Field guide for the description and classification of humus forms

Field guide

Humus Forms

Description and classification of humus forms for ecological applications

Bas van Delft,
Rein de Waal,
Rolf Kemmers,
Peter Mekkink
Jan Sevink (translation)

Alterra, Wageningen, 2006

Abstract

Delft, Bas van, Rein de Waal, Rolf Kemmers, Peter Mekkink & Jan Sevink (translation), 2006. *Field guide humus forms, description and classification of humus forms for ecological applications*. Wageningen, Alterra, Research Institute for the Green Environment. 92 pp., 51 fig. 2 tab.; 43 ref.

This field guide aims to support the field description and classification of humus forms. Humus forms are approached as manifestations of ecosystem functioning and characteristics, implying that the study of humus forms provides ecologically relevant information on site conditions such as availability of moisture, soil acidity and nutrient status. This is reflected in the structure of this guide. First, attention is paid to the soil organic matter cycle and the role of various organisms in this cycle. The second part deals with the description of humus forms in the field, defines relevant individual characteristics of these forms and provides a comprehensive system for registration of these characteristics. The last part concerns the classification of humus forms. Concepts and classification criteria are dealt with in an extensive appendix.

Key words: humus form, humus profile, ecological soil typology, organic matter, ecology, ecopedology

The Dutch version of this guide was produced by order of the Ministry of Agriculture, Nature and Food Quality (LNV), within the DWK-program 395 ‘Soil and Groundwater Data’. It primarily serves to classify Dutch humus forms, adjectives used at lower levels of classification being derived from the Dutch soil classification system or being traditional Dutch terms that are used for specific soil and humus form materials and properties. The specific adjectives cannot be translated into internationally accepted (English) equivalents, since a comparable international system lacks. Consequently, no attempt has been made to translate these adjectives in this English version of the field guide. It should be realized, however, that the principles on which the classification is based, its differentiating criteria and class boundaries used are generally applicable and language independent.

P.O. Box 47; 6700 AA Wageningen; The Netherlands
Phone: + 31 317 474700; fax: +31 317 419000; e-mail: info.alterra@wur.nl

Contents

Preface

Why would you be interested in studying humus forms? It is not exactly the most appealing part of nature in comparison to plants and animals that are generally much more evident and apt to strike your imagination. Nevertheless, from the beginning of the nineties onward Alterra studies humus forms and does so because it realized that a lot can be learned about the functioning of ecosystems through such study. We feel that now the time has come that the knowledge acquired should be made available to others who may benefit from it. This field guide thus is meant for a wide array of researchers, students, nature managers, soil scientist, ecologists... , in short everybody who attempts to improve his or her insight into the functioning of a specific ecosystem by studying its humus form. We feel that this field guide may support such attempt and hope that its users will become equally strong advocates of the ecologically indicative value of the humus form.

The user of this guide is expected to have some knowledge about ecosystem functioning, in particular of its abiotic aspects. Reasons for this are that within a rather comprehensive field guide it is impossible to deal with all aspects of this functioning. By providing literature references and a glossary (Appendix 1) we try to support users that are in want of more detailed knowledge. Our overall aim remains to promote a broad approach in ecosystem studies, considering the humus form as the major link between living (biotic) and dead (abiotic) ecosystem components.

This guide is based on the experience and knowledge obtained through a large number of research projects executed during the past decade and could be realized by using funds made available through the DWK-program 395 'Soil and Groundwater data'. Many people were indirectly involved in its production: The ecological typology of soils, on which this guide is based, is the result of a close cooperation between Rein de Waal, Rolf Kemmers, Bas van Delft and Peter Mekkink, all from Alterra. We are greatly indebted to Eke Buis who thoroughly revised the earlier existing classification scheme and produced the system published in this guide including the taxonomy that stands behind it. Lastly, Jan Sevink from the University of Amsterdam, who shares our interest in humus forms and cooperated in several of the projects earlier mentioned, produced this English translation of the earlier Dutch guide.

This field guide is a tool for the study of humus forms. More tools are available through our website: www.humusvormen.wur.nl. These are mostly in Dutch, but we are working on translations, so please check this website regularly.

For any questions or remarks about these products, please contact Bas van Delft: Bas.vandelft@wur.nl.

If you wish to be informed about new developments in ecological typology of soils, please forward your e-mail address to the above address.

Wishing you success,

Bas van Delft
Rein de Waal
Rolf Kemmers
Peter Mekkink

Wageningen, 2004.

Jan Sevink

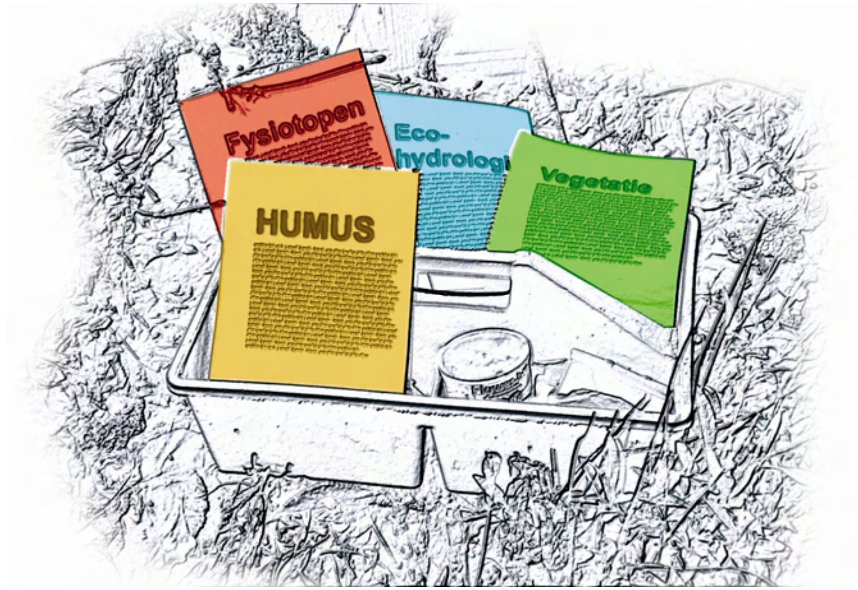
Amsterdam, 2006.

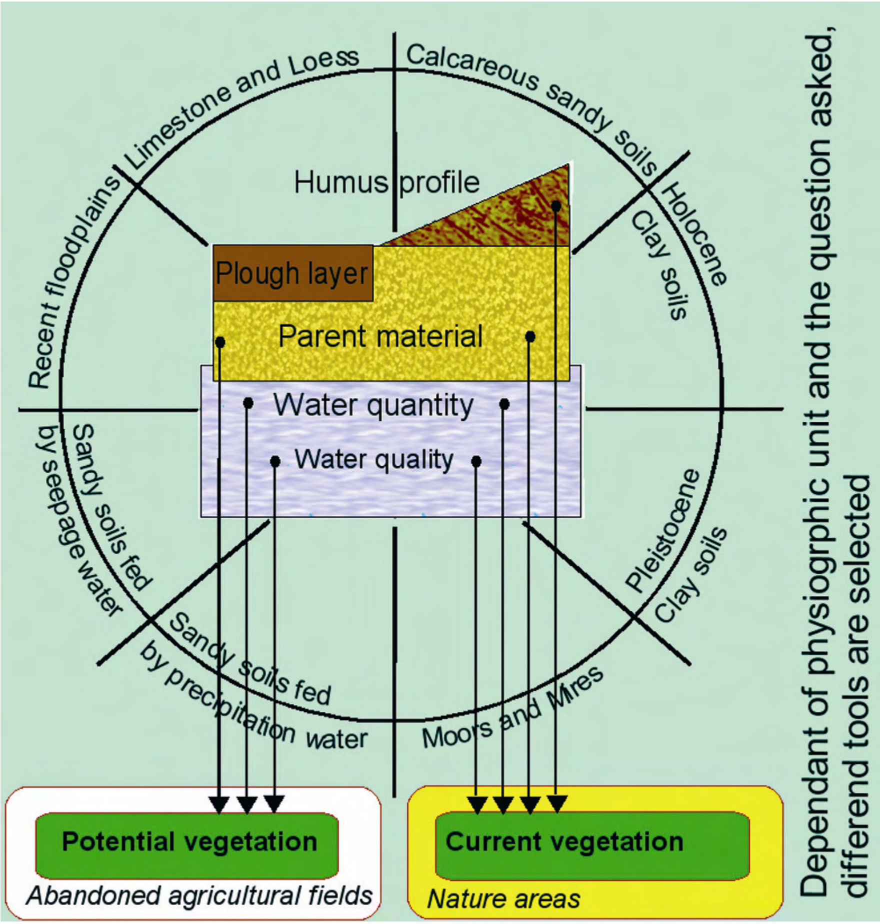
Introduction

Ecological soil typology as a tool kit

The description of humus forms presented in this guide serves primarily to obtain insight into the actual site conditions for vegetation. Under natural conditions the composition and development of vegetation are largely controlled by site characteristics such as 'moisture status', 'nutrient status', 'soil acidity' and 'soil salinity'. These site characteristics also strongly affect the organic matter cycle and connected release of nutrients that are contained in the vegetation and its litter. In other words, by means of this guide we want to emphasize and illustrate that the humus form provides much information on site conditions that are relevant for nature managers and planners. To start with, we give a brief description of the organic matter cycle and how this results in a number of layers or 'horizons' that can be identified in a soil. Several layers may occur stacked on top of each other and together constituting a humus form profile. By describing the humus form we thus collect information on the organic matter cycle and, more indirectly, on site conditions that control the vegetation and its development.

The humus form description does not stand alone, but forms part of a larger 'tool box' for ecological soil classification (Kemmers, et al., 2002). Often various types of data have to be used for the ecological description of a site, depending on the questions asked and scale to which the answers should refer. Thus a study on the potentials for nature development could be based on a physiotope map, derived from a geomorphological map and soil map and groundwater data, eventually in combination with analyses on the nutrient status of the plough layer. In case of existing nature areas, additional relevant information can be provided by studying the humus form. To understand the effect of groundwater flow (infiltration and seepage) on the development of a site, however, an eco-hydrological system analysis may be required.





The tools to be chosen additionally depend on the physiographic unit:

- For sandy soils fed by precipitation (e.g. podzols) a water quality analysis will provide little extra information, while their humus form is highly indicative for the soil acidity and availability of nutrients for vegetation.
- For sandy soils fed by seepage (e.g. brook earth soils), water quality data combined with information on the humus form and, in some instances, the extent to which iron accumulated in the topsoil are highly relevant for proper insight into the acid buffering capacity and extent of parching.
- In a peat soil, the water quality history may be visible in the humus form as for example when sphagnum peat (acid and nutrient poor) occurs on top of sedge peat (neutral/basic, moderate nutrient rich).

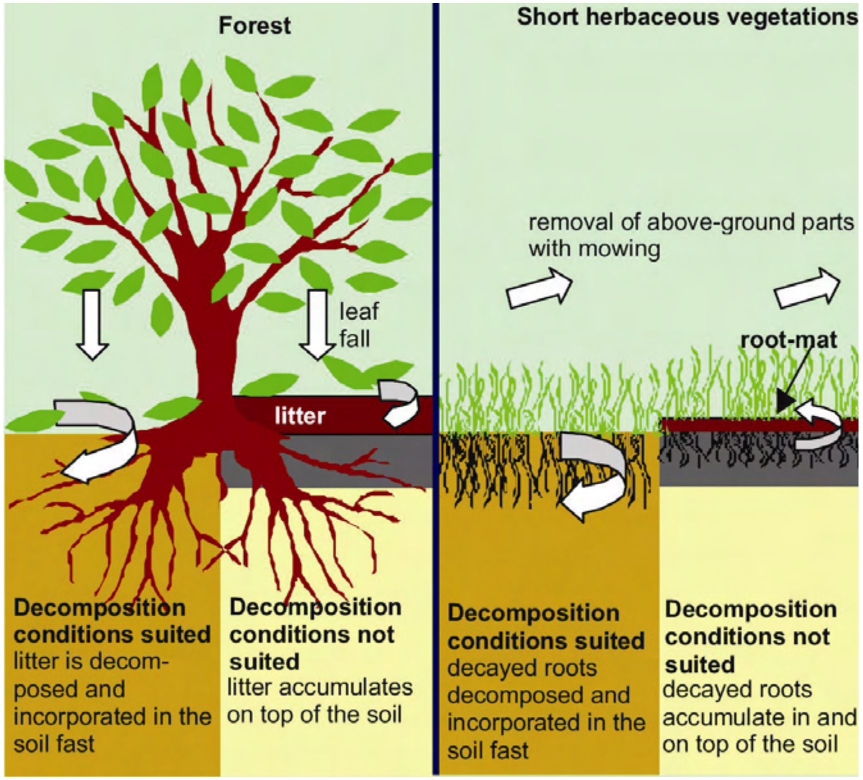
Time and money spent on research can be more efficiently used if methods selected from the ‘tool box’ are based on a smart choice, requiring previous identification of questions to be answered and the position of the area of study in the landscape. Such smart choice may even involve that for different parts of the area different methods are employed. For a further elaboration of the ‘tool box’ concept in ecological soil studies, we refer to the publications of Kemmers en de Waal (1999), Kemmers, et al. (2001a) and Hommel en de Waal (2003).

This field guide deals with the tool ‘humus form’. We hope that with this guide you will be able to produce a proper description of a humus form and to classify it according to the system presented in this guide. However, these activities are not very useful, if results cannot be combined with other information on the site and its surroundings. An integrated approach, which consists of relating humus form characteristics to other site conditions and factors such as geology, soil, groundwater and vegetation, clearly has an added value. This results from the fact that the total provides more information than the sum of the parts; the basis of an integrated approach of which examples can be found in the following publications: Kemmers (1996), Stortelder, et al. (1998), Kemmers en de Waal (1999), Kemmers, et al. (2000), Hennekens, et al. (2001), Brouwer, et al. (2002), Kemmers, et al. (2002), van Delft, et al. (2002), Hommel en de Waal (2003).

Organic matter cycle, engine of the ecosystem

Where plants grow, organic matter is produced through photosynthesis and at some stage reaches the soil in the form of dead leaves, fruits and branches (on the soil) or dead roots (in the soil). In the end, every plant and tree dies, its organic matter becoming part of the 'decomposition cycle' in which the organic matter decays into its basic components, which largely are water and carbon dioxide. The total stock of organic matter in an ecosystem not only comprises 'producers' (plants) and their litter, but also the 'consumers': the animals and other organisms such as bacteria and fungi that live on the organic matter produced by plants. Whether dead or alive, these consumers contribute to the total stock of organic matter, a contribution which in some ecosystems may be surprisingly large. It should be emphasized that not always organic matter produced is cycled through the system. In grasslands that are mowed, for example, part of the above ground biomass is removed. Grazing has a similar, but even more complex impact: Part of the organic matter returns to the soil in the form of manure and a smaller part is stored in the living animal itself, which generally at some stage will be removed to be consumed. Another example is forestry where part of the wood is harvested and exported from the system.

Organisms contain nutrients that were taken up actively (plants) or passively (animals) from the environment in which they live. When decomposition starts, involving a combination of biological, chemical and physical processes, these nutrients are released from the decomposing organic matter to become available for uptake by plants. Rates of decomposition vary considerably and depend on the type of ecosystem. If conditions are suited (moist, neutral-basic, easily decomposable litter), decomposition proceeds fast and litter may be broken down within a period ranging from a few months to a year. Under less suited conditions, decomposition lags behind the supply of fresh litter and consequently litter in various stages of decomposition accumulates on top of and in the soil. This is most evident in forests on acid, dry and nutrient poor sites, where a thick litter layer develops on top of the mineral soil. Under short herbaceous vegetations it leads to a surficial mat of dead roots, such as in *Deschampsia flexuosa* dominated grasslands. Under very wet conditions, it is the lack of oxygen that retards decomposition and leads to peat formation. Litter decomposition rates not only depend on external environmental factors such as drainage, acidity and nutrient status of the site, but also on characteristics of the litter itself. Litter from lime-trees, for example, decomposes much more rapid than litter from oak or beech (Stortelder, et al., 1998, de Waal, 1999, Hommel, et al., 2002, Hommel en de Waal, 2003). Well known is the difference between leaf litter from deciduous versus coniferous trees, the first decomposing much more rapidly. This has to do with differences in composition of the litter, such as in aromatic compounds that are known to impede decomposition (see page 43 and Hegnauer 1973).



