HISTOSOLS (HS)

The Reference Soil Group of the Histosols comprises soils formed in ' organic soil material'. These vary from soils developed in moss peat in boreal, arctic and subarctic regions, via moss peat, reeds/sedge peat and forest peat in temperate regions to mangrove peat and swamp forest peat in the humid tropics. Histosols are found at all altitudes but the vast majority occurs in lowlands. Common international names are 'peat soils', 'muck soils', 'bog soils' and 'organic soils'.

Definition of Histosols

Soils,

1 having a histic or folic horizon, and
either 10 cm or more thick from the soil surface to a lithic or paralithic contact,
or 40 cm or more thick and starting within 30 cm from the soil surface; and

2 having no andic or vitric horizon starting within 30 cm from the soil surface.

Common soil units:

Glacic, Thionic, Cryic, Gelic, Salic, Folic, Fibric, Sapric, Ombric, Rheic, Alcalic, Toxic, Dystric, Eutric, Haplic.

Summary description of Histosols

Connotation: peat and muck soils; from Gr. histos, tissue.

Parent material: incompletely decomposed plant remains, with or without admixtures of sand, silt or clay.

Environment: Histosols occur extensively in boreal, arctic and subarctic regions. Elsewhere, they are confined to poorly drained basins and depressions, swamp and marshlands with shallow groundwater, and highland areas with a high precipitation/evapotranspiration ratio.

Profile development: Transformation of plant remains through biochemical disintegration and formation of humic substances creates a surface layer of mould. Translocated organic material may accumulate in deeper tiers but is more often leached from the soil.

Use: Sustainable use of peat lands is limited to extensive forms of forestry or grazing. If carefully managed, Histosols can be very produc-tive under capital-intensive forms of arable cropping/horticulture, at the cost of sharply increased mineralization losses. Deep peat formations and peat in northern regions are best left untouched. In places, peat bogs are mined, e.g. for production of growth substrate for horticulture, or to fuel power stations.

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Regional distribution of Histosols

The total extent of Histosols in the world is estimated at some 325 - 375 million ha, of which the majority are located in the boreal, subarctic and low arctic regions of the northern hemisphere. The rest occurs in temperate lowlands and cool montane areas; only one-tenth of all Histosols is found in the tropics. Histosols are largely confined to the USA and Canada, Western Europe and northern Scandinavia, and to northern regions east of the Ural mountain range. Some 20 million hectares of tropical, acid, forest peat border the Sunda shelf in Southeast Asia. Smaller areas of tropical Histosols are in river deltas, e.g. in the Orinoco delta and the delta of the Mekong river, and in depression areas at some altitude. Figure 1 presents a sketch map of the main occurrences of Histosols worldwide.

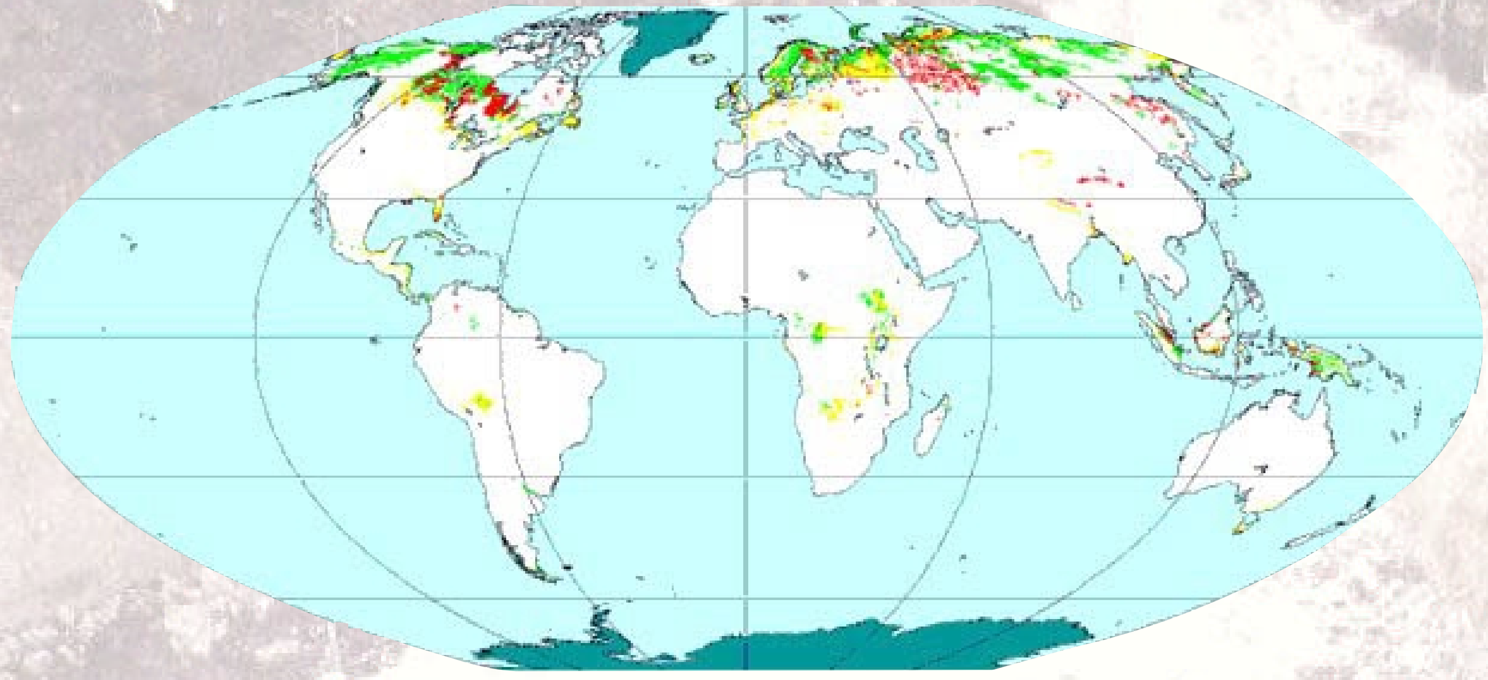

Figure 1. Histosols worldwide.

