified	
– because of the place regarding which the decision is taken	
– because of the spatial scale of the area regarding which the decision is taken	
– because of the time/date/era of the decision	
– because of the period over which the decision will have consequences.	

Table 5/6. Checklist against the Modifiers - Elements to be considered when decisions arise as to the use of a mire or peatland

(2) International co-operation: Formal channels of co-operation exist in the United Nations and its constituent bodies; in other international organisations; and through and between NGOs[27]. It is through such co-operation that agreement can be reached on global plans, structures for co-operation, and monitoring progress. It can also lead to international standardisation of terminology, compilation of comparable data, and agreed criteria for attaching importance to mires and peatlands.

The organisations sponsoring this document should take the lead in implementation by putting in place a mechanism whereby the actions at international level are (i) initiated, (ii) given target time-scales for implementation, and (iii) monitored.

(3) Guidelines for Global Action on Peatlands28 (GGAP): A specific example of an instrument in international co-operation is the "Guidelines for Global Action on Peatlands (GGAP) (§1.4). The principal "themes" identified in the GGAP are summarised in Chapter 1.

(4) Certification: Other industries including forestry and hydropower have drawn up systems for encouraging environmentally acceptable ways of conducting their business. In the case of hydropower[29] a set of ethical considerations, recommendations and guidelines has been compiled. In the case of forestry[30] a system of certification has been established. The essential elements of the forestry system are a set of Principles and Criteria to be followed in harvesting forestry products; the establishment of certifying organisations; and a Forestry Stewardship Council to accredit certifying bodies.

The system gives assurance to consumers that if they buy certified products these have been produced or harvested in accordance with accepted environmental principles. It gives assurance to wholesalers and retailers that they will not be subjected to negative publicity or campaigns. It gives the industry a context within which it can operate with predictability. It gives those interested in protecting the environment a way of using market forces to control or eliminate destructive processes and to change the way of thinking of the industry. The negatives of such a system include (a) for industry the cost; (b) for environmentalists the fact that it controls but may not eliminate the harvesting of virgin forests or the flooding of valleys; and (c) there remain markets in which uncertified products can be sold. Eco-labelling can be used as part of such a system. Eco-labelling is a process by which an agreed authority certifies that a product has been produced in an environmentally friendly way.

The peat industries, including extraction, agriculture and forestry might or might not lend themselves to certification systems. Such a system is, however, an available instrument to be considered.

5.6.2 Instruments at regional level involving groups of countries

A number of regional bodies have been set up by groups of countries in different parts of the world. They have available to them similar instruments to those available at international and national levels. For example regional international law can be established by treaties between these countries, they could agree on common licensing systems and they could co-operate on the establishment of protected areas.

5.6.3 Instruments at a national level

(1) Public policy and administration: Each country should provide a context of national policies within which Wise Use decisions can be made. National policies should cover environmental protection, land use planning, the development of industry and agriculture, property rights and other relevant matters.

Action	Name of organisation taking lead responsibility	Status of Action taken
Establishment of structures for co-operation[32]		
Establishment of structures for monitoring progress		
Development and application of standardised terminology and classification systems.		
Establishment of a global data base of mires and peatlands.		
Establishment of criteria to attach international importance to individual mires and peatlands		
Detecting changes and trends in the quantity and quality of the peatland resource		
Development and implementation of peatland education and public awareness		
Ensuring that policy and legislative instruments are in place		
Development and use of wise use guidelines		
Put in place research networks, regional centres of expertise and institutional capacity		
Establish communication and co-ordination mechanisms for implementation and support.		

Table 5/7. Checklist to follow up on action at international level[31].

National policies should, in general, be implemented through legislation, stimulation (incentives), and education. There should be an adequate public administration function to administer these instruments in regard to mires and peatlands, and to carry out the necessary regulatory functions.

Relevant national policies[33] should, inter alia, include

1. promoting the formulation and implementation of a Wise Use strategy for mires and peatlands, including a peatlands conservation strategy;
2. increasing knowledge and promoting public awareness of peatlands and their values through education and the mass media;
3. carrying out an inventory of peatland in different categories (classes and degrees of use or degradation),
4. applying an internationally agreed classification system for peatland types;
5. placing responsibility for peatlands within a transparent administrative system and establishing or strengthening mire- and peatland-related institutions;
6. supporting research into mires and peatlands.

(2) Legislation[34]: The *Wise* Use of mires and peatlands should, in each country, take place in a context of legislation. Legislation should cover such areas as

- Land-use planning
- Protection of wildlife, of habitats and of specific areas[35]
- Environmental protection, including the licensing of industrial, agricultural and service activities likely to impact on the environment.

International agreements (including, but not restricted to, the Ramsar Convention and the Convention on Biological Diversity) should be incorporated into domestic legislation.

(3) Land-use planning: Land-use planning is a process or procedure to plan the use of land for the common good. It is carried out, as appropriate, by State, Regional or Local Government authorities. Land-use planning involves

- The preparation and updating of a development plan for each area, setting out the overall strategy for the planning of the area. Such a plan provides for the zoning of land for particular uses; the provision for infrastructure; conservation and protection; integration with the social, community and cultural requirements of the area and its population; the preservation of the character of a landscape; and the control of building and other development.
- A system of controls by the Planning Authority which controls the carrying out of any works in, on, over or under land in accordance with the area plan. It involves the Planning Authority giving or refusing permission for the use or development of land, and the setting of conditions for that use or development.
- Public access to, and participation in, the planning process.

Planning laws normally provide for the use of Environmental Impact Assessments (EIAs), whereby the probable or possible impact on the environment of a proposed project is assessed. An Environmental Impact Statement (EIS) is a written document submitted by, or on behalf of, a developer to a Planning Authority. It is a public document, part of a process of public consultation and participation[36]. It is advisable for land-use planning officials to be aware of the values and functions of peatlands.

(4) Licensing: All development of peatlands should take place within a national environmental licensing system. Such a system should be enshrined in law and should govern the licensing and regulation of industrial and agricultural processes on mires and peatlands as part of an overall licensing system. The purpose of a licensing system is to prevent or eliminate environmental pollution, or where that is not practicable, to limit, abate or reduce it. The system should seek to control emissions of pollutants into the air, and the discharge of solid or liquid effluent into water or their deposit on or in the ground, and the disposal of waste. Such legislation normally involves the establishment of an independent agency to carry out the licensing and to monitor the implementation of licence conditions.

In the case of developments on peatlands, a licence should govern the emission of dust into the air, the release of particulates into watercourses, noise disturbance from operations, and other relevant matters. Licences should ensure the responsible planning of the after-use of cutaway peatlands.

(5) Property rights and compensation: In any country the legal basis for ownership, and the pattern of ownership of mires and peatlands, is fundamental to the implementation of any Wise Use guidelines. For example, in Canada large areas of mires and peatlands are owned by the State, which can decide on whether or not to allow a mire or peatland be developed. In Ireland bog ownership is divided between small plots used for the extraction of sod peat for domestic heating: a decision, for example, to cease development on a bog would have serious income implications for large numbers of people. In Finland and Sweden mires and peatlands are owned by landowners, who lease them to forestry developers or extraction companies and who naturally expect a say in what happens to their property. In Lower Saxony in Germany the fact that the great majority of peatland was in private ownership has dictated its distribution between agriculture, peat extraction and pristine mires. In Kalimantan in Indonesia the lack of defined property rights has left to the government the power to designate/permit rights of usage.

The property and other rights of landowners and the rights of all those with an interest in land[37] should be well-defined and secure. Landowners and others with an interest in land should be fully compensated if public policy interferes with their rights. More detailed information on patterns of property ownership in some selected countries is given in Appendix 4 to this document.

(6) Rehabilitation of degraded peatland: The type of after-use which is appropriate for peatlands after they cease to be used for agriculture, extraction, or forestry will vary according to the extent of the resource in a country, drainage patterns and hydrological regime, sub-soil type and nutrient status, and socio-economic conditions. In each location and in each country the appropriate form of rehabilitation should be made a licensing condition for any new development on mires or peatlands.

(7) Establishment of Protected areas: Governments can provide legal protection[38] to mires and peatlands. Legislation varies from country to country as do its terms and designations. A designation available in all signatory countries is that of Ramsar site. Among the various terms used are “Special Areas of Conservation” and “Natural Heritage Areas” in the EU; “Nature Reserves” in Norway; “National Parks” and “Natural Monuments” in Japan[39]; “Nature Reserves” (zapovedniks) and “Wildlife Refuges and other resource areas” (zakazniks) in Russia[40]; “National Park” in Poland[41]; “Managed Resource Area” in Lesotho[42]. The level of legal protection varies. Some categories of protected sites are set aside and actively supervised and managed to preserve them as they are. The protection given to other sites, for example, allows licensed activities to take place there. Notes on the six management categories agreed by IUCN are contained in Appendix 8.

(8) Education and Awareness[43]: Education is critical for promoting sustainable development and improving the capacity of people to address the conservation and development issues relevant to mires and peatlands. Education programmes related to mires and peatlands should follow the principles of environmental education.

Environmental education is education that helps people to understand the forces (both natural and man-made) which determine human behaviour in relation to the environment. Peatland education should include a broad base of understanding, experience and skills, that enable people to analyse and evaluate their own relationship to mires and peatlands on both a local and global scale. People also need to be taught skills that enable them to take part in decision-making and in actions as consumers and producers which will lead to a sustainable use of this resource.

Such a programme of education is life-long and aimed at all sectors in society - citizens, communities, business and industry. It may begin in schools but will also require a considerable re-design of professional and occupational training in higher education and in-service training.

The following are guidelines for such programmes of mire and peatland education:

1. They should be targeted at citizens, communities, industry and the non-institutional sector.
2. Support should be given for the development and dissemination of multi-disciplinary resources which are linked to the official curriculum and which focus on mires and peatlands as a topic for environmental education.
3. Every institute for further and higher education should be encouraged to produce a policy for the integration of mire and peatland education and Wise Use within all relevant courses.
4. Educators should be actively encouraged to make use of new resources through in-service training programmes.
5. A network of centres for mire and peatland education should be established, which would promote good mire and peatland education practice.
6. Communities, industry and the non-institutional sector should be empowered to prepare mire and peatland sites for educational use.
7. Citizens should be provided with educational materials that will enable them to make informed choices concerning lifestyle and consumer behaviour.

(9) Socio-economic policy: Some countries (or wider political bodies such as the EU) have socio-economic policies. Such policies often include a commitment to promoting economic activity or employment in particular regions. In some cases these policies may involve the utilisation of peatlands with a view to social benefits. For example employment[44] provided by Bord na Mona p.l.c in the midlands of Ireland and by Vapo Oy in the interior of Finland enables small farmers to earn enough money to keep their farms, and provides the possibility of wider economic activity in small towns and rural areas. Such socio-economic policies are usually incidental to energy or economic policies.

5.6.4 Instruments at sub-national level involving provinces and regions

(1) Integrated catchment management[45]: Integrated catchment management (ICM) is the management of rivers and the surrounding catchment or basin as a whole. Even remote ecosystems can be affected by the demands from distant urban areas. ICM is useful in identifying and solving such basin-wide problems, resolving sectoral conflicts and cross-boundary questions in the management of a water resource. It is particularly useful in

In relation to a particular country, has it or does it -	
Ratified the principal international environmental conventions and has it incorporated relevant international legislation into domestic legislation	
Have in place national policies relevant to mires and peatlands	
Have a body of relevant legislation governing land use planning and environmental protection.	
Have an adequate public administration function to administer legislation governing mires and peatlands.	
Have a comprehensive and participative land-use-planning system.	
Operate a system of licensing for the commercial development of peatlands.	
Have clear property laws where mires and peatlands are concerned incorporating a legal framework which protects the rights of individuals and communities over land	
Require the appropriate rehabilitation of mires and peatlands after use.	
Established sufficient protected areas according to internationally accepted criteria	
Have a policy for increasing knowledge and promoting public awareness of peatlands and their values through education and the mass media.	
Encourage the exercise of civic responsibility in regard, inter alia, to mires and peatlands.	
Play an active role in stimulating wise use policies at the internation al level	
Operate any incentives to develop mires and peatlands within the context of overall coherent economic and social policies.	

Table 5/8. Checklist of actions to be taken at national level.

Ensure that mires and peatlands are seen in the context of integrated catchment management.	
Apply the Ecosystem Approach to catchment management.	

Table 5/9 Checklist of actions to be taken at sub-national regional or local government level the management of mires and peatlands because they are sensitive to problems arising elsewhere in a catchment, and can adversely affect large areas outside their immediate vicinity when they are developed inappropriately.

(2) Ecosystem Approach[46]: The Ecosystem Approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. The principles involved are contained in Appendix 3 to this document.

Depending on the legislative system in a particular country some of the instruments at national level apply instead at the sub-national level.

5.6.5 Instruments at the level of enterprises[47]

(1) Corporate Governance and commercial strategy: Corporate governance is the system by which commercial companies and institutions are directed and controlled[48]. It is normal practice for boards of directors to be appointed in companies and institutions and for these boards to be responsible for their governance. The responsibilities of the board include setting the company's or institution's strategic aims, providing the leadership to put them into effect, supervising the management, and reporting on their stewardship to their shareholders (in the case of companies) or to their sponsors (in the case of institutions).

Where management, or development where such is permitted, of a mire or peatland is in the hands of a company or institution with strong and ethical corporate governance it is far more likely that the management and/or development will be carried out in a responsible manner. Where such bodies have well-thought-out commercial strategies they will only contemplate the development of a mire or peatland if it makes long-term commercial sense (cf. the principle of motivation at § 5.4 above). Good corporate governance combined with sound commercial strategy are unlikely to lead to piecemeal or short-term destruction of mires.

(2) Cost-benefit analysis[49]: Cost-benefit analysis (CBA) is a comparison of the estimated costs of an action with the estimated benefits it is likely or intended to produce. It is a technique to evaluate the worth of an idea or project; a measure of the extent to which the overall benefits outweigh the overall costs, and with how much certainty; and a comparison of alternatives - a Cost-benefit analysis of a single course of action cannot be carried out.

In summary, a Cost-benefit analysis should:

- describe the issue to be resolved;
- set out the proposal, the alternatives, the benefits and costs, the risks[50];
- calculate the Net Present Value[51] of the proposal and the alternatives;
- outline who will enjoy the benefits and when;
- outline the options included and those excluded; the assumptions made; and the period over which the analysis is calculated.

The use of cost-benefit analysis will not necessarily ensure the best use of a mire or peatland from an environmental perspective[52]. However, it would at least ensure that only viable proposals for development were implemented.