Many organisms are involved in the decomposition of organic matter, ranging from microscopically small bacteria to mammals such as moles, whose burrowing leads to incorporation of decomposing organic matter in the mineral soil. Burrowing soil animals also affect soil structure, enhancing aeration which stimulates organic matter decomposition. Various groups of soil organisms can be distinguished, each playing a specific role in the decomposition of organic matter.

For soil fauna the most current subdivision is according to the size of the organisms (Bakker, 1991). Brief descriptions of the various groups, arranged according to their size, are presented below. Another approach of soil fauna is to distinguish between functional groups or food guilds like microbes, bacteria and fungivores and their predators (Brussaard, 1996)

Megafauna

These animals are vertebrates amongst which the mole. By digging long tunnels and throwing up mole-hills, they loosen the soil and in places homogenize it. They feed on earthworms and therefore have no direct impact on litter decomposition. Moles occur in soils with a sufficiently large earth worm population that are not too moist.

Though wild boars cannot be classified as soil fauna, in places they have a major impact on the litter layer through their rummaging. Similar, though lesser prominent impacts are caused by large herbivores such as horses and cattle.

Rummaging by wild boars (photograph archive Alterra; Joop van Osch)

Human impacts on the soil are manifold, amongst which in particular ploughing and digging, as well as long-continued manuring, which throughout NW-Europe has led to the development of so-called plaggen soils. Prior to afforestation, many soils were deeply dug, as a result of which earlier soil horizon differentiation was obliterated. Upon afforestation, soil profile development starts over again, but the disturbance has lasting consequences for the organic matter cycle and for a long time remains visible in the profile (see figure page 51). The same holds for the impact of former agrarian land use on the humus

form, which also shows up in the status of those nutrients that are directly linked to the organic matter cycle such as nitrogen and phosphorus.

Macrofauna (4-250 mm)

Animals belonging to this group include larger insects, snails, slugs and earthworms.

Earthworms

Earthworms are the most important members of this group, playing a manifest role in the organic matter cycle. Under optimal conditions they may occur in large quantities, values up to 3 tons/ha being reported (Schouten et al., 2000). Distinction can be made between larger species (5-25 cm) that live in deeper mineral horizons ('deep burrowers' or Anecic earthworms) and smaller species (0,5-5 cm) that live in the topsoil ('soil burrowers' or Endogeic earthworms) or in the litter layer ('litter worms' or Epigeic earthworms).

Frontal parts of worms belonging to the first group, the genus *Lumbricus*, are pigmented because they regularly surface to eat litter (see figure on the left). The pigment serves as protection against the UV radiation in sunlight. They comminute the litter and pull it into the soil, exuding slime that promotes its pre-digestion by microbes, after which they consume this pre-digested litter. Upon burrowing the tunnels in which they live, excrements are produced in which partly decomposed plant residues are intimately mixed with mineral material (see figure on the right). In loamy and clayey soils these form stable aggregates in which the organic matter is protected against further decomposition. The organic matter is bound to clay, forming so-called 'clay-humus complexes'.

Regularly moving up and down between the topsoil and deeper mineral horizons, these large worms thoroughly mix the organic

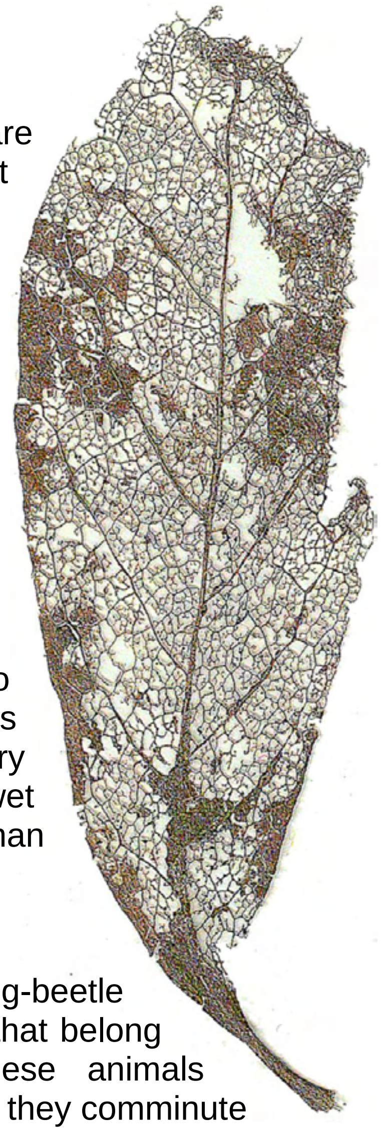
matter through the soil, producing a humic topsoil. Though these worms burrow to a depth of more than one meter, impacts are most prominent in the upper decimetres of the soil where they produce a dark humic Ah horizon. In a humus form, this worm activity shows up as channels filled in with humic material (see photograph page 16). Since the large worms are capable of ingesting large volumes of soil because of their sheer mass, they often completely mask impacts by other faunal groups. Ah-horizon).

The soil burrowers, which particularly inhabit the humic topsoil, intensively mix organic matter and mineral soil material producing a crumb structure and contributing to the development of an Ah-horizon. Since they never surface, they are hardly pigmented. They live on the organic matter in the soil, particularly on died-back roots.

Species that live in the litter layer eat litter and thus contribute to its comminution. Since they live close to the surface, they are strongly pigmented and thus are dark coloured.

.

The optimal environment for earthworms is a moist, well aerated and near neutral soil, with a fair supply of easily decomposable litter. In such soil, litter will be rapidly decomposed and a homogeneous humic topsoil will be formed with a loose structure. Earthworm activity declines with *drought* (dry sandy soils), with lesser *aeration* (shallow groundwater, dense soils), with scarce supply of easily decomposable *litter* (oligotrophic vegetation), or with a more acid *soil reaction* (pH-KCl < 4,5). Litter worms are less sensitive to soil acidity.



Potworms

Potworms (Enchytraeidae) are related to earthworms, but transparent and much smaller (1-5 mm). They largely feed on microbes, though some species live on litter, feeding on mesophyll between leaf veins thus producing the so-called ‘leaf skeletons’. Since potworms mix organic and mineral material, they also contribute to the development of a humic mineral topsoil (Ah).

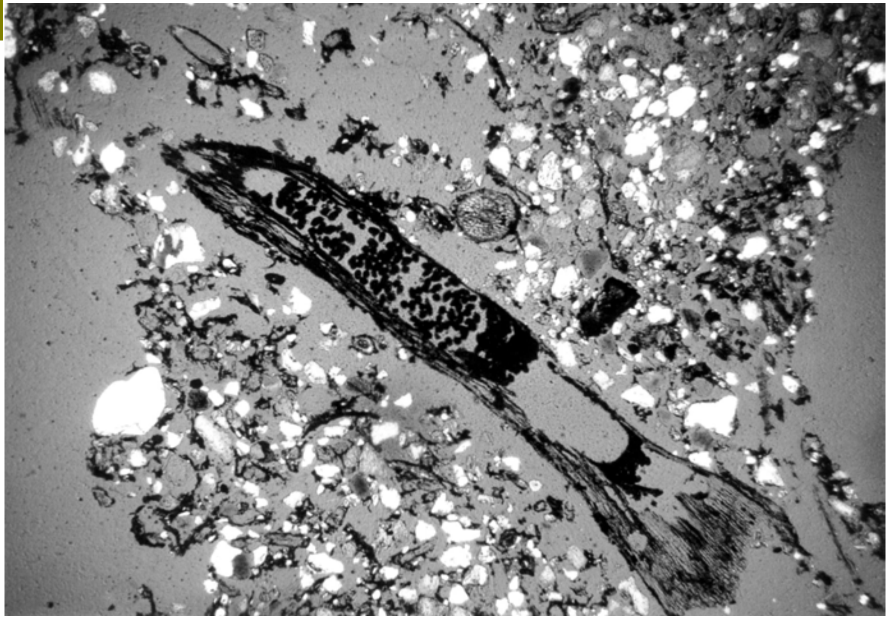
Potworms are less sensitive to most environmental conditions than earthworms, but are very sensitive to drought. Under wet conditions they thrive better than earthworms.

Insects

Millipedes and various dung-beetle species are examples of insects that belong to the macrofauna group. These animals largely live in the litter layer where they comminute the litter, but some species partially live in the soil for example during their larval stage or as adults.

Mesofauna (0,2 – 4 mm)

Animal groups that belong to the mesofauna include for example *mites (Acarina)* en *springtails (Collembola)*



Thin section of root remains with mite droppings (photograph 7.6 x 5.4 mm)

Mites

The mite group is highly varied with *carnivores* that feed on other small soil animals as well as *detrivores* that feed on dead organic material (*detritus*). In contrast to earthworms, mites do not mix organic material through the soil but eat it in place, producing small rounded excrements, also referred to as droppings (see photograph). Such type of organic matter has been described as moderhumus.

Springtails

Springtails eat bacteria and fungi as well as detritus. They will only occur in relatively moist soils.

Micro-organisms

Fungi and *bacteria,* though mostly invisible to the naked eye, form by far the major component of the soil biomass.

Fungi

Saprophytic *fungi* largely occur in the litter layer where they invade organic matter through their thread-like mycelium and decompose it in place. They are capable of breaking down the brown pigments in leaf litter thus liberating the nutrients contained in it (Jabiol, et al., 1995).

They need a rather humid environment. This mycelium constitutes an important source of food for soil fauna. Thus, with increasing activity of the soil fauna, the visibility of fungal growth becomes less, though fungal activity may still be considerable. On soils with many deeply burrowing earthworms the litter layer is minimal or even absent and under such conditions these fungi hardly occur. Contrary, when faunal activity is limited such as in acid soils, mycelium may abound, to occur as abundant white threads that may even form mats. The fruit bodies of these fungi are better known as mushrooms.

Bacteria

Bacteria play an important role in the decomposition of organic matter, notably in the breakdown of organic compounds into its basic components, also described as mineralization, thus liberating the nutrients contained in it. Most bacteria require oxygen to do so, but not all of them, some being capable to live under anaerobic conditions. Part of these nutrients may be immobilized again by bacterial uptake. Recently empirical evidence has become available that under optimal conditions for soil life microbes might be of main importance in controlling low levels of plant available nutrients by immobilizatior

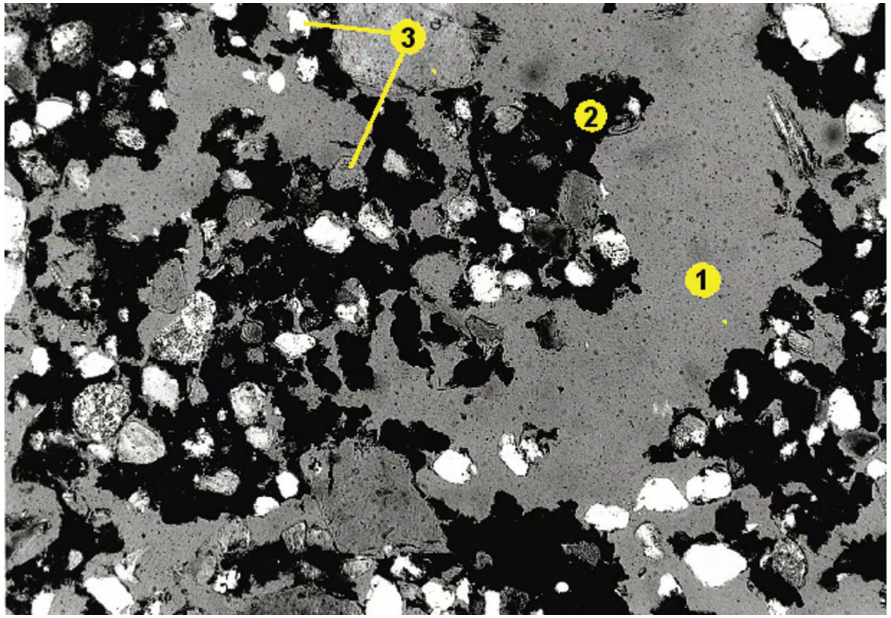
Formation of iropn sulphides upon anaerobic decomposition of organic matter

Since bacteria are not capable of actively moving through the soil, they depend on the transporting activities of soil fauna to reach new resources and form new colonies. They particularly profit from earthworm activities.

In places where other soil organisms cannot live as for example with shallow groundwater, some anaerobic bacteria thrive and are capable of decomposing organic matter. Under such conditions, often sulphate is reduced to produce hydrogen sulphide, which then binds to iron to produce iron sulphides (e.g. pyrite). This hydrogen sulphide has a characteristic rotten egg smell. The photograph on page 19 shows the anaerobic part of a soil profile which has a black colour because of the presence of iron sulphides

Position in the organic matter cycle

All soil organisms described above have their own specific position in the organic matter cycle. Consequently, their influence is highly diverse and species may mutually affect each other, thus creating a very complex food web. An overview of the various major activities of each of the groups of soil organisms is given in table 1. Larger soil animals (e.g. earthworms) determine whether litter is present at the surface and the extent of *bioturbation* (mixing of litter and mineral material). The impact of smaller animals and decomposing micro-organisms is much more local and their activities do not result in bioturbation.



Caption: *Fill of a worm channel in an Ah-horizon. 1: pores, 2: humified organic matter, 3: sand grains. (photograph size 2.24 x 1.6 mm)*

Table 1 Position of soil organisms in the organic matter cycle (after Jabiol et al., 1995)

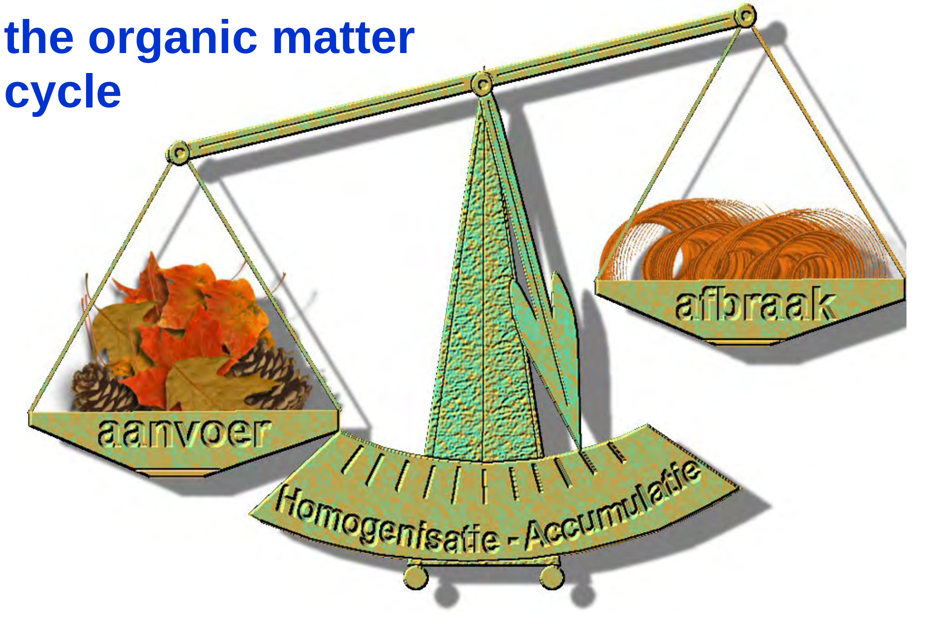
Fast decomposition of litter	Intermixing of organic and mineral parts (bioturbation)	Fragmentation of litter	Soil structure (formation of aggregates)	Formation of clay-humus complexes	Decay of Brown pigment	Accumulation of fine organic particals (droppings)
Deep burrowing worms or Anecic earthworms						
YES	Important	Important	YES	YES	YES	No
Soil burrowing worms or Endogeic earthworms						
No	Yes	No	YES macroaggregates	YES	?	No
Litter worms or Epigeic earthworms						
No	No	YES	No	No	?	YES
Pot worms						
No	No/Yes species living in the soil do	partly: formation of leaf skeletons	No/Yes micro aggregates	No	No	YES In the litter layer
Mites and springtails						
No	No	Yes	No	No	No	YES
Fungi						
Occsionally, local	No	No	No	indirect	YES	No
Bacteria						
No	No	No	YES	YES	No	No

Food webs

The soil ecosystem is far too complex to be systematically dealt with here. Nevertheless, for those studying humus forms, it is important to understand and realize that many organisms play a role in litter decomposition and that these function in a complex food web, also described as *trophic* system. The actual decomposition of organic matter is largely by fungi, bacteria, earthworms and potworms. However, a wide range of soil animals lives on fungi and bacteria and in fact are *herbivores*. The system is marked by feed-backs and complex interactions. Earthworms, for example, favour other soil organisms because their excrements are relatively high in nitrogen and contain partially decomposed organic matter. Enzymes that are produced in the guts of these earthworms promote the decomposition of e.g. cellulose and chitin, which thus also become available to other soil organisms.