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Associations with other Reference Soil Groups

Organic soil materials in northern regions could accumulate there because decay of organic debris is retarded by frost in the cold season and by prolonged water-saturation of the thawed surface soil during summer. Permafrost-affected Histosols are associated with Cryosols and with soils that have gleyic or stagnic properties, e.g. Gleysols in Alaska and in the northern part of the former USSR. Where the (sub)arctic region grades into the cool Temperate Zone, associations with Podzols can be expected.
Histosols that formed in organic soil material under the permanent influence of groundwater ('*low moor peat*') occupy the lower parts of fluvial, lacustrine and marine landscapes, mainly in temperate regions. Other soils in the same environment are Fluvisols, Gleysols and, in coastal regions, Solonchaks (e.g. adjacent to coastal mangrove peat). Histosols in lacustrine landforms are commonly associated with Vertisols.
Rain-dependent Histosols are found in environments with sufficiently high and evenly spread rainfall, e.g. in raised 'dome' peat formations ('*high moor peat*') in lowland areas and in up-land areas with blanket peat, where paucity of nutrient elements, acidity and near-permanent wetness retard decay of organic debris. Lateral linkages exist with a variety of Reference Soil Groups, including Andosols, Podzols, Fluvisols, Gleysols, Cambisols and Regosols.

Genesis of Histosols

Histosols are unlike all other soils in that they are formed in 'organic soil material' with physical, chemical and mechanical properties that differ strongly from those of mineral soil materials. 'Organic soil material' is soil material that contains more than 20 percent organic matter by weight, roughly equivalent to 30 – 35 percent by volume. Organic soil material accumulates in conditions where plant matter is produced by an adapted ('climax') vegetation, and where decomposition of plant debris is slowed by:

- low temperatures,
- persistent water saturation of the soil body,
- extreme acidity or paucity of nutrient elements ('*oligotrophy*'), and/or
- high levels of electrolytes or organic toxins.

Figure 2 indicates that a surplus of organic soil material can build up in cold and temperate regions, and under swamp conditions even in the tropics. Organic soil materials that formed in different environments are generally of different botanical composition; the degree of decomposition and content of mineral admixtures are equally varied.

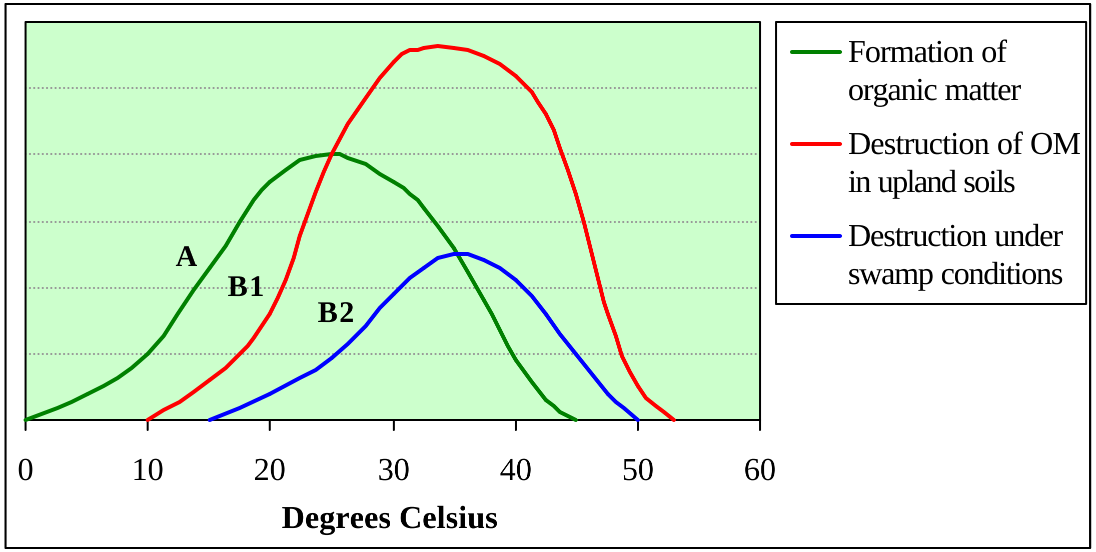

Figure 2. Comparative rates of production (A) and decomposition (B1 in aerated soil; B2 under water) of organic matter as influenced by the temperature and aeration status of the soil matrix. (After Mohr, Van Baren & Van Schuylenborg, 1972).

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Note: In view of the limited agricultural significance of the (extensive!) northern Histosols, and because Histosols in temperate and tropical climates are under much stronger attack, the following discussion will focus on Histosol development and Histosol deterioration in temperate and tropical climates.

