# Methods (last updated 27-01-2004)

The IMCG Global Peatland Database is still in a preliminary phase of development. Many of the available sources have not yet been included, various correction options have not yet been applied to the data, and summarizing conclusions have not yet been drawn. In presenting the present incomplete data we hope to stimulate further inventory and increase awareness of the global peatland resource.

## 1 Definitions

> "It remains only to point out that without a precise definition of the concept of peatland any useful peatland statistics cannot be collected and that all cartographic exercises and statistical studies of the area and distribution of peatland carried out without such definition (as well as all concludions based on these) must be handled with appropriate care."
>
> C.A. Weber 1902/2002.

International peatland terminology is acknowledged to be in a state of confusion (Joosten & Clarke 2002). The same terms are used for expressing totally different concepts. To give some examples:

- Shrier (1985) uses the term "mire" as an equivalent to "peat resources" or "peat deposits", whereas e.g. Rydin et al. (1999) define "mires" as "wetlands with a vegetation which usually forms peat". Consequently Rydin et al (1999) exclude, for example, all alder swamp forests from their "mire" concept, even if the soil is peat, and inspite of the fact that some alder forests do show extremely high peat accumulation rates (Barthelmes 2001).
- The Russian word "boloto" is actually a geographical term that characterizes a specific landscape with specific vegetation, humidity, and soil processes. "Torfjannyje boloto" can be equalled with a "boloto on a peatland", independent of whether the prevalent vegetation can produce peat or not. Agronomists, however, may use the same expression to indicate a "torfjannaja počva", i.e. a peat soil (Pjavtschenko in Largin 1960). Consequently, some authors will include an arable field on peat in their "torfjannyje boloto" concept, whereas others don't. Similarly the Finnish "suo" does include areas without peat formation and even without peat, but excludes peatlands used as arable fields, but includes again vegetation bare peatlands used for peat extraction (source).

For international comparison, we have tried to adjust the variety of existing data to uniform standards. In the IMCG Global Peatland Database the following concepts and terms have been used:

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

**Peat** is sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material.
This criterion is consistent with common definitions. In various inventories, other (mostly higher) percentages of organic material are used. Higher percentages exclude sedentates with

a high proportion of clastic material or carbonates, like flood mires (incl. mangroves and salt marshes) and calcareous spring mires.

A **peatland** is an area with or without vegetation with a naturally accumulated peat layer at the surface. To provide a uniform standard, the data with respect to peatlands – unless stated otherwise - concern peatlands with a **minimum peat depth of 30 cm**[1] to which all available data are recalculated.
The criterion "minimum peat depth of 30 cm" excludes many (sub)arctic and (sub)alpine areas with a shallow peat layer.

A **suo** is a wetland with or without a peat layer dominated by a vegetation that may produce peat. Areas with a peat depth > 0 cm and < 30 cm are listed under "suo".

A **mire** is a peatland (and therefore in our tables with a minimum peat thickness of 30 cm) where peat is currently being formed and accumulating.
A peatland with a peat thickness of > 30 cm and with a peat producing vegetation is both a "mire" and a "suo". Because mires are defined as peatlands, the "original" occurrence of mires and the original occurrence of peatlands are identical.

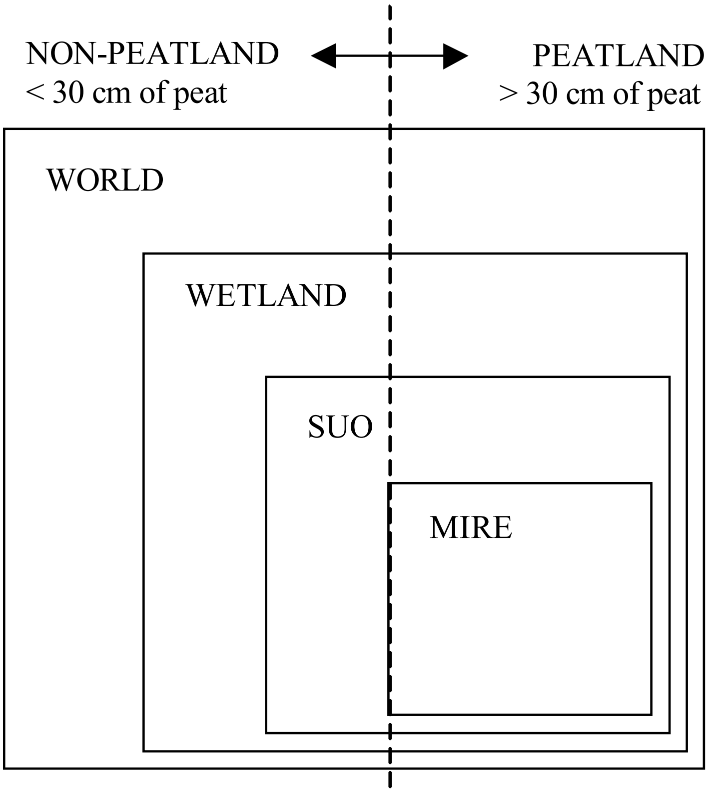

**Fig. 1**: Relationship between the concepts of mire, suo, wetland and peatland, used in this inventory

---

[1] The International Society of Soil Science, the Sub-commission for Peat Soils, at its congress in Zürich 1936 defined peatlands as follows: "For land to be designated as peatland, the depth of the peat layer, excluding the thickness of the plant layer, must be at least 20 cm on drained and 30 cm on undrained land." (Tibbets 1969). In Germany the "peatland" limit was in former times 20 cm and currently 30 cm (Schneider 1976), in Ireland the limit is 45 cm for undrained and 30 cm for drained areas, whereas the FAO/UNESCO Soil Map of the World defines Histosols as having an organic horizon of greater than 40 cm, with a 60 cm limit applying in case of *Sphagnum* peatlands (Bord na Mona 1985), to give only some examples of different inventory and mapping approaches. Our criterion of 30 cm concurs with that of Kivinen (1980), Kivinen & Pakarinen (1980, 1981).

