Supplementary materials

Figure S1. A soil monolith including the O and A horizons (Photo Gerhard Milbert).

Figure S2. Frame for describing and sampling organic surface layers (Photo Gerhard Milbert).

Practical information for description and sampling of humus forms

The identification of humus forms is done by a vertical cut of the topsoil. A monolith including the O, H and A horizons is taken and every horizon is described, considering type, thickness, distinctness of boundaries, structure, morphologic features and root density (Table S2 to Table S9). Each horizon is carefully described and sampled from top to bottom. Spatial variability and the effect of trees are considered by taking 3 to 5 monoliths under the middle third of a treetop.

Table S1. Definitions of diagnostic horizons and morphologic features of O horizons adapted from [12].

Code	Label	Morphologic features of O horizons	Hori-zon
br	tanned	brown to dark brown coloured leaf blades	Ol
fl	spotted	leaf blades with dark spots of irregularly shapes (1 - 10 mm Ø, < 10%)	Ol
ke	notched	leaf blades with lateral notches	Ol
lo	porous	irregularly perforated leaf blades	Ol
pu	dotted	scattered dots, covering less than 5% of leaf blades surfaces	Ol
ri	fissured	fissured leaf blades, mainly along the leaf veins	Ol
we	wavy	bulging along or across the leaf veins	Ol
bl	bleached	partially bleached plant residues	Of
fr	fragmented	parts and shaped parts of unrecognisable leaf blades	Of
gr	grey	gray coloured plant residues	Of
ru	rudimented	vestiges of leaf blades with recognisable leaf shapes	Of
sk	skeletonised	areas between leaf veins are partly or totally absent	Of
sp	speckled	plant residues intensely dotted or mottled	Of

Soil horizons, relevant for humus forms (definition and description) [12]

The distinct features of the horizons are numbered hierarchically. The numbering of the distinct features of the master horizon symbol is continued in the definitions for horizons and subordinate modified horizons. Terms defining the structure and packing of O horizons are listed in Table S4, terms describing the morphologic features of O horizons are listed above (Table S1).

Horizont **Description** (new defined horizons are written in red)

O Organic master or topsoil horizon, aeromorphic to aero-hydromorphic, consisting of dead biomass (mainly plant litter).
[O from **o**rganic]

1. organic carbon content ≥ 15 mass % and
2. developed under aeromorphic to aero-hydromorphic conditions

Organic fine matter (OFM; fine humus) is dark-coloured, amorphous organic matter in O and H horizons and their interlocking horizons, which doesn't have any macroscopic tissue structures.

Ol O horizon, consists almost exclusively of undecomposed or poorly decomposed dead plant biomass, partly dotted, mottled, browned, wavy, weakly cracked, pitted and notched (Figure 7). [l from **l**itter]

3. Proportion of organic fine matter < 10 vol.%

Owl Ol modified horizon, temporarily influenced by stagnic water or groundwater. Vegetation indicates wetness in the topsoil.
[w from **w**ater-influenced]

4. temporarily reducing conditions and
5. distinct grey to black colouration and

6.	above recently water-influenced hydromorphic A or H-horizon

(→ *Moist Mull*)

Of	O horizon consisting of dead plant biomass, more decomposed than in the Ol horizon. Remains of sprout, leaf and needle are crushed, skeletonised, fragmented to rudimentary, mostly bleached or greyish. Packing of the leaf litter: loose, glued together or stacked. Packing of the needle litter: loose, attached to felted. Organic fine matter is clearly recognisable.
[f from **f**ragmented]

3.	Proportion of organic fine matter 10 - < 70 vol.%

(→ *F Mull*)

Olf	Of transition horizon (Ol-Of), in which the macroscopically detectable needle and leaf debris predominates over the organic fine matter (Figure 7b).
[l from **l**itter]

3.	Proportion of organic fine matter 10 - < 30 vol.%

Ohf	Of transition horizon (Oh-Of) with a high to predominant proportion of organic fine matter and lower proportions of macroscopically recognisable remains of dead plant biomass/litter (Figure 7c).
[h from **h**umified]

3.	Proportion of organic fine matter 30 - < 70 vol.%

Odf	Of modified horizon with root felt.
[d from "stark **d**urchwurzelt" (german for strong rooting)]