The majority of all peat bogs in the Temperate Zone and in the tropics are found in lowland areas, e.g. in coastal plains and deltas and in fluvial and lacustrine inland areas. Local depressions/pools in such wetlands are gradually filled in with reeds and sedges and with the remains of aquatic plants that accumulate in the deeper parts. The margins of a depression area are the first to become 'dry'. This prompts the vegetation, differentiated in floral belts adapted to different degrees of wetness, to shift toward the center of the depression. Eventually, the entire depression is filled with '*topogenous peat*' ('*low moor peat*', formed under the influence of groundwater). The transition from the mineral substrata to the overlying peat body may be gradual but a thin transitional layer of black, smeary, completely decomposed organic sediment ('*gyttja*') is not uncommon (see Figure 3).
Topogenous peat is shallow by nature. Only where its accumulation coincides with gradual tectonic lowering of the land surface can it reach a great depth. Topogenous peat deposits in the Drama Plain, Greece, for instance, are in places deeper than 300 meters.

In upland areas where temperatures are 'low' and rainfall/fog is evenly spread over the year, rain-dependent '*ombrogenous peat*' ('*high moor peat*') may form where microbial activity is depressed by severe acidity, oligotrophy and/or organic toxins. The 'blanket peats' of Scotland are an example of (shallow) ombrogenous peat that lies directly over hard bedrock.
Ombrogenous peat formations in lowland areas normally overlie topogenous peat. After a depression is completely filled with topogenous peat, accumulation of organic soil material *may* continue. This happens where rainfall is high and evenly spread over the year, and microbial activity is suppressed by low temperature, wetness, acidity/oligotrophy and/or salt or organic toxins. The then formed peat mass rises over the mean water level and becomes increasingly ombrogenous in character as it is ever less enriched with mineral material (clay, nutrients) carried on with floods. As long as a peat body is still shallow, the vegetation can draw nutrients from the underlying mineral base. Once the peat has grown to a depth that puts the subsoil out of the reach of living roots, uptake of nutrient elements from outside stops while losses of nutrients (e.g. through leaching) continue; the vegetation

must survive on a gradually decreasing quantity of cycling nutrients. The (climax) vegetation adapts to this gradual change by becoming poorer in quality and species composition. An initially heavy *mixed swamp forest* degrades slowly into light *monotonous forest* with only few tree species, and ultimately into *stunted forest* which produces insufficient organic material for further vertical growth of the bog. The net rate of vertical peat accumulation seems to decrease over time according to a roughly exponential pattern. Carbon dating of deep (8 to 12 m) dome peat formations under swamp forest in Sarawak and Indonesia suggest that the initial accumulation rate of 0.25 to 0.45 cm/year decreased in the course of 3 to 5 millennia to 0.05 cm/year and less (Anderson, 1964).