In this overview, the presence of *peat* has been used as a prerequisite for classifying an area as a peatland or a mire. In the literature, often “peatlands” or “mires” have been described purely as a vegetational concept, without reference to the presence of peat. These records are not systematically included.
In citing references, we “translate” the terms used into the terms defined above when it is sufficiently clear with is meant with the various terms. When this is not completely clear, we use the original terms (or a close English equivalent in case of other languages) in “parentheses”.

## 2 Coverage

This overview concentrates on, but not restricts itself to, freshwater peatlands. Some peat accumulating or peat soil containing ecosystem types are generally overlooked, because they are - erroneously - not considered to be peatlands or mires. Because of absence of information, they are not sufficiently covered in our inventory. These ecosystems include

- Mangroves: Approximately 75% of all tropical coastlines are inhabited by mangrove (halophytic trees/shrubs) taxa. The densely arranged aerial roots (pneumatophores) of mangroves reduce wave dynamics, whereas their subaerial roots promote sedimentation. Peat formation is dependent on the mangrove type and its position within the tidal zone. Mangroves may form autochthonous peat, comprised mainly of intertwined rootlets and soft (parenchymatous) parts of larger roots. They may furthermore collect allochthonous peat-like sediments, which may be distinguished from real peat by the presence of marine invertebrate shells intermixed with finely divided plant debris (www.colby.edu/~ragastal/Paleobotany/marginalmarine.html).
  It is not clear to what extent mangroves are peat accumulating. Peat accumulating mangroves, i.e. mangroves in which mangrove roots, rather than above-ground sedimentary tissues (leaves, twigs) are peat-forming, are reported by e.g. Davis (1946), Kawalec (1976), Fujimoto & Miyagi (1993), Fujimoto et al. (1995), Korpijaakko & Korpijaakko (1996), Phillips & Bustin (1996), Lezine (1997), Middleton & McKee (2001), and Cahoon et al. 2003 (see also www.geol.sc.edu/COHEN/ COHEN/peat.htm). In our overview we have only included mangroves in the peatlands when the presence of peat was explicitly stated.
  Spalding et al (1997), based on areal estimates for 114 countries (see also WCMC 1998), estimate the global area of mangroves at 181,000 km$^2$. Considerable margins of error, however, exist because of differences in definition, age, scale, and accuracy of different national sources. Approximately 43% of the world’s mangroves are located in Indonesia (42,550 km$^2$), Brazil (13,400 km$^2$), Australia (11,500 km$^2$) and Nigeria (10,515 km$^2$). Each has between 25% and 50% of the mangroves in their respective regions, giving these countries a significant responsibility for the global status of mangrove ecosystems (Spalding et al 1997). Vast areas of mangroves have been and are continuing to be destroyed (Saenger et al 1983, Ellison 1994).
- Salt marshes: Outside the tropics, salt-marsh grasses and sedges replace the mangroves, the mangrove-marsh transition being dependent on the increased number of mangrove killing frost days. The plants occupying the marshes trap sediment during tidal cycles. The sedimentation rates are high in low marshes (at or slightly below base level), but lower in high marshes (up to 1 m above base level, or above the high-tide level). In the sediments autochthonous and allochthonous (including algae) organic material may accumulate. (www.colby.edu/~ragastal/Paleobotany/marginalmarine.html). Salt marshes are generally not peat accumulating, but organic peats from marine grasses have been reported by Middelburg et al. (1997).

Salt-marsh peatlands with fibrous peat, consisting of the remains of plants that have grown in salt or brackish water, often mixed with considerable amounts of washed in clay or silt, have been reported from America, both on the westcoast (e.g. Rigg 1958) and the eastcoast (Waksman et al. 1943, Middelburg et al. 1997). Marine transgression mires („Küstenüberflutungsmoore“) are abundant in the brackish Baltic Sea shores (Succow & Joosten 2001).

Not all peat found under salt marshes has originated under salt marsh conditions. The peat may also have been formed under freshwater conditions but afterwards have been covered by salt marsh sediments because of raising sea levels.

Spiers (1999) was not able to estimate the global extent of salt marshes, because of large information gaps for this particular wetland habitat throughout the world.