(3) Environmental Management System: An environmental management system is a structured system, integrated into the overall management process, which monitors and controls the impact of an enterprise's activities on the environment. The enterprise first establishes an environmental policy with stringent objectives and then puts in place procedures to achieve conformance with these objectives. An essential part of a management system is that it be audited, preferably by an external certifying authority. An example of an internationally accepted standard for environment management systems is the ISO 14001 standard. Smaller enterprises may not have the resources to aspire to a full international standard, but can implement simple but effective systems.

(4) Rehabilitation of degraded peatland: It is the responsibility of the exploiting enterprise to ensure the implementation of the type of after-use which was made a licensing condition. The appropriate form of rehabilitation should be planned in advance.

The restoration of peatlands to peat-accumulating ecosystems has been undertaken in, among others, Germany[53], Belarus[54], Finland[55], Canada[56] and the U.S.A[57]. In Finland[58] and Ireland[59], large areas of peatlands from which peat has been extracted for energy use are suitable for agriculture and forestry. In Ireland[60] and Finland[61] wetlands have been formed from cutaway peatland creating habitats for a variety of vegetation and wildlife. Areas of cutaway peatland have also been allowed to re-vegetate naturally[62].

In rehabilitating degraded peatland attention should be paid to the whole scale of potential mire and peatland functions and values, including among others (i) restoring or re-creating habitats, (ii) the effects on the carbon balance and (iii) the effects on local hydrology of the chosen after-use.

(5) Education and Awareness: The responsibility to provide education and awareness programmes lies not only at the national level, but also at the level of the enterprise, in accordance with the scale of the enterprise.

(6) Technology Improvement: Enterprises extracting or using peat can avail of technology improvements to reduce emissions of all kinds. Manufacturing and combustion technologies improve all the time, and the use of these technologies, for example, in briquette factories and power generation units, can greatly improve environmental performance. Similarly, agriculture and forestry can optimise the relationship between maximum productivity and minimum negative environmental side-effects by adapting land management, drainage and fertilisation intensities, frequencies, and techniques.

(7) Product diversification: Enterprises extracting peat for use as a soil improver or manufacturing peat-based growing media can also use their expertise to manufacture growing media containing alternative materials (see Table 3/6) such as green waste, coir and bark.

(8) Alternative energy: Peat extraction companies often have access to large areas of land, particularly cutaway, which could be used for alternative energies such as the growing of biomass or the establishment of wind farms.

(9) Codes of conduct: Codes of conduct are dealt with at 5.7 below. They are can be used as instruments at the level of the enterprise to ensure compliance with the Framework.

5.6.6 Instruments at the level of the individual person

(1) Civic responsibility: It is in no single individual's immediate interest to moderate his or her consumption or behaviour. However where, through international agreement or national policies or legislation, norms of behaviour are established individuals should exercise civic responsibility in abiding by these norms. Even when such laws and agreements have not been established every individual has to take responsibility for the results of his or her actions[63].

Does the enterprise conduct all activities which exploit mires or peatlands on the basis of sound commercial strategy.	
Does the enterprise with responsibility for mires or peatlands operate on the basis of accepted principles of corporate governance.	
Are all decisions to exploit a mire or peatland taken on the basis of cost-benefit analysis.	
Does the enterprise operate an environmental management system.	
Does the enterprise have an acceptable policy on the after-use of degraded peatlands.	
Does the enterprise promote knowledge and awareness of mires and peatlands.	
Does the enterprise, if involved in agriculture, horticulture or forestry on peatlands, have a policy to minimise negative environmental side effects by adapting land management, drainage and fertilisation intensities, frequencies, and techniques.	
If the enterprise extracts peat for energy generation does it have a policy of using the latest available technology with respect to impact reduction.	
If the enterprise extracts peat for energy generation, does it also promote the use of alternative energies.	
If the enterprise extracts peat for use as a soil improver or in growing media does it conduct research into, and/or use, alternative growing media.	
Does the enterprise take its decisions in relation to mires and peatlands in accordance with the criteria outlined in Tables 5/3 and 5/4.	
Does the enterprise play an active role in stimulating Wise Use policies on the regional, national and international level.	

Table 5/10. Analysis to be undertaken at enterprise level

(2) Education and Awareness: It is not enough for countries or enterprises to make information available, it is also necessary for individuals to inform themselves and to avail of the programmes which are put in place[64].

5.7 CODES OF CONDUCT

Codes of conduct consist of lists of criteria to be applied to the circumstances of a particular case. Two examples are given in the appendices to this document:

– Appendix 5: Code of conduct which might be applied by a wholesale or retail company to its suppliers of peat-based horticultural products;
– Appendix 6: Code of conduct which might be applied by a regional or local government or administrative authority to a facility for the conversion of peat to energy.

These are examples only. Actual codes of conduct have to be drawn up by the principals in each case. There are many other circumstances in which codes of conduct might be drawn up - for example governing the afteruse of cutaway peatland. An example of an existing document which could be used as a code of conduct in particular circumstances would be the list of actions appended to the Penang Statement on Tropical Peatlands[65].

Codes of conduct can be drawn up to replace parts of this Framework. For example, in countries or provinces which do not have in place some or all of the "instruments at a national level" codes of conduct could be used in their stead.

5.8 NON-ANTHROPOCENTRIC APPROACHES[66]

In §3.2 the question of attributing intrinsic value to entities other than human beings was raised. In §4.10 a brief outline of non-anthropocentric approaches was given.
The acknowledgement of a right to subsistence, freedom, and autonomy of non-human entities - independent of their contribution to the fulfilment of human needs and wants - leads to competing moral claims when the interests of human beings and non-human entities clash[67].

Conflicts between human and non-human interests cannot be resolved by simply giving greater weight to human claims[68] and thereby letting them override the competing claims of non-human entities. This does not imply that we may never harm other entities under any circumstances whatever[69]. Any harm we inflict, however, must be justified by a valid moral reason[70].

Attributing intrinsic value to non-human entities (such as species and ecosystems) would impose additional boundaries[71] to human behaviour[72]. Additional rules would also be required because non-human entities cannot defend their own position[73]. Whereas information exchange, discussion, negotiation, and fair compromises may contribute substantially to resolving inter-human conflicts, in conflicts between human and non-human interests only human beings can decide to adjust their behaviour.

Parallel to the Universal Declaration of Human Rights, a non-anthropocentric approach would imply that no harm be done to any entity with intrinsic value[74] and that no constraints be placed on the freedom of such entities[75]. These veto duties[76] would prohibit the doing of harm, but would not prescribe the counteracting of harm that is not caused by human beings[77].

Additional principles of a non-anthropocentric approach might include:

The principle of self-defence: Interventions in the basic interests of non-human entities, including their killing or destruction, are allowed if no other possibility exists to save human lives from serious threats arising from these entities.

This principle is based on the fact, that - in a situation of equal value of different entities - it can not be expected that one sacrifices oneself when another entity (e.g. an animal, a virus, a storm, a meteorite) behaves harmfully.

The principle of proportionality: Where there is a conflict between human interests and those of non-human entities, basic interests ("needs") prevail over non-basic interests ("wants"), no matter from which entities, human or other, the competing claims arise.

This principle would reflect General Consideration 1 of the anthropocentric approach in §5.3. To asses the needs of non-human entities, human beings can seek to understand their standpoint and judge what is, from their point of view, important or not important for their overall well-being. With respect to animals, ethology (behavioural studies) may facilitate such assessment. This principle implies, for example, that - in case of pathocentrism or biocentrism - it is not permissible to kill animals "just for fun" as in recreational hunting and fishing.

The principle of distributive justice: When the basic interests ("needs") of human beings compete with the basic interests ("needs") of non-human entities, both interests should be fairly taken into account.

The principle of distributive justice would require us to devise ways of transforming situations of confrontation between human beings and non-human entities into situations of mutual accommodation whenever possible[78]. Sometimes, however, the clash between basic human interests and the basic interests of non-human entities could not be avoided. The most obvious case would arise from the need for human beings to consume non-human beings as food. The principle of distributive justice entails that it is morally permissible for human beings to kill other organisms for survival. For if human beings refrained from eating other organisms they would be sacrificing their lives for the sake of these other organisms. The other organisms are not of greater intrinsic value, so there is no obligation to further their interests at the cost of the basic interests of human beings.

The principle of restitutive justice: When non-human rights have been infringed by human beings, the harm has to be compensated or repaired.

This principle parallels the anthropocentric principle of compensation. It should apply whenever the application of the principle of distributive justice leads to an inevitable injustice to non-human entities. In order to restore the balance of justice between human beings and non-human entities, the compensation should provide an amount of good that equals (as far as can be reasonable estimated) the amount of harm to be compensated for.

This section reflects a premise of this document that it is essential to listen to and consider different points of view if conflicts are to be resolved. As mentioned in §3.2, participants in any given conflict may include both anthropocentrists and non-anthropocentrists. As stated in that section, convergence at the level of practical conclusions may be reached in spite of participants starting from different premises.

5.9 DIALOGUE

In the resolution of conflicts regarding mires and peatlands, the most important ***General Consideration*** is that parties may have different moral positions and that they have the right to have different preferences; the most important ***principle***s are those of clarity, information, motivation, and responsibility; the ***modifier*** takes into account that aspects of space and time may modify the principles (while recognizing that there is also responsibility for the larger scale and longer term); the most important ***instrument*** is dialogue.

One of the reasons why this document has gone to such lengths to discuss the characteristics of peatlands, different approaches to values, and the causes of conflicts is that understanding the other side's point of view is the first and essential step in dialogue. The decision framework which this document recommends is a rational procedure which, if followed, should resolve or minimise most conflicts. It can only do so, however, if it is informed by understanding and conducted through dialogue.

A Framework informed by knowledge and rationality will not remove emotion, vested interest or political manoeuvring from conflicts. It will, however, provide decision-makers with a basis for deciding between different options. If the parties to a conflict cannot be brought to agree, at least those deciding between them have a basis for wise decisions.

5.10 CONCLUSION

The four operative chapters of this document outlined

what are mires and peatlands - their main characteristics - how widespread they are and where they are found

why people attribute value to other beings and things - the types of human values - the values of mires and peatlands - their functions that give rise to these values

why conflicts arise - the difference between needs and wants - rights - the types of conflicts - conflicts arising from different approaches to values - the bases for resolving conflicts

a basis for conflict resolution to be found in a rational decision-making process based on an understanding of the different values of opposing parties - identifying in each case what is essential, whether resources are abundant, the potential negative effects of a decision, the potential benefits, and the circumstances and conditions which will apply in the case of implementation. The decision-making process is summarised again in Figure 5/3.

For this Wise Use Framework to be of value two steps need to be taken -

- it should be widely disseminated and communicated, and
- the bodies which participated in its preparation should continue their co-operation to establish a global data base of mires and peatlands, standardised terminology and classification systems, international criteria for peatland valuation, and a means of tracking changes in the peatland resource.

It is hoped that this document will contribute to a wider understanding of mires and peatlands and their many functions, and that it will in practice help in avoiding or resolving future conflicts. For it to succeed it will need to form the basis of continuing co-operation between those who have helped to create it.

This summary Figure outlines the structure of the Framework but does not include all the elements at each stage of the process

Criteria for decision
- will the intervention satisfy human needs
- are the resources to be provided essential for human life
- can the resource or service be provided continuously
- are the resources abundant
- would the intervention negatively affect other functions.

General Considerations
- would the intervention affect human rights
- does it relate to needs or wants
- would the benefits accrue widely or just to a privileged few
- is the intervention the best way to achieve the desired aims

Principles
- is everyone is talking the same language
- has adequate information been made publicly available
- will the intervention produce greater advantage than not intervening
- other Principles ...

Modifiers
should the Principles be modified because of when or where the proposed intervention is to occur

Instruments based on countries
will the intervention
- take place in a context of national policies
- be governed by land-use-planning and licensing laws
- require rehabilitation after use
- be governed by other instruments ...

Instruments based on enterprises
Will the enterprise undertaking interventions employ
- good corporate governance and commercial strategy
- cost-benefit analysis
- environmental management systems
- other appropriate instruments ...

Figure 5/3 Framework for making decisions on interventions in peatlands

1 World Commission on Environment and Development, 1987, as quoted in §3.2.

2 Rio Declaration (UNED 1992) as quoted in §3.2.

3 Throughout this document the words 'use' and 'intervention' are employed to include any decision on a peatland - be it a decision to drain a mire or one to preserve it.

4 Cf. Convention on Biological Diversity (Rio de Janeiro, 5 June 1992): "*Sustainable use*" means the use of components of biological diversity **in a way and at a rate that does not lead to the long-term decline** of biological diversity, ...".

5 For example, the effect of a function (peat for horticulture) on the function itself (peat for horticulture). In this case question 3 might read "Does the use of this peat for horticulture enable the continuous provision of peat for horticulture?". Question 4 might read "Are sphagnum peat mires abundant and do they remain abundant?" The effect of a function on other functions is dealt with in Table 5/2. In this case the questions in Table 5/2 would examine the effect of peat for horticulture from this mire (a production function) on e.g. the hydrology of the catchment (a regulation function).

6 In the sense of the physical survival of the person.

7 From a societal point of view, it might be **wiser** not to do so, but that is a matter of precedence and priority (see §4.6 and §4.7) and of different focal points of responsibility at different organisational levels (see the "principle of responsibility" in §5.4(6)).

8 See §3.4.

9 Guideline A1 of the GAP: see §1.4 and Ramsar 2001.

10 Cf. UN General Assembly Resolution 37/7 and Annex (28 October 1982): "16. All planning shall include, among its essential elements, the formulation of strategies for the conservation of nature, the establishment of inventories of ecosystems and assessments of the effects on nature of proposed policies and activities; all of these elements shall be disclosed to the public by appropriate means in time to permit effective consultation and participation."

11 In the widest sense of the word.

12 Again, in the widest sense of the word.

13 A greater advantage for society may consist of:
- a greater benefit for all present and future members of society, or
- a greater benefit for the less favoured (cf. §4.6).