3.	Proportion of living fine roots ≥ 50 vol.%

Owf	Of modified horizon, temporarily influenced by stagnic water or groundwater. Vegetation indicates wetness in the A horizon (Figure 14).
[w from **w**ater influenced]

4.	temporarily anaerobic conditions and
5.	grey to black colouring of the litter and
6.	above recently water influenced hydromorphic A or H horizon

(→ *Moist F Mull*)

Oh	O horizon with dominating organic fine matter and only a small proportion of macroscopically recognisable remains of dead plant biomass/litter.
[h from **h**umified]

3.	Proportion of organic fine matter ≥ 70 vol.%

Oxh	Oh modified horizon with clearly recognisable droppings of soil fauna, temporarily very high biological activity, thickness ≥ 5 cm (Figure 17).
[x from biological mi**x**ed]

4.	loosely packed and
5.	material predominantly to exclusively with a fine granular structure

Obh Oh modified horizon, with signs of medium biological activity, recognisable excrements of soil fauna, partly rounded, Obh horizon hard to separate from the mineral soil.
[b from "**b**röckelig" (german for friable)]

4. loosely packed and

5. easily breaking to subangular blocky aggregates or powdery material of organic fine matter

(→ *Moder*)

Owbh Obh modified horizon, temporarily influenced by stagnic water or groundwater. Vegetation indicates wetness in the A horizon (Figure 18).
[w from **w**ater influenced]

4. temporarily anaerobic conditions and

5. when moist, smeary consistency of the black organic fine matter and

6. above recently water influenced hydromorphic A or H horizon

(→ *Moist Moder*)

Odh Oh modified horizon with root felt
[d from "stark **d**urchwurzelt" (german for strong rooting)]

3. Proportion of living fine roots ≥ 50 vol.%

(→ *Rhizo Moder*)

Oih Oh modified horizon, very thin, film-forming horizon at mineral soil surface or thin patches of Oh material here and there.
[i from f**i**lm-like]

4. film-forming, thickness < 5 mm or

5. thickness ≥ 5 mm and patchy (in pocket-like depressions of the mineral soil surface)

(→ *Mull-like Moder*)

Ovh Oh modified horizon, contact with solid rock or coarse material, pH value and base saturation on limestone higher than in the overlaying Oh horizon, contains particles of limestone, high biological activity, very low thickness 1 – 3 cm.
[v from german = vererdet, meaning an increased mineral content]

4. material is friable under moist conditions, biological active and

5. deep black-coloured on limestone, black or deep brown-coloured on lime free material

(→ *Tangel*)

Okh Oh transition horizon (Obh-Osh), strongly to extremely acidic, biologically inactive organic fine matter, originated from heather or coniferous litter. Okh horizon easy to separate from the mineral soil, compact, breakable into pieces with blunt or rounded edges, mostly strong to very strong rooting (Figure 19).
[k from german = kompakt; engl. compact]

4. compact packing and

5. the material is breaking in coarse, incompletely separate aggregates with blund or rounded edges and

6. aggregates do not fit together without gaps after breaking

(→ *Moder-like Mor*)

Osh Oh modified horizon, strongly to extremely acidic, consisting of biologically inactive organic fine matter, originated from heather or coniferous litter. The separability between the sharp-edged crushable Osh horizon and the mineral soil is usually very good (Figure 21).
[s from **s**harp edged]

4. compact packing and
5. material breaks into aggregates with sharp division surfaces that fit together again without gaps (→ *Mor*)

Owsh Osh modified horizon, temporarily influenced by stagnic water or groundwater. Vegetation indicates wetness in the A horizon.
[w from **w**ater influenced]

6. temporary anaerobic conditions and
7. when moist, smeary consistency of the black organic fine matter and
8. above hydromorphic A horizon (→ *Moist Mor*)

A Dark-coloured mineral A horizon with accumulation of organic matter formed in situ, to which organic fertilisation or fresh sedimentation may also have contributed. The organic matter has usually entered the soil through roots, bioturbation, ploughing or digging activity. In acidified soils below the humus layer, dissolved organic matter may also have washed in. Features of the subsoil horizons are absent or weakly developed. The horizon may also have developed from a U or H horizon. Reasons for this can be:

a. The decomposition of organic matter predominates over the accumulation of new organic matter or

b. Mixing (ploughing activity and peatland melioration) with mineral substrates decreases the organic matter content.