Feed-back in a food web: Cow eats plants → Fungus decomposes manure.

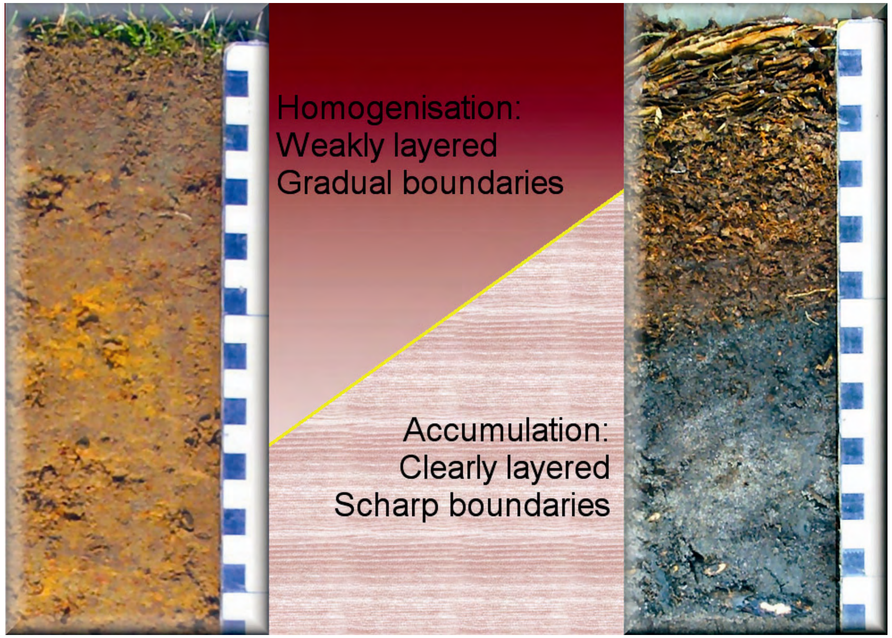
Humus form as balance of the organic matter cycle



In the preceding sections we described the components of the organic matter cycle, being supply of litter on the one hand, and its decomposition by a range of soil organisms and its incorporation in the soil, on the other hand. The nature and rate of these processes depend on environmental factors such as climate, parent material and drainage, but also on the composition of the litter (depending on vegetation). Climate, parent material and drainage are considered to be *'independent factors'*, which control '*dependent factors*' such as the humus form. The role of vegetation as 'independent factor', notably the tree species in forest stands, has been extensively described by Stortelder, et al. (1998), de Waal (1999), Hommel, et al. (2002) and Hommel en de Waal (2003).

The relation between litter input and its decomposition shows up in the extent to which organic matter is incorporated in the soil (homogenisation or turbation), or accumulates on top of the mineral soil in the form of a more or less distinct litter layer. If the balance is towards accumulation, the profile exhibits clear horizon differentiation with sharp horizon boundaries, whereas in soils in which decomposition is rapid homogenisation as a result of bioturbation leads to limited contrasts between horizons and very gradual boundaries.

The humus form comprises the total of humic soil horizons or layers that occurs at a given site. This humus form thus registers the local balance between input and decomposition of organic matter. By studying the humus form, we thus may learn a lot about the functioning of the ecosystem at a certain site.



Control by environmental factors

While the various groups of soil organisms are sensitive to environmental factors (acidity, drainage, toxic substances), changes in these factors affect the entire organic matter cycle. Under very wet conditions many organisms stop functioning, but potworms remain active as long as oxygen is available. If the soil becomes anaerobic, decomposition of organic matter depends entirely on anaerobic bacteria whose activities may induce the formation of sulphides (see photograph on page 19). Under conditions that are suited for earthworms (humid and not too acid) organic matter is intimately mixed through the soil, from which bacteria profit whereas this is unfavourable for fungi. The latter thrive in poorly drained and acid forest soils. Changes in environmental conditions, such as acidification or parching, thus affect the organic matter cycle particularly through its impacts on soil organisms.

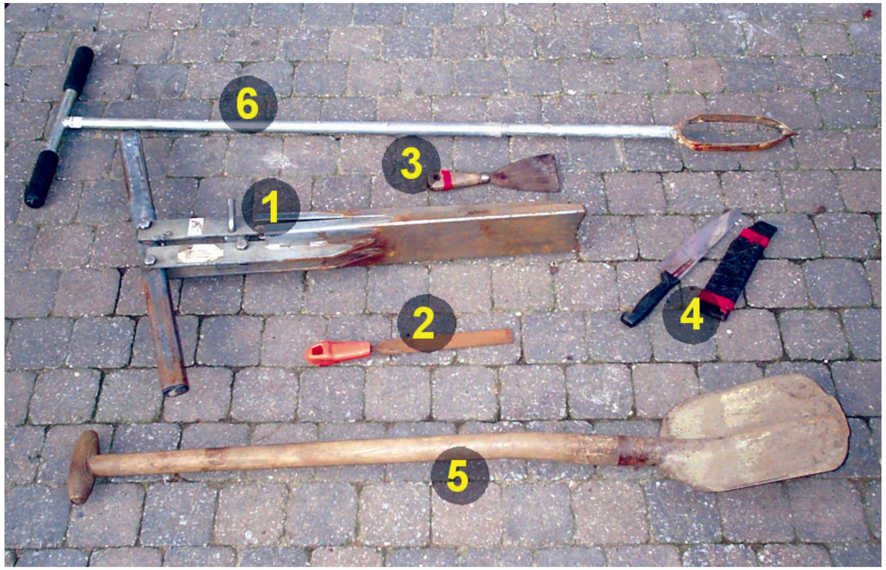
Profile description

Humus form studies start with a proper description of the humus form profile. This involves the collection of adequate data on the profile itself, but also additional information on its surroundings since this can be crucial for appropriate interpretation of the data collected. This chapter focuses on how such description can be produced, including its technical aspects. The description starts with a proper preparation, including the tools to be used, the selection of a profile and the properties to be recorded. These may differ depending on the nature of the terrain.

In the terrain, the first question to be answered is 'what is the best location to describe the characteristic humus form of a certain site?' This may lead to the conclusion that we should select and describe several profiles in order to register the spatial variability within an association[1] of humus forms. Once the exact location has been determined, the next question is how the profile should be prepared for description, selecting the method that ensures an optimal visibility of the profile characteristics to be studied. Finally, we pay attention to the actual recording of the *properties* of the humus form, in which we distinguish between a minimum package and additional information that supports the interpretation of the observations on the humus form.

[1] See Appendix 1; Glossary

Tools



Tools and materials shown (see photographs) are the most common appliances used in the field study of humus form profiles. Not all materials shown will invariably be required and it may very well be that the reader invents more appropriate tools. We see this summary as an indication for what might be useful in the field. In other words, we have to carefully consider what we really need since it is rather silly to walk around with a heavy load of tools that turn out to be rather useless.

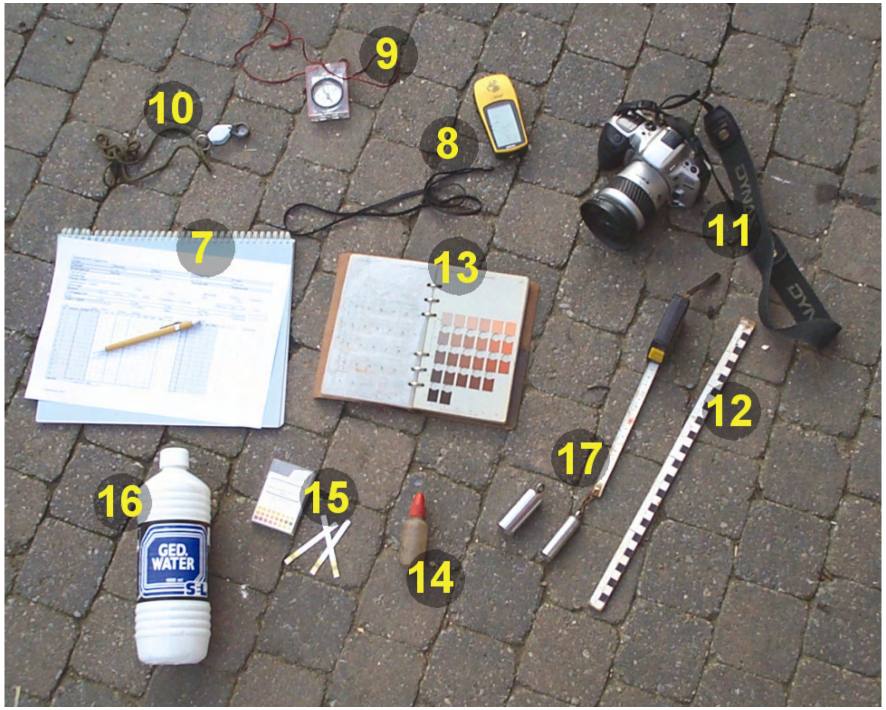
Packing list

1. Wardenaar sampler to cut humus forms.
2. Iron file to whet the sampler.
3. Putty knife for preparing the humus form.
4. Scalloped knife to cut e.g. peat profiles.
5. Shovel to dig profile pits and trenches.
6. Soil auger to sample the deeper soil horizons..
7. Forms or notebook for recording profile data.
8. GPS to establish the topographic position of the site.
9. Compass to establish the exposition of the site in sloping terrain. Preferentially, it should also be suited to assess the slope inclination (geological compass).
10. Pocket-lens; very handy to study small aggregates and to identify droppings and fungal mycelia.
11. (Digital) photo camera to record the morphology of the profile, but also the landscape and surroundings. Useful for later presentations of data, but also to aid the memory while interpreting these data.
12. Ruler with clear bars to be used for photographs
13. Munsell colour scale for recording colour of horizons and mottles.
14. Hydrochloric acid (10% solution) to test for lime.
15. Indicator strips (Merck) to estimate soil acidity in the field using demineralised water. The pH value obtained is more or less equivalent to pH-KCl.
16. Demineralised water to be used with the indicator strips (15).

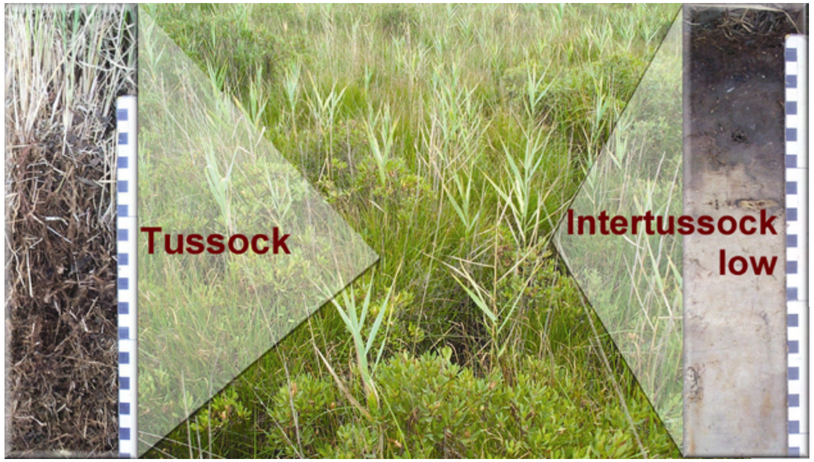
17. Gauging clock with tape measure to record the groundwater-level in the auger hole or in a nearby gauge tube.

Not shown on the photographs, but often useful:

- Plastic sheet to put soil material on when working in vulnerable vegetations. Dumping soil material in such vegetation might cause disturbances.
- Sand ruler, aiding in the estimation of soil texture.
- pH/EGV-meter for the study of groundwater (seepage water, rainwater, salinity)



Examples of variation in humus forms at short (below) or larger distance (above)



Cutting a humus form profile

Where?

The decision on where to exactly cut and describe a profile will be based on various considerations, such as:

- For what surface should the description be representative?
  - A point location connected with a vegetation survey, a soil sample or a gauge tube?
  - A stage within a gradient along a transect?
  - An area within a specific vegetation unit or a plot in a forest stand?
- What variation can we expect?
  - In grasslands, short-range spatial variability is often limited.
  - In forest, variability will strongly depend on the age, management and structure of the stand.
  - In some stands, short-range spatial variability in the humus form may be strong, such as in the border zone of fens where Molinia caerulea forms tussocks.
  - Stochastically determined variability such as wind throw or rabbit holes.
  - As an aselect sample as part of a sampling strategy

Trench for description of short distance variation. (Photograph by Peter Mekkink).

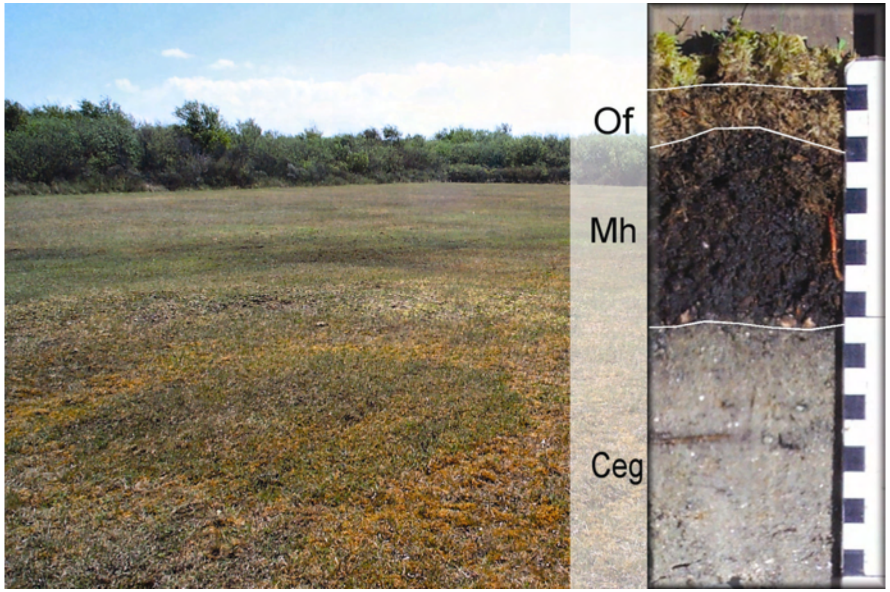
Some preliminary cuts with the Wardenaar sampler may serve to gain insight into the extent of variability, before deciding on the exact location of the representative humus form to be described. Additionally, one should always pay attention to the spatial variability in the humus form. If the variation within the area to be characterised is too large, one should decide for several humus form descriptions to be made that together represent the association of humus forms within the area.