- <u>Paddies</u>: Especially in Southeast Asia peat soils have been reclaimed for rice cultivation and are often consequently classified as paddy soils, not as organic soils (Kawaguchi & Kyuma 1977). Because of cultivation practise the peat may rapidly disappear. Therefore, these originally organic soils will not be recognized anymore as former peatlands when reclamation took place further in the past. Kawaguchi & Kyuma (1977) give an example of an area near Banjarmasin, South Kalimantan, that was reclaimed for rice cultivation in the 1930s. The place is even called Gambut, which means "peat", but already in the 1970s all peat had disappeared, leaving acidic clay soils
- <u>Paludified forests</u>: Paludified forests are forests in which paludification and peat formation have proceeded to such an extent that the soil is covered with a layer of peat, but where the trees still largely root in the mineral subsoil. Paludification of mineral soils results from rising groundwater levels by an increase in water supply (by changes in climate or land use) or by a decrease in run-off (by sea level rise, beaver dams, the origin of water stagnating layers in the soil). Paludified forests are often not included in peatland inventories because they are regarded as "forests", even when the peatlayer exceeds 30 cm (Minayeva & Glushkov 2001).
- <u>Cloud forests and elfin woodlands</u>: Cloud forests and elfin woodlands ("dwarf cloud forests") include forests in the humid tropics that are frequently covered in clouds or mist; thus receiving additional humidity, other than rainfall, through the capture and/or condensation of water droplets (horizontal precipitation) (Stadtmüller 1987). They are characterized by the abundance of epiphytes, especially mosses and Hymenophylaceae (Walter 1979), and in most cases the presence of Cyateacea (tree ferns) (Kroener, 1968, Troll 1970). In all cloud forests of restricted growth, corresponding with dense and persistent cloud zones, a fairly thick layer of practically undecomposed organic matter ("peat") is noted (Stadtmüller 1987). The soils in cloud forests with vigorous growth and high trees do not show this phenomenon (Huber 1976). Lotschert (1959) mentions a layer of organic material more than a metre deep in a cloud forest in El Salvador. Brewer-Carias (1973) reported that the soil of the Cerro de la Neblina cloud forest in Venezuela was covered with a thick layer of raw humus that in certain localities reached more than four metres in depth. Possibly a large part of this "peat" consists of leave material (cf. Whitmore & Burnham 1969), i.e. it is a sediment, not a sedentate, and therefore no peat according to our definition. Cloud forests are reported from a total of 605 sites in the world with tropical montane cloud forests having been identified to date in 41 countries. The highest concentration is found in Latin America, where 280 sites are found in 12 countries, the majority in Venezuela, Mexico, Ecuador, and Colombia. In south-east Asia, 228 sites have been identified in 14 countries principally in Indonesia and Malaysia and to a lesser extent in Sri Lanka, Philippines and Papua New Guinea. In Africa, 97 sites have been recorded in 21 countries, with many cloud forests found on relatively isolated mountains which are scattered across the continent. For detailed information on their distribution, consult http://www.unep-wcmc.org/forest/cloudforest/english/maps.htm

Bockor (1979) estimated the total surface of cloud forests in the humid tropics in the early 1970s at 500,000 km$^2$. Losses of cloud forests, through conversion to grazing and crop land and though fuelwood cutting, are higher than for any other tropical forest biome and may amount to over 1 % per year (Bruijnzeel & Hamilton 2000).

- Paramos: Páramos are ecosystems within the tropical regions of Mexico, Central and South America, Africa, Malesia including New Guinea, and Hawaii, that occur between the upper limit of continuous, closed-canopy forest (i.e., forest line or timberline) and the upper limit of plant life (i.e., snow line) between about 3000 m and 5000 m. Locally these areas are known as "zacatonales" (the Mexican and Guatemalan volcanic highlands), "páramo" (Central and northern South America), "jalca" (northern Peru), "puna" (drier areas of the altiplano of the central Andes), "afroalpine" and "moorland" (East Africa), and "tropical-alpine" (Malesia). Tussock grasses, large rosette plants, shrubs with evergreen, coriaceous and sclerophyllous leaves, and cushion plants characterize the vegetation.
  In the tropics of the Americas, the páramo ecosystem is discontinuously distributed between 11°N and 8°S latitudes. It is concentrated in the northwest corner of South America, mostly in Venezuela, Colombia, and Ecuador, but there are outliers in Costa Rica, Panama, and northern Peru. Other neotropical areas that have páramo-like vegetation include Pico Duarte in the Dominican Republic, the "zacatonales" of Mexico, Pico Naiguatá (Avila and the Silla de Caracas areas) in the Cordillera Costal of north-central Venezuela, Pico de la Neblina along the Venezuela/Brazil border, scattered "humid puna" areas of the eastern slopes of the Peruvian Andes, the "yungas" region of northeastern Bolivia, scattered areas in Chile and Argentina, and the Itatiaia area of eastern Brazil.
  Páramos have a generally cold and humid climate with sudden changes in the weather and a diurnal fluctuation in temperature from below freezing to as much as 30°C, which often results in a daily freeze-and-thaw cycle that has been referred to as "summer every day and winter every night".
  Most páramo soils are relatively young and only slightly developed. At its middle elevations (i.e., grass páramo), páramo soils are relatively deep, humic, black or dark brownish, and acidic with pH ranging from about 3.7 to 5.5. They are continuously moist or even saturated with water due to the daily formation of dew or frost and the water-retaining capabilities of the highly organic, peat-like content. Swampy or boggy azonal sites, called cushion mires or "turberas", are common, especially in the uppermost grass páramo. Here species of the spectacular cushion plant growth form attain their best development, e.g., *Azorella aretioides*, *A. multifida* and *A. pedunculata* (Apiaceae), *Oreobolus obtusangulus* (Cyperaceae), the moss-like *Distichia muscoides* (Juncaceae), and *Plantago rigida* (Plantaginaceae). Other wet or flooded azonal communities such as marshes ("pantanos" or "ciénagas"), seeps, and springs, can be found in the páramos (http://www.botanypages.org/neill/paramos/1_introduction.htm#future).
- Dambos: Dambos are seasonally or permanently wet grassy valleys, depressions, or seepage zones on slopes. Locally, they are known as “bas-fonds” or “marigots” in French speaking West and Central Africa, “inland valleys” or “bolis” in Sierra Leone, “fadama” in Nigeria, “vleis” (Africaans), “bani” (Shona), “mapani”, “mbugas” (Tanzania) or “dambos” in Eastern and Southern Africa (Mharapara et al. 1998, Sonou 1998). Dambos partly contain organic soils (“dambo peats”, cf. Brammer 1973, Mukanda 1998).
- Cryosols: Cryosols are perennially frozen mineral and organic soils that contain cryic horizons within 100 (uncryoturbated and organic soils) or 200 (cryoturbated soils) cm of the soil surface. Cryosols cover approximately 18 x 10$^6$ km$^2$, or about 13% of the land area of the world, dominate the Arctic regions, are widespread in the Subarctic, discontinuous in Boreal areas, and sporadic in more temperate mountainous regions. As a