1. A horizon with visible content of organic matter and
2. organic carbon content < 15 mass % and
3. with accumulation of in-situ organic matter, which may also originate from organic fertilization or fresh sedimentation.

In addition to those explicitly defined horizons, deviation modified horizons can be formed with the following additional symbols:

c (secondary carbonate)

d (root felt)

k cultitropic (modified by cultivation)

z (secondary salt accumulation).

Am A modified horizon, at the mineral soil surface in the current or former floodplain of a stream or in the marshland of the sea; with altered mineral contents due to sedimentation during flooding

4. with admixture of organic soil matter and mineral soil material from periodic or episodic (from the Holocene) sedimentation during flooding by river or sea water; and
5. higher base saturation or higher levels of nitrogen, phosphorus or heavy metals from the flood water and its sediment load or from the upward seepage water compared to the surrounding soils; and

6. in case of ending of the fluvial flooding dynamics (diking), further accumulation of substances by upward seepage

Note: After the end of the flooding and the upward seepage dynamics, the Am horizon becomes relictic (rAm) and leads to the variety "relictic flooded" (ra) in the corresponding floodplain soil.

Ah A horizon with accumulated organic carbon, the content of which mostly decreases from top to bottom of the horizon [h from **h**umic].

4. Organic carbon content ≥ 0.5 mass % (h2) and
5. the criteria for Ai-, Au-, Ab-, Ax- und Aa-Horizons are not fulfilled

Adh Ah modified horizon, with root felt [d from stark **d**urchwurzelt (german for strong rooting)] (→ *Rhizo L Mull, Rhizo F Mull*)

Aih Ah transition horizon (Ai-Ah), very thin, organic matter consists mostly of undecomposed plant remains/litter [i from **i**nitial].

4. Organic carbon content ≥ 0.5 mass % and
5. thickness < 2 cm and continuously developed

Au A modified horizon, with low base saturation. Dark-coloured because of humus, with well-developed and stable aggregate structure, not hardening when drying out, with pronounced bioturbation (earthworm activity, usually clearly visible deeper in the profile). Usually soil texture loamy sand (Sl3) or finer (more loamy). In forests usually humus form Mull [u from **u**mbra].

4. Organic carbon content≥ 1mass %and
5. a) value ≤ 3 und chroma ≤ 4 or
   b) value ≤ 4 and chroma ≤ 3 and
6. stable granular or stable fine subpolyhedral structure (aggregates< gro4) ≥ 50 % of the volume and
7. earthworm burrows exist and
8. base saturation (eff.) < 50 %

Ax A modified horizon, with higher base saturation, dark-coloured because of the humus, with well-development and stable aggregate structure, not hardening, when drying out, with pronounced bioturbation (earthworm activity). In Forests usually humus form L-Mull. Often affected because of ploughing [x from biological mi**x**ing] (Figure 6).

4. Organic carbon content ≥ 0.5 mass % and
5. a) value ≤ 3 und chroma ≤ 4 or
   b) value ≤ 4 and chroma ≤ 3 and
6. stable granular or stable fine subpolyhedral structure (aggregates< gro4) ≥ 50 % of the volume and
7. earthworm burrows exist and
8. base saturation (eff.)< 50 %

Ai A modified horizon, with initial soil formation and thus only low accumulation of organic matter [i from **i**nitial].

4. a) Organic carbon content ≥ 0.5 mass %, horizon patchily developed and < 2 cm thick or

   b) Organic carbon content < 0.5 mass % and horizon ≥ 2 cm thick.

Aa A modified horizon, developed under long standing groundwater or stagnic water conditions and inhibited mineralisation. Due to lack of oxygen, organic fine matter is extremely accumulated [a from **a**nmoor].

4. Organic carbon content of 8 to < 15 mass %, and
5. developed under the influence of groundwater or stagnic water in the A horizon and
6. under dry conditions fine subpolyhedral or granular structure and
7. coherent and smeary when moist

Ab A modified horizon, developed after drainage from an H or U horizon, where decomposition of organic matter predominates compared to the accumulation of new organic matter, or where mixing (ploughing activity and peatland melioration) with mineral substrates decreases the organic matter content [b from A**b**bau (german for decomposition].