14 Cf. UN General Assembly Resolution 1803 (XVII) on Permanent Sovereignty over Natural Resources (14 December 1962): "1. The rights of peoples and nations to permanent sovereignty over their natural wealth and resources must be exercised in the interest of their national development and of **the well-being of the people** of the State concerned."
Cf. Declaration of the United Nations Conference on the Human Environment (Stockholm, 16 June 1972): "Principle 2: The natural resources of the earth, including the air, water, land, flora and fauna and especially representative samples of natural ecosystems, must be safeguarded for the benefit of **present and future generations** through careful planning or management, as appropriate. ... Principle 5: The non-renewable resources of the earth must be employed in such a way as to guard against the danger of their future exhaustion and to ensure that benefits from such employment are shared by **all mankind**."
Cf. UN Framework Convention on Climate Change (New York, 9 May 1992): "Affirming that responses to climate change should be coordinated with social and economic developments in an integrated matter,..., taking into full account the legitimate priority needs of **developing countries** for the achievement of sustained economic growth and the eradication of poverty. ... Article 3.1. The Parties should protect the climate system for the benefit of **present and future generations of humankind...**".
Cf. the Convention on Biological Biodiversity (Rio de Janeiro, 5 June 1992): "Recognizing that economic and social development and poverty eradication are the first and overriding priorities of **developing countries**, Aware that conservation and sustainable use of biological diversity is of critical importance for meeting the food, health and other needs of **the growing world population...**; ."sustainable use" means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of **present and future generations**."
Cf. The Rio Declaration on Environment and Development (Rio de Janeiro, 13 June 1992): "Principle 3: The right to development must be fulfilled so to equitably meet development and environmental needs **of present and future generations....** Principle 8: To achieve sustainable development and a higher quality of life **for all people**, States should reduce and eliminate unsustainable patterns of production and consumption..." (our emphasis).

15 Cf. UN General Assembly Resolution 37/7 and Annex (28 October 1982): "11. (b) Activities which are likely to pose a significant risk to nature shall be preceded by an exhaustive examination; their proponents shall demonstrate that expected benefits outweigh potential damage to nature, and where potential adverse effects are not fully understood, the activities should not proceed.. (c) Activities which may disturb nature shall be preceded by assessment of their consequences, and environmental impact studies of development projects shall be conducted sufficiently in advance, and if they are to be undertaken, such activities shall be planned and carried out so as to minimise potential adverse effects. ... 15. Knowledge of nature shall be broadly disseminated by all possible means, particularly by ecological education as an integral part of general education. ... 18. Constant efforts shall be made to increase knowledge of nature by scientific research and to disseminate such

knowledge unimpeded by restrictions of any kind. 19. The status of natural processes, ecosystems and species shall be closely monitored to enable early detection of degradation or threat, ensure timely intervention and facilitate the evaluation of conservation policies and methods."
cf. The Rio Declaration on Environment and Development (Rio de Janeiro, 13 June 1992): "Principle 17: Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority."

[16] As individuals we pursue self-interest, largely heedless of the cumulative effects of our individual actions. Though the maintenance of a healthy environment is in everyone's general interest, it is in no individual's personal interest to moderate his or her consumption. Eventually, a tragedy may result (Hardin 1968), unless the community sets limits to individual consumption.

[17] Cf. The World Charter for Nature (UN General Assembly Resolution 37/7 and Annex, 28 October 1982): "7. In the planning and implementation of social and economic development activities, due account shall be taken of the fact that the conservation of nature is an integral part of those activities. ... 10 (b) The productivity of soils shall be maintained or enhanced through measures which safeguard their long-term fertility and the process of organic decomposition, and prevent erosion and all other forms of degradation. (c) Resources, including water, which are not consumed as they are used shall be reused or recycled. (d) Non-renewable resources which are consumed as they are used shall be exploited with restraint, taking into account their abundance, the rational possibilities of converting them for consumption, and the compatibility of their exploitation with the functioning of natural systems. 11. Activities which might have an impact on nature shall be controlled, and the best available technologies that minimize significant risks to nature or other adverse effects shall be used; in particular (a) Activities which are likely to cause irreversible damage to nature shall be avoided. ...(c) Activities which may disturb nature ... shall be planned and carried out so as to minimise potential adverse effects".

[18] Including if necessary a ban on exploitation.

[19] cf. The Rio Declaration on Environment and Development (Rio de Janeiro, 13 June 1992): "Principle 15: In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental damage." U.N. - Agenda 21.

[20] Cf. UN General Assembly Resolution 37/7 and Annex (28 October 1982): "11 (d).Agriculture, grazing, forestry and fisheries practices shall be adapted to the natural characteristics and constraints of given areas".
See also the definition of Wise Use by the Ramsar Convention: "their sustainable utilisation ... in a way compatible with the maintenance of the natural properties of the ecosystem" (see §1.2).

[21] Cf. The World Charter for Nature (UN General Assembly Resolution 37/7 and Annex, 28 October 1982): "2. The genetic viability on the earth shall not be compromised; the population levels of all life forms, wild and domesticated, must be at least sufficient for their survival, and to this end necessary habitats shall be safeguarded. 3. All areas of the earth, both land and sea, shall be subject to these principles of conservation; special attention shall be given to unique areas, to representative samples of all the different types of ecosystems and to the habitats of rare or endangered species.. ... 10 (a) Living resources shall not be utilized in excess of their natural capacity for regeneration."

[22] Cf. Declaration of the United Nations Conference on the Human Environment (Stockholm, 16 June 1972): "Principle 3: The capacity of the earth to produce vital renewable resources must be maintained and, wherever practicable, restored or improved."
cf. UN General Assembly Resolution 37/7 and Annex (28 October 1982): "11 (e) Areas degraded by human activities shall be rehabilitated for purposes in accord with their natural potential and compatible with the well-being of affected populations".

[23] Cf. The Rio Declaration on Environment and Development (Rio de Janeiro, 13 June 1992): "Principle 16: National authorities should endeavour to promote the internalisation of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment."

[24] Cf. UN Framework Convention on Climate Change (New York, 9 May 1992): "Recognising ... that standards applied by some countries may be inappropriate and of unwarranted economic and social costs to other countries, in particular developing countries. ... Article 3.1 The Parties should protect the climate system ... in accordance with their common but differentiated responsibilities and respective capabilities....".

[25] In the case of some instruments at national level, they are agreed between groups of countries. An example of this is the European Union.

[26] Examples: responsible implementing body, commercial company, community group, village.

[27] Non-governmental organisations such as the World Conservation Union, the International Peat Society, the International Mire Conservation Group, Wetlands International and the Society of Wetland Scientists.

[28] Ramsar 2001.

[29] International Energy Agency 2000.

[30] www.fscoax.org

[31] Based largely on the Guidelines for Global Action on Peatlands (GGAP), Ramsar 2001.
[32] Including, for example, international co-operation under the Ramsar Convention.
[33] Cf. Safford & Maltby 1998.
[34] Cf. Shine & de Klemm 1999.
[35] National parks, nature reserves, areas of conservation, heritage areas, sites of scientific interest. See also " (7) Establishment of Protected Areas" below.
[36] Cf. Shine & de Klemm 1999, pp 221-225.
[37] E.g. rights of commonage, grazing rights, traditional rights of indigenous peoples, hunting rights.
[38] For a detailed description of the legal protection process in Switzerland see Kohli 1994. A similar description for Norway is to be found in Moen 1995b.
[39] Iwakuma 1995.
[40] Minaeva & Sirin 2000.
[41] Okruszko & Byczkowski 2000.
[42] Backéus & Grab 1995.
[43] Based on information provided by Catherine O'Connell. See also Guidelines D1 to D4 of the GGAP - Ramsar 2001.
[44] See §3.4.6.
[45] Safford & Maltby 1998.
[46] UNEP 2000. The Ecosystem Approach is an instrument intended for implementation at a variety of levels. For convenience it has been included at the sub-national level.
[47] 'Enterprises' include responsible implementing body, commercial company, community group, village.
[48] Cf. Cadbury 1992.
[49] Jeffreys 1995; Fricker n/a. Cost-Benefit Analysis is an instrument intended for implementation at a variety of levels. For convenience it has been included at the enterprise level.
[50] Elements of Life Cycle Analysis and chain analysis should be included in the Cost-benefit analysis and the Environmental Impact Assessment. This is in order to take into consideration indirect effects such as changes elsewhere in the market caused by the action, or the consequences of people changing the location of their jobs.
[51] Net Present Value is a method of expressing future amounts in current terms. This is done by discounting an amount by a percentage for every year into the future.
For example, an annual cost of $1,000 over 3 years, discounted at a compounding discount rate of 10% would appear at present as:
- 1st year = $1,000 (no discounting)
- 2nd year = $900 ($1,000 less 10%)
- 3rd year = $810 ($1,000 less 10%, then less 10% again)

The actual Net Present Value is calculated by subtracting the present value of all costs from the present value of all benefits for an option. It can be difficult to put a monetary value on such benefits as biodiversity or naturalness (cf. §4.8).
[52] See discussion in §4.8.
[53] Blankenburg 1996, Blankenburg & Hennings 1996, Kratz & Pfadenhauer 1996.
[54] Bambalov et al. 1996.
[55] Vasander & Roderfeld 1996.
[56] Boudreau & Rochefort 2000, Le Quéré & Samson 2000.
[57] Johnson et al. 2000.
[58] Vasander & Roderfeld 1996.
[59] O'Malley 1988.
[60] McNally 1996.
[61] E.g. Vikberg 1996.
[62] Rowlands & Feehan 2000.
[63] Cf. Joosten 1997.
[64] Persons who refuse to inform themselves and thus to modify their behaviour appropriately are said to suffer from "invincible ignorance."
[65] Ramsar 1999.
[66] Non-anthropocentric approaches are highly diverse with respect to what entities are considered to have intrinsic moral value and regarding the characteristics by which this value is judged (see Tables 3/1 and 3/2). In contrast to anthropocentrism (see the Universal Declaration on Human Rights and associated judgement systems in §4.6), hardly any generalised rules / principles / guidelines have been formulated for the multitude of non-anthropocentric approaches. This section illustrates the kind of reflections that follow from a non-anthropocentric approach. It is inspired by the biocentric considerations of Taylor (1986) and departs from the presumption that all entities with intrinsic value have equal value.
[67] Not all types of conflicts identified in §4.3 can occur between humans and nonhumans. Conflicts dealing with different understanding, different judgements, and different positions do not apply, because such conflicts require a high level of self-consciousness and abstraction, that is largely lacking outside the human realm. The most common conflict type is the conflict between different precedences, i.e. between "me" and "you", "those here" and "them there", and "some few" and "that many" in which the subjects now also include nonhuman entities.
[68] In anthropocentrism non-human entities do not belong to the same value category as human beings. Human beings are considered to have both intrinsic and instrumental value, whereas other entities only have instrumental value. In non-anthropocentric approaches non-human entities also have intrinsic value. It is a matter of much debate whether value differences exist within the category of intrinsic value, i.e. whether some entities are intrinsically more valuable than others, and what characteristics would inspire such differences. The acceptance of differences could imply that value graduations have also to be made between human beings, i.e. that some human beings have to be considered as intrinsically less valuable than others (Gorke 1999). See also § 4.10.
[69] Taylor 1986; cf. §5.5.
[70] Cf. §4.9.

Surwold Meeting, Germany. Photo: Raimo Sopo, November 1997. (§ 1.3)

The Murnauer Moos, one of the last living mires of Germany. Photo: Michael Succow, October 1997. (§ 2.3)

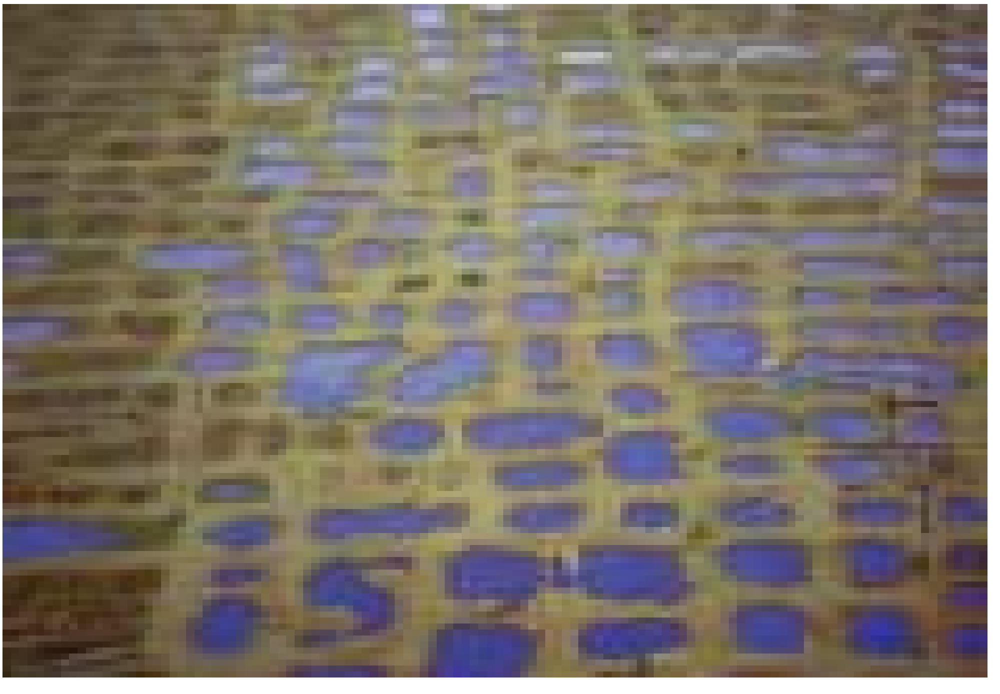
Martimoaapa, a large mire complex in northern Finland. Photo: Aarno Torvinen. (§ 2.3)

Kettlehole mire on the Onega peninsula, White Sea, Russia. Photo: Michael Succow, July 1997. (§ 2.3)

Peatland-lake landscape in West Siberia, Russia. Photo: Michael Succow, August 2001. (§ 2.3)

Palsa mire in the central part of West Siberia, Russia. Photo: Andrej Sirin. (§ 2.3)