How?

For cutting a profile, several alternatives exist that depend on the soil type:

- Profiles in sandy soils can be easily cut with the Wardenaar sampler, allowing for taking undisturbed samples to a depth of about 40 cm and a width of about 10 cm. In this field guide, nearly all photographs of humus forms are from samples taken in that way. An alternative is to dig a shallow profile pit or trench in which spatial variability can be observed. For rapid observations on the upper part of the humus form a scalloped knife may be very useful

- The Wardenaar sampler can also be used in clay soils and soils with a clay cover, provided that the clay is not too dry or too heavy. In the latter cases, working with the Wardenaar sampler may be very difficult and it might be better and much easier to dig a shallow profile pit.
- In soils with a peaty topsoil and moulded peat, the Wardenaar sampler can be used, provided that the material is not too soft, such as in soft peat soils and quaking bogs. In such cases, it is easier to cut a monolith with a sharp scalloped knife.
- The method we choose thus largely depends on the soil type and personal preferences. Nevertheless, while cutting the profile we have to aim at minimal disturbance of the soil. In other words, do not make cuts that are bigger than needed (the Wardenaar sampler is very much suited for this) and replace the soil material as much as possible in its original stratification. In vulnerable vegetations, we advise to put the soil material on a plastic sheet during the description and sampling. Additionally, it is better to stay outside test squares or permanent quadrates when making profile descriptions in connection with vegetation relevees.



To what depth?

The classification of humus forms is based on the properties of the upper 40 cm of a profile (see Chapter '*Classification*'), implying that the profile should be described to at least such depth. However, information on deeper layers is often highly relevant for further interpretation, particularly regarding the groundwater regime, depth of decalcification, textural profile and rooting densities. It is therefore desirable to study the profile by augering to a depth of 120 cm below the surface or to the mean lowest groundwater level (MLGL).

Preparing the profile

The profile needs to be well prepared before starting the description. This involves the removal with a (putty) knife of bits and pieces of displaced soil material that adhere to the surface that is to be described. Moreover, whether cut with the Wardenaar sampler or with a spade, the structure of layers is often slightly disturbed which may be rectified by such preparation. This additionally may serve to improve the visibility of root density and distribution.

Recording profile characteristics

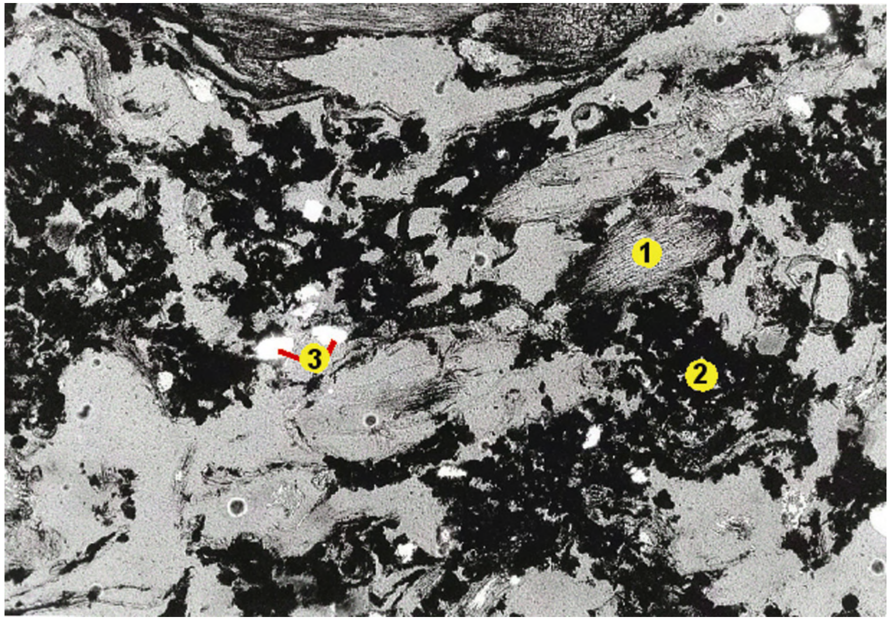
It is advisable to photograph the prepared profile prior to its description, eventually indicating horizons distinguished or special features. Such photographs as well as those of the landscape and vegetation can be very useful at later stages of the research and for documentation.

For the description a form is used that can be downloaded from the Alterra website. In appendix 2 it is presented in reduced size. Attention is paid to profile characteristics (layer information), but also to site characteristics and general information on the profile (general information).

In both categories of ‘general’ and ‘layer’ information, several characteristics have to be registered (‘obligatory characteristics’) since data on these are required for identifcation of the humus form type and for administrative

purposes. This is the so-called *‘minimum data package’* that should always be recorded. Information on other characteristics is not essential for these purposes, but may be relevant depending on the aims of the research. Thus, it may well be that we need lesser information for a comparison of points or units within a larger area than for a process study aiming at their description or explanation for a certain site. In the first case, we might do with a concise description that allows for identification of the humus form only, while in the second case we will need a more extensive description. Such full profile description will take more time, particularly from less experienced people. Nevertheless, we should realize that taking less data may eventually lead to disappointing results or to higher costs when it turns out afterwards that additional information needs to be collected.

Part of the information will be descriptive in nature, such as remarks concerning the location. For most characteristics, however, we use fixed classes and codes that are derived from classes and codes used in existing



Detail of an OM-horizon with clearly recognizable organic matter fractions. 1: root remains, 2: mite droppings, 3: sand grains (size photograph 5.6 x 4.0 mm)

systems for soil profile description (ten Cate, et al., 1995) and humus profile description (van Delft, 2001). Results are recorded on the field form (Appendix 2). In appendix 3 fields that have to be filled in on the form are elucidated.

And further…

A correct profile description, in which sufficient information has been recorded, is a valuable tool for understanding the relations between humus form, site conditions and vegetation. Sometimes it is meaningful to acquire additional information by means of micromorphological observations, soil chemical analyses or chemical analysis of groundwater.

Micromorphology

Through studying thin sections much information can be gathered on, for example, the distribution within a humus form of various organic matter fractions (see photograph). This may provide insight into the main soil organisms that contribute to the decomposition of organic matter in the profile concerned and, through that information, on the conditions in the soil. Human impacts (disturbance, compaction) are also readily observable (Pulleman et al., 2005). Furthermore, observations can be made on the genesis of minerals that are indicative for specific site-related processes, such as calcite and pyrite.

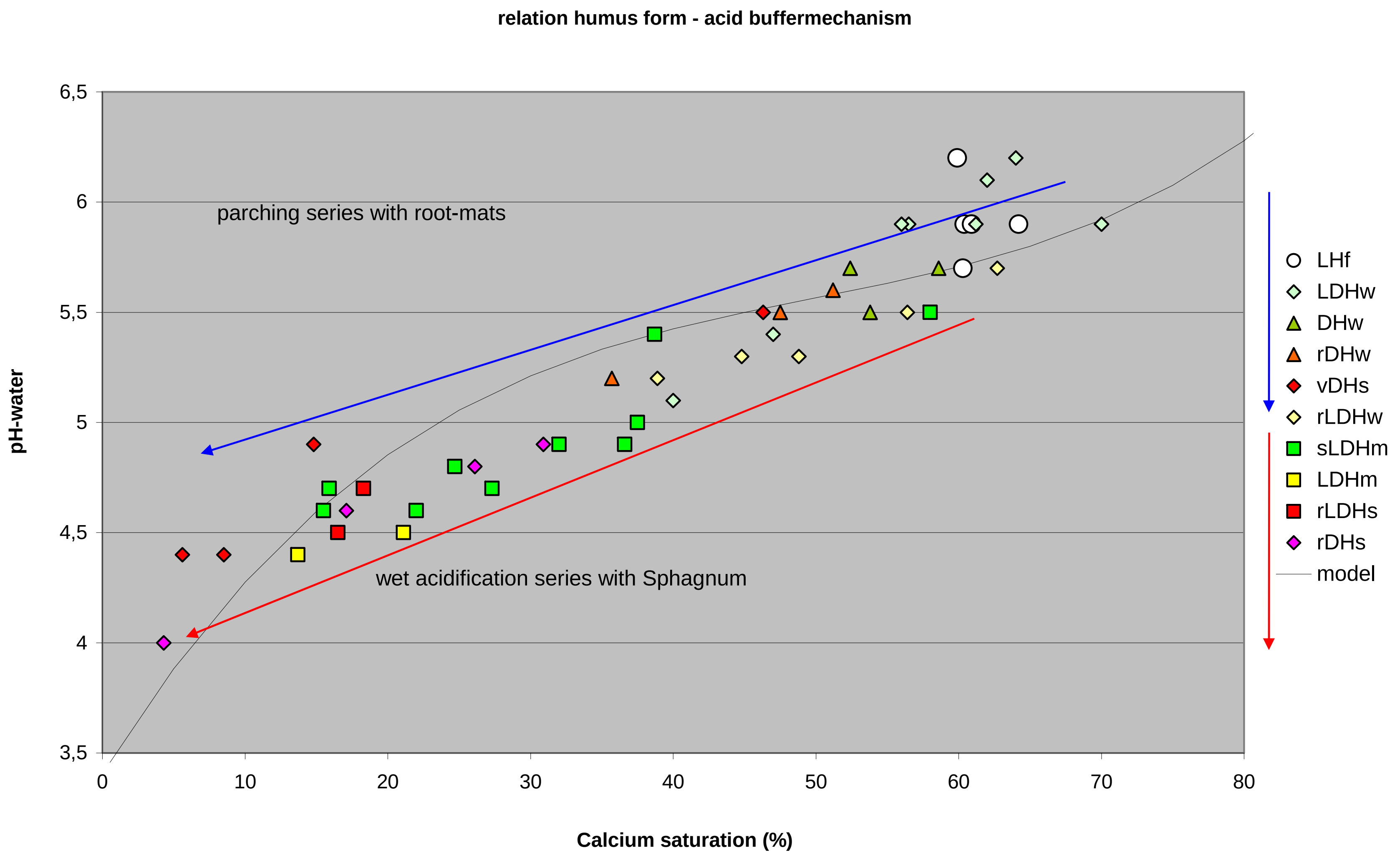
Soil chemical research

Soil chemical analyses may be relevant for a number of applications.

- Determination of the organic matter content may serve to check field estimations of such content.
- Determination of the lime content and composition of the exchange complex provides an indication for the extent to which acid is buffered in the soil (acid buffering capacity). The figure on page 34 provides an example of how humus forms depend on acid buffering during successional series that are connected with acidification and parching. Humus forms indicated in the right upper part are characteristic for sites with a high Ca-saturation as a result of which the soil reaction is buffered around pH (H_2O) = 6. Towards the lower left corner, buffering declines and the soil reaction becomes more acid. In the corresponding humus forms the accumulation of organic matter increases. For an explanation of the humus form codes we refer to the chapter on classification. Further examples of such series are presented by van Delft, et al. (2002), Waal en Bijlsma (2003).
- Analysis of the nutrient status (C/N, C/P, P-saturation, P-availability) provides information on the position of humus forms within a dystrophication sere (Kemmers, et al., 2001b).

Analysis of water samples

The eco-hydrological position of a site can be elucidated by chemical analysis of water samples. They may for example explain why humus forms that are characteristic for an infiltration regime occur on presumable seepage water dependent sites (Jansen, et al., 1994).



For an explanation of the figure above, see previous page.

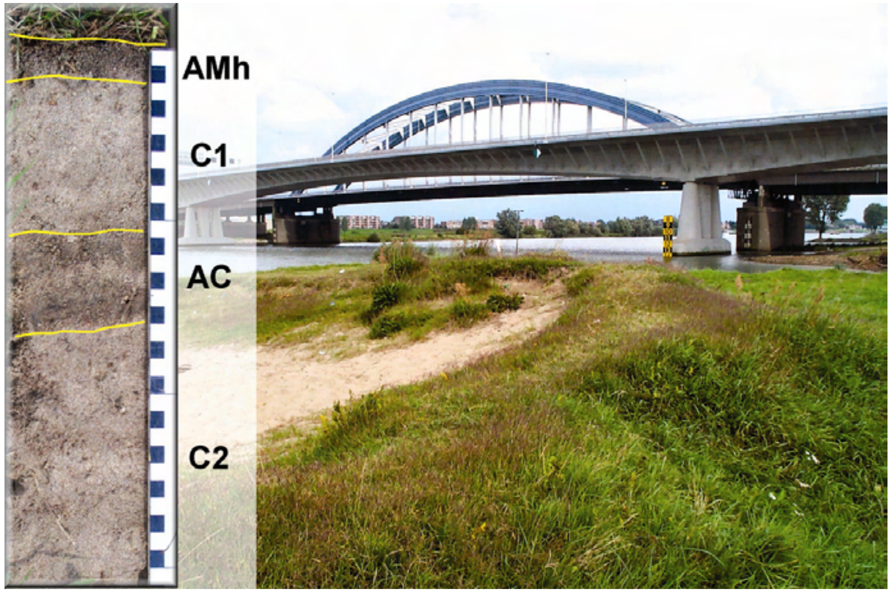
Horizons

This chapter is devoted to the horizon designation as used in the humus form description. In the introduction we already explained how the organic matter cycle results in a number of characteristic layers that each differ from the layers above and below. Such layers are named horizons, each of them having a specific place within the organic matter cycle. The assemblage of horizons together constituting the humus form thus represents the combined effect of litter input and decomposition at a certain site.

When describing a humus form profile, we record the thickness and a number of specific properties of the horizons present (see chapter "profile description"). The thickness of horizons is recorded in cm, with the exception of the upper part of the profile where you may use a mm scale for recording thicknesses. At depths >40 cm values generally are rounded off to 5 cm.

The main subdivision for horizons is between ectorganic and endorganic horizons; a distinction based on the provenance of the organic matter. In ectorganic horizons, the organic matter is directly derived from plant litter that accumulated on top of the profile. Endorganic horizons are those in which the organic matter is due to roots or to admixture through biological and physical processes (turbation). Though endorganic horizons are often relatively low in organic matter and formed by admixture of organic matter in mineral soil material, peat layers i.e. non-decomposed organic matter that accumulated under anaerobic conditions are also considered as endorganic horizons. The humus form is restricted to those horizons containing relevant amounts of live or dead organic matter i.e. identifiable as such and being related to the actual soil surface. However, it will often be necessary to also describe the deeper soil horizons. These will be dealt with under 'Other horizons'.

We distinguish a number of master horizons, which often are further subdivided, for example according to the extent to which identifiable plant residues occur. Additionally, we often see transitional horizons, i.e. horizons that must be considered as transitional between two master horizons.



An example is the AC horizon that can be a horizon that is transitional between an A horizon and a C horizon, having characteristics of both horizons. However, it can also be a horizon that represents a successional phase, such as an initially mineral soil horizon (clay or sand) in which some organic matter is present as a result of bioturbation, but still insufficient to identify it as an Ah horizon. An example of the latter is the profile on page 35.

The horizon designation used here largely conforms to the horizon designation in the current Dutch soil profile description system (Bakker en Schelling, 1989, Steur, 1991, ten Cate, et al., 1995). Differences are an extension of the number of horizons that is identified, as well as a deviating classification for peaty and peat horizons (O-horizons, see page 44).