4. Content of organic carbon from 8 to < 15 mass %; and
5. developed after drainage from an H or U horizon and
6. smeary when moist and
7. single grain or subpolyhedral or fine polyhedral structure and
8. black-coloured when moist, grey-or black-coloured when dry

Ap A modified horizon, shaped by regular tillage and thus homogenised. Often contains mixed-in portions of the subsoil following below the A horizon. Horizon thickness corresponds to the depth of tillage [p from **p**loughed].

4. homogenised by tillage and
5. with clear or sharp and planar lower boundary (in relict and fossile horizons possibly without sharp edges).

E Mineral master horizon, depleted by translocation of clay minerals, iron (hydr)oxides or humus.

Ee E horizon, podzolised, strongly lightened by translocation of iron (hydr)oxides and humus substances, acid bleached. Transition to the following horizon often cone- or tongue-shaped [e from **e**luviated].

1. light, pale soil matrix and
2. a) purplish or mottled by acid bleaching, or
   b) bleached quartz grains and
3. hardly any organic matter

Ah-Ee Ee transition horizon.

2. acid bleached and
3. organic carbon content ≥ 0.5 mass % and
4. uneven proportion of humus, in the form of mottling and diffuse bleaching (partly mottled due to microbial decomposition) or due to accumulation of humus from the organic layer.

Ee-Ah Ah transition horizon, weakly podzolised.

1. acid bleached and
4. under humus layer, thin, grey or black-grey coloured layer due to humus accumulation

H Organic master horizon formed primarily by peat formation from the remains of peat-forming plants on the surface of the site under topogenous or ombrogenic excess of water. As a result of drainage and agricultural management, H horizons may be aerobically altered in a secondary pedogenic manner (Hm, Hv, Ha, Ht); after rewetting, these horizons may appear as relict horizons. Peat-forming plants are plant species that grow under special permanently wet and predominantly anaerobic site conditions.

Peat formation is the soil-forming process of accumulation of plant residues in a predominantly water-saturated environment. It is controlled by plant species, water balance, oxygen and nutrient content of the water and the duration of aeration phases. Depending on the formation conditions, different types of peat develop with varying degrees of humification as well as different humus forms and soil types.

Peat is a growing organic formation consisting predominantly of dead plant material of different degrees of humification.

1. organic carbon content ≥ 15 mass % and
2. formed from the remains of peat-forming plants.

Notes: The degrees of humification according to von Post are given in Table S14 Depending on their formation, the H horizons are differentiated by additional geogenic symbols into hH, uH and nH horizons.

Hn H horizon of the topsoil with current peat formation from the dead remains of peat-forming mosses and peat-forming higher plants. In the fluctuating area of bog, stagnant water or groundwater and temporary overflow. The organic matter consists of extremely low to completely humified plant remains [n from **n**ew].

3. Saturated with water all year to predominantly saturated or flooded and
4. formed under predominantly anaerobic and only very briefly aerobic conditions and
5. peat formation through incomplete decomposition of plant remains and
6. dense elastic network of living, aerial plant roots or basal sections of mosses and
7. no segregation structure and
8. current vegetation dominated by peat-forming plants.

Hfn Hn modified horizon, peat-forming horizon, permanently waterlogged or flooded, predominantly anaerobic with very weak aerobic conditions due to aerial roots or water table fluctuations; very clearly recognisable plant structures in the extremely low or moderately humified peat [f from fibrum, **f**ibre] (Figure 23).

9. degree of humification according to von Post H1 – H4

Hen Hn modified horizon, peat-forming horizon, seasonally waterlogged or flooded, predominantly anaerobic with seasonally weakly aerobic conditions due to aerial roots and water table fluctuations; weakly to indistinctly recognisable plant structures in medium to highly humified peat [e from h**e**mic] (Figure 24).

9. degree of humification according to von Post H5 - H7

Hhn Hn modified horizon, peat formation horizon, predominantly water-saturated or flooded during the course of the year, with intermittent aerobic conditions due to aerial roots and water level fluctuations or aeration; very indistinct or no longer recognisable plant structures in very highly or completely humified peat [h from completely **h**umified = sapric] (Figure 25).

9. degree of humification according to von Post H8 - H10

Table S2. Root density (number of roots per aera or volume*) and allocation Adapted from [12].