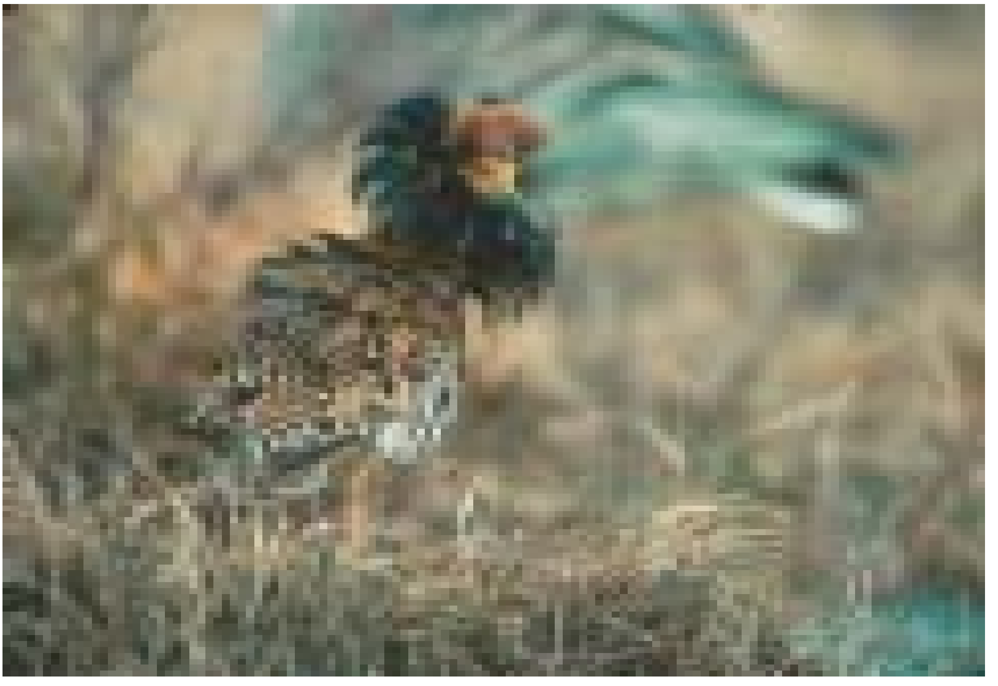
Polygon mires from aircraft. Northern part of West Siberia, Russia. Photo: Ludmila Usova. (§ 2.3)



Polygon mires in the Lena Delta, Yakutia, Russia. Photo: Michael Succow, August 1997. (§ 2.3)

Marine transgression mires (left) bordering bogs (right) in the Northern Dwina area, Archangelsk, Russia. Photo: Michael Succow, June 1999. (§ 2.3)

The red Sphagnum magellanicum, *one of the most abundant* Sphagnum *species in the world, in Tierra del Fuego, Argentina. Photo: Hans Joosten, March 2000. (§ 2.7)*



*Ruff (*Philomachus pugnax*), Finland. Photo: Markku Aikioniemi. (§ 2.7)*

Sloping fen on the Onega peninsula, White Sea, Russia, with Eriophorum latifolium (Cyperaceae)*. Photo: Michael Succow, July 1997. (§ 2.7)*

Bog prepared for milled peat extraction, Ireland. Photo: Bord na Móna. (§ 3.4.1 (a))

Vacuum harvester, Canada. Photo: Premier Tech. (§ 3.4.1 (a))

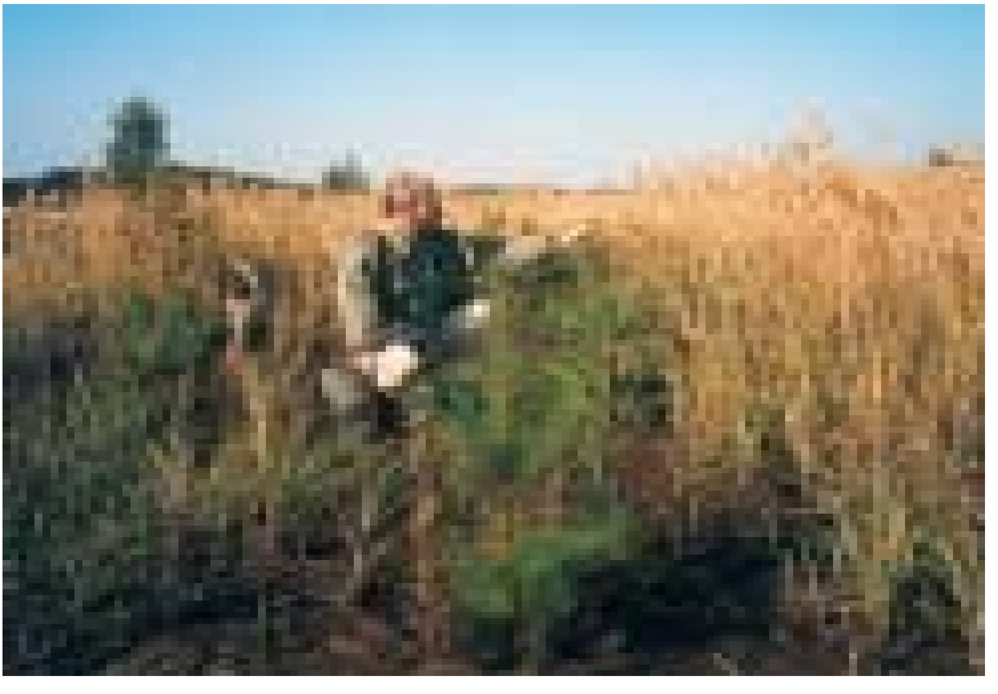
*Lettuce (*Lactuca sativum *var*. capitáda*) grown in a peat-based blocking medium, Germany. Photo: Klasmann-Deilmann GmbH. (§ 3.4.1 (ab))*

Litter peat used as bedding material for cattle, pigs, poultry, and horses, Finland. Photo: Vapo Oy. (§ 3.4.1 (ac))

Peat-fired power station, Edenderry, Ireland. Photo: Bord na Móna. (§ 3.4.1 (ac))

Reed canary grass (Pharalris arundinacea) for energy production, grown on cutaway peatland sites, Finland. Photo: Vapo Oy. (Table 3/9)

Cloudberries, Finland. Photo: Aarno Torvinen. (§ 3.4.1 (ca))



Scots Pine seedlings planted on a cutaway peatland in Vasikkaneva, Finland. Photo: Raimo Sopo, September 2001. (§ 3.4.1 (ea))

Cattle on a meadow established on a cutaway peatland in Valkeasuo, Finland. Photo: Raimo Sopo, July 2001. (§ 5.6.5 (4))

Cranberry field, Québec, Canada. Photo: Gerry Hood. (§ 3.4.1 (ea))

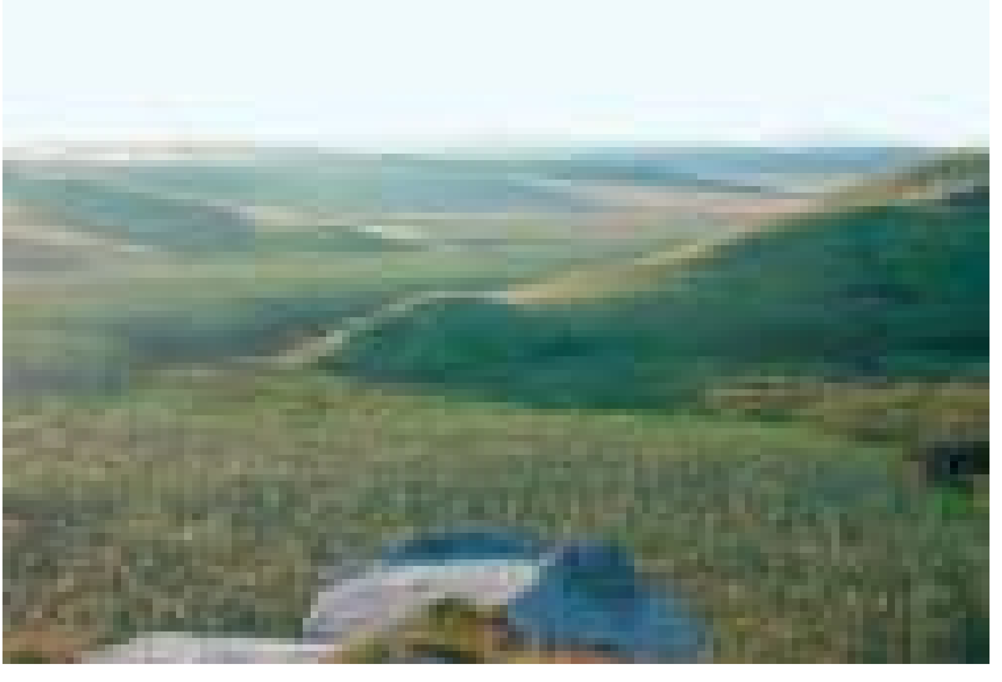
Mega Rice project drainage and irrigation channel in 1999, excavated along a tropical peatland watershed in Central Kalimantan, Indonesia. Photo: Jack Rieley & Susan Page. (§ 3.4.1 (ea))

Tropical agriculture: smallholding on tropical peat near Kalampangan, Central Kalimantan, Indonesia. Photo: Jack Rieley & Susan Page. (§ 3.4.1 (ea))

Pristine peat swamp forest, Central Kalimantan, Indonesia Photo: Jack Rieley & Susan Page. (§ 3.4.1 (eb))

Wood harvesting from a drained peatland area during summer, Finland. Photo: Juhani Päivänen. (§ 3.4.1 (eb))

*Recently excavated ditch in peat soil. Mixed tree stand (*Pinus sylvestris, Betula pubescens *and* Picea abies*), Southern Finland. Photo: Juhani Päivänen. (§ 3.4.1 (eb))*



The Watervalvlei mire, an almost pristine percolation peatland in the Highveld of South Africa, threatened by inundation for hydro-electricity. Photo: Jan Sliva, March 2001. (§ 3.4.2)

Fire on a pristine raised bog, central part of European Russia. Photo: Stanislav Vompersky. (§ 3.4.3 (m))

Effect of the 1997 fires on the peat swamp area near Palangka Raya, Central Kalimantan, Indonesia. Photo: Suwido Limin. (§ 3.4.3 (m))

A shallow lake formed on the bottom of a cutaway peatland in Rantsila, Finland. Photo: Raimo Sopo, September 1997. (§ 5.6.5 (4))

Dr Harri Vasander showing a sample of peat moss taken from a sod peat pit in Aitoneva, Finland about 40 years after peat cutting was finished. Photo: Raimo Sopo, June 1997. (§ 5.6.5 (4))

[71] See §§ 5.3 and 5.4. These additional boundaries, or rules, would involve the adaptation of the general anthropocentric considerations and principles to include non-human entities with intrinsic value in the objects/subjects of Tables 5/1 and 5/2, the general considerations 1 and 2 and of the guidance principles 4, 6, 8, 10 and 14.

[72] E.g. limits on our population, habits of consumption, and technologies of food production as current practices in these areas are based on attributing only instrumental values to organisms.

[73] Cf. Stone 1988. In the anthropocentric realm this also applies to mentally disabled and unborn human beings.

[74] I.e. the "rule of nonmaleficence" of Taylor 1986.

[75] I.e. the "rule of non-interference" of Taylor 1986, implying a "hands off" policy. Depending on the type of non-anthropocentric approach, these entities may include individual organisms, species, or whole ecosystems. A constraint is any condition that hinders or prevents the normal activity and development of the entity in question.

[76] In contrast to active, prescriptive duties; cf. Table 4/3.

[77] That entities suffer and die does not itself call for corrective action when human beings have had nothing to do with the cause of that suffering and death. Suffering and death are integral aspects of nature.

[78] Methods to accomplish this would include (1) permanent habitat allocation: the permanent setting aside of wilderness areas where other entities may behave "according to their own will", independent of any human objectives and free from human interference; (2) common conservation: the sharing of resources while they are being used by both human beings and non-human entities; (3) environmental integration: the integration of human constructions and activities into natural surroundings in a way that avoids serious ecosystem disturbance and environmental degradation; (4) rotation: giving other entities their chance at deriving benefits from a particular area of the Earth, after human beings have also benefited from that area for a limited period of time. By occupying the area at different time periods, both human beings and non-human entities can meet basic needs. (Taylor 1986).

GLOSSARY OF CONCEPTS AND TERMS

This Glossary sets out the meanings of a number of concepts described and terms used in this document. The words and phrases used are for the purposes of this document. Their use here is not intended to pre-empt further discussion on their meaning.

Aapa mire	Minerotrophic, sloping, and patterned mire
Abiotic	Non-biotic (see biotic).
Absorbed	Retained within the peat matrix (like a sponge).
Acrotelm	Upper peat-producing layer of a mire with a distinct hydraulic conductivity gradient in which water level fluctuations and horizontal water flow occur; the acrotelm stabilises hydraulic conditions.
Acrotelm mire	A mire in which an acrotelm enables peat accumulation.
Activated carbon	Powdered or granular carbon used for purifying by adsorption.
Aerobic	Having or containing oxygen.
Aerosols	Extremely small particles of liquid or dust in the atmosphere.
Aesthetic function	The appreciation of beauty.
Afforestation	Establishing new forests on un-forested land.
Agnostics	Persons uncertain of all claims to knowledge.
Air-water regime	The degree of saturation of, and the amount of oxygen in, the soil.
Albedo	The fraction of sunlight that is reflected by earth, ice, and clouds back into space.
Allogenic	Being genetically dissimilar or having another origin; allogenic material is material that stems from outside of a system.
Anaerobic	Not requiring air or oxygen for life; applied especially to microbes to which free oxygen is unnecessary.
Anoxic	Relating to or marked by a severe deficiency of oxygen.
Anthropocentrism	Moral position that ascribes intrinsic value only to human beings.
Anthropogenic	Resulting from human activity.
Anti-greenhouse gas	A gas which cools the atmosphere.
Archive function	Function as carrier of information about the past.
Arthropods	Invertebrates having jointed limbs and a segmented body with an exoskeleton made of chitin; e.g. insects, crabs.
Axiology	The theory of the nature and significance of values.
Azonal climatic conditions	Not fitting the general pattern of climate zones.

Balneology	The use of baths for medical purposes.
Bequest function	Value relating to what is left for future generations.
Biocentrism	Moral position that ascribes intrinsic value to all living beings.
Biochemical mechanisms	Involving chemical processes in living organisms.
Biodiversity	The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. (Convention on Biological Diversity)
Biogenic	Produced by living organisms or biological processes, organic.
Biogeochemical	Involving chemical processes both in the biosphere and in the geosphere, e.g. the circulation of elements within ecosystems (for example, the nitrogen cycle).
Biogeographic	Dealing with geographic distibutional patterns of flora and fauna.
Biomass	a. The total mass of living matter in a given place. b. Vegetable material used as an energy source.
Biophysical equilibrium	A situation that is biologically and physically stable (steady state).
Biosphere	The totality of living organisms.
Biotic	Pertaining to life.
Bituminous coal	Coal rich in volatile hydrocarbons which flames in burning.
Blanket bog	Bog which forms a blanket-like layer over the underlying mineral soil.
Bog	Mire raised above the surrounding landscape and only fed by precipitation.
Boreal	Biogeographical zone between the temperate and the subarctic.
Calcareous mires	Mires rich in calcium carbonates.
Carbon cycle	The processes by which carbon is cycled through the environment. Carbon, in the form of carbon dioxide, is absorbed from the atmosphere and used by plants in the process of photosynthesis to store energy. Plants and animals then return carbon dioxide to the atmosphere through respiration when they consume this energy. On a much longer time-scale, carbon is also cycled into and out of other substances including peat, coal and lime.
Carbon dioxide	A gas made up of one atom of carbon and two atoms of oxygen which is produced whenever carbon-based fuels are burned (or oxidised more slowly in plants and animals). Abbreviated as CO_2.
Carbonisation	The process of charring or coking so as to reduce organic material to carbon.
Catchment area	The geographical area draining into a river or reservoir.
Cation	Positively charged ion.
Cation exchange capacity	Capacity to remove cations from a solution and retain them.