result, Cryosols are widespread in Canada and Alaska, cover large areas in Russia and China, and occur in some areas in Mongolia. They also occur in smaller areas in permafrost regions in the countries of northern Europe, in Greenland, in the ice-free areas of Antarctica, and at high elevations in mountainous regions such as the Rockies (North America), Andes (South America), Himalayas (Asia), and Alps (Europe). Cryosols are often associated with both a significant accumulation of organic matter at the surface and cryoturbated organic matter in the subsoil. Patterned ground is commonly associated with Cryosols. The patterned ground types associated with mineral Cryosols are earth hummocks, and sorted and nonsorted circles, nets, stripes, steps and polygons. Organic Cryosols (Histic Cryosols) are commonly associated with palsas, peat plateaus, peat hummocks, polygonal peat plateaus, and low- and high- centered lowland polygons. It has been estimated that 27% of the world's soil carbon occurs in the Arctic, Subarctic and Boreal ecosystems (http://nsidc.org/data/docs/noaa/g01175_caps/).

## 3 Reliability of the basis data

The data presented in the final conclusions try to weigh up conflicting information[2] from a variety of sources and to make an informed guess. as to the actual situation.
An international overview of peatland/mire areas is complicated by the following, often interrelated, aspects (cf. Andriesse 1988):

- Typological differences: Inventory and mapping of peatlands depend on interests (agriculture, forestry, peat extraction, conservation) and local classification traditions. Typologies and criteria therefore differ considerably from country to country, from discipline to discipline, from time to time, and from object to object. In Canada, for example, the thickness criterion of organic soils is 24 inches (60 cm) for fibric Sphagnum peats and 16 inches (40 cm) for other types of peats (Rennie 1977). In one country and within one discipline criteria may change with time. In Germany, for example, in former times "peatlands" only had to have 20 cm of peat, whereas currently a minimum thickness of 30 cm is required (Schneider 1976). Such changing concept should lead to a change of the figures involved. In the "Schneider- series", a series of publications from the same author dealing with global peatland distribution (Schneider 1958, 1976, 1980, Schneider & Schneider 1990, Pfadenhauer et al. 1993), the figures, however, only change for Germany. For other countries the figures remain the same, indicating that also Schneider – who was apparently aware of them - saw no way to systematically deal with the typological differences involved.
  In this review we have - where possible – recalculated the data with a different minimum peat depth to the 30 cm criterium (see § 1.4 Calculation of the 30 cm criterion area). Differences in the concept of "peat" were not considered as the necessary information of local inventories is generally missing (cf. the concept of "muck").
  Also the minimum amount of organic material necessary to identify a substrate as "peat" differs in various typologies. 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 2001). 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 1999). The 30% criterion we use is a value often encountered in definitions of peats and organic soils in international literature. It is a

---

[2] "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).

practical criterion, because between 8 – 30 % it is impossible to estimate the content of organic material in the field (Schweikle Bad Wurzach, pers. comm.. 2003).