Key for identification of horizons

1. Horizon consists of:
   a. More or less decomposed residues of above ground litter, such as leaves, needles, branches and stems of trees and plants: *Ectorganic horizon* → 2
   b. Living peat moss: ***S-horizon → page 41***
   c. Largely dead (partially living) roots: *Root mat* → 7
   d. Peaty material or peat, other than litter, originating through accumulation of plant residues in a wet to aquatic environment (> 15% organic matter): *organic, semiterrestric horizon* → 9
   e. Mineral material (sand, loam, clay) with more than 0,5 % but < 15% organic matter: *Humic horizon* → 13
   f. Mineral material (sand, loam, clay, rock) with less than 0,5 % organic matter: *Other horizons* → 17
   g. Heterogeneous mixture of mineral, humic and/or organic material: ***Reworked horizon → page 51***
2. The litter is:
   a. Recently fallen, non-decomposed with readily identifiable plant residues (mostly leaves and needles), < 10% fine organic matter: *L-horizon* → 3
   b. Partially decomposed, fragmented plant structures are generally recognizable as to origin, 10-70% fine organic material: *F-horizon* → 4
   c. Nearly completely humified, small amounts of macroscopically recognizable plant residues may occur, > 70% fine organic material: *H-horizon* → 5
3. Litter largely intact and only slightly discoloured
   a. Yes: ***Ln-horizon → page 39***
   b. No: ***Lv-horizon → page 39***
4. Litter decomposition in F-horizon through:
   a. Fungi, with prominent layered structure (like pages in a book) and presence of fungal hyphae: ***Fm-horizon → page 39***

   b. Soil fauna, evidenced by the abundance of droppings; fungal hyphae lack and structure is non-matted: ***Fz-horizon → page 39***
   c. Both fungi and soil fauna (droppings); structure is non-matted: ***Fa-horizon → page 39***
5. Macroscopically recognizable plant residues in H-horizon:
   a. Absent → 6
   b. Poorly recognizable residues: ***Hr-horizon → page 40***
   c. Containing abundant decaying wood: ***Hw-horizon → page 40***
6. Structure of the H-horizon
   a. Massive or blocky: ***Hh-horizon → page 40***
   b. Consisting of fine moder (droppings) : ***Hz-horizon → page 40***
7. (1c) Ratio between root residues and other material:
   a. Mat of poorly decomposed roots, some humified material in between: ***Mf-horizon → page 42***
   b. Mat of partially decomposed roots, with much humified material in between: ***Mm-horizon → page 42***
   c. Nearly completely humified organic matter, some root fragments may occur: ***Mh-horizon → page 42***
   d. Organic matter content < 15%, but with many (dead)roots: ***AMh-horizon → page 42***
   e. May contain many (dead) roots, but organic matter in between roots consists of (moulded) peat: *OM-horizon* 8
8. Peat between the roots
   a. Slightly decomposed: ***OMf-horizon → page 46***
   b. Partially decomposed, plant residues recognizable: ***OMm-horizon → page 46***
   c. Moulded, few recognizable plant residues: ***OMh-horizon → page 46***
9. (1d) Organic matter content
   a. 15 – 30%: *OA-horizon* → 10
   b. > 30%: *O-horizon* → 11
10. (9a) Recognizable plant residues
   a. Distinctly present: ***OAm-horizon → page 46***
   b. Nearly absent: ***OAh-horizon → page 46***
11. Plant residues
   a. Hardly decomposed, easily identifiable as Peat Moss, Hair moss, Sedges or Reed etc. Little fine organic matter between the plant residues. Mostly light brown to dark brown coloured: ***Of-horizon → page 44***
   b. Partially decomposed, plant species often recognizable, abundant fine organic matter between the plant residues. Brown to dark brown coloured: ***Om-horizon → page 44***
   c. Moulded, poorly recognizable plant residues → 12
   d. Many (dead) roots: *OM-horizon* 8
12. Environmental conditions during moulding
   a. Aerobic, mesotrophic or eutrophic, pH-KCl > 3,5, dark brown-black, from peat that is richer than peat moss peat: ***Oh-horizon → page 44***

b. Aerobic, oligotrophic, pH-KCl < 3,5, black, from peat moss peat: ***Od-horizon → page 44***

c. Anaerobic, mesotrophic, pH-KCl > 5, brown to black, slack (gyttja): ***Og-horizon → page 44***

13. (1e) Organic matter content

a. > 2 %: The colour is mostly dark brown to black or dark grey. If white or light grey, in between the sand grains abundant black organic matter (magnifying glass). Fingers turn black upon rubbing the material → 14

b. 0,5 – 2 %: The colour is pale brown or grey and is only slightly different from the underlying C-horizons. Upon rubbing, fingers do not turn black 16

c. < 0,5 %: The dominant colour of the horizon is yellow, pale brown or brown. The material dominantly consists of sand, loam or clay. Thin dark fibres of illuviated organic matter may occur → 17

14. Position and dominant colour (moist) of the horizon

a. Dark grey to black, formed at or near the mineral soil surface: *A-horizons* 15

b. In sandy soils, grey with many bleached sand grains mostly below an A horizon and overlying E or B-horizon (including initial B-horizons): ***AE-horizon → page 50***

c. In sandy soils: a white to light grey horizon composed of bleached sand grains; or in loamy soils a pallid horizon with a lower clay content than the underlying B-horizon: ***E-horizon → page 48***

d. A yellow, brown to black horizon (by illuviation or weathering) mostly below an E or AE horizon and grading into a C-horizon: ***B-horizon → page 49***

15. Organic matter in the A-horizon

a. Mixed with mineral material through natural homogenisation (bioturbation): ***Ah-horizon → page 47***

b. Mixed with mineral material through tillage: ***Ap-horizon → page 47***

c. Anthropogenic in origin (such as plaggen soils): ***Aa-horizon → page 47***

16. Dominant colour of the horizon

a. Grey: ***AC-horizon → page 50***

b. Brown: ***BC-horizon → page 50***

17. (1f) Mineral material consisting of:

a. More or less loose fragments (grains) that can be augered by hand: ***C-horizon → page 49***

b. Hard rock; cannot be augered by hand: ***R-horizon → page 50***

Ectorganic horizons

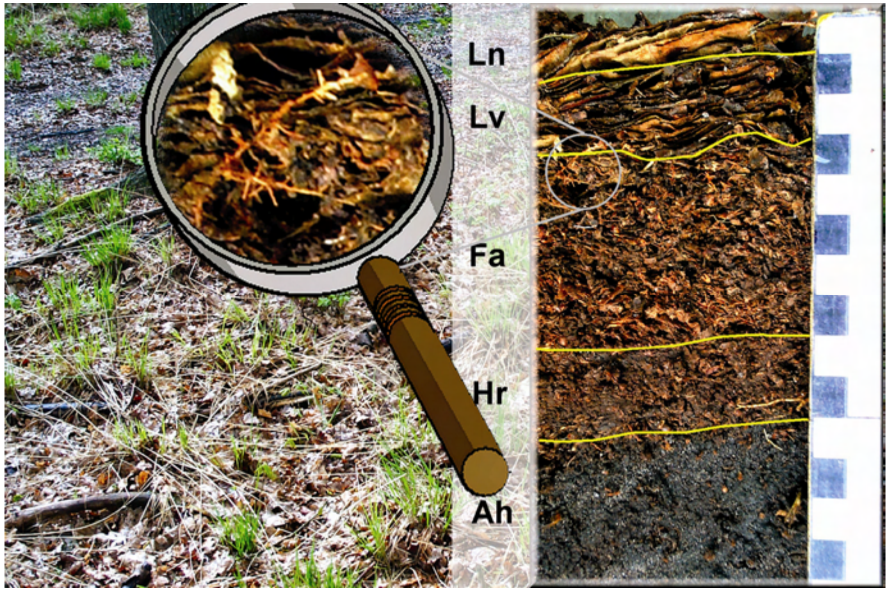
The ectorganic horizons comprise the typical 'litter horizons' L, F and H, and the layer of living peat moss that may occur as surface horizon in semi-terrestric soils. All horizons have in common that they originate through accumulation of aboveground litter on top of the (mineral) soil.

L-Horizons *(Litter)*
L-horizons consist of fresh litter in which entire original structures (leaves, needles, fruits) are discernible. Contents of fine organic matter, resulting from decomposition, are very low or nil (< 10%). Litter that is largely intact and little discoloured, can be defined as an Ln-horizon (new). Such litter is often less than one year old. After some time, litter changes through physical, chemical and biological processes. Leaves and needles are comminuted, pigments are leached or decay through fungal activities (see page 18). Where potworms are active, leaf skeleton may occur, the mesophyll being consumed by these worms (see page 17). L-horizons in which such processes occurred are identified as Lv-horizons *(variative)*.

L-horizons are subject to rapid changes. Apart from the above mentioned processes, as a result of which the fresh litter (Ln-horizon) is transformed into a F-horizon with an intermediate stage (Lv-horizon), in soils with a high biological activity litter may disappear within less than a year, being comminuted and mixed into the mineral soil by earthworms (see page 16). Humus forms of such soils belong to the *mull-type humus forms* (see page 58).

F-horizons *(fragmented)*

F-horizons consist of partially decomposed litter. The plant residues are fragmented and fine organic matter may be quite abundant (< 70%), but the residues are still macroscopically well recognizable. In profiles with an ectorganic layer, this is the layer in which decomposition is most active and consequently most nutrients are released. For that reason, often many roots are encountered in the F-horizon (see photograph next page).



Organic matter decomposition in the F-horizon is particularly through mesofauna and fungi (see page 18). Based on the dominant type of biotic activity, we distinguish three types of F-horizons:

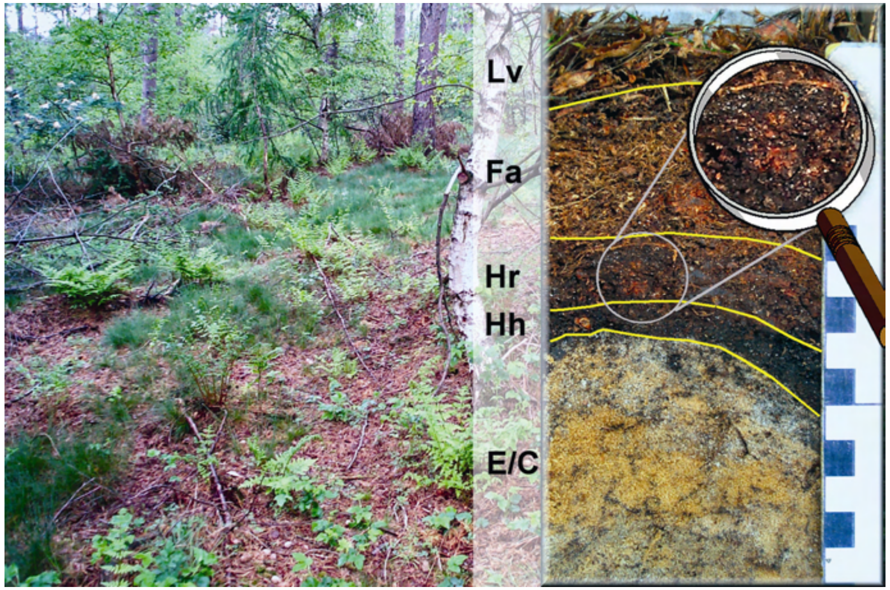
- Fm-horizon *(mycogenous)* if decomposition is largely through fungi. This is evidenced by the abundant presence of fungal hyphae, interweaving this horizon that in broad-leaved forest often has a matted banded structure, like pages in a book.
- Fz-horizon *(zoogenous)* if decomposition is largely through mesofauna. Fungal hyphae are rare or absent and fine faunal droppings or dropping residues abound in between the plant residues (magnifying glass).
- Fa-horizon *(amphi)* if decomposition is through both mesofauna and fungi. Fungal hyphae occur as well as faunal droppings.

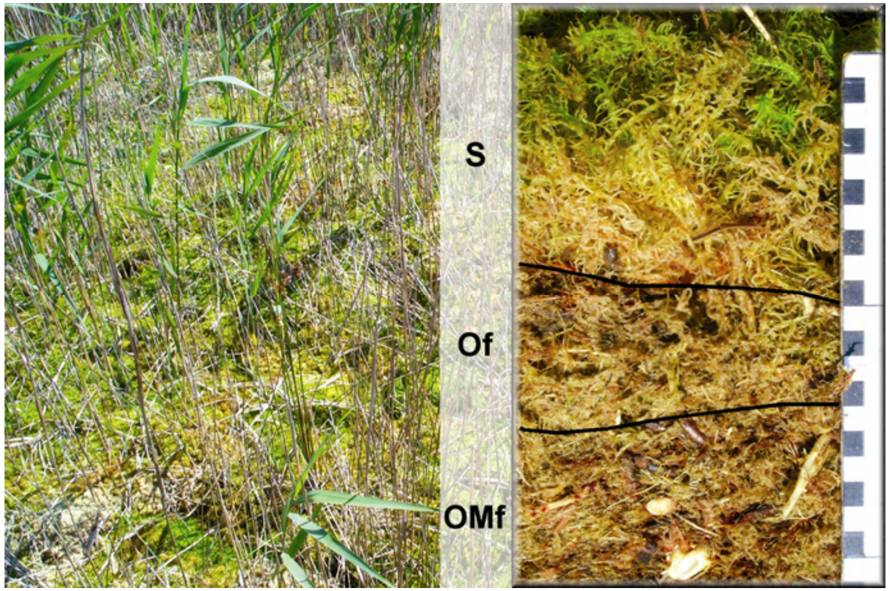
Within Fz- en Fa-horizons often successional phases can be identified with lesser fine organic material in the upper part of the horizon and in the younger stages, than in the lower part and in older stages. The lower part of a F-horizon exhibits characteristics of a H-horizon, but because of the occurrence of identifiable plant residues is still considered to be a F-horizon. In such cases, a further subdivision can be applied into an Fz1 or Fa1-horizon for the upper part of the horizon if with 10-30% fine organic material and an Fz2 or Fa2-horizon for the lower if with 30-70%.

H-horizons *(Humus)*

H-horizons represent that part of the ectorganic humus form in which organic matter is most strongly decomposed. The organic matter constituting this layer may originate from litter that was deposited on this profile decades ago. It now largely consists of fine organic matter (> 70%) in the form of mesofauna droppings and macroscopically unidentifiable plant residues. Often, some residues of bark and other woody material occur. Four sub horizons are recognized:

- Hh-horizon *(humic)* Completely humified, mostly black with a massive to blocky structure
- Hr-horizon (*residues*) In addition to fine organic matter, contains identifiable residues such as residues of roots, bark or wood. Mostly dark reddish brown coloured.
- Hw-horizon (*wood*) Contains many wood remnants in addition to dominant fine organic matter.
- Hz-horizon *(zoogenous)* The fine organic matter consists mainly of mesofauna dropping. Saw-dust like structure





S-horizon *(Sphagnum)*

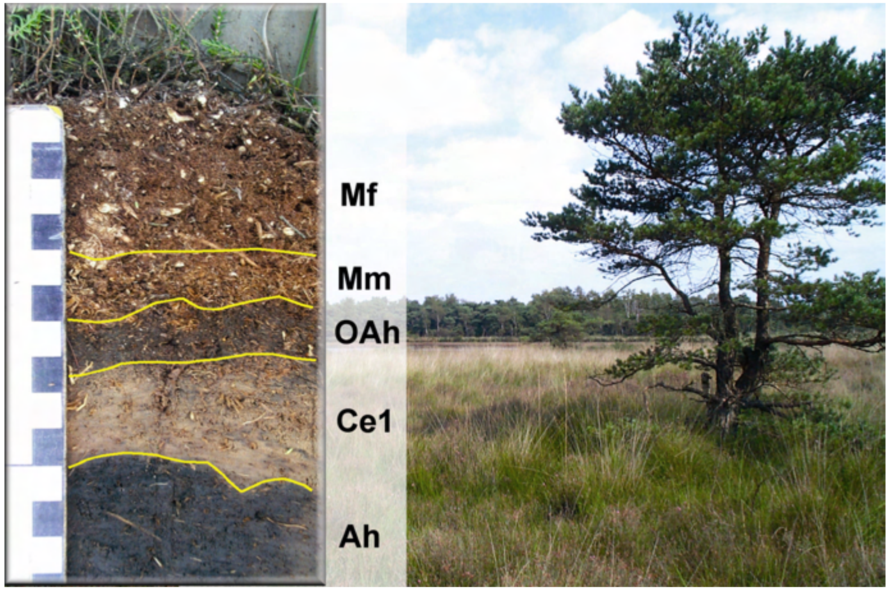
In semiterrestric soils with living peat moss an ectorganic S-horizon can be distinguished that comprises the living part of the peat moss layer. Since peat moss continues to grow at the top of this layer and dies off in its lower part, it may be hard to define where the S-horizon grades into the underlying Of-horizon. Living peat moss in general has a somewhat firmer structure than the dead peat moss and a clearly green colour. The lower parts of peat mosses are often slightly more yellow, receiving lesser or no sunlight. The colour of the died off peat moss constituting the Of-horizon is more light brownish.