Catotelm	Permanently water-saturated peat layer of relatively low hydraulic conductivity with a low rate of decay.
Chaos	A property of some non-linear dynamic systems which exhibit sensitive dependence on initial conditions. Extremely small differences in initial states lead to strongly different later states. Such systems may still be completely deterministic in that any future state of the system depends only on the initial conditions and the equations describing the change of the system with time. It may, however, require arbitrarily high precision to actually calculate a future state to within some finite precision.
Clastic material	Material made up of fragments of pre-existing rock, like sand or clay.
Clearcut strips	Strips within a forest which have been cleared of all trees.
Climate	The average pattern of weather in a place.
Co-generation	Combined generation of heat and power. Also referred to as CHP.
Cognition function	Value related to the pursuit of knowledge.
Coir	The fibre of coconut husks.
Commonage	The right of taking profit in land in common with others, without owning the land. The most usual forms of commonage were the right to pasture cattle, the right to extract peat, the right to fish a water, and the right to take wood.
Compost	A mixture of decaying organic matter used to improve soil structure and provide nutrients.
Conductivity	Conduction between opposite faces of a cube of material.
Conservation	The keeping entire, the keeping unchanged, preservation. Used in the sense of a deliberate or political decision to preserve.
Conservation value	All aggregate values pursued by conservation.
Container crops	Crops grown in sealed containers.
Contingency	A possible event or occurrence or result.
Corporate governance	The system by which commercial companies and institutions are directed and controlled.
Cosmogenic isotopes	Isotopes produced by cosmic radiation.
Cosmos	The ordered universe.
Cost-benefit analysis	A comparison of the estimated costs of an action with the estimated benefits it is likely or intended to produce.
Cryo-therapeutic	Use of cold for therapeutic treatment of injuries (for example, ice packs).
Cut-away peatland	What is left of a peatland after all the peat which can be economically removed has been extracted.
Decomposition	A complex process consisting of loss of organic matter (= mineralisation), loss of physical structure and change in chemical state.
Deep ecology	A moral position ascribing intrinsic value to all entities.

Deforestation	Cutting most or all of the trees in a forested area. Deforestation contributes to warming by releasing carbon dioxide, changing the albedo (amount of sunlight reflected from the surface) and reducing the amount of carbon dioxide taken out of the atmosphere by trees.
Deglaciation	Melting of glaciers at the end of the Ice Age.
Degraded soils	Soils that have lost their original instrumental (mostly agricultural) value.
Denitrification	The process by which nitrates or nitrites are reduced to nitrogen-containing gases, as by bacterial action on soil.
Discount rate	A measure of how cost and benefits that will happen in the future compare to cost and benefits today. The opportunity cost of applying resources.
Discounting	A method of estimating the present value of future cash flows. By extension, a method for estimating the present value of future events.
Distributional concerns	Concerns regarding the distribution of benefits to different sections of the population.
Ecocentrism	Moral position that attaches intrinsic value to all entities, i.e. to everything that is.
Ecological compensation	The principle that harmful effects on ecosystems, e.g. mires and peatlands, should be balanced by compensatory conservation measures by the user.
Ecological egalitarianism	The moral position that every form of life has equal value.
Ecology	a. The science of the relationships between organisms and their environments. b. The relationship between organisms and their environment.
Economic value	Contribution made to economic well-being.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Ecosystem Approach	A strategy for the integrated management of the land, water and living resources of an ecosystem which promotes conservation and sustainable use in an equitable way. It recognises that human beings are an integral component of many ecosystems.
Egalitarian principle	The principle that one should be concerned not only with the total good but also with its distribution: a smaller quantity of good that is equally distributed is preferred to a larger total of which some have a disproportionate share.
Endogenous	Derived or originating internally.
Entity	Anything which exists whether physically or conceptually.
Environmental Impact Statement	A public document assessing the probable or possible impact on the environment of a proposed project.

Ethical justification	Motivation based on ideas of right and wrong.
Eudaimonistic values	From eudaimonia = Greek “good life”. Values relating to the enrichment of life.
Euphotic	Relating to the uppermost layer of water that receives sufficient light for photosynthesis and the growth of plants.
Eutrophic	Nutrient-rich.
Evapotranspiration	Total loss of water by physical evaporation and biological transpiration.
Existence function	Value related to why human beings exist; the notion of ecological and evolutionary connection, that we share this world with other entities to which we are related and for which we have a responsibility
Exogenous	Derived or originating externally.
Exploitation	The use for any economic purpose. The term is used without any pejorative meaning.
Feature	(Synonymous with *characteristic*): a property that distinguish an entity from other entities within a specific collection of entities. A feature is always a property of an entity; a property, however, is not always a feature.
Feedback	The mechanism by which the result of an action influences the action. Positive feedbacks work by stimulating the causing action, leading to continuously increasing results. Negative feedbacks hinder the action. In climate change, negative feedbacks work to slow down or offset warming while positive feedbacks work to speed up or amplify warming.
Fen	Peatland which in addition to precipitation water also receives water that has been in contact with mineral soil or bedrock.
Fennoscandia	Norway, Sweden, Denmark and Finland.
Financial discounting	A method of estimating the present value of future cash flows. A method of estimating future well-being in which not the well-being itself, but the monetary costs and benefits which determine future well-being, are discounted.
Flark	Usually elongated, wet and muddy depressions in string mires, may be several metres in length. The term is applied to any water filled or sedgy area between strings. On slopes flarks are narrow, only a few metres wide.
Flood mires	Mires in which periodical flooding by an adjacent open water body (sea, lake, river) enables peat accumulation.
Fluidised-bed	A two-phase system consisting of a mass of small particles suspended in a fluid, which maintains the stability of the system. The bed acts like a fluid.
Fluvial mires	Mires associated with rivers.

Fossil fuels	Fuels derived from the ancient remains of plants and animals, preserved in rocks in the earth's crust with high carbon and hydrogen content.
Function	A directional action of an entity that positively affects the object of the action (i.e. is useful). Function is the complement of *use*, i.e. one entity uses the function provided by another entity.
Geochemistry	The chemistry of the crust of the earth.
Geogenous	Originating from bedrock (e.g. water feeding a mire).
Geological	Relating to the study of the earth's crust from earliest time to the commencement of the historical period.
Geomorphology	The science of form of the earth's surface, including structure and development.
Geosphere	The solid part of the earth, as distinct from the atmosphere, the hydrosphere, the pedosphere, the biosphere and the noosphere.
Greenhouse effect	Warming that results when solar radiation is trapped by the atmosphere; caused by atmospheric gases that allow sunshine to pass through but absorb heat that is radiated back from the warmed surface of the earth.
Greenhouse gases	Any gas in the atmosphere that contributes to the greenhouse effect. These include carbon dioxide, methane, ozone, nitrous oxide, CFCs, and water vapour. Most occur naturally as well as being created by human activity.
Grossform	German term referring to the landform or overall shape of a mire or peatland.
Growing media	The media in which plants are grown, including soil, various forms of compost, rockwool, peat.
Heat capacity	The amount of heat required to raise the temperature of an object by one degree Celsius.
History function	Value related to cultural continuity.
Holism	1. A moral position that attaches intrinsic value to groupings or systems. 2. The scientific perspective that wholes are more thanthe simple sum of their parts.
Holistic	Pertaining to holism.
Holistic rationalism	The idea that this world is the "best" of all possible worlds, with a maximum economy of premises and fundamental laws, a maximum diversity of resulting phenomena, and its consistency, order, or harmony.
Holocene	The period since approximately 10,000 years ago (i.e. since the last glaciation).
Horizontal mire	Mire without a pronounced slope.
Humic	Relating to decomposed organic matter in the soil.

Humic ameliorant	Soil improver based on humus.
Humification	The process by which organic matter decomposes to form humus or peat.
Humus	Partially decomposed organic matter; the organic component of soil.
Hydraulic characteristics	Factors affecting water movement and storage.
Hydraulic conductivity	Coefficient of proportionality describing the rate at which water can move through an aquifer or other permeable medium.
Hydrochemistry	The study of the chemistry of water.
Hydrogenetic mire types	Types of mires which are defined by their peat formation strategy as dependent on water dynamics.
Hydrology	The study of water movement.
Hydrolysates	Products of hydrolysis.
Hydrolysis	Decomposition of a chemical compound by reaction with water, such as the dissociation of a dissolved salt or the catalytic conversion of starch to glucose.
Hydroscopic	Having the ability to absorb water readily from the atmosphere.
Hysteresis effect	Being dependent on the history or on direction, e.g. that the way back is different from the way to, or that the answer depends on whether a question – with the same factual content – is formulated negatively or positively.
Identity function	The values related to the ability to identify one's position in the world. They are limited to self-conscious beings who are able to think abstractly.
Immersion mire	Hydrogenetic mire type in which peat is produced by plants immersed in open water (e.g. many *Phragmites* stands). Many immersion mires can be referred to in more familiar terms as "emergent marsh" or "reed swamp".[1]
Industrial cut-away peatlands	Cut-away peatlands after the extraction of peat on an industrial scale.
Instrumental values	Values which represent clear means to an end. Such values are equal to functions.
Integrated catchment management	The management of rivers or basins and the surrounding catchment as a whole.
Intergenerational justice	Balance between the wellbeing of both present-day and future generations.
Intermediate cuttings	Silvicultural cuttings (thinning cuttings) in the stage of tree stand development between young stand treatment/cleaning and regeneration cutting (regeneration felling). A simple synonym for intermediate cutting is thinning cutting.
Intrinsic moral value	The value that an entity has as such, independent of everything else, i.e. independent of external valuers.

Inundation mires	Flood mires.
Irreversible	That cannot be changed back.
Isotope	Atoms of the same element (having the same atomic number) which have a different nuclear mass and atomic weight from other atoms of the same element are called isotopes of that element.
Kettle hole mire	A mire in a kettle-shaped basin. Sometimes erroneously used for self-sealing mire.
Kinesitherapy	The treatment of disorders by the appropriate of muscular movements.
Lacustrine muds	Muds formed in lakes.
Land-use planning	A process or procedure to provide for the planning of the use of land for the common good and in the interests of sustainable development.
Layering	The process of rooting branches, twigs, or stems that are still attached to a parent plant, as by placing a specially treated part in moist soil.
Licensing system	A system of control to regulate the effects of an activity, for example its environmental effects, by means of conditions attached to permits or licences.
Lignite	Brown coal.
Lithogenous	Stemming from the lithosphere, as in lithogenous water (deep groundwater.)
Litter	a. An absorbent material, such as granulated clay or straw, for covering the floor of an animal's cage or excretory box. b. The uppermost layer of the soil consisting chiefly of fallen leaves and other decaying organic matter.
Living beings	A term inclusive of all forms of life.
LORCA	Long-term apparent rate of carbon accumulation.
Lysimeter	An instrument for measuring evapotranspiration or water percolation. It consists of a large cylinder filled with soil or peat that is put into a vertical position and buried in soil so that the upper surface of the lysimeter is at the same level as the soil surface.
Macerated	Made soft or separated into constituents by soaking.
Macroclimate	The climate in a region as a whole.
Material life support values	Values which contribute to the maintenance of physical health.
Mean-end relationships	How means relate to ends.
Meta-ethical	Relating to the study of the meaning and nature of ethical terms.
Meteoric	Atmospheric.

Methane	A greenhouse gas consisting of one molecule of carbon and four molecules of hydrogen. Methane is produced naturally from rotting organic matter. Human sources of methane include agricultural activities such as growing rice and raising livestock, land-fills, coal mines, and natural gas systems. Abbreviated as CH_4.
Microclimate	The specific climate of a small area.
Milled peat	Peat milled on the surface of a peatland to form crumb.
Mimetical desire	The instinct of human beings to imitate what those around them do: social behaviour which mimics that of others.
Minerotrophic	Also supplied with nutrients by the geosphere.
Mire	A peatland where peat is currently being formed and accumulating.
Modifiers	Factors which modify principles.
Monetarisation	The attribution of monetary value to entities or services which are not normally seen to have a financial or commercial value.
Moral perspective	Way of looking at life, an approach which aims to answer the question of right or wrong.
Moral pluralism	An approach that acknowledges that various moral perspectives are equally justifiable.
Moral standing	The right to be morally considered.
Morphology	The study of the form, structure and origin of organisms or of the Earth's physical features.
Multiplier effect	The relationship between direct and direct/indirect employment. The factor by which one multiplies direct employment to calculate total employment.
Myopic behaviour	Attaching less value to future than to present events and things solely because they lie in the future.
Naturalistic approach	Approach that regards values as objective properties of an entity, independent of the person making the valuation.
Naturalness	The quality of not having been deliberately influenced by human beings.
Nature mysticism	The intuitive feeling of humanity's unity with all nature.
Needs	Things or qualities which are necessary for survival.
Neoteny	The phenomenon that infantile characteristics are prolonged into maturity.
Net present value	A method of expressing future amounts in current terms.
Nihilism	A doctrine holding that all values are baseless and that nothing can be known.
Nitrous oxide	A greenhouse gas consisting of two molecules of nitrogen and one molecule of oxygen. Nitrous oxide is created when fuels are burned and may also be released during denitrification. Abbreviated as N_2O.
Non-anthropocentric approaches	Moral positions that do not consider human beings as being the only entities that possess intrinsic moral value.