Root density					
Fine roots (< 2 mm Ø)			**Coarse roots (≥2 mm Ø**		**Label**
Code	Roots dm^{-2}	Roots/Volume (%)	Code	Roots dm^{-2}	
Wf0	0		Wg0	0	none
Wf1	1–2		Wg1	1	very low
Wf2	3–5		Wg2	2	low
Wf3	6–10		Wg3	3	medium
Wf4	11–20		Wg4	4	high
Wf5	21–50		Wg5	5	very high
Wf6	> 50		Wg6	> 5	extreme, root felt
Wff *		> 50			root felt
nb			nb		not determinated

Spreading of roots			
Code		**Label**	**Description**
ag		preferential at surface of aggregates	Roots are growing at ped faces and do not penetrate inside
gl		regular, uniform	homogeneous distribution of roots within horizons
kl		within cracks	occurrence of roots mainly within cracks and fissures
lag		laminated, banded	banded occurrence of roots in cause of hampering root penetration at ped faces or at faces of horizons or layers
lok		high density within cracks and tubes	abundant root density solely/only within cracks and fissures
ugl		irregular	preferential root pathways within macropores (earthworm channels, fissures, pedotubules, vesicular voids)
nb		not determined	
	Examples: Wf3 + Wg1 =medium density of fine roots and very low density of coarse roots Wf4, kl = high density of fine roots within cracks und fissures Wf3, lok (ugl) = medium irregular density of fine roots within cracks und fissures		

Table S3. Proportion of fungus mycelium of O-horizons, adapted from [12].

Proportion of fungus mycelium		
Code	**% by surface area**	**Description**
Pm0	0	none
Pm2	< 2	low
Pm3	2 - <5	medium
Pm4	5 - < 10	high
Pm5	10 - < 30	very high
Pm6	> 30	extremely high
nb		not determinated
Allocation of fungus mycelia		
Code	**Label**	**Description**
ag	coating ped faces	Intensive cross-linkages of fungus mycelia on ped faces of Hv and Ha horizons
gl	evenly spread	fungus mycelia evenly spreading the horizon
lag	laminated or banded	fungus mycelia coating batches of plant residues
ugl	irregular	irregulary spots of fungus mycelia
nb	not determined	
PM3, ag = medium proportion of fungal mycelium at aggregate surfaces two attributes divided by comma are describable		

Table S4. Structure and packing of organic material in O horizons, adapted from [12].

Code	Label	Description	Diagnostic for	Litter type
bi	flexural	needle litter is strongly glued together or stuck together by organic fine substance and by fungal mycelia, resulting in a flexible and without sharp breakable layer, which is liftable all in one	Of	needle litter
br	brittle	loosely packed structure, easily breaking to subangular blocky or powdery material of organic fine matter	Oh	leaf and needle litter
fi	film-like	very thin (< 3mm) film-forming Oh horizon at mineral soil surface	Oh	leaf and needle litter
kr	granular	biogenetic granular ped formation with partly rounded and loosely packed aggregates, predominantly developed from droppings of soil mesofauna (collembola, mites, enchytraeidae, insect larvae)	Ovh/Oxh	leaf and needle litter
ks	compact, breakable into pieces with sharp edges	consolidated organic fine matter with marginal parts of visible plant residues, under bending stress breakable into pieces with sharp edges that fit together again without gaps	Osh	leaf and needle litter
ku	compact, breakable into pieces with blunt or rounded edges	densely packed organic fine matter with marginal percentage of visible plant residues, under bending stress breakable into pieces, which can not be recombined without gaps	Okh	leaf, needle and dwarf-shrub litter
lo	incoherent	loosely packed plant residues, leaf litter without cohesion, needle litter with low cohesion	Ol, Of	leaf and needle litter
ls	loose, powdery	organic fine matter falling into subangular blocky pieces or powder	Obh	leaf and needle litter
lu	patchy	plant residues of O horizon covering an area of 10-30 %	Ol, Of	leaf and needle litter
si	layer-like	needle litter residues intertwined in layers, as layer only partially liftable	Ol, Of	needle litter
su	sparse	plant residues covering an area of less than 10 %	Ol, Of	leaf and needle litter

sp	bulky	needle residues with disordered and felted packing (layer-like), connected by organic fine matter and fungus mycelia, can be separated in major parts	Of	needle litter
ta	batch-like	leaf residues densely packed and glued into batches	Of	leaf litter
ve	clotted	leaf blades and litter with considerable adhesion, sticking together	Ol, Of	leaf litter
vn	cross-linked	needle residues clearly adhering together	Ol, Of	needle litter
vz	felted	matted needle residues	Of	needle litter

Table S5. Soil structure of A horizons (types of structure, description), modified from [29].