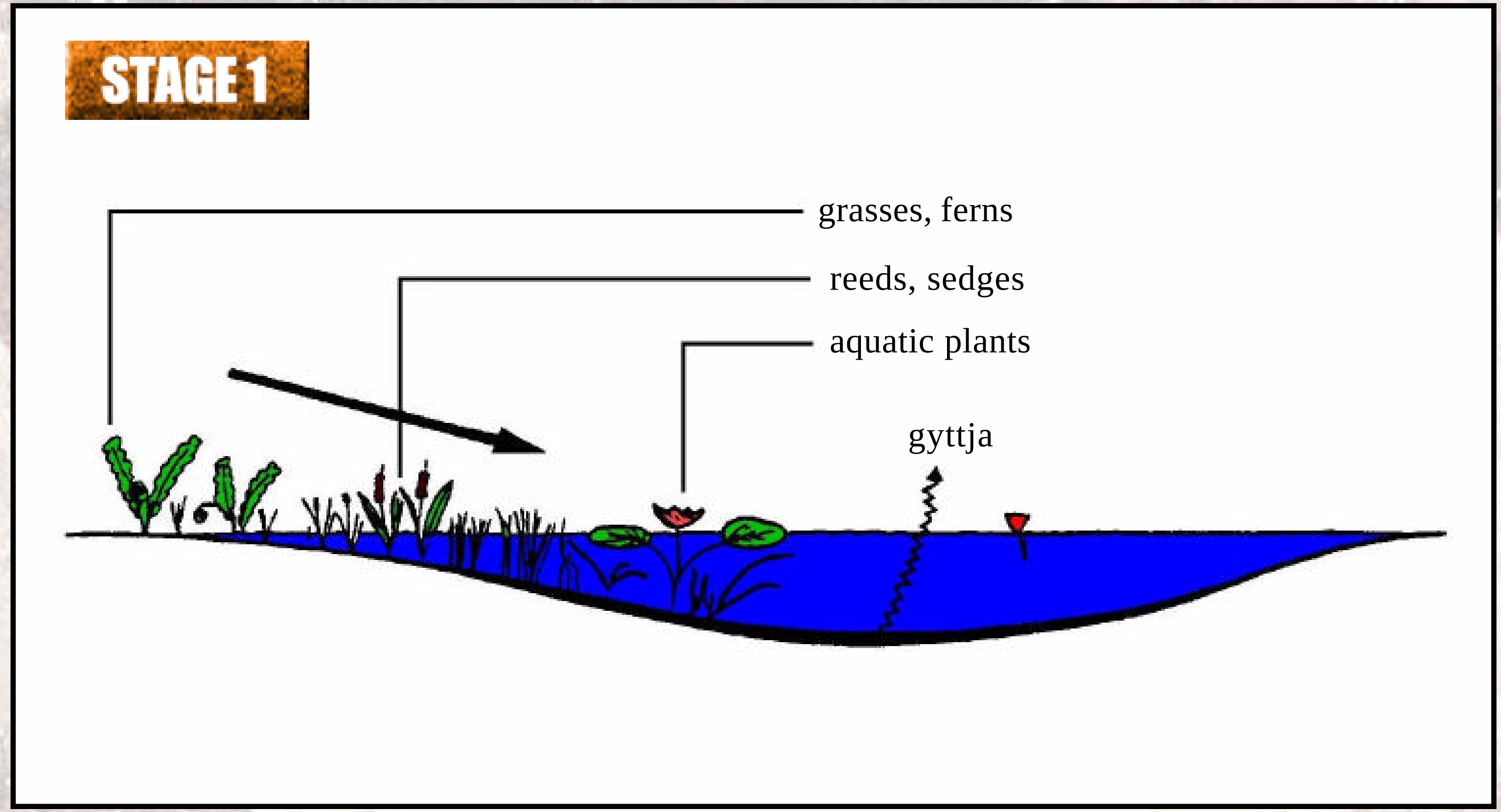

Figure 3. A depression is gradually filled in with topogenous peat, which is then overgrown by a laterally expanding ombrogenous peat mass. Note the changing composition of the vegetation. Click the button to see the three different stadia.

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As the peat mass rises over its surroundings, the continual precipitation surplus (a precondition for the formation of ombrogenous peat) drains away to the fringe of the bog where it creates a wet zone. Topogenous peat can grow there and become covered with ombrogenous peat later on. Peat bodies from several nuclei (depressions) in a plain will eventually merge into one coherent peat body. The limit to vertical growth, in combination with continuing lateral expansion, explains the characteristic dome shape of ombrogenous 'raised bogs'.

- *In northern regions*, peats are predominantly ombrogenous. Many are permafrost soils that have a 30-50 cm thawed (active) layer.
- *In temperate regions*, topogenous *'low moor peat'* is mainly woody forest peat and peat derived from grassy marsh vegetation. The *'high moor peat'* of ombrogenous raised bogs is mostly moss (*Sphagnum*) peat; 'Blanket peat' in upland areas formed under a vegetation of heather and other low shrubs.
- *In the tropics*, lowland peat is almost exclusively ombrogenous and made up of woody rain forest debris. Topogenous peat in the tropics and subtropics is confined to comparatively small occurrences in coastal plains and lagoonal areas and to filled-in lakes at high elevation. This peat is less woody than ombrogenous forest peat (e.g. Papyrus swamps, sawgrass peat, etc.) but richer in mineral constituents (*'ash'*).

The degree of decomposition of organic soil material has direct implications for the management of Histosols and is an important diagnostic criterion in their classification. 'Sapric' peat consists for less than one-sixth of recognizable plant tissue after the material is gently rubbed. Such well-decomposed peat constitutes the body of many *'low moor peat'* formations (there are numerous exceptions!). 'Fibric' peat consists for more than two-thirds of recognizable plant tissue (after rubbing) and constitutes the core of many ombrogenous raised bogs. Here too, there are many exceptions: raw and brittle mangrove peat is an example of fibric *'low moor peat'*. 'Hemic' peat is intermediate between fibric and sapric peat.