Non-material life support values	A range of values relating to the mind, sensation, and the spirit.
Noocentrism	Moral position that ascribes intrinsic value only to rational beings.
N_{org}	Nitrogen in organic form.
Normal problems	Problems that can be solved by progress and/or through investment.
Normative principles	Principles of behaviour which make it possible to resolve value conflicts in a rational way.
Norms	Generalised expectations of behaviour, as in guidelines, conventions and laws.
Oligotrophic	Poor to extremely poor in nutrients.
Ombrogenous	Only receiving precipitation water.
Ombrotrophic	Only supplied with nutrients by the atmosphere.
Option function	The same as bequest functions - those relating to what is left for future generations. Relate to the importance people place on a safe future.
Organic	Material which results from carbon chemical biosynthesis.
Organismic	Relating to an organism as a whole.
Organo-mineral fertilisers	Combined organic and mineral fertilisers.
Oscillation	Fluctuation; variation; change back and forth.
Osmosis	The passage of water through a semi-permeable membrane into a more concentrated solution, ending by equalising the concentrations on both sides of the membrane.
Oxic	Containing oxygen, aerobic. Usually used in reference to a microbial habitat.
Oxidation	A reaction in which the atoms in an element lose electrons (often – but not limited to – to oxygen) See under 'oxidative peat losses'.
Oxidative peat losses	Losses of peat resulting from the reaction of peat with oxygen (after drainage).
Ozone	An unstable gas in which three atoms of oxygen occur together. Ozone is a greenhouse gas. In the atmosphere ozone occurs at two different altitudes. Low altitude *tropospheric ozone* is a form of air pollution (part of smog) produced by the emissions from cars and trucks. High in the atmosphere a thin layer of *stratospheric ozone* is naturally created by sunlight. This ozone layer shields the earth from dangerous (cancer-causing) ultraviolet radiation from the sun. Several gases (notably chlorofluorocarbons, CFCs) speed the breakdown of ozone in the ozone layer. While serious in its own right, this is largely a different problem from the problem of global warming. Abbreviated as O_3.

Palaeo-ecological values	Values relating to the reconstruction of human and environmental past.
Palaeophysiology	Science of the process of life in animals and plants in the past.
Palsa	Term of Finnish origin for a peat-covered mound with a permafrost core; usually ombrotrophic, generally much less than 50 metres across and from one to several metres high.
Palsa mire	Peatland complex of the discontinuous permafrost region,with palsas, (peat plateaus) rising above the adjacent unfrozen peatland (usually fen).
Paludification	The formation of waterlogged conditions: also refers to peat accumulation which starts directly over a formerly dry mineral soil.
Palynology	Analysis of microscopic remains of organisms.
Palynomorph-morphology	Study of the form of microscopic remains of organisms.
Paradigm examples	Example that serve as pattern or model.
Pasture	Grassland used for the growing of grass to be grazed by farm animals. Grazing land.
Pathocentrism	The moral position that all beings which can feel have value.
Peat	Sedentarily accumulated material consisting of at least 30% (dry weight) of dead organic material.
Peat extraction	The excavation and drying of wet peat and the collection, transport and storage of the dried product.
Peat oxidates	Substances that develop by the chemical or biochemical oxidation of peat.
Peatland	An area with or without vegetation with a naturally accumulated peat layer at the surface.
Pedogenic alteration	Alteration arising from processes occurring within the soil.
Pedological	Relating to the study of soil.
Percolation mires	Sloping mires in which hardly any water level fluctuations occur, with scarcely decomposed peat with high hydraulic conductivity. As a substantial water flux occurs through the peat, percolation mires are only found in landscapes where water supply is large and evenly distributed over the year.
Perlite	A natural volcanic glass similar to obsidian but having distinctive concentric cracks and a relatively high water content. In a fluffy heat-expanded form perlite is used as a lightweight aggregate, in fire-resistant insulation, and in soil for potted plants.
Permafrost	Ground that is permanently frozen.
Physico-chemical properties	Total of physical and chemical properties.
Photosynthesis	The process in certain plants and organisms by which, using light as an energy source, carbohydrates are synthesised from carbon dioxide and water.

Pingo	An Eskimo term for arctic mound or conical hill consisting of an outer layer of soil (including peat) and vegetation, covering a core of solid ice and which exists for at least 2 winters.
Pisciculture	The rearing of fishes in ponds, lakes or fish farms.
Polder	An area where the water level can be artificially regulated largely independently of the surrounding area.
Polluter pays principle	The principle that the cost of measures to prevent, control and reduce damage should be borne by the responsible party.
Polygon	A feature of patterned ground caused by permafrost, consisting of a closed, roughly equidimensional figure bounded by several sides, in peat mainly with high or low centres and ridges along the margins.
Praxis	A model, example, or collection of examples: a practice.
Precautionary principle	The principle that where there are threats of serious damage, measures to prevent this damage should not be avoided because of lack of full scientific certainty.
Precipitation	Rainfall, snow, hailstones, dew and frost.
Preference approach	Approach that regards values as only resulting from the preferences of the person making the valuation.
Prescription duties	Duties to take certain actions arising from the rights of others.
Pristine	Which has not been disturbed by human activity.
Production functions	Values related to the capacity to provide resources (food, raw materials, etc.)
Property	Any inherent quality of an entity.
Proportionality	The state of being properly related in size, degree, importance, or other measurable characteristic.
Proxy functions	Functions acting as substitutes for other functions. Include sensations that are experienced as pleasant, agreeable or beneficial.
Prudential	Exercising prudence, good judgment, or common sense.Used in "prudential argument": acting as though animals and other non-human beings have intrinsic value, so as to avoid the possibility that some people will treat human beings in the same way as non-humans are sometimes treated.
Public participation	A consultation process in which all stakeholders can actively participate.
Pulverised fuel	Fuel which has been ground to a fine dust.
Pyrolysis	Decomposition of a substance by heat.
Radiative forcing	The greenhouse warming impact of an atmospheric gas.
Raised bog	Usually dome-shaped peatland that has its water level above that of the surrounding mineral soil due to its moisture being fed only by the atmosphere.
Rational beings	Beings who exercise reason or self-consciousness.
Recreation function	Function in providing opportunities for recreation.

Redox process	A reversible chemical reaction in which one reaction is an oxidation and the reverse is a reduction: oxidation-reduction.
Reductivism	An approach that tries to reduce complexities (about value) to simple principles and single measures.
Regeneration	Re-growth of a destroyed mire.
Regulation functions	Values relating to the capacity to regulate essential ecological and environmental processes and life-support systems, including the maintenance of adequate climatic, atmospheric, hydrologic, pedologic, ecologic and genetic conditions.
Regulatory functions	The regulation functions of government or public administration ensuring that laws and regulations are observed.
Resource	An available supply that can be drawn on when needed.
Restitution	The act of making good or compensating for loss, damage, or injury.
Schwingmoor mires	Mires with floating mats, e.g. papyrus swamp islands.
Sea level rise	An increase in the average level of the ocean caused by expansion when water is warmed and by addition of more water when ice caps melt.
Sedentarily accumulating ecosystems	Ecosystems that accumulate organic material which is produced on the spot and not transported after its production and death.
Sedentary	Produced on the spot and not transported after its production and death.
Sedimentation	Deposition of matter after transport by water or ice or wind.
Seed-tree groups	A method of regenerating a forest stand in which all trees are removed from the area except for a small number of seed-bearing trees that are left in small groups. The objective is to create an even-aged stand.
Self-sealing mires	A mire which grows by forming an impervious layer in the previously permeable mineral subsoil, impeding water outflow.
Sentient beings	Beings with the capacity to experience pleasure and pain.
Sentimental argument	The argument that non-human beings should not be violated to prevent suffering of human beings who suffer when non-human beings are violated.
Sequester	To remove or segregate, for example from the atmosphere.
Signalization function	Value related to the provision of signals and indications.
Sink	A place where material is removed or stored. For example, the oceans absorb about 50% of the carbon dioxide released into the atmosphere. Scientists refer to oceans and mires as a carbon dioxide *sinks*.
Sloping mire	Mire with a sloping surface.
Social amenity value	Value related to social contacts that improve the quality of life.
Social role	A person's role in society.

Socio-economic benefits	Improvements to social and economic conditions, such as increases in income in an area or the creation of employment.
Solar forcing	Changes in the warming impact of the sun's radiation on the earth's surface.
Soligenous	Originating from soil and surface.
Speciesism	The belief that a particular species (e.g. *Homo sapiens*) is superior to others (cf. racism, sexism).
Spirituality functions	Values related to the provision of reflection and spiritual enrichment.
Sporopollenine	A polymer that constitutes the outer wall of spores and pollen grains.
Spring mire	Mire that is mainly fed by spring water.
Stakeholders	All persons and organisations having a direct interest.
Storage coefficient	The volume of water that can be stored as a proportion of the volume of soil/peat in which it is stored.
Stratigraphy	The geological study of strata, or beds, of sedimentary rock.
Stratosphere	The upper part of the earth's atmosphere, above about eleven kilometres.
Strong sustainability	A view which does not accept substitutability and argues for keeping the stock of different types of resources intact separately.
Subsidence	The lowering of the level of a mire due to drainage.
Substitutability	The degree to which another product can be substituted for the product in question.
Substitutable	Capable of being replaced by an alternative that will achieve the same or similar ends.
Substrate	An underlying layer, e.g. the substance on which a crop grows.
Suo	An area with or without a peat layer dominated by a normally peat-producing vegetation.
Surface flow mire	Mire in which, because of strongly decomposed peat, most water overflows the peat.
Surfactant	A substance capable of reducing the surface tension of a liquid in which it is dissolved.
Surficial	Occurring on or near the surface of the earth..
Sustainable development	Economic development which can meet the needs of the present without compromising the ability of future generations to meet their own needs.
Symbolisation functions	Functionss that provide embodiments of other functions (like mascots, symbols, money).
Taxonomic	Of or pertaining to the classification of organisms in an ordered system that indicates natural relationships (systematics).
Technological optimists	Persons who expect that the science of ecology will eventually provide sufficient understanding of ecological processes and relationships to enable an effective control of ecosystems and natural resources.

Terrestrial	Living or growing on land.
Terrestrialisation	The accumulation of sediments and peats in open water.
Terrestrialisation mire	Mire formed by peat formation in open water.
Tertiary	The era from 65-3 million years ago.
Thallasogenous	Stemming from the sea.
Theism	The argument that all beings are God, the image of God, or created to glorify God.
Thinnings	Trees cut at various stages in the growth of a forest to allow space for adjacent trees to grow.
Topogenous	Originated as a result of the features of an area.
Topography	Physical features of an area.
Trace element	A chemical element required in minute quantities by an organism to maintain proper physical functioning.
Transformation functions	Functions related to the provision of the possibility to modifying and changing preferences, e.g. the development of other tastes, the improvement of social skills, and the growing awareness of existence values.
Transgression	The spread of an open water body over adjacent land.
Translocation	Removal of things or activities from one place to another;
Transpiration	The emission of water vapour by plants (or animals).
Trophic conditions	Nutrient availability.
Troposphere	The lower portion of the earth's atmosphere in which human beings live.
Typology	Listing and explanation of types.
Upper Carboniferous	Era from 320-290 million years ago.
Use	The application or employment of an entity for a purpose. That entity is therefore useful. Use is the complement of function, i.e. the same action (relation, factor) can be seen as a **function** (from the perspective of the provider) or as a **use** (from the perspective of the recipient). The words 'use' and 'utilisation' are used interchangeably in this document.
Utilisation	Use in any way, including conservation.
Utility discounting	A method of estimating the present value of future benefits or benefits to future generations. It assumes that future well-being is given less weight than present well-being.
Value	The worth attached to entities.
Vascular plants	The higher plants, characterised by the possession of true roots, stems and leaves and through whose tissues liquids are conducted.
Veto duties	Duties to avoid certain actions arising from the rights of others.
Vital issues	Issues about which it cannot be prudently assumed that progress will solve the problems associated with them.

Volatiles	Substances that change readily to a vapour.
Von Post scale	A ten-point scale devised by the Swedish scientist Lennart Von Post measuring the degree of decomposition (or humification) of peat.
Wants	Amenities/commodities/peripheral interests.
Water rise mires	Mires in depressions which result from an externally induced rising water table that does not lead to the origin of pools or lakes.
Weak sustainability	A view which permits the depletion of natural resources if artificial substitutes can be found and if the profits are invested rationally.
Weather	The condition of the atmosphere at a particular place and time measured in terms in wind, temperature, humidity, atmospheric pressure, and precipitation.
Wetland	An area that is inundated or saturated by water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.
Wise Use	Use for which reasonable people, now and in the future, will not attribute blame.
World-view	A person's set of values which is based both on "objective" observations, and on subjective interpretations and projections.
Xeromorphy	The total of morphological features that show adaptation to dry habitats.

Acknowledgements: Geddie, W, 1959, Chambers's Twentieth Century Dictionary, London. Water Words Dictionary, Nevada Division of Water Planning, Department of Conservation and Natural Resources. http://www.state.nv.us/cnr/ndwp/dict-1/waterwds.htm. Dictionary.com. http://www.dictionary.com/. CancerWEB's On-line Medical Dictionary.

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[1] Words such as "**swamp**" and "**marsh**" are avoided in this document (see footnote 3 of Chapter 2)

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APPENDICES

APPENDIX 1

EXTENT OF MIRE AND PEATLAND RESOURCE

The tables in this Appendix supplement the information in §2.4 of Chapter 2. In these tables Estimated peatland/mire area (> 30 cm peat, > 30% organic material) per country/region in km^2. Total area (1998) of country/region according to Encarta.