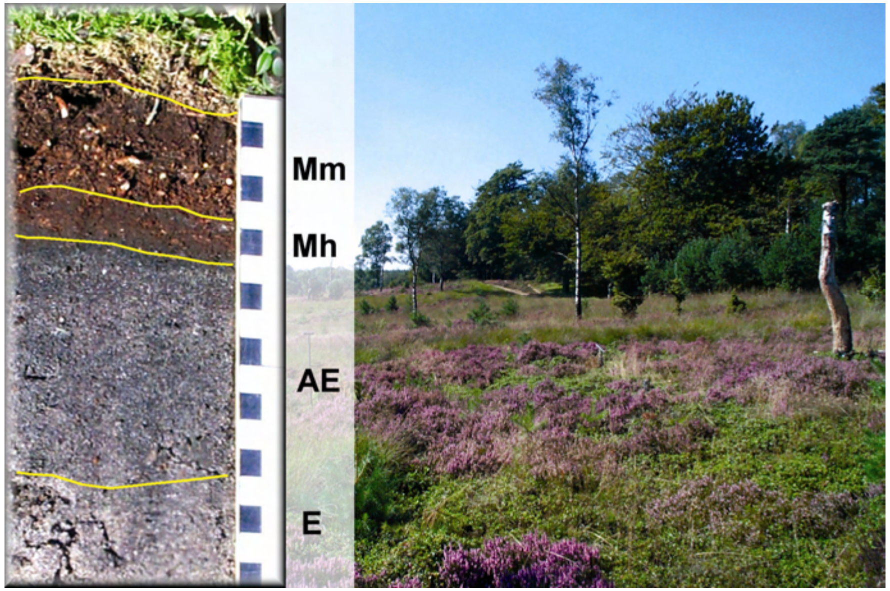
Endorganic horizons

Endorganic horizons are formed by incorporation of organic matter in the mineral soil (A-horizons, e.g. through bioturbation) or by in situ accumulation of organic matter (M- and O-horizons).

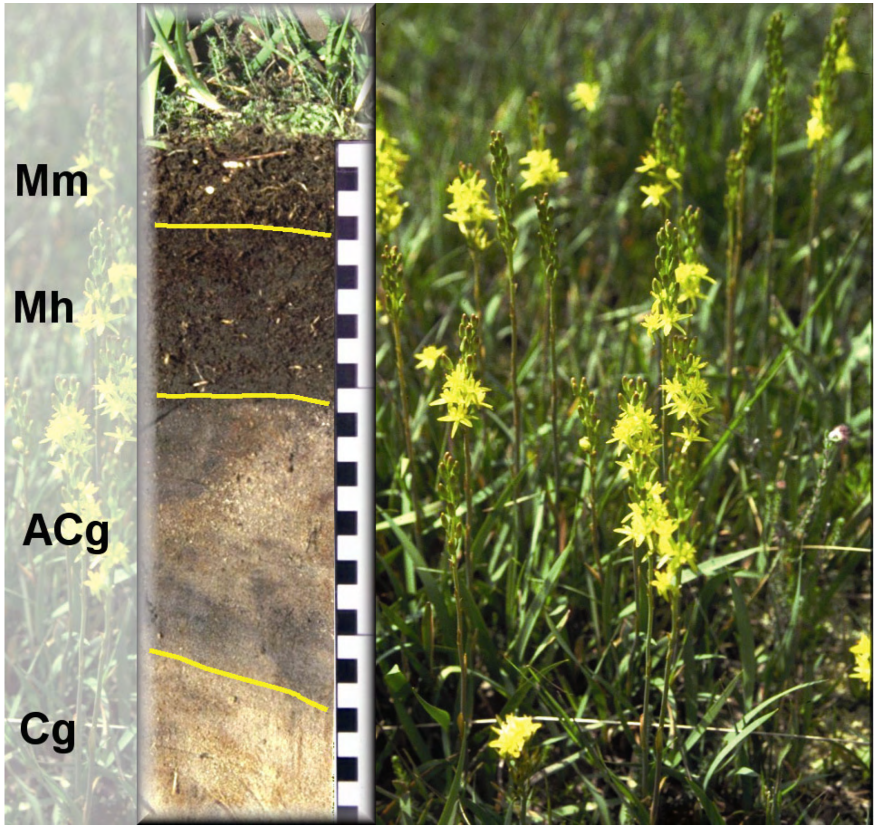
M-horizons *(Mat)*

M-horizons are formed when the input of dead roots exceeds their decomposition. As a result, a mat of dead (and living) roots may form, which can often be easily detached from the profile. Such root mats prevail on sites with herbaceous vegetation (heath, grassland), but they also are to be found under forest. Their genesis can be





attributed to various causes, which however can all be traced back to environmental conditions that cause a retarded litter decomposition (see the Introduction). These conditions can be summarized as ‘too wet, too acid or too dry’, and often result from a combination of these. Considering that soil fauna and flora are particularly active if the soil is moist and slightly acid to basic, as a result of which organic matter is readily decomposed and an Ah-horizon forms, we expect M-horizons to be formed if conditions deviate from these. This indeed can readily be observed when comparing humus forms along a gradient, such as an increasingly poorer drainage with concurrent lesser decomposition (see photograph left). The trend is



particularly evident if the poorer drainage is due to stagnation of infiltrating rainwater. On the opposite side of the gradient decomposition is also retarded, but now due to drought or to a soil reaction which is too acid for an active soil fauna as a result of prolonged leaching by infiltrating rainwater (see photograph previous page). In both cases, under herbaceous vegetation a root mat develops.

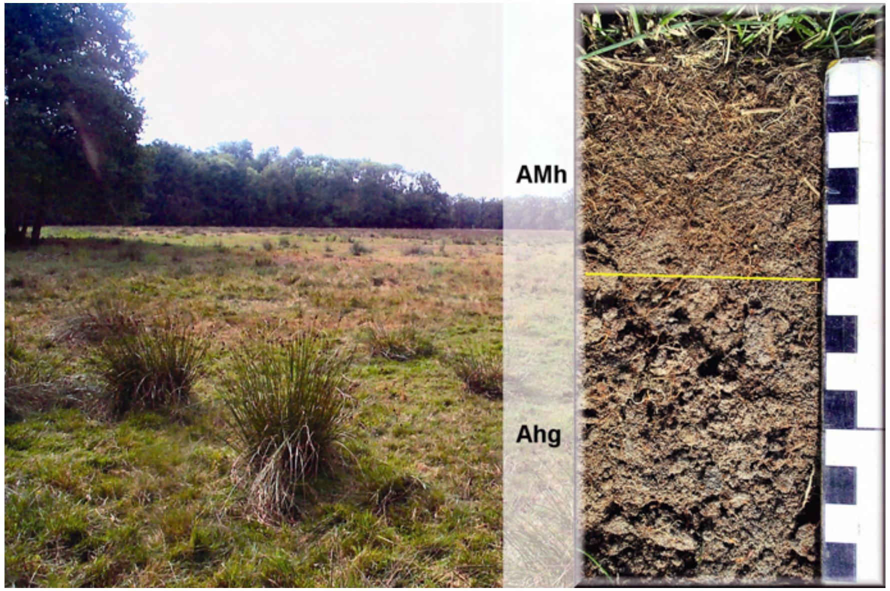
Apart from environmental conditions, the occurrence of a root mat may also be linked to the specific characteristics of the root material. In Bog Asphodel dominated vegetation, for example, thick root mats are common, which is attributed to the presence of aromatic compounds in these roots that strongly retard soil fauna activity.

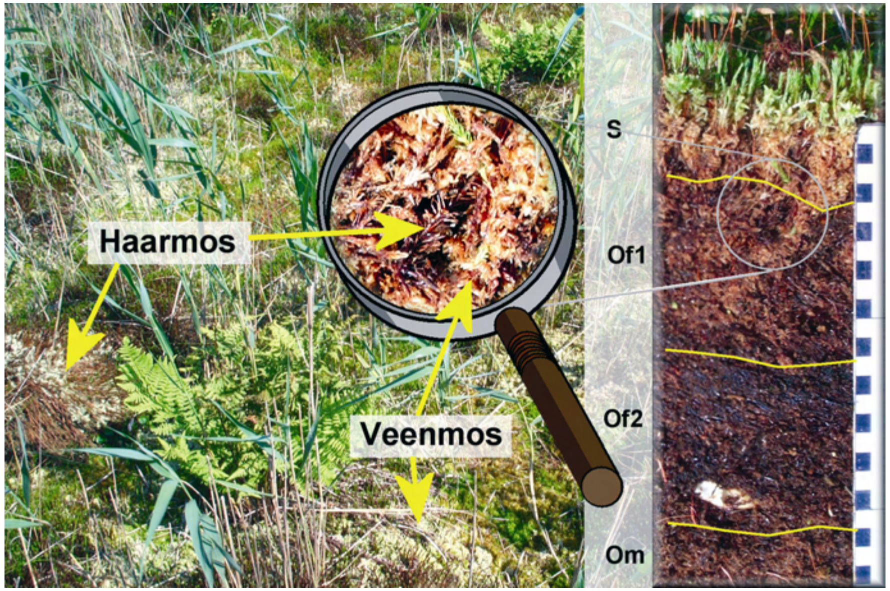
Depending on the extent to which roots are decomposed, the following sub horizons can be distinguished:

- Mf-horizon *(fibric)* if the horizon largely consists of dead (and living) roots. The root mat is hard to pull apart. In between the roots some fine organic matter may occur and also peat moss is often encountered. Mf-horizons are particularly common in wet and acid soils where infiltrating rainwater stagnates.
- In Mm-horizons (*mesic*) the roots are partially decomposed, with fine organic matter in between them. Depending on environmental conditions, decomposition may be through a range of organisms. However, mesofauna is likely to play an important role (see page 18).
- Mh-horizons (*humic*) consist of more or less humified root residues, in which some roots are still discernible. Because of the low content of identifiable plant residues, a Mh-horizon may be easily taken for a H-horizon, but the (historical) vegetation and overlying horizons generally provide sufficient clues for its identification. Under wet conditions underneath the

Mh-horizon a highly organic layer may be encountered that should be considered as a (remnant of a) peat layer. Such layer is to be classified as an OAh or Od-horizon, and is shown in the photograph from wet heath land at the beginning of this section (page 42).

- AMh-horizons are transitional between M and Ah-horizons. Their organic matter content is <15%, for which reason these horizons should be classified as mineral horizon. Often such horizons develop in the upper part of an A-horizon as a result of retarded decomposition of organic matter and concurrent accumulation of dead roots. This may be a first indication for changing environmental conditions.





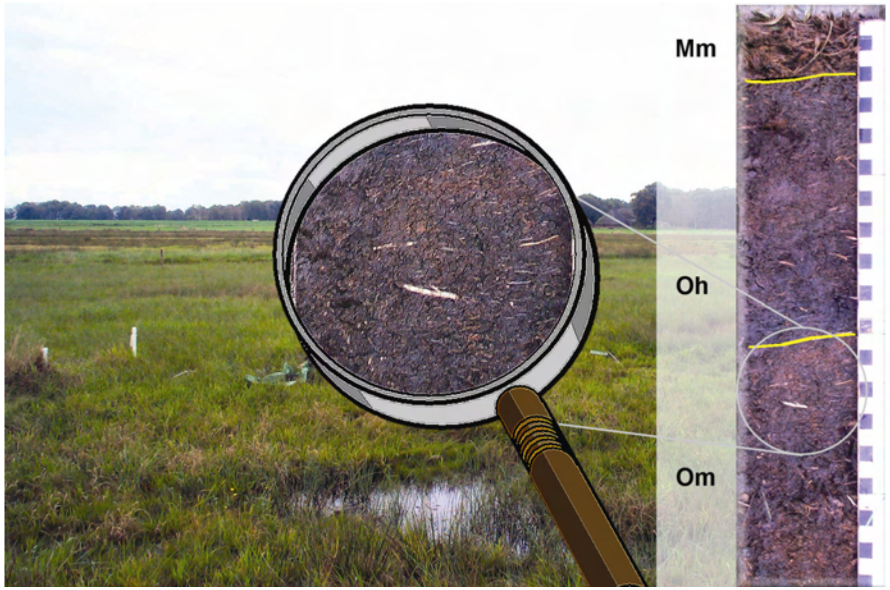
O-horizons *(Organic)*

In O-horizons, organic matter accumulated under semiterrestric conditions (peat accumulation, see page 14). Here, the main cause for the retarded decomposition of organic matter is the (permanent) wetness. In so far as decomposition takes places, it depends strongly on the soil reaction and nutrient status of the water in this horizon. O-horizons are subdivided on the basis of the degree of decomposition and conditions under which this took place:

- Of-horizons *(fibric)* consist of peat that virtually lacks traces of decomposition due to its permanent saturation with (acid) water. However, the resistance

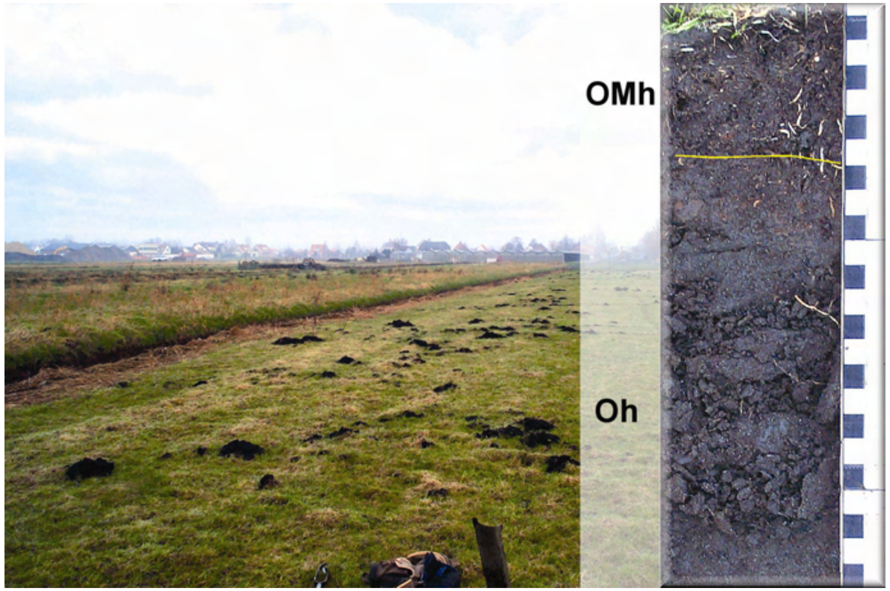
of the organic matter against decomposition also plays a role, such as poorly decomposable peat moss. Peat moss layers are indicative for a phase in the peat development during which the nutrient status was largely rainwater controlled. Sometimes layers of hair moss are encountered that developed upon superficial desiccation of the peat (see photograph previous page). In lowland peats that were continuously wet, Of-horizons may occur that are composed of sedge peat.
Horizon code in a soil profile description: C