- Scale differences: Information is only collected for a specific spatial scale. Inventories generally only consider peatlands of a certain minimum extent, e.g. larger than 3, 10, or 100 ha. In a later phase we will try to correct for these differences (see § 5 Coverage of small peatlands). Furthermore, the FAO/UNESCO Soil Map of the World (SMW; 1: 5,000,000, 1974 - 1981) from which many peatland distribution data in tropical countries are derived, has legend units that largely consist of associations of different soil types. Such associations were necessary because of the low resolution. During the composition of the SMW the percentages of the various soils in the associations has not been recorded explicitly, but there are some general mapping rules that allow an estimation of these percentages: e.g. dominant soil type 60%, associated soil type 30%, inclusion 10% of the map unit.
- Time differences: As the area of peatlands/mires may change considerably in time because of mire expansion or peat oxidation/extraction, the data presented in inventories are only valid for a specific period. To present a uniform base line, the "original occurrence" of peatlands/mires was estimated (see § 1.6 Original occurrence).
- Changing national borders and names: National borders have been changing considerably in the 19th and 20th century, particularly in Europe, complicating the use of older inventories. We present the data according to the present borders of the countries involved. Where reliable data for individual countries are unavailable, data for former collective states are used.
- Calculation or printing errors and quotation mistakes. Some examples:
  - Von Bülow (1929) mentions detailed figures for Southern Sweden (totalling 11,848 km$^2$) and a lump figure for Northern Sweden (7,000 – 9,000 km$^2$). He arrives at a total peatland area for Sweden of 80,000 – 100,000 km$^2$. It is apparent that somewhere a calculation or typing error must be present.
  - In the data for Switzerland a jump takes place between Von Bülow (1929) with a "peatland" area of 5,464 ha and Kivinen & Pakarinen (1980) with an area of 550 km$^2$. This "jump" of a factor ten could have been caused by wrongly converting hectares into km$^2$.
  - Lappalainen & Żurek (1996a) give a 1000 times too high figures for the peat volume of Romania because the original figure in m$^3$ is wrongly converted to Mm$^3$.
  - Markov et al. (1988) present a figure for the area of Canadian „peat resources“ a figure of 129,500 km$^2$, that is exactly 10 times smaller than that of the "peatland" area of Moore & Bellamy (1974).
  - Figures are sometimes misquoted because acres are confused with hectares, hectares (cf. hm$^2$) with km$^2$, etc.
- Confusion occurs between geographical areas and nations (cf. Great Britain/United Kingdom, Japan, New Zealand), and may have occurred with countries with changing names (cf. Congo – Zaire - Congo, Pakistan - Bangladesh), and between areas or countries with similar names (cf. the various Guyanas and Guineas). We discuss these possible errors in the country texts.
- Pseudo-exactness is introduced through recalculation of figures in the metric system by which a greater exactness is suggested than in reality has been assessed. A quoted area of 2,328 ha for the Negril Morass in Jamaica, for example, gives the impression of being much more exact than the original figure of 6,000 acres (Robinson 1983).
- Repetition of source error: In most literature, the facts and figures presented are copied from older literature and "recycled" through a number of publications without checking, discussing or referring to the inventory techniques, the level of accuracy, and the (often very different) concepts used to arrive at the data. Many publications do not at all refer to

the data source or only in very general terms. Schneider (1980) and Schneider & Schneider (1990), for example, just state: “composed after various sources mentioned in the reference list”. Pfadenhauer et al. (1993) refer to “a number of different sources” and then list as examples a number of largely irrelevant publications. From the figures they present it becomes clear that Markov et al. (1988) have used Moore & Bellamy (1974) as a source of some of their data, although this publication is missing from their reference list.

We have tried to reconstruct the “quotation pathway” in order to arrive at the “original” source of the data presented. In a quotation sequence the data may be expected to become “less unreliable” as with every consecutive citation more people (should) have given consideration to their probability. Special attent is paid in this respect to key publications that are often cited for peatland distribution data.

The figures of losses presented here are to a large extent “guesstimates”, as adequate data are not available for the majority of countries. 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.

In general we appliedf the “priority rule”: we accept the first estimate unless there are good and motivated reasons to deviate from it.

## 4 Calculation of the 30 cm criterion area

Many data do not use a minimum peat depth of 30 cm but use different depths. To recalculate such deviant data to the 30 cm criterion the correlation was sought for regions or areas for which data on different peat depths are available.

Further analysis required
Russia
Sri Lanka
Estonia

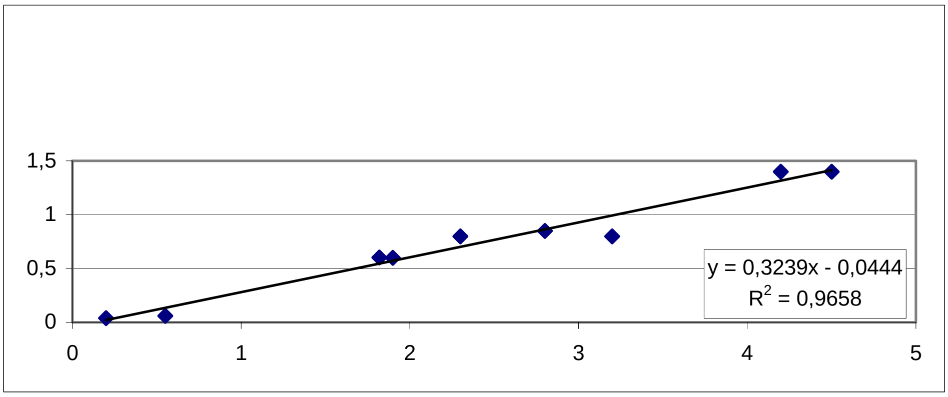

Fig. 1. Relation between suos and peatlands for the European part of the former USSR excluding Northern Territory, Leningrad Province, and Karelian ASSR (after data from Tjuremnov 1949).