0 = no peatland occurrences encountered, peatlands probably absent
? = no peatland occurrences encountered, peatland probably present
1 = peatland occurrence recorded, but may be (substantially) smaller than 1 km^2

Table A1/1: Mire and peatland resources of Europe

Country	Total area (km^2)	Original peatland area (km^2)	2002 peatland area (km^2)	2002 mire area (km^2)
Albania	28,748	600	179	4
Andorra	468	10	5	2
Austria	83,858	500	200	100
Azores	2,335	1	1	1
Belarus	207,595	29,390	23,500	11,412
Belgium	30,528	700	160	3
Bosnia and Herzegovina	51,129	200	150	10
Bulgaria	110,994	800	25	5
Channel Islands	205	?	?	?
Croatia	56,510	5	1	1
Czech Republic	78,864	500	200	50
Denmark	43,094	10,000	1,400	50
Estonia	45,227	11,000	10,000	3,000
Faroe Islands	1,400	30	30	25
Finland	338,145	96,000	85,000	32,000
France	543,965	2,000	1,500	100
FYRO Macedonia	25,713	50	30	5
Germany	356,970	16,250	13,000	100
Gibraltar	6	0	0	0

Country (continued)	Total area (km^2)	Original peatland area (km^2)	2002 peatland area (km^2)	2002 mire area (km^2)
Greece	131,957	500	71	13
Hungary	93,030	1,000	330	30
Iceland	103,000	9,000	8,000	3,500
Ireland	70,273	12,000	11,500	2,100
Isle of Man	572	?	?	?
Italy	301,323	1,200	300	30
Jan Mayen	373	0	0	0
Latvia	63,700	7,000	6,600	4,663
Liechtenstein	160	1	1	1
Lithuania	65,300	4,800	3,520	750
Luxembourg	2,586	4	3	1
Malta	316	1	0	0
Moldova	33,700	30	10	1
Monaco	2	0	0	0
Netherlands	41,526	15,000	2,350	150
Norway	385,639	30,000	28,000	22,000
Poland	312,684	20,000	12,500	2,000
Portugal	92,345	200	20	2
Romania	237,500	2,000	1,000	500
Russia European part		243,000	213,000	150,000
San Marino	61	0	0	0
Slovakia	49,035	260	26	13
Slovenia	20,253	150	100	10
Spain	505,990	300	60	10
Svalbard /Spitsbergen	62,160	10	10	10
Sweden	449,964	70,000	66,000	55,000
Switzerland	41,285	2,000	300	200
Ukraine	603,700	11,000	8,000	5,800
United Kingdom	244,110	19,000	17,500	1,000
Vatican City	0.44	0	0	0
Yugoslavia (Serbia and Montenegro)	102,173	1,000	300	50
Total		617,492	514,882	294,702

Table A1/2 Mire and peatland resources of Asia

Country	Total area	Peatland area
Afghanistan	652,225	120
Armenia	29,800	55
Azerbaijan	86,600	10
Bahrain	707	0
Bangladesh	147,570	300
Bhutan	47,000	1
Brunei	5,765	1,000
Cambodia	181,035	7,000
China	9,571,300	7,000
Cyprus	9,251	1
East-Timor	14,609	???
Fiji	18,376	40
Georgia	69,700	200
India	3,165,596	300
Indonesia	1,904,443	270,000
Iran	1,648,000	10
Iraq	438,317	100
Israel	21,946	40
Jammu and Kashmir	222,236	100
Japan	377,837	2,000
Jordan	89,556	1
Kazakhstan	2,717,300	50
Kuwait	17,818	0
Kyrgyzstan	198,500	100
Laos	236,800	200
Lebanon	10,452	1
Malaysia	329,758	25,000
Maldives	298	1
Mongolia	1,566,500	50
Myanmar	676,552	500
Nepal	147,181	1
North Korea	120,538	1,300
Oman	309,500	0
Pakistan	796,095	100
Papua New Guinea	462,840	28,942

Philippines	300,000	100
Qatar	11,427	0
Russia Asian part		1,177,000
Saudi Arabia	2,240,000	0
Seychelles	454	0
Singapore	648	1
South Korea	99,268	5
Sri Lanka	65,610	35
Syria	185,180	3
Taiwan	36,000	???
Tajikistan	143,100	???
Thailand	513,115	500
Turkey	779,452	120
Turkmenistan	488,100	0
United Arab Emirates	83,600	0
Uzbekistan	447,400	???
Vietnam	331,690	1,000
Yemen	527,970	???
Total		1,523,287

Table A1/3 *Mire and peatland resources of Africa*

Country	Total area	Peatland area
Algeria	2,381,741	10
Angola	1,246,700	100
Benin	112,622	100
Botswana	581,730	3,000
Burkina Faso	274,200	10
Burundi	27,834	150
Cameroon	475,442	100
Canary Islands (Spain)	7,273	0
Cape Verde	4,033	0
Central African Republic	622,436	100
Chad	1,284,000	10
Comoros	1,862	???
Congo	342,000	4,000
Democratic Republic of the Congo	2,344,885	14,000
Djibouti	23,200	0
Egypt	997,739	10
Equatorial Guinea	28,051	???
Eritrea	121,144	???
Ethiopia	1,133,380	200
Gabon	267,667	80
Ghana	238,500	100
Guinea	245,857	1,000
Guinea-Bissau	36,125	???
Ivory Coast	322,462	300
Kenya	582,646	1,600
Lesotho	30,355	20
Liberia	99,067	400
Libya	1,757,000	0
Madagascar	587,041	1,500
Madeira (Portugal)	794	???
Malawi	118,484	900
Mali	1,240,192	400
Mauritania	1,031,000	60
Mauritius	2,040	1
Morocco	453,730	10
Mozambique	799,380	2,000

Country	Total area	Peatland area
Namibia	824,269	10
Niger	1,267,000	30
Nigeria	923,768	120
Réunion	2,512	1
Rwanda	26,338	800
São Tomé and Príncipe	1,001	???
Senegal	196,722	20
Sierra Leone	71,740	1
Somalia	637,700	0
South Africa	1,219,090	300
St Helena (UK)	324	80
Sudan	2,505,800	1,400
Swaziland	17,363	???
Tanzania	945,100	100
The Gambia	11,295	100
Togo	56,785	10
Tunisia	164,418	1
Uganda	241,138	14,000
Zambia	752,614	10,000
Zimbabwe	390,759	1,400
Total	27,696,607	58,534

Table A1/4 Mire and peatland resources of North, Central and South America

Country	Total area	Peatland area
Antigua and Barbuda	442	???
Argentina	2,780,400	2,400
Bahamas	13,939	10
Barbados	430	0
Belize	22,965	680
Bermudas	53	1
Brazil	8,547,404	55,000
Bolivia	1,098,581	20
Canada	9,970,610	1,235,000
Chile	756,626	10,470
Colombia	1,141,748	10,000
Costa Rica	51,060	370
Cuba	114,525	6,000
Dominica	750	1
Dominican Republic	48,400	10
Easter Island (Chile)	117	1
Ecuador	272,045	5,000
El Salvador	21,041	90
Falkland Islands / Islas Malvinas	12,173	11,510
French Guiana	91,000	1,620
Galápagos Islands (Ecuador)	7,844	1
Greenland	2,175,600	5
Grenada	344	???
Guadeloupe (France)	1,780	2
Guatemala	108,889	1
Guyana	214,969	8,000
Haiti	27,750	1
Hawaii (U.S.A.)	16,179	1
Honduras	112,492	4,530
Jamaica	10,991	100
Juan Fernández Islands (Chile)	180	1
Mexico	1,964,382	1,000
Nicaragua	129,494	3,710
Panama	75,517	7,870
Paraguay	406,752	100

Country	Total area	Peatland area
Peru	1,280,000	50,000
Puerto Rico (U.S.A)	9,104	100
St Kitts and Nevis	269	1
St Lucia	616	???
St Vincent and the Grenadines	389	???
Suriname	163,265	1,130
Trinidad and Tobago	5,128	10
United States of America	9,629,047	625,000
Uruguay	176,215	1,000
Venezuela	912,050	10,000
Total	42,373,555	2,050,746

Table A1/5 Peatland resources of Australia, New Zealand, the Pacific and Antarctica

Country	Total area	Peatland area
American Samoa (USA)	195	0
Antarctica	14,200,000	3,000
Auckland Islands (New Zealand)	570	560
Australia (excl. Tasmania)	7,614,500	1,330
Chatham Islands (New Zealand)	963	450
Guam (U.S.A.)	541	0
Kiribati	811	2
Marshall Islands	181	0
Martinique	1,102	1
Micronesia (Federated States of)	702	33
Nauru	21	0
New Caledonia and Dependencies (France)	19,058	1
New Zealand	270,534	2,600
Palau	488	1
Samoa	2,831	1
Solomon Islands	27,556	10
Tasmania	68,331	20
Tonga	750	???
Tuvalu	26	0
Vanuatu	12,190	???
Total	22,221,350	8,009

APPENDIX 2

MIRES AND PEATLANDS AND THE GLOBAL CLIMATE[1]

This appendix is a longer version of the "Regulation of the global climate" material in §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.

A2.1 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 simply 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[4] and the proportion of emitted methane consequently increases. 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[5]. As all these gases have a different radiative forcing[6], the effect on the radiation balance of the atmosphere differs with mire/peatland type and type of exploitation[7].

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[8]:

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

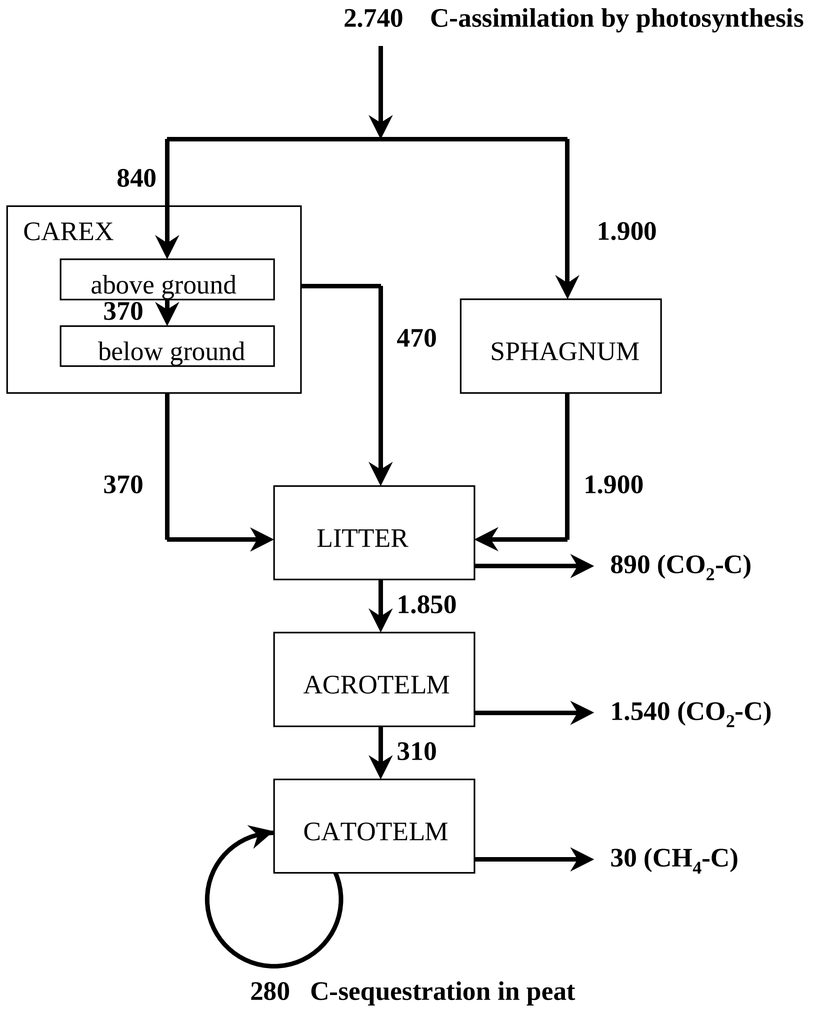

Figure A2/1 *Carbon fluxes and carbon sequestration (10^3 g C ha^{-1} $year^{-1}$) in a pristine bog (Pradeaux, French Central Massif, 1250 m over sea level NN)*[9]

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.

A2.2 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 A2/1) including: carbon sequestration by plant photosynthesis (primary production), direct carbon losses during litter decomposition[10], 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 – 70·10^{12} g C per year[11]. This is approximately 1% of the 6,000 ·10^{12} g C emitted by global fossil fuel consumption in 1990[12], or 10 % of the 660 ·10^{12} g C emitted by USA electric utilities in 1998[13].

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[14]. 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[15].

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[16]. Global methane production is dominated by natural wetlands, rice paddies, and animal livestock (Table A2/1).

Wetlands[18]	115
bogs/tundra (boreal)	35
swamps/alluvial	80
Rice production[19]	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

Table A2/1: Net sources of global atmospheric emissions of methane (in 10^{12} g CH_4 $year^{-1}$)[17]

Methane emissions in mires are highly variable, but generally higher in pristine fens than in pristine bogs (Table A2/2).

Nitrous oxide is a greenhouse gas and also causes destruction of stratospheric ozone[27]. Nitrous oxide emissions from pristine mires are very low (Table A2/3). Occasionally, even a consumption of nitrous oxide may take place due to the reduction of nitrous oxide to dinitrogen (N_2) under anoxic conditions.

Region	Methane emission	
	bogs	**fens**
Globally[20]	20	101
USA, temperate zone[21]	7 – 1132	0.8 - 1820*
Sweden[22]	11	228
Finland[23]	20 – 220	135 - 480
England[24]	10 – 40	
Germany[25]		293
Germany (rewetted)[26]	81	529 - 980*
Median (lower – upper quartile)	**53** (20 – 84)	**297** (190 – 480)

Table A2/2: Methane emissions (in 10^3 g C ha^{-1} $year^{-1}$) from pristine and rewetted mires

Region	Nitrous oxide emission	
	bogs	**fens**
Finland[28]	0.04	0.04
Sweden, Finland[29]	0.0 to 0.2	
USA, temperate zone (flooded)[30]		0.1 - 0.5
Germany[31]		0.6 - 1.2
Germany (flooded)[32]		- 0.7 to - 0.2
Median	**0.04**	**0.10**

Table A2/3: Nitrous oxide emissions (in kg N ha^{-1} $year^{-1}$) from pristine or rewetted mires

Because all gases have a different lifetime in the atmosphere and a different “global warming potential” (see Table A2/4), 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[33]). This is due to the changing impact of CH_4 emissions.

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

Table A2/4: The atmospheric lifetime and the IPCC (1996) accepted global warming potentials over different time horizons of radiatively important gases[34].

		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

Table A2/5: Global Warming Potential (GWP in kg CO_2-C-equivalents ha^{-1} $year^{-1}$) of pristine mires using different time scales

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 A2/5) 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 time-scale pristine bogs have a negative global warming potential and fens a small positive potential.

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. 400-800·10^{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[35].
- **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[36].
- **Methyl bromide (CH_3Br) and methyl chloride (CH_3Cl)[37]**, that have a cooling effect through their ability to destroy stratospheric ozone[38].

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

A2.3 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[39].

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[40].

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 A2/6). 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[41], whereas depths of 17 - 60 cm already lead to 80 % of the maximum value[42]. At water levels deeper than 90 cm, drought inhibits peat mineralisation again[43].

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 A2/7).

Methane emissions from drained peatlands are generally very low (Table A2/8), 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.

Region	CO_2 emission in kg C ha^{-1} $y.^{-1}$	
	bogs	**fens**
Finland[44]	1500 – 2500	3140
Canada[45]		1910
North-east Germany[46]		2800 - 6580
North-west Germany[47]	0 – 4840[2]	4119 - 4318
Sweden[48]	3500	
Median	**2350**	**3465**

Table A2/6: CO_2 emissions from drained peatlands used as grassland.

Region	CO_2 emission in kg C ha^{-1} $y.^{-1}$	
	bogs	**fens**
North West Germany[50]	4400	13200
South Germany[51]		6600-9900
Poland[52]		11220
Median	**4400**	**10560**

Table A2/7: CO_2 emissions from drained peatlands used as arable land[49].