- In Om-horizons *(mesic)* the peat is largely decomposed. Plant species are often still identifiable, but in between the larger fragments fine organic



matter is common. Om-horizons may develop under periodically aerobic conditions as a result of which some moulding took place, or under anaerobic mesotrophic neutral to basic conditions when bacteria decompose organic matter (see page 19)
Horizon code in a soil profile description: Cw

- Oh-horizons (*humic*) are so strongly moulded that identifiable plant residues virtually lack. Upon moulding of mesotrophic and eutrophic peat large amounts of nutrients may be released, inducing a tangled vegetation with for example abundant nettles and brambles. In an Oh-horizon earthworms may abound, as is testified by the molehills on the next photograph that reflect the large population of earthworms in such soils (see page 16). Oh-horizons generally occur in the upper part of the profile, while deeper the extent of moulding declines and Om or even Of horizons are encountered. In artificially drained peat soils, often a major part of the soil has been moulded with a concurrent loss of organic matter by mineralization and significant lowering of the ground level. Additionally, the organic matter content of the Oh-horizon declines and may become <30% in which case the horizon is coded as OAh-horizon.
Horizon code in a soil profile description: Ah

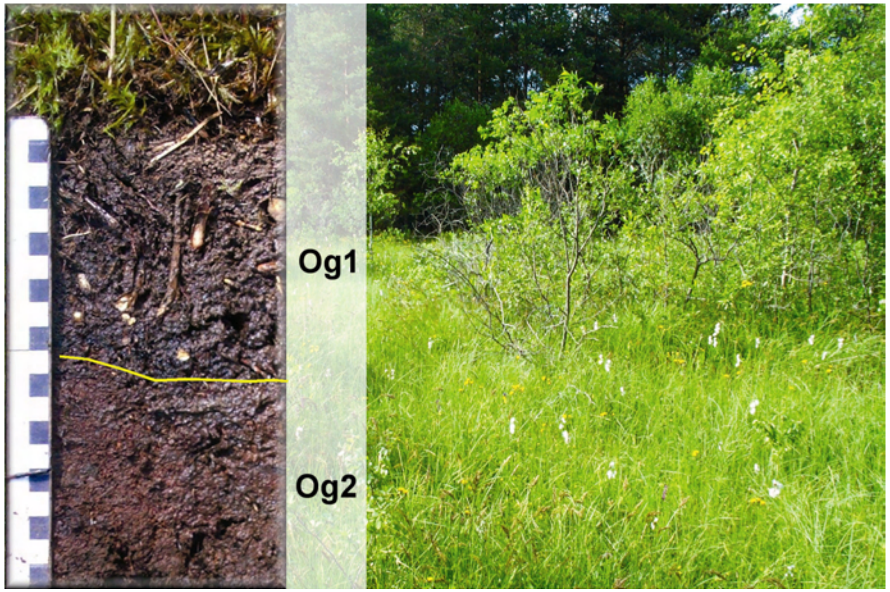


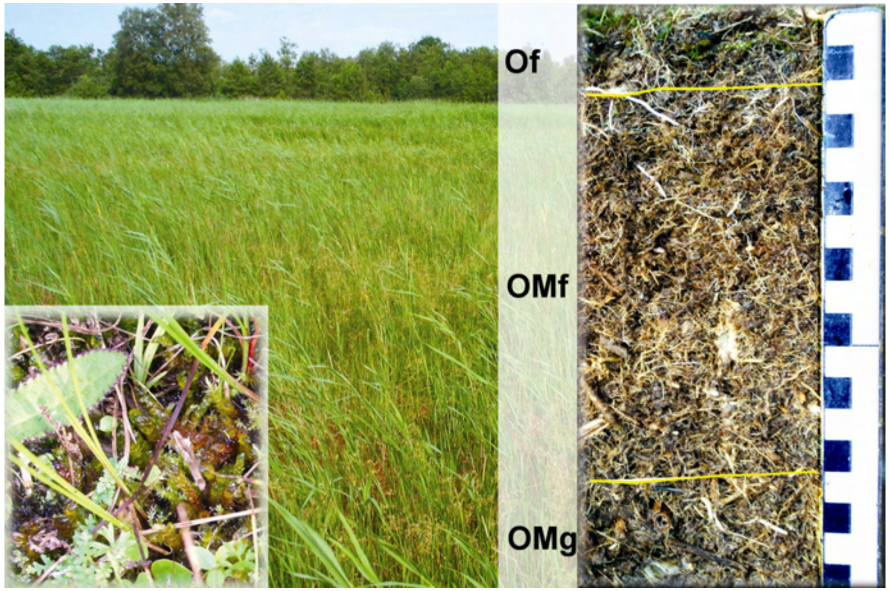
- Od-horizons (*detrital*) have also been formed by moulding of peat. The difference with Oh-horizons is that they developed from oligotrophic, acid peat, notably composed of peat moss. They are therefore particularly encountered in acid environments such as near heath pools or in drained highland moors.

- Og-horizons *(gyttja)* form by anaerobic decomposition under mesotrophic, neutral-basic conditions, such as in seepage zones and near springs with carbonate rich waters. Decomposition is largely by (sulphur) bacteria.
  Horizon code in a soil profile description: Ah

Here too, a number of transitional horizons can be distinguished:

- OMf-, OMm-, OMh- en OMg-horizons are transitional between O and M-horizons. They are found in the upper part of peat profiles and constitute an important part of the scraw in a quaking bog (see photograph on page 47). The scraw consists of a dense mat of roots, mostly of sedges and reed, from which it derives its coherence. The horizon is indicated as OM with a small letter suffix that depends on the extent of decomposition of the peat in between the roots.
  Horizon code *in a soil profile description: Mf, Mm or Mh*



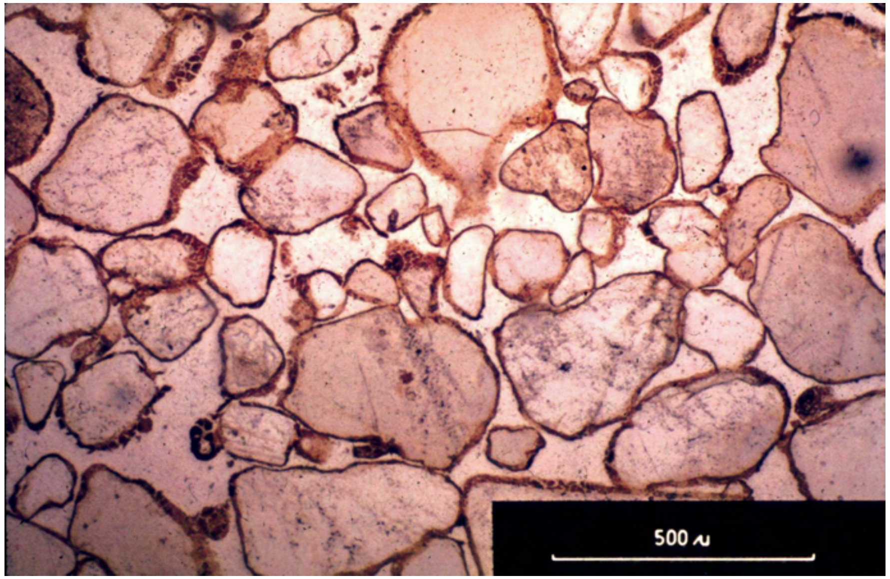


- OAh-, OAm-horizons are very humic mineral horizons (15-30% organic matter). In the OAh-horizons identifiable plant residues lack. This horizon originates through intensive moulding and therefore should be considered as transitional between the Oh and Ah-horizon. In the OAm-horizon such identifiable plant residues still occur.
  Horizon code in a soil profile description: Ah

A-horizons

A-horizons are mineral horizons in which the organic matter is largely or completely decomposed. Depending on the provenance of the organic matter three types of A-horizons are distinguished:

- In Ah-horizons, organic matter has been mixed with the mineral material through biological homogenisation (see page 16). Part of the organic matter is from dead roots, while in soils with an active fauna it is largely from above ground litter that was comminuted and incorporated through bioturbation. In some soils above the Ap or Aa-horizon, a separate Ah-horizon can be identified formed through such bioturbation (see photograph below). Such identification is useful since its presence indicates that site conditions favour an active soil fauna and flora.



- In agricultural soils, crop residues, organic manure and fertilizer are mechanically mixed through the soil, causing Ap-horizons to be formed. Though bioturbation still may play a role, its impacts are obliterated by the regular soil labour.
- Continued use of manure from deep litter houses, consisting of a mixture of organic and mineral material, may result in the formation of a mineral earthy layer that is described as an Aa-horizon (*anthropogenic*).

E-horizon *(eluviate)*
An E-horizon is a horizon depleted in clay and/or sesquioxides (largely aluminium and iron hydroxides) by vertical and sometimes lateral eluviation. In general an E-horizon has a lower organic matter content than the overlying A-horizon. Its whitish to greyish colour reflects the dominance of uncoated silt and sand size primary particles and loss of sesquioxides by leaching. The combination of such an E and Bh or Bs horizons is typical for (humus)podzol. The combination of an E with a Bt-horizon is typical for illuvial clay soils (brikgronden, luvisols).

B-horizons

B-horizons are marked by illuviation of clay, sesquioxides and/or organic matter from overlying soil horizons or are formed by weathering.

- Bh-horizons with illuviated (amorphous) humus (and Al-(hydr)oxides) in a humus-podzol (see photograph on page 48, left);
- Bhs-horizons if in addition to the humus and aluminium also Fe-(hydr)oxides are illuviated;
- Bt-horizon with illuviated clay characterized by the occurrence of clay cutans and a higher clay content and firmer structure compared to the over and underlying horizons;
- Bw-horizons which are changed in colour, clay content and/or structure by weathering in situ. It lacks illuviation of amorphous humus, clay and Fe-(hydr)oxides.
- In the Netherlands, in slightly loamy sand moder humus may have accumulated in the Bw-horizon (moderpodzols). Sometimes a "s" is added (Bws, Bvs in Germany) to indicate that illuviation of iron occurred. In fact this is an Bh or Bhs-horizon which has developed from a Bw-horizon (degraded moderpodzol).

For more information on horizon definitions see (a.o. FAO 1988, Ten Cate et al. 1995, Scheffer et al. 1982).

Other horizons

All horizons discussed above are 'humus form horizons', because organic matter is a smaller or larger, but important component of these horizons. In a description of such forms we therefore could limit ourselves to these horizons. Nevertheless, we also have to pay attention to horizons that are relevant for a full description of the humus form profile, particularly since they may occur within 40 cm from the ground surface and that depth limit is used for humus form classification.

C-horizons

These are mineral horizons that lack soil formation and that do not have the characteristics of 'hard rock' in which case they are classified as R-horizons. C-horizons may occur in soils that are too recent to be affected by soil formation, such as drift sands (see photograph on page 48, right) and recent river deposits. In such very recent deposits, C-horizons may be very close to the ground surface with only a shallow ectorganic layer.

A special type of C-horizon is the layer of secondary lime that may form in connection with seepage of lime-rich water. Where such seepage water comes in contact with the atmosphere, carbon dioxide may escape and consequently lime precipitates. This secondary lime is also described as ‘marsh chalk’ and may occur in connection with seepage, for example in brook and dune valleys.

When a layer largely consists of lime, it is described as Ck-horizon

R-horizon *(Rock)*
Hard rock is indicated as R-horizon. Such horizon does not occur in the Netherlands, apart from some small areas in South Limburg.

W-horizon *(Water)*
Evidently, water cannot be considered as a soil or humus horizon. However, below a scraw free water may occur on which this scraw floats, while at some depth peat is encountered. For a full description of such profile, including the depth at which the peat is encountered and the type of peat, we use the W-horizon for the layer of free water with a high content of suspended organic particles.

Transitional horizons

Transitions between the horizons described above often are gradual. If such transitional horizon cannot be clearly identified as a specific master horizon, it is described as transitional between two master horizons. Examples are: AE, AB, AC and BC (see photographs on pages 35, 42 and 43).

Reworked horizons

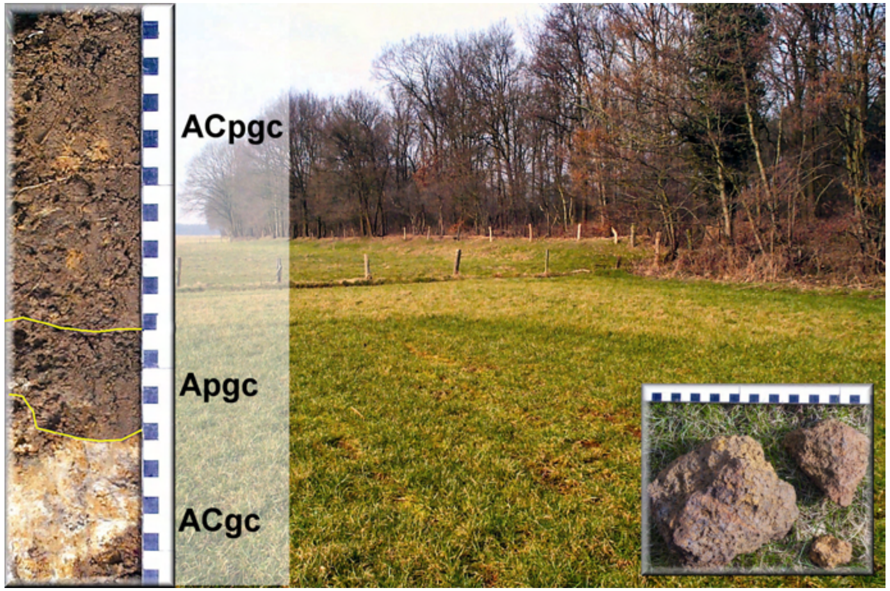
Many Dutch soils have been disturbed in the past (see page 15). In particular in forests that were laid out as part of extensive relief works in the Thirties of the last century, soils have been deeply worked to improve the rooting conditions for trees. In some places soils were worked to more than one meter depth. Processed layers can still be identified as a heterogeneous mixture of several original soil horizons. In the description, such mixture is indicated, using the symbols of the main contributing horizons, separated by a slash, for example A/B/C (see photograph above). When classifying the profile, we consider such horizons as new parent material, i.e. as C-horizon. On the contrary, horizons that developed as a result of later soil formation, after the original soil was worked, are described individually. An example is the AE-horizon (see photograph left) that formed after the soil was worked. Together with the overlying Fa and Hr horizon, this AE-horizon provides information about the current site conditions.

Suffixes

By means of suffixes we are able to provide additional information on the horizons distinguished. Many of these suffixes pertain to drainage conditions, more specifically to the groundwater regime and related hydromorphic properties.