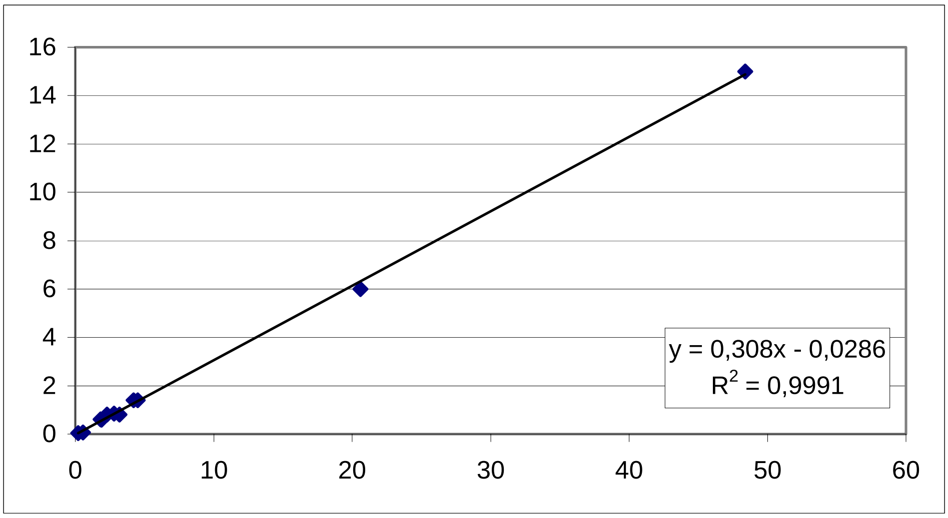

Fig. 2. Relation between suos and peatlands for the European part of the former USSR (after data from Tjuremnov 1949).

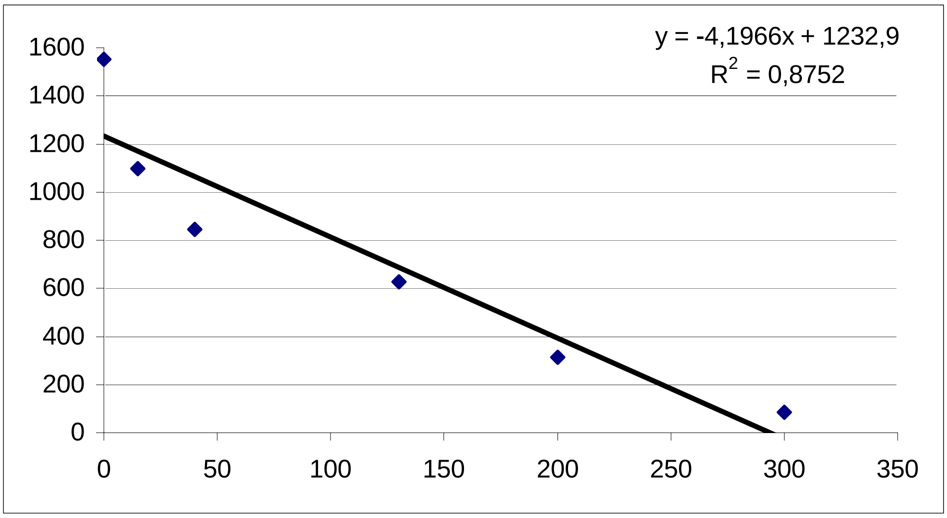

Fig. 3: Peat thickness distribution in three peatlands on Sumatra (after data from Rieley et al. 1996b, 1997). X axis: minimum peat thickness in cm, Y axis: area in hectares (Linear correlation).

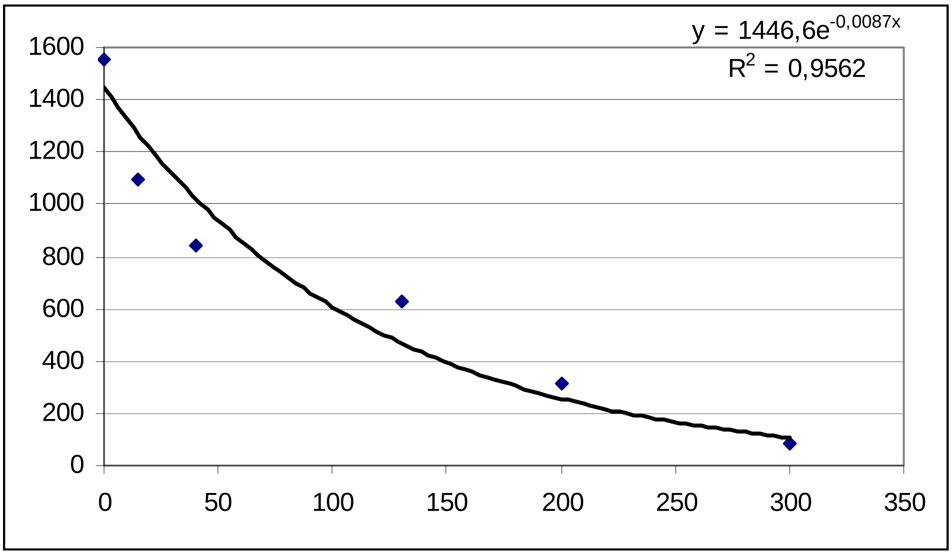

Fig. 4: Peat thickness distribution in three peatlands on Sumatra (after data from Rieley et al. 1996b, 1997). X axis: minimum peat thickness in cm, Y axis: area in hectares. (Exponential correlation).

## 5 Coverage of small peatlands

welke landen hebben zulke data? Polen (deels), Lithauen (schatting)

## 6 Original occurrence

For the 'original occurrence' of mires, 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 climate maximum[3]. Changes in the areal extent of mires and peatlands are therefore largely attributable to human activities, both on site as outside the peatland area (e.g. hydrological changes outside the mire area).