Region	CH_4 emission in kg C ha^{-1} $y.^{-1}$	
	bogs	**fens**
Canada[53]	- 0.8 to + 0.3	- 0.8 to + 0.3
Sweden[54]	0.8	
Finland[55]	2 to 21	- 0.5 to + 5.0
North-east Germany[56]		0.6 to 3.5
North-west Germany[57]		- 1.4 to + 0.3
Median	**2**	**0**

***Table A2/8**: Methane emissions from drained peatlands used as grassland. Negative values correspond to a net uptake and absorption of methane into the soil.*

Region	N_2O emission in kg N ha^{-1} $y.^{-1}$	
	bogs	**fens**
Finland[59]	0.04	1.2 to 1.5
Sweden, Finland (forest)[60]	0	
USA, temperate zone[61]		5.7 to 13.1
Netherlands[62]		2.2 to 13.3
South Germany[63]		4.2
North-east Germany[64]		0.6 to 14.0
North-west Germany[65]		5.0 to 16.0
Median	**0.02**	**5.7**

Table A2/9: Nitrous oxide emissions from drained peatlands used as grassland.

Nitrous oxide emissions from bogs are low (Table A2/9) 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[58].

Figure A2/2 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 to tilled bogs. Fertilisation and liming of grasslands strongly increases peat mineralisation[66].

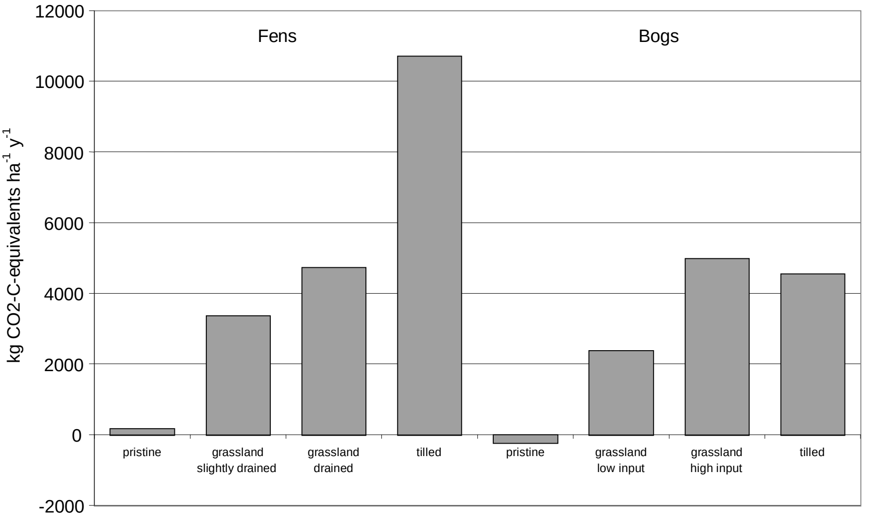

Figure A2/2: Rough estimates of the global warming potential of fens and bogs (in kg CO_2 equivalents ha^{-1} y^{-1}) under different types of land use (compiled by Heinrich Höper 2000).[67]

A2.4 THE ROLE OF PEATLANDS DRAINED FOR FORESTRY[68].

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[69], 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.

Peatland drainage for forestry also leads to changes in the *litter* carbon store. The “moist litter”[70] 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[71] 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. A2/3), 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[72], the cumulative carbon losses from peat oxidation prevail on the long run[73] (see Fig. A2/3).

With respect to gas exchange, the drainage of peatlands for forestry generally leads to an increase in CO_2 emissions[75], 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[76].

A2.5 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[77] some 50 kg CO_2-C, 11,3 g CH_4-C and 4.3 mg N_2O-N are eventually emitted[78]. Efficient drainage in the extraction areas may maintain high rates of CO_2 emissions[79] while CH_4[80] and N_2O emissions remain fairly low[81].

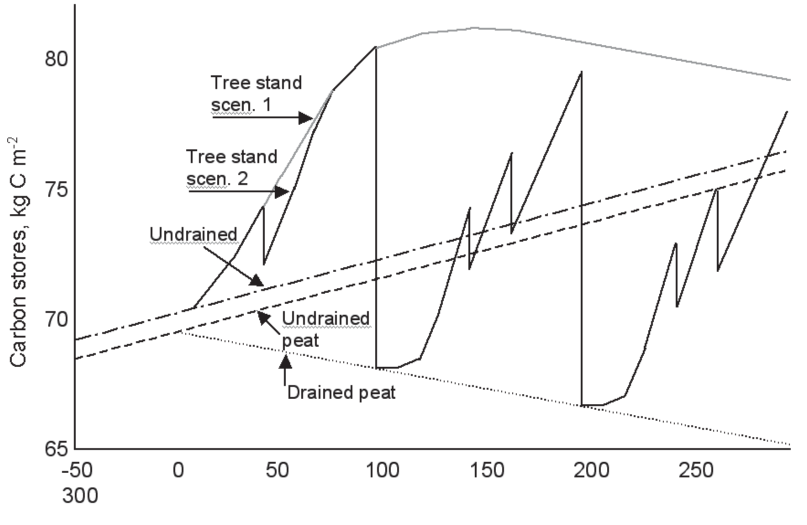

Fig. A2/3[74] Dynamics of the carbon stores of a tall sedge pine fen site (oligotrophic nutrient status) during the 300 years after drainage. Tree stand scenario 1: Total carbon store of an untreated drained tree stand. Tree stand scenario 2: Total carbon store of a drained production forest. Tree stand stores are shown as a difference between the total (continuous line) and peat store lines (dashed line).

	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[84]	+ 2184 ± 178
Totals	**973 ± 2312**

Table A2/10: Annual carbon balances of Finnish peatlands under different land-use forms (- sequestration; + emission)[83].

A2.6 NATIONAL BALANCES

Detailed national calculations with respect to peat carbon stores and radiative forcing are only available for Finland[82]. Table A2/10 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 A2/11 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[85]. 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.

A2.7 THE ROLE OF PEATLAND FIRES

In many areas of the world natural fires ignited by lightning strikes were normal phenomena in peatlands[87]. 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

		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 ± 0.75	+ 8.32 ± 0.71
Totals		**+ 18.97 ± 8.97**	**+ 8.06 ± 8.81**

Table A2/11: Summary of radiative forcing of Finnish peatlands under different land-use forms using different time horizons[86].

nomadic agriculture, of agricultural residues, and of biomass as fuel for cooking and heating[88].

Peatland fires may lead to the ignition of the peat layers, especially after drainage[89]. 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[90].

Emissions from biomass and peatland burning represent a large perturbation of global atmospheric chemistry[91]. In the 1982-3 drought and fire in East Kalimantan, the area affected by fire included 5500 km^2 of peat-swamp forest[92]. 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 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 [93], being equal to 10 % of the global annual emission from fossil fuel consumption[94].

A2.8 THE ROLE OF PEATLAND INUNDATION AND REWETTING

Peatlands are inundated for rice cultivation[95], water reservoirs (especially for hydro-electricity[96]), and mire restoration. Higher water table depths generally lower the carbon mineralisation rate[97]. 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[98]. Inundation of peatlands to create water reservoirs leads to significant emissions of both CO_2 and CH_4 [99]. 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[100]. In practice, however, rewetting of fen grasslands often leads to increased CH_4 emissions[101], while CO_2 emissions may remain continuously high[102]. 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[103].

Rewetting of drained alder forests leads to increased emissions of CH_4, but to decreasing N_2O- emissions[104].

A2.9 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[105]. As mires are concentrated in humid or cool regions, a changing climate can be expected to seriously affect their carbon balance and radiative forcing.

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[106].

Some researchers stress the importance of alterations in the water table level[107], 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[108] and suggest that a net loss of carbon will take place in northern fens but a net gain in northern bogs[109].

The behaviour of permafrost peatlands will also be important, as both decomposition and net primary production are accelerated following permafrost melt[110]. In general, methane emissions from peatland ecosystems will decrease with drying[111]. 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[112].

APPENDIX 3

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 4

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[113]: 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.[114] 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" [115]

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."[116]

Finland[117]: 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 separate all-mire areas. Traditional ways of using peatlands include peat cutting for litter in 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*[118] 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 other owners.

Estonia[119]: 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[120]: 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, 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[121]: 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[122]: 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[123]. 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[124].

Germany[125]: 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[126]: 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 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 of 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 5

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***[127].

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

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 forany 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 6

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 5 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 forany 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 7

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 8

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.

[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. All radiation (energy) is eventually transferred back to space but at longer wavelengths. For longer wavelengths a radiating body has to be warmer in order to lose the same amount of energy.
[4] Ivanov 1981, Couwenberg & Joosten 1999.
[5] See §A2.3.
[6] See §A2.2.
[7] Cf. §A2.3.
[8] See §A2.3, A2.4, A2.5, A2.6, A2.7.
[9] Francez & Vasander 1995.
[10] Francez & Vasander 1995.
[11] See §2.5.
[12] Committee on Global Change Research 1999.
[13] The Global Climate Change Task Force Of The Council On Engineering and Council On Public Affairs, 1998.
[14] Houghton et al. 1990.
[15] Franzén 1994, Franzén et al. 1996. See also Rodhe & Malmer 1997, Franzén 1997.
[16] Scholes et al. 2000.
[17] Reeburgh & Crill 1996.
[18] 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).
[19] More recent estimates of the total CH_4 emission from rice paddies amount to 50 ± 20 $\cdot 10^{12}$ g y^{-1} (Neue 1997).
[20] Aselmann & Crutzen 1990.
[21] Harriss et al. 1985, Bridgeham et al. 1995.
[22] Svensson 1976.
[23] Silvola et al. 1994b, Martikainen et al. 1992, 1994, 1995.
[24] Clymo & Reddaway 1971.
[25] Augustin et al. 1996.
[26] Pfeiffer 1993; Meyer 1999.
[27] Crutzen, 1979.
[28] Martikainen et al. 1993.
[29] Hillebrand 1993.
[30] Goodroad & Keeney 1984.
[31] Augustin et al. 1996.
[32] Meyer 1999.
[33] Crill et al. 2000.
[34] Crill et al. 2000.
[35] Scholes et al. 2000.
[36] Charlson et al. 1987, DeMello & Hines 1994, Kiene & Hines 1995, Lomans et al. 1997, 1999, Watson & Liss 1998, Lomans 2001.
[37] Varner et al. 1999.
[38] Daniel et al. 1995.
[39] Roulet 2000b.
[40] Mundel 1976.
[41] Höper 2000.
[42] Mundel 1976.
[43] Wild & Pfadenhauer 1997.
[44] Silvola 1986, Silvola et al. 1994a.
[45] Glenn et al. 1993.
[46] Mundel 1976.
[47] Segeberg & Schröder 1952, Kuntze 1992, Meyer 1999.
[48] Hillebrand 1993.
[49] 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.
[50] Kuntze 1973, Eggelsmann 1976.
[51] Schuch 1977.
[52] Okruszko 1989.
[53] Glenn et al. 1993.
[54] Svensson 1976.
[55] Lien et al. 1992, Martikainen et al. 1992, 1994, 1995.
[56] Augustin et al. 1996.
[57] Meyer et al. 1997.
[58] Personal communication from Heinrich Höper.
[59] Martikainen et al. 1993.
[60] Hillebrand 1993.
[61] Goodroad & Keeney 1984.
[62] Velthof & Oenema 1983.
[63] Flessa & Klemisch 1997.
[64] Augustin et al. 1996.
[65] Tschirsich 1994, Meyer 1999.
[66] As becomes apparent from comparing data from Segeberg & Schröder 1952 and Kuntze 1992.
[67] Similar results were found by Kasimir-Klemedtsson et al. 1997.
[68] 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.
[69] See also §3.4.1 (eb).
[70] Stegmann et al. 2001.
[71] In the boreal zone consisting of remains of conifer needles, branches, rootlets, forest mosses etc.
[72] Provided that the forest management continues and the peatland remains sufficiently drained.
[73] Cannell et al. 1993; Laine & Minkkinen 1996, Minkkinen & Laine 1998, Minkkinen 1999.
[74] From Laine and Minkkinen 1996. Reproduced by kind permission of the Finnish Peatland Society.
[75] 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).

[76] Cf. Augustin et al. 1998, Augustin 2001.

[77] With a bulk DW density of 100 kg m^{-3} and a C content of 50%.

[78] Hillebrand, 1993.

[79] 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.

[80] In a Swedish study, the CH_4 emission during the growing season was similar to emissions from virgin peatlands (Sundh et al. 2000).

[81] Crill et al. 2000.

[82] See, however, also Roulet 2000b.

[83] After Crill et al. (2000): Tables 6 and 13.

[84] Mean value and S.D. for the years 1994 - 1998.

[85] 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).

[86] After Crill et al.(2000): Tables 6, 13, and 15.

[87] Brown 1990, Kangas 1990, Paijmans 1990, Kuhry 1994, Frost 1995, Zoltai et al. 1998, Morrissey et al. 2000, Joosten 2001.

[88] Goldammer 1999a, Nepstad et al. 1999, Scholes et al. 2000.

[89] Maltby 1986.

[90] Ellery et al. 1989, Maltby et al. 1990, Grundling et al. 1998.

[91] Goldhammer 1999a.

[92] Scholes et al. 2000.

[93] Page et al. 2000.

[94] See §A2.2.

[95] See §3.4.1 (ea).

[96] See §3.4.2 (f).

[97] Mundel 1976.

[98] See Table A2/1 (Net sources of global atmospheric emissions of methane).

[99] Rudd et al. 1993, see also Moore 1994, Nykänen et al. 1996.

[100] Cf. Kamp et al. 2000.

[101] Tuittila et al. 2000.

[102] Tuittila et al. 2000.

[103] Flessa et al. 1997. See also Komulainen et al. 1999.

[104] Westermann & Ahring 1987, Grosse et al. 1992, Gonzalez et al. 1995, Augustin et al. 1998.

[105] Schouten et al. 1992.

[106] Roulet 2000a, Martikainen et al 2000.

[107] Laine 2000, Martikainen et al 2000.

[108] Pastor et al. 2000, Bridgham et al. 2000.

[109] Laine 2000, Pastor et al. 2000, Bridgham et al. 2000.

[110] Turetsky et al. 2000.

[111] Laine 2000.

[112] 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."

[113] Based on information provided by Katherine Meenan.

[114] Lucas 1970.

[115] Fuel Research Board 1921.

[116] Feehan & O'Donovan 1996 p. 30. See also O'Kelly 1959.

[117] Based on information provided by Timo Nyronen and Veijo Klemetti.

[118] A network of protected areas established by the European Union.

[119] Based on information provided by Rein Raudsep.

[120] Based on information provided by Lars-Eric Larsson.

[121] Based on information provided by Nikolai Bambalov.

[122] Based on information provided by Gerry Hood.

[123] Rubec, 1996.

[124] Rubec 1988.

[125] Based on information provided by Hartmut Falkenberg.

[126] Based on information provided by Adi Jaya and Jack Rieley.

[127] 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.

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