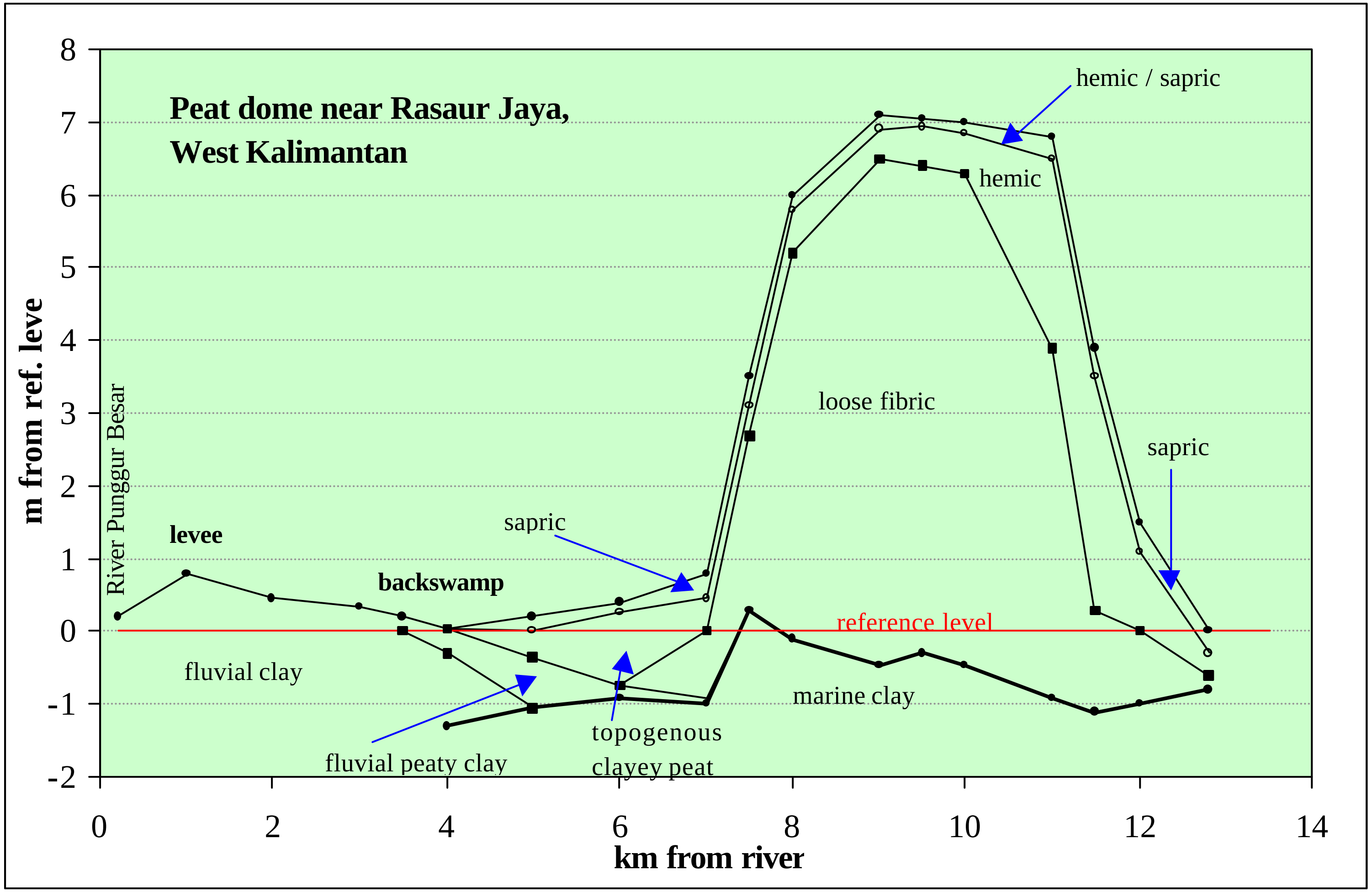

Figure 4. Cross-section of a small coastal 'raised dome' formation near Pontianak, Indonesia. Note the fibric core of the ombrogenous dome, the better decomposed (hemic and sapric) shell, and the occurrence of sapric and clayey topogenous peat at the foot of the dome.

Ombrogenous '*high moor peat*' in the Temperate Zone is mostly moss (*Sphagnum*) peat. The upper tiers of such 'dome' peat formations tend to be less decomposed than peat at some depth. This is in sharp contrast with raised (forest) peat formations in the wet tropics that are most decomposed in the top 10-30 cm layer. This difference is caused by the difference in botanical composition.

Sphagnum has no root system as most other plants have and grows only at its top end. Base parts that become covered by new growth die off and become humified, and conserved, in the acid and oxygen-poor water of the dome's core. Tropical raised bogs formed under swamp forest. The surface tier of the peat dome is aerated from time to time and is chemically enriched with nutrients through litter fall. All this promotes microbial activity and decomposition of the organic surface soil. Once this relatively well decomposed surface material becomes covered with younger peat in the course of further vertical growth of the bog, the water table rises (bogs are sponges!) and brings the former surface horizon within the permanently saturated zone and below the zone of active nutrient cycling. Decomposition of the organic material becomes negligible while soluble and fine-grained insoluble decomposition products continue to be removed with effluent water. The result is a loose, coarse fibric and increasingly lignin/wood-rich skeletal core.

In horizontal direction there is a similar differentiation. Permanently saturated central dome areas consist of less decomposed peat than comparable layers nearer to the fringe of the dome where the peat is younger, (relatively) rich in nutrients, occasionally aerated and subject to more intensive microbial attack. Figure 4 shows the different degrees of peat decomposition in a tropical raised bog.

Characteristics of Histosols

The exceptionally large total pore volume of Histosols (typically > 85%), their perishable nature and their normally poor chemical properties pose formidable problems to farmers and others concerned with conserving management and use of Histosols.

Morphological characteristics:
Most Histosols have H- or HCr-profiles. Transformation of plant remains, through biochemical disintegration and formation of humic substances, creates a surface layer of mould. Translocated organic material may accumulate in deeper tiers but is more often leached from the soil.

Hydrological characteristics:
The central areas of virgin topogenous peat bodies and of ombrogenous formations in lowlands are nearly always saturated with near-stagnant water. The fringe areas of extensive raised bogs have a less monotonous water regime, with drier areas near natural depressions due to gravity drainage of the immediate surroundings. The opposite seems true for smaller domes where the water regime is less buffered; radial drainage of such domes results in occasional floods near the margins while the center may, at times, be quite dry at the surface.

Physical characteristics:
Fibric Histosols are loosely packed in their natural state, with a bulk density (ρ) that is typically between 0.05 and 0.15 Mg/m^3 Surface tiers of ombrogenous forest peat contain (still) more mineral ‘ash’ than the subsurface layers and are slightly denser (ρ -values of the order of 0.15 to 0.25 Mg/m^3). Reclaimed (drained and cropped) peat formations acquire a higher bulk density (say, 0.4 Mg/m^3) after a few years of consolidation and decomposition of the peat.
The specific gravity (ρs) of organic soil material with a low content of mineral constituents (less than, say, 3 percent by weight) is nearly always close to 1.4 Mg/m^3. It follows that the total pore fraction (= 1-ρ /ρs) of most ombrogenous Fibric Histosols exceeds 0.9 m^3/m^3; skeletal subsurface tiers consist for only 5 to 10 volume percent of solid matter *(sic!)*.