Fig. 5 shows the area of Sphagnum peatlands in various parts of the world during the last 21000 years.

---

[3] Substantial areas of peatlands have been inundated by the rising sea levels during the Lateglacial and Holocene (cf. Godwin 1943, 1945, Jelgersma 1961, Fries 1964, Emery et al. 1965, Hoppe 1965, Streif 1982, Rasch & Jensen 1997, Thieler et al. 2000) or covered by sediments following earthquakes (http://www.pgc.nrcan.gc.ca/seismo/hist/megapap.htm). As our inventories only concern the present-day (semi-)terrestrial areas with peats laying at the surface, these former peatlands are not taken into consideration.

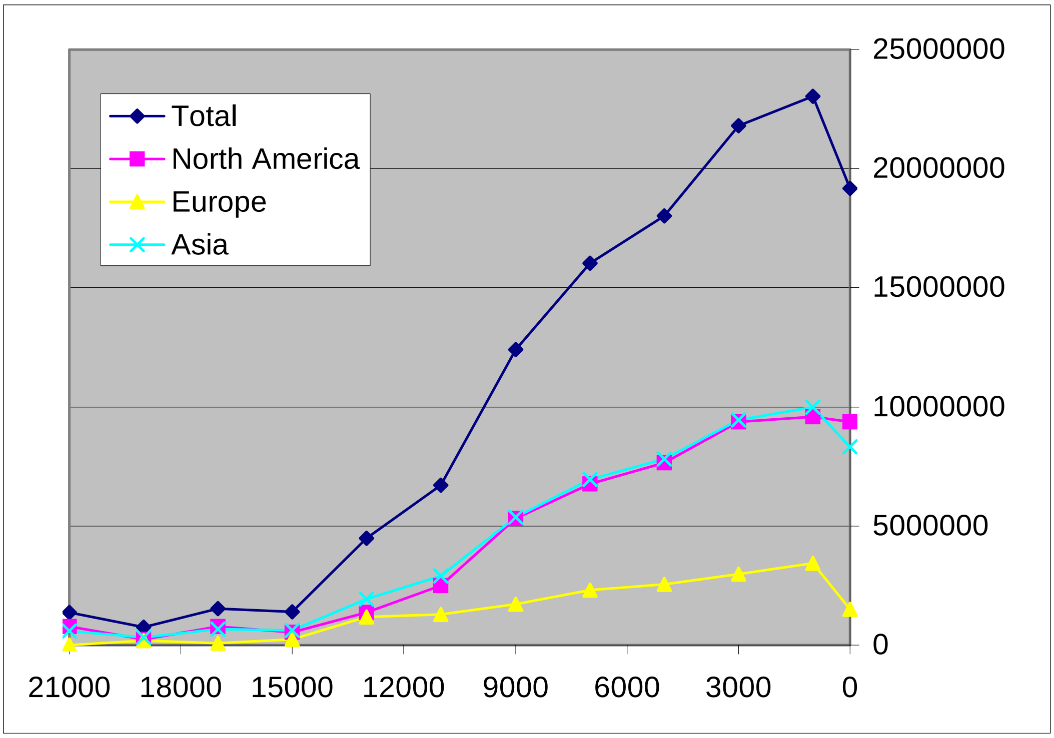

Fig. 5: The area of Sphagnum peatlands in North America, Europe, and Asia in the last 21,000 years. X- axis: years BP, y-axis: area in km$^2$. After Gajewski et al. 2001.

Human activities have not only led to a destruction of mires, but also to their origin and expansion (Moore 1975, Törnqvist & Joosten 1988, Bennett et al. 1998). 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.

In some areas of the world, mires and suos may still be actively expanding. In the Central Forest Biosphere Nature Reserve (European Russia) the area of paludified forests increased with 10% between 1939 and 1984 (Minayeva & Glushkov 2001).
Finnish studies
Varlyguin (2001) estimates the current annual rate of paludification in the entire boreal part of West Siberia on approximately 250 km$^2$. This paludification has a largely anthropogenic cause as the vast majority of the newly paludified areas are found upstream of roads, pipelines, and oil wells or are associated with forest clear-cutting and subsidence following oil withdrawal.

Drainage of peatlands leads to peat subsidence and oxidation/mineralisation of the peat (Okey 1918, Powers 1932, Fowler 1933, Edelman 1947, Weir 1950, Stephens 1956, Harris et al. 1962, Prus-Chacinsky 1962, Mitza & Irwin 1964, Kuntze 1992) and a decrease of the peat depth in time. When the peat layer become less than 30 cm thick, the area is not called a peatland anymore according to our inventory definition. The peat may eventually disappear completely (Borger 1975, Kawaguchi & Kyuma 1977, Leenders 1989) and former peatlands change into humus rich mineral soils (Ilnicki xxx). Consequently these former peatlands are excluded from recent geological or pedological inventories that use a minimum peat thickness for classifying peat soils/deposits.
To estimate the "original peatland occurrence" from recent inventories, historic land use intensity has to be taken into account.