Type	**Description**
Granular	Spheroidal; biogenic; many visible pores; bounded by curved or very irregular faces; limited accommodation to the faces of surrounding aggregates
Subangular blocky	Bounded by undulating rough faces; number of faces variable; many vertices rounded; limited accommodation to the faces of surrounding aggregates
Angular blocky	Bounded by relatively flat smooth, roughly equal faces; number of faces variable; most vertices angular; usually much accommodation to the faces of surrounding aggregates
Prismatic	Bounded by relatively flat faces; vertically elongated units with angular vertices and flat tops; much accommodation to the faces of surrounding aggregates
Pseudosand/ Pseudosilt	Spheroidal units of sand and silt size, composed of kaolinite-oxide complexes; the complexes may be interconnected to each other; hand-texturing first yields the impression of a dominance of sand and silt and after prolonged squeezing proves the dominance of clay
Platy	Bounded by relatively flat horizontal faces; much accommodation to the faces of surrounding aggregates
Single grain	Entirely non-coherent, e.g., loose sand
Massive	Material is a coherent mass (not necessarily cemented)
Cloddy	Artificial clods created by disturbance; e.g., ploughing

Table S6. Size classes for soil structural units, adapted from [12].

Dominating size class		
Code	**Diameter [mm]**	**Description**
gro1	< 0.5	extremely fine
gro2	0.5 - < 1	very fine
gro3	1 - < 2	fine
gro4	2 - < 5	fine to medium
gro5	5 - < 20	medium
gro6	20 - < 50	medium to coarse
gro7	50 - < 100	coarse
gro8	100 - < 200	very coarse
gro9	200 < 500	extremely coarse

Table S7. Grade of structural units (mineral soil, peat), adapted from [12].

Code	**Label**	**Description**
Vf1	very weak	The units are barely observable in place. When gently disturbed, the soil material parts into a mixture of whole and broken units.
Vf2	weak	After impact the soil material parts in numerous lumps or aggregates
Vf3	moderate	After impact the soil material parts in only some lumps or aggregates which are divisible manually into more lumps or aggregates
Vf4	strong	After impact the soil material parts in only some lumps or aggregates which are not or hardly divisible manually into lumps or aggregates
Vf5	very strong	After impact the soil material parts barely in lumps or aggregates which are not divisible manually into lumps or aggregates
nb	not detected	

Use the spade, take out a large sample (common soil moisture), make sure that the aggregates of the first-level structure, if present, are undisturbed. After dropping the sample from a height of 1 m observe the structure (type, size class, grade). If applicable, report two size classes, the dominant one first. Report for every type and size class the abundance (as percentage by volume of the layer).

Table S8. Distinctness of lower horizon boundaries, adapted from [12].

Class	**Widths of boundaries**			
	Mineral soil, peat		**O horizons (forest floor)**	
abrupt			ssa	< 1 mm
very clear	sc	< 20 mm	sca	< 3 mm
clear	de	20 to < 50 mm	dea	3 to < 6 mm
diffuse	di	≥ 50 mm	dia	≥ 6 mm
not determined	nb			

Table S9. Degree of decomposition and humification of peat, adapted from [13,14].

	code	degree of decomposition and humification (von Post scale)	features (attributes) of peat with permanently wet formation conditions		
			proportion of macroscopically recognisable remains of dead plant biomass/litter	**going outside your fingers by squeezing peat material in your hand**	**peat material, inside your hand after squeezing**
fibric	H1	extreme low	distincly and visibly	uncolored clear water	not slurry-like
	H2	very low		yellowish brown almost clear water	
	H3	low		brown dimmish water	
	H4	moderate		brown muddy water	
hemic	H5	medium		muddy water and somewhat of the peat material	somewhat slurry-like
	H6	medium to strong	dimly	up to 1/3 of the peat material	almost pulb-like
	H7	strong	in some degree recognisable	approximately 1/2 of the peat material	recognisable remains of dead plant well visible
humic, sapric	H8	very strong	almost slurred	approximately 2/3 of the peat material	only remains of plant fibres and wood recognisable
	H9	extreme strong	almost not recognisable	almost the complete peat material	
	H10	complete	not recognisable	complete peat material	no recognisable remains of dead plant

To determine the degree of decomposition and humification of peat with permanently wet formation conditions you have to squeeze a hen's egg-like part of peat inside your hand. You evaluate the color of percolating water and the features of the peat inside and outside your hand.