Fibric peat has many wide pores. Its saturated hydraulic conductivity exceeds 1.6 m/d and may even be greater than 30 m/d. Well decomposed sapric peat has finer pores and is less permeable. Virgin woody peat is nearly always very permeable to water; compacted (reclaimed/drained) peat has a much lower Total Pore Fraction than virgin peat. Stratified peat may be virtually impermeable, irrespective of its fiber content.

Total pore space values measured on the peat dome of Figure 4 are presented in Table 1. Note the vertical and horizontal differentiation in packing density and its correlation with the vegetation type.

Table 1. Total Pore Fractions (TPF = 1 - ρ /ρs) calculated for a peat dome near Pontianak, Indonesia.

VEG. TYPE	Mixed Swamp Forest (Dome fringe)		Transition	Monotonous Forest (Dome center)		
SITE (km)**		13	11.4	10.9	9.4	8.0
10-20 cm	ρ:	0.20	0.15	0.13	0.14	0.13
	ρs:	1.39	1.28	1.42	1.52	1.44
	TPF:	**0.86**	**0.88**	**0.91**	**0.91**	**0.91**
70-80 cm	ρ:	0.23*	0.11	0.10	0.10	0.09
	ρs:	1.67*	1.24	1.35	1.48	1.29
	TPF:	**0.86**	**0.91**	**0.93**	**0.93**	**0.93**

* Clayey peat from shallow fringe area

** See Figure 4

The loose structure and flexible peat fibers explain also the low bearing capacity and poor trafficability of most peat formations. The low penetration resistance makes it difficult to use normal farm machinery and even light equipment may get stuck because of high rolling resistance and slip. The bearing capacity of a peat body is determined by the water content of the peat, and by internal friction and 'effective normal stress' (stress transmitted through the peat skeleton). The bearing capacity increases upon reclamation (consolidation) of the peat.

Chemical characteristics:
The wide variation in the physical characteristics of Histosols is matched by an equally wide variation in chemical soil conditions. Chemically rich '*eutrophic*' low moor peat may have a field-pH over 6, whereas rain-dependent raised bogs are poor in plant nutrients and have field-pH values that are typically between 3 and 5.5. Extremely acid Histosols, with a field-pH value around 2, have been observed in coastal regions where pyrite (FeS_2) containing peat bogs were drained. Alkaline peat (field-pH around 7.8) has been reported from the Maldives.

The organic fraction of peat consists of lignin, cellulose, hemicellulose and small quantities of proteins, waxes, tannins, resin, suberin, etc. Ombrogenous moss peat in temperate climates consists largely of cellulose whereas peat from deep lowland peat formations in Indonesia and Malaysia consists for two-thirds of lignin, with cellulose/hemicellulose accounting for only 1-10 percent of the dry sample weight.

One important organic fraction in organic soil materials is not contained in fresh plant debris but is synthesized in the course of microbial transformation of the organic soil materials: '*humic substances*', a mixture of humins and humic and fulvic acids. Humic substances form stable complexes with metal ions. These are easily leached out of the peat mass with effluent water. (Geographic names such as 'Rio Negro', 'Blakkawatra', 'Cola Creek', 'Air hitam', 'Zwartewater', and many more, testify of the constant leaching of organic compounds from peat bogs.)

Table 2 presents ranges in total microelement contents of virgin, deep and extremely poor Fibric Histosols in ombrogenous forest peat in Indonesia. The higher element contents of surface tiers reflect the cycling of elements by the vegetation.

Table 2. Microelement contents (kg/ha) of ombrogenous forest peat in Indonesia.

	0 - 25 cm	80 - 100 cm
Cobalt	0.1-0.2	0.05-0.1
Copper	0.8-8.0	0.2-0.8
Iron	143-175	67-220
Manganese	4.1-25	1.1-7.1
Molybdenum	0.6-1.0	0.3-0.6
Zinc	2.8-4.4	1.8-4.8

Note that a considerable part of all nutrients/elements in the system are stored in the vegetation; the values presented in Table 2 are by no means indicative of the total quantities present immediately after felling and burning of the (forest) vegetation.

The same holds for the contents of macro- and secondary nutrients in the soil. In forest peat, nutrient levels are highest in the top 25 cm of the soil. Felling of the natural forest (part of the 'reclamation' process of peat lands) upsets this pattern because of interrupted nutrient cycling, release of nutrients from decaying organic materials, increased leaching of nutrients, volatilization upon heating (burning) of the peat, etc.

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The quantities of nitrogen contained in the 0-20 cm surface tier of tropical ombrogenous forest peat are of the order of 2,000 to 4,000 kgN/ha, of which only a very small portion is ‘available' to plants. The contents of 'total ash', K_2O, P_2O_5 and SiO_2 of the surface soil decrease sharply after clearing of the forest vegetation whereas contents of CaO and MgO tend to increase. The quantities of Na, Cl and SO_4 depend strongly on local conditions such as the distance from the sea and the presence of pyrite in the peat. Ombrogenous moss peat (in temperate regions)contains much less plant nutrients than forest peat that supports a far greater biomasss with intensive cyclingof nutrient elements.