The rate of peat mineralization is a function of land use intensity (incl. drainage depth, intensity and type of land use[4]), climatic conditions, and peat type. As the climatic conditions determine the possible peat type, the latter two parameters are to some extent correlated. The rate of "peatland" disappearance is furthermore determined by the depth distribution of the peatlands, deep peatlands taking more time to disappear (becoming less thick than 30 cm) than shallow ones.

Ilnicki (1996a) expects – on the basis of a mathematical model based on 24 years of observations in the Agricultural Experimental Station in Polesje -, that within 20 years 34% of the drained peatlands in Belarus will have been transformed into anthropogenic mineral soils, being a rate of 1.7 % per year. Similarly the area of peatlands (> 1m peat) in the Korsa Lowland (Nesterenko) decreased with 26 % during 25 years of agricultural utilisation (1.0 % per year). For the German situation an annual rate of disapperance of around 0,5 % can be deduced in case peatlands are drained for agriculture or peat extraction (Table 1).

Table 1: Peatland losses in various German federal states

| Federal State | peatland loss | | period | annual loss (%) | references |
|---|---|---|---|---|---|
| | $km^2$ | % | | | |
| Schleswig-Holstein | 300 | 17 | 1954 - 1998 | 0.39 | Couwenberg & Joosten 2001 |
| Niedersachsen (bog) | 500 | 24 | 1980 - 1997 | 1.41 | Schneekloth 1983, Stähle et al. 1997 |
| Mecklenburg-Vorpommern | 288 | 13 | 1965 - 1995 | 0.43 | Lenschow 2001 |
| Bayern | 800 | 40 | 1914 - 1992 | 0.51 | Schuch 1993, Schuch & Zollner 1996 |
| Brandenburg | 600 | 28 | 1965 - 2000 | 0.81 | H. Lehrkamp pers. comm. 2001 |
| Baden-Württemberg | | 12 | (1960) - (1995) | 0.27 - 0.60 | Kracht & Schweikle 2001 |

Notes (still to worked into the text):

Deze lineaire losses moeten waarschijnlijk exponentiele worden

**Dömsödi**, J. 1988. Über den Verlust von Mooren im Karpatenbecken. *Telma* 18: 29 - 42.
**Stephens**, J.C. 1956. Subsidence of organic soils in the Florida Everglades. Proc. Soil Science Society 20: 77-80. Gives isopachous charts showing the original depth of peat soils in 1912, in 1925, and in 1950 for the agricultural area near Lake Okeechobee and projected to the year A.D. 2000.
**Fowler**, G. 1933. Shrinkage of the Peat-Covered Fenlands. Geog. Journ. 1933, 2pp,

In Malaysia, within the Western Johore Integrated Agricultural Development Project, total subsidence has reached almost 3 m since about 1960, with average rates of approximately 5 cm

---

per year declining later to 2 cm per year (Wösten et al. 1997). Approximately 60 % oif the toal subsidence was estimated to be due to oxidation and around 40% due to shrinkage.

**Wösten**, J.H.M., Ismail, A.B. & Van Wijk, A.L.M. 1997. Peat subsidence and its practical implications: a case study in Malaysia. Geoderma 78: 25-36.

In 20 years after drainage the Okeelanta peatland in Florida lost 5 feet of depth
**Clayton**, B.S. 1937. Subsidence of Florida peat soil. Trans. Sixth Comm. Internat. Soc. Soil Sci (Zürich) B: 340 – 343. (from Waksman 1942)
For many older American data, see Waksman 1942.

That drainage and associated burning eventually could lead to a complete loss of the wetland resource, was already expressed in the 1790s in an account from Lanarkshire (Scotland): ”Moss, of this kind, repeatedly burnt, becomes thinner and thinner, till it disappears almost or altogether, and leaves the clay, that was once three or four feet down, on the surface. Some hundreds of acres have been converted in this manner from moss to make arable land” (Fenton 1970).

In the UK, the best historical data on wastage is from the peat fenlands of eastern England. Measurements vary depending on the height of the controlled water-table, the extent and constancy of cultivation and the type of peat. Fenmen, who have worked the peatland all their lives, talk of a wastage rate of an inch (2.5cm) a year.

Archaeological workers have estimated wastage to be 0.6cm a year for the 200 years of windmill drainage and about 2.5cm a year for the period of power plant drainage and intensive cultivation.

Normal drainage practice in the Fens would aerate the upper 90 to 150cm above the groundwater-table during the summer growing season and maintain the water-table at about 60cm depth during winter.

Easily accessible articles on this subject are:

Stephens, J.C. (1956) Subsidence of organic soils in the Florida Everglades. Proc. Soil Sci. Soc. Am. 20, 77-80.

Richardson, S.J. and Smith, J. (1977) Peat wastage in the English Fens. Journal of Soil Science 28, 485-489.

Hutchinson, J.N. (1980) The record of peat wastage in the East Anglian Fenlands at Holme Post, 1848-1978 AD. Journal of Ecology 68, 229-249. [This author estimates a loss of 3.83 metres of peat over 100 years]
Maslow et al. (1996) show that subsidence through biological oxidation in the second phase of agricultural use of peatlands reamins considerable, varying from 1 to 10 cm in the first ten years to a constant value of 1 – 2 cm per year after 60 – 130 year.

**Middleton**, B.A., and McKee, K.L., 2001, Degradation of mangrove tissues and implications for peat formation in Belizean island forests: Journal of Ecology 89: 818-828.