Table S10. Litter decomposability of different forest tree species, adapted from [30].

Decomposability	Duration of decomposition	Tree species
very high	few weeks after start of growing season	Elm (*Ulmus*), Black Alder *(Alnus glutinosa)*, Wild Cherry (Prunus avium), Common Ash *(Fraxinus excelsior)*, Robinia (*Robinia pseudoacacia*)
high	within one year	Black Cherry *(Prunus serotina)*, Common Hornbeam (*Carpinus betulus*), Sycamore Maple (*Acer pseudoplatanus*), Small and Large leaved Lime (*Tilia platyphyllos and Tilia cordata*)
moderate	within two years	Norway Maple (Acer plantanoides), Mountain Ash (*Sorbus aucuparia*), European Aspen (*Populus tremula*) , Birch species, Great Sallow (*Salix caprea*)
low	within three years	Sessile Oak *(Quercus petraea)*, English Oak *(Quercus robur)*, European Beech *(Fagus Sylvatica)*, Red Oak *(Quercus rubra)*
very low	within five years	Douglas Fir (*Pseudotsuga menziesii*), Silver Fir (*Abies alba*), Norway Spruce *(Picea abies)*, Scots Pine *(Pinus sylvestris)*, European Larch (*Larix decidua*)

Table S11. Classification of CN and CP ratio of organic surface layer and mineral soil horizons, adapted from [31] (pp. 176).

C/N	<10	10 - < 12	12 - < 16	16 - < 20	20 - < 25	25 - < 35	≥ 35
C/P	< 50	50 - < 100	100 - < 200	200 - < 400	400 - < 800	800 - < 1200	> 1200
Label	very low	low	low to medium	moderate	moderate to high	high	very high

The reference horizon for Mull humus forms is the Ah horizon, otherwise the Oh horizon.

Table S12. Chemical and physical key parameters to characterise humus forms, modified from [32].

Parameter	Unit	Horizon			Relevance
		Ol, Of	Oh	A	
Physical soil parameter					
Organic layer weight	kg m^{-2}	X	X		Calculation stock of nutrients, forest floor
Coarse fragments	% (volume)		X	X	Calculation stock of nutrients, water balance
Particle size distribution	% (mass)			X	Calculation of CEC and water balance
Bulk density	kg dm^{-3}, kg m^{-2}			X	Calculation stock of nutrients and atmospheric N and metal deposition
Chemical soil parameter					
pH (H_2O) (field measurement)	-		X	X	acidity or alkalinity of the soil solution
pH($CaCl_2$), pH (KCl)	-	X	X	X	acidity or alkalinity of the soil solution, acid input
Organic carbon	g kg^{-1}	X	X	X	Forest nutrition, atmospheric N deposition, climate change, C- & N sinks, CN ratio
Total nitrogen	g kg^{-1}	X	X	X	
Carbonates	g kg^{-1}		X	X	
Aqua Regia extracted P, Ca, K, Mg, Mn, S; Al, Fe	mg kg^{-1}	X	X	X	Atmospheric deposition of basic cations, stock of main nutrients, CP ratio, weathering rates, critical loads of acidity, atmospheric metal deposition
Aqua Regia extracted Cu, Pb, Cd, Zn, Cr, Ni, Hg,	mg kg^{-1}	X	X	X	
Exchangeable Acidity	cmol(+) kg^{-1}		X	X	Buffering acid input
Exchangeable Cations: Ca, Mg, K, Na, Al, Fe, Mn, H	cmol(+)kg^{-1}		X	X	Base saturation, medium available nutrition

Table S13. Classification of base saturation in percentage of cation exchange capacity (CEC), adapted from [12].

Code	**Base saturation level**	**[% CEC]**
BS1	very low	< 5
BS2	low	5 to < 20
BS3	moderate	20 to < 50
BS4	high	50 to < 80
BS5	very high	80 to 100