Figure 5 illustrates that nutrient elements in young and mature Fibric Histosols in (tropical) forest peat are concentrated in the upper 10 cm of the soil where a dense root mat occurs, and that living roots are absent (and ‘ash’ contents low) in deeper layers. It is generally true that nutrient element levels are lowest in genetically old Histosols, with the exception of Rheic Histosols, which receive nutrients from outside and cannot be included in any generalized account of the chemical properties of peat soils.

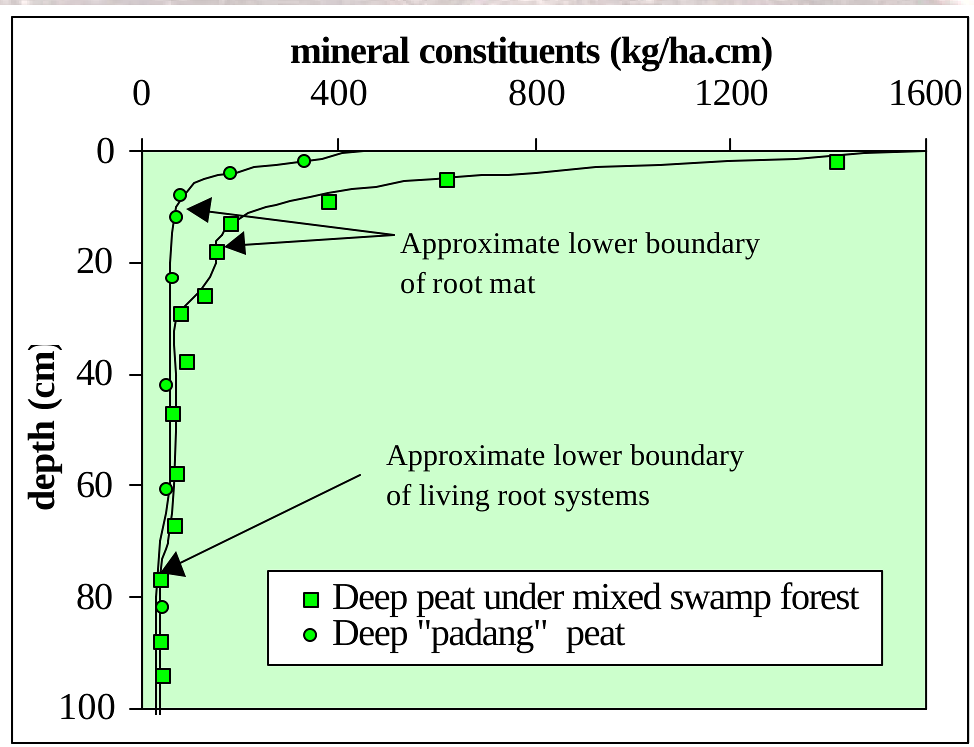

Figure 5. Distribution of mineral constituents in two deep, virgin, ombrogenous forest peat formations in Kalimantan

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Management and use of Histosols

The properties of the organic soil material (botanical composition, stratification, degree of de-composition, packing density, wood content, mineral admixtures, etc.) and the type of peat bog (basin peat, raised bog, etc.) determine the management requirements and use possibilities of Histosols. Northern Histosols are of little use for agriculture but they are part of a unique ecosystem and a habitat for many plant and animal species. In North America and northern Europe there is a growing tendency towards preservation and conservation of the delicate peat lands. Elsewhere more and more bogs are 'reclaimed' for agriculture, horticulture and forestry.

Natural peat bogs must be drained and normally also limed and fertilized, to permit cultivation of 'normal' crops. Centrally guided reclamation projects are (almost) exclusive to the Temperate Zone where millions of hectares have been 'opened'. In many instances this initiated the gradual degradation, and ultimately the loss, of the precious peat. In the tropics, increasing numbers of landless farmers venture out into the peat lands where they clear the forest and cause raging peat fires in the process. Most of them abandon their land again after only a few years; the few who succeed are on shallow, topogenous peat. Since a few decades, increasing areas of tropical peat land are planted to oil palm and pulp wood tree species such as *Acacia mangium*, *Acacia crassi-carpa* and *Eucalyptus sp*. This practice may be less than ideal but it is far less destructive than arable subsistence farming.

'Reclamation' of peat lands for agricultural uses starts nearly always with the construction of shallow drainage ditches. As a rule, the natural vegetation is left standing for a while because it accelerates drying of the peat. One-meter-deep drains at 20-40 m intervals are satisfactory in most cases but well decomposed or clayey peat may require narrower spacing. Woody dome peat formations could in some cases be drained with ditches 100 m apart. It is not advisable to install a complex drainage system right at the start of reclamation because uneven subsidence of the land surface is likely to disrupt the connections between sucker drains and collecting drains.

The drainage system will have to be ad-justed after some time of operation because peat proper-ties change. The soil's hydraulic conduc-tivity might decrease in the course of drainage following the col-lapse of large pores, the formation of an illuvial horizon, or the effects of tillage. On the other hand, the soil may actually become more per-meable after some time because of decaying wood providing pas-sage for the escape of water or because of increasing biological activity (roots, animals) or the forma-tion of cracks. In practice, draining peat lands is a matter of experi-ence and standard formulas that are applicable to mineral soils are of little value. Farmers in the tropics prefer to use shallow, hand-dug drainage ditches that can be deepened as needed.

It is difficult to say exactly *when* peat reclamation is com-pleted. Reclamation and cultivation overlap and in most instances cropping is even part of reclamation. In the case of forest peat, suitable annual crops may produce fair yields for a few years thanks to the nutrients that are still contained in the surface soil and in the (ashes of) decaying biomass. The uneven distribution of these nutrients over a field ex-plains the irregular growth that is typical of young reclamation areas. After 3 or 4 years the peat has settled and subsidence of the land surface has slowed enough that trees and shrubs can be planted. These may grow satisfactorily for some time but yields will eventually decrease if the land is not fertilized.

Small farmers sometimes resort to some sort of 'controlled' burning of the peat to 'liberate' nu-tri-ents and to raise the pH of the surface soil. Burning has undoubted-ly a stimulating effect on plant growth but the desirability of burning and its precise effects are still open to discussion. Those in favour of con-trolled burning claim that it is not more destructive than oxidation in the long run but concentrates cer-tain nutrients (N, P, K, Ca, Mg, S) in the surface soil and renders them more available to the plant. Others are of the opinion that burning should be discouraged alto-gether because most of the liberated nitrogen and sulphur are lost to the atmosphere and other nutrients are largely leached out of the surface soil. The overall deterioration of the soil structure (the burnt layer is usually by far the richest part of the profile) and the resulting uneven soil surface are additional arguments against burning.

The difficulties that confront farmers on Histosols become evident if one considers the differences in 'plant engineering' between 'normal' crops and the native peat swamp vegetation. The latter is adapted to an environment with prolonged water-saturation, strong acidity, oligotrophy and/or noxious levels of salt or other toxins. Such conditions made it possible that organic soil material could accumulate but they are incompatible with the needs of most crops. Most arable crops need a deep, moist (not wet), well-aerated soil for development of a healthy root system. This means that the peat must be drained. Drainage affects the peat in several ways:

- Drained peat will consolidate as a consequence of '*settlement*' of the peat mass once the buoyancy of the water in water-saturated natural peat is removed: the peat mass settles under its own weight. Consolidation of the peat is enhanced by '*shrinkage*' of flexible peat fibers that collapse under the capillary forces, which develop when the peat is drained. Consolida-tion of drained peat is initially rapid but becomes gradually less felt as the bulk density (ρ) of the soil mass increases. Consolidation causes loss of drained soil *volume* and subsidence of the land surface. This means that the depth of drains must be regularly adjusted to maintain freeboard and healthy root growth. Increasing the drainage depth will again accelerate con-solidation, and loss of surface elevation, until - after a number of successive adjustments that accelerate consolidation ever less strongly - a situation of near-stability is reached. As a rule of thumb, this happens when the dry bulk density of the soil mass has become close to $\rho = 0.4$ Mg/m^3.
- Aeration of peat accelerates the rate of microbial decomposition of the peat ('*mineralization*'). In contrast with consolidation, mineralization is an ongoing process; it causes both loss of peat *volume* and loss of peat *mass*. The rate of mineralization increases after liming and/or fertilization of the soil. Mineralization rates reported for 'reclaimed' tropical forest peat planted to horticultural crops, with liming and full fertilizer application, are as high as 10 cm/year; net mineralization losses under plantation forest (*Acacia sp*.), with a closed canopy and much greater leaf fall than horticultural crops, are probably negligible. Liming and fertilization are indispensable for good yields but enhance the rate of peat mineralization. Ombrogenous peat in particular requires massive applications of lime or ground (magnesium) lime-stone to raise the pH of the soil to a level that permits satisfactory crop production. Normally, full fertilization with N-P-K fertilizers must be combined with application of small quantities of sulfur, copper, zinc, manganese, molyb-denum and iron.

Reclamation of Histosols has also indirect effects. Some are favourable, others are not:

- The initially low packing density (and high Total Pore Volume) of newly reclaimed Histosols is associated with poor accessibility and trafficability of the peatland and with poor anchorage of crops. Uneven subsidence of the land and leaning and tree fall are prominent in young reclamation areas. When peat consolidates after drainage, its packing density increases. The rate of peat mineralization slows down as the fraction of easily decomposable organic com-pounds in the surface peat decreases relative to the fractions of 'stable humus' and 'ash'. All of this results in a denser and more stable peat body, that is better trafficable, provides better an-chorage to plant roots and is less prone to loss of surface peat (and exposure of lateral roots).
- Strong desiccation of organic soil material may drastically and irreversibly alter its colloidal properties. Loss of organic soil material by wind erosion is a problem in areas with deeply drained Histosols, particularly in the Temperate Zone. Plowing such soils produces huge clouds of peat dust that can be seen from far away. Overheating of deeply drained forest peat e.g. where newly opened tropical peat is exposed to direct sunlight, converts valuable surface peat into dry, hydrophobic granules and dust that are highly susceptible to both water and wind erosion.

In summary, peat lands must be protected and conserved because of their intrinsic value and because prospects for sustained agricultural use are meager. If they must be used for plant production, sensible forms of forestry or plantation cropping are to be preferred over annual cropping, horticulture or, the ultimate nightmare, 'harvesting' of the peat material for power generation or 'production' of horticultural growth substrate, 'active carbon', flower pots, etc. Peat lands that are used for arable crop production will mineralize at sharply increased rates because they *must* be drained, limed and fertilized to ensure satisfactory crop growth. It is particularly important to conserve the peat if loss of surface elevation may mean loss of land. This danger is real e.g. where the underlying mineral substratum is below the general drainage basis (e.g. the current river level) and/or where the peat has poor agricultural properties (e.g. contains potentially acid 'pyritic' marine sediment).