Hydromorphic properties

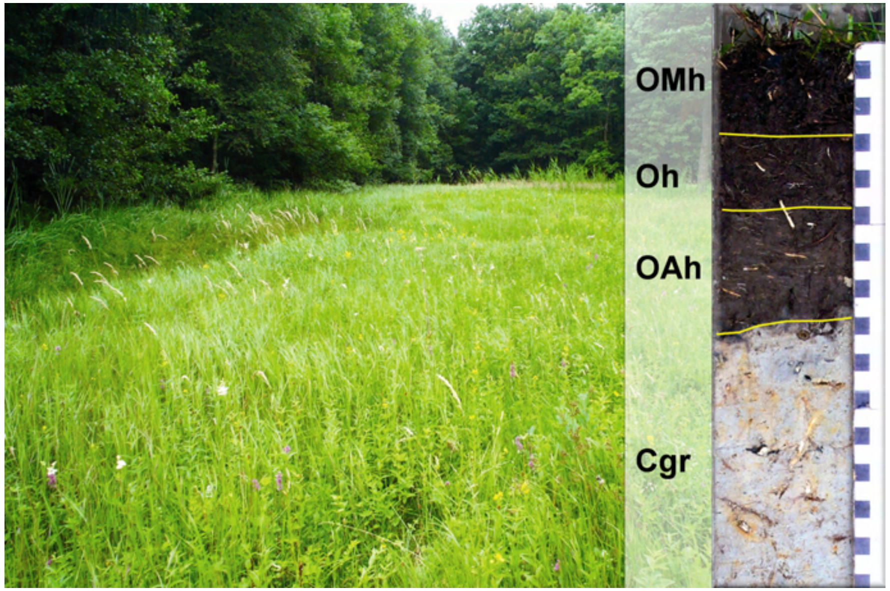
- e This code is used for partly deferrified horizons or horizons in witch iron is no longer bound to the sand grains but bound to moder humus in aggregates (*moderpodzol, sol brun pozolique, brown podzolic soil, Podsol braunerde*). The mobility of iron hydroxides is evidenced by the occurrence of bleached sand grains. If used for A-horizons, this suffix is indicative for initial podzolization. Aluminium is in most cases already partly leaching.
- g Used for horizons having iron mottles.



c Suffix indicative for horizons that are very high in iron (see photograph above). Generally used together with the suffix g (Ahgc) since it generally concerns oxidised iron compounds. However, it may also pertain to horizons that are largely reduced (Crc). The suffix is used if the horizon has more than 40% iron-manganese mottles, iron concretions, or iron cementations. Often such extreme iron accumulations result from strong seepage of groundwater that is high in dissolved iron[2]. However, such seepage may have occurred in the past and no longer be active today. The precipitated iron compounds, because of their insolubility under aerated conditions, may persist for a long time.

r Code for completely reduced horizons. In mineral soils, these horizons generally have a grey to blueish grey colour and lack rust mottling. Reduced peat layers are often brown in colour and sometimes emit the characteristic rotten egg smell of hydrogen sulphide (H2S) that is produced by sulphur bacteria (see page 19)

gr Often a transitional horizon occurs that is partly reduced, but also exhibits rust mottles. Such horizon is indicated with the suffix gr.



[2] The accumulation may be very significant, leading to the development of dense cemented horizons, also described as bog iron ore. In the past, in several brook valleys this bog ore has been mined for local iron production.

i (inorganic) For organic horizons the suffix i can be used to indicate that the horizon contains mineral material. This may result from aeolian deposition of sand (drift sands) or sedimentation during flooding.

Other suffixes

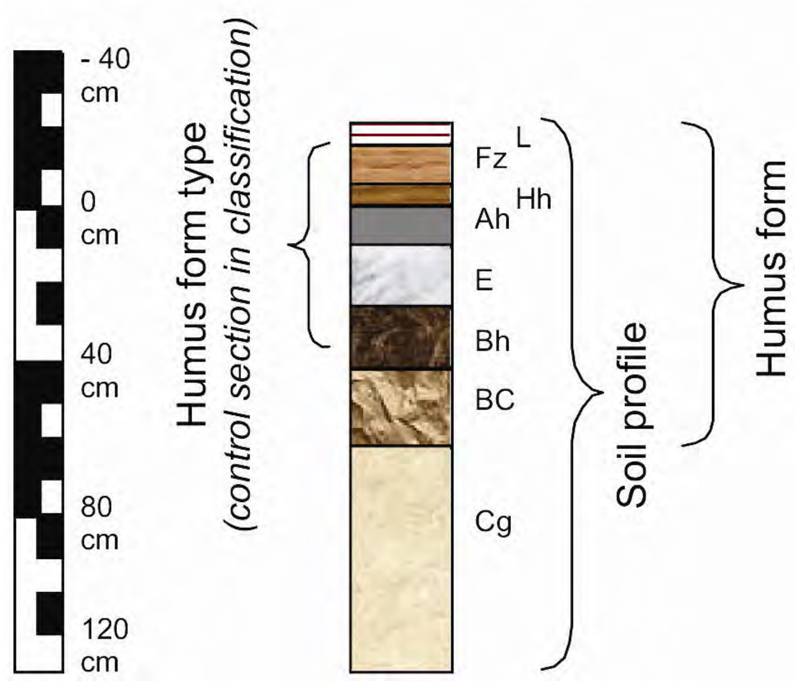
b *(buried)* This suffix is used for soil horizons that are buried under more recent sediment in which later soil horizons may have developed. Such situations for example occur in drift sand areas and in raised soils. That horizons have been buried under more recent material thus is indicated by adding the suffix b.

Classification

By studying the humus form in relation to its site characteristics and vegetation we may obtain extensive information on ecosystem functioning. For such purpose we can do with a proper profile description. However, if we want to compare humus forms from different locations or even survey these forms, we need a system that allows us to group humus forms on the basis of shared properties. We produced such humus form classification as part of a more comprehensive ecological soil typology (Kemmers en de Waal, 1999, van Delft, 2001, van Delft, et al., 2002, Buis en van Delft, 2003, Hommel en de Waal, 2003). This classification is largely based on the Canadian system (Klinka, et al., 1981, Green, et al., 1993) and uses the concept of the humus form.

Relevant for the classification is the upper 40 cm of the humus form profile, exclusive of L and S horizons. This is schematically indicated in the figure to the right. The soil profile includes at least the upper 120 cm of the soil, while the humus form comprises all layers containing organic matter that relates to processes connected with the actual soil surface, its classification being based on the upper 40 cm of this profile.

Major concepts used to classify the humus forms include the 'dominant organic horizon group' and 'dominant horizon', as well as 'terrestric' and 'semiterrestric' sites and humus forms. These concepts are elucidated below



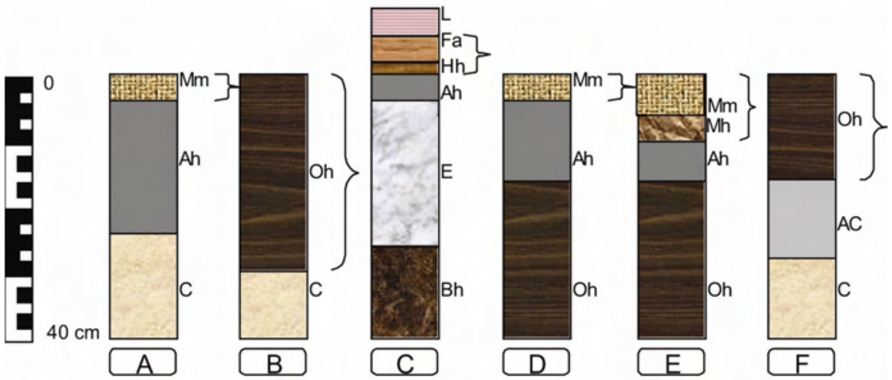
Classification of Dominant Horizon Groups.

Position relative to soil surface	Organic matter content	Origin of organic matter	Horizons	Horizon group
Ectorganic: litter, on top of the soil surface	Organic: > 15% organic matter	Litter (terrestrial)	(L), F, H	Litter
Endorganic: Humus horizons below soil surface, formed by peat formation, accumulation of dead roots or eluviation of organic matter.		Accumulation of organic matter (semiterrestrial)	O, OA, OM	Peat
		Accumulation of dead roots (terrestrial)	M, AM	Root
	Mineral: < 15% organic matter	Homogenization and podsolization	A, E, B	Mineral

Dominant organic horizon group

Four groups of horizons have been distinguished of which the characteristics are given in table 2. Thicknesses of horizons that belong to a certain group are summed, the group that is thickest being defined as ‘dominant’. For horizons to be considered, the lower boundary is set at 40 cm depth, but with one exception: If the upper boundary of a mineral horizon group that is more than 5 cm thick occurs within a depth of less than 40 cm, peaty horizons that eventually are present underneath are not considered (profiles D and E in figure on page 57). This implies for example that in peaty soils having an intercalated clayey mineral layer that is more than 5 cm thick underlying peaty horizons are not considered.

On page 57 the concept ‘dominant organic horizon group’ is graphically illustrated. In profiles A to C and F the dominant group is defined on the basis of the thickness criterion over the full 40 cm depth, whereas in the other profiles (D and E) a mineral horizon group occurs with a thickness of 5 cm or more.



Some examples of humus forms. Dominant Horizon Groups are indicated by braces

Dominant horizon

In some cases, further subdivision of the humus forms requires the identification of the dominant horizon within a group, which is defined as follows:
'The dominant horizon is the thickest horizon within a specific horizon group (excluding M horizons) in the upper geological stratum, provided that this stratum is thicker than 5 cm'.

Geological strata as defined here include peat, clay, loam and sand, i.e. types of parent material as defined by organic matter content and granulometry.

In some cases the dominant horizon within a group needs to be defined. An example is that of the dominant F horizon which is thus defined as the thickest F horizon within the F horizon group (Fa, Fm or Fz).

If thicknesses of two horizons (or groups of horizons) are identical, the upper one is considered as dominant. The reason is that horizons or groups closer to the soil surface are more relevant for vegetation and soil biota.

(Semi)terrestric sites

Semiterrestric sites are those that are strongly influenced by (ground)water. Correspondingly, humus forms developed under such conditions are '*semiterrestric humus forms*'. Diagnostic features of such humus forms include:

- Presence of earthy or peaty layers (O horizons)
- In mineral profiles that lack a podzol, the presence of hydromorphic properties within 25 cm from the surface.

Humus forms that do not meet these requirements are terrestric humus forms.

Outline of the classification

The classification is hierarchical, with 5 orders at the highest level (*mull, mullmoder, moder, mormoder* and *mor*). At this level the main diagnostic criteria are the extent to which organic matter is decomposed or has accumulated. Drainage is the criterion used for the subdivision into a total of 9 semiterrestric and terrestric suborders.

The further subdivision into groups and subgroups is based on several criteria that may vary according to the suborder concerned. Criteria for example include loam content or depth of decalcification, the degree of decomposition of peat, the presence of a root mat and various types of litter horizons. If considered relevant, characteristics that are not differentiating at these levels can be used to define '*phases*'. An overview of the phases distinguished is given in the lower section of the classification key (page 63).

Humus forms are classified according to the key that is presented below. A table with an overview of all humus forms distinguished can be found on the website of Alterra (see preface). Additionally, on this website a MS-Access program can be found by which humus forms can be classified interactively through responses to a series of questions (Buis en van Delft, 2003).

Key for humus form classification

Order

1. Total thickness of all ectorganic horizons (F-, H-, O-, M-, AMh), above a mineral layer that is at least 5 cm thick, is:
   a. < 2 cm: *Mull* → *8*
   b. ≥ 2 cm → *8*
2. Thickness of Ah-horizon (inclusive of Aa and Ap)
   a. Ah-horizon > Sum of all overlying organic horizons (F-, H-, O-, M-): *Mullmoder* → *31*
   b. Ah-horizon lacks or is thinner than the sum of all overlying organic horizons (F, H, O, M) → *3*
3. Dominant O-horizon
   a. Oh-, Og, Od of OAh-: *Eerdmoder* → *44*
   b. Of-, Om-, of OAm-: *Semiterrestric mor* → *64*
   c. No dominant O-horizon → *4*
4. Hydromorphic properties
   a. < 25 cm and no podzol (even at depth > 40 cm): *Hydromoder* → 48
   b. Not within 25 cm or with a podzol (may be at > 40 cm depth) → *5*
5. Dominant ectorganic horizon group
   a. M-horizons dominant → *6*
   b. F- or H-horizons dominant → *7*
6. Dominant root horizon
   a. Mh-, or AMh-horizon dominant: *Xeromoder* → *54*
   b. Mm-horizon dominant:
      RDXh - Heidexeromormoder

   c. Mf-horizon dominant: ***RXh - Heidexeromor***
7. Dominant ectorganic horizon
   a. Hz or Fz is dominant ectorganic horizon: *Xeromoder* → 55
   b. Hr, Hh, or Fa is dominant ectorganic horizon: *Xeromormoder* → *60*
   c. Fm: *Xeromor* → 74

Mull

8. (1) Hydromorphic properties (not stagnic)
   a. < 25 cm and no podzol (even not > 40 cm) *Hydromull* → 9
   b. Not within 25 cm or with a podzol (even > 40 cm): *Terrestric mull* → 15
9. Upper A-horizon > 2 cm
   a. Aa- or Ap-horizon: ***LHa - Akkerhydromull***
   b. Ah-horizon or A-horizon lacks → 10
10. Topsoil with brackish or seawater
    a. Yes → 11
    b. No → 12
11. Loam content
    a. < 20 % (or clay < 8%): ***LHq – Wadhydromull***
    b. ≥ 20 % (or clay ≥ 8%): ***LHi – Slikhydromull***
12. Loam content
    a. ≥ 20 % (or clay ≥ 8%) → 13
    b. < 20 % (or clay < 8%) → 14
13. Depth to calcareous material
    a. 0 – 40 cm: ***LHn - Kleihydromull***
    b. > 40 cm: ***LHf - Beekhydromull***
14. Depth to calcareous material
    a. 0 – 20 cm: ***LHc - Vlakhydromull***
    b. 20 – 40 cm: ***LHd - Duinhydromull***
    c. > 40 cm: ***LHz - Zandhydromull***
15. (8) Thickness A-horizon
    a. < 2 cm or < 2 % organic matter: *Vaagmull* → 16
    b. ≥ 2 cm and > 2 % organic matter → 20
16. Podzol (AE-, E-, B-, or BC-horizon) within 40 cm depth
    a. Present: ***LVh – Heidevaagmull***
    b. Absent → **17**
17. Loam content
    a. < 20 % (or clay < 8%) → 18
    b. ≥ 20 % (or clay ≥ 8%)→ 19
18. Depth to calcareous material
    a. 0 – 20 cm: ***LVc - Vlakvaagmull***
    b. ≥ 20 cm: ***LVz - Zandvaagmull***
19. Depth to calcareous material
    a. 0 – 20 cm: ***LVn - Nesvaagmull***
    b. ≥ 20 cm: ***LVf - Beekvaagmull***
20. (15) Upper A-horizon > 2 cm
    a. Aa- or Ap-horizon: *Akkermull* → *21*
    b. Ah-horizon → 25
21. Podzol (AE-, E-, B-, or BC-horizon) within 40 cm depth
    a. Present: ***LAh – Heideakkermull***
    b. Absent → 22
22. Loam content
    a. < 20 % (or clay < 8%) → 23
    b. ≥ 20 % (or clay ≥ 8%) → 24

23. Depth to calcareous material
    a. 0 – 20 cm: ***LAk – Kroftakkermull***
    b. ≥ 20 cm; ***LAe – Enkakkermull***
24. Depth to calcareous material
    a. 0 – 20 cm: ***LAt – Tuinakkermull***
    b. ≥ 20 cm: ***LAr – Radeakkermull***
25. (20) Loam content
    a. < 20 % (or clay < 8%): *Zandmull* → *26*
    b. ≥ 20 % (or clay ≥ 8%)→ 28
26. Depth to calcareous material
    a. 0 – 20 cm: ***LZk - Kalkzandmull***
    b. 20 – 40 cm and with an AE-horizon: ***LZd - Duinzandmull***
27. Organic matter content of the Ah-horizon
    a. < 8 %: ***LWk – Kalkwormmull***
    b. ≥ 8 % on highly calcareous parent material ((weathered) limestone): ***LK – Krijtmull***
28. Organic horizons (F-, H-, M-) < 2 cm
    a. F- or H-horizon: ***LWe – Ectowormmull***
    b. M-horizon: ***LWs – Schraalwormmull***
    c. None: ***LWz – Zure wormmull***
29. Organic matter content of the Ah-horizon
    a. < 8 %: ***LWk – Kalkwormmull***
    b. ≥ 8 % on highly calcareous parent material ((weathered) limestone): ***LK – Krijtmull***
30. Organic horizons (F-, H-, M-) < 2 cm
    a. F- or H-horizon: ***LWe – Ectowormmull***
    b. M-horizon: ***LWs – Schraalwormmull***
    c. None: ***LWz – Zure wormmull***

Mullmoder

31. (2) Thickness O-horizons
    a. ≥ 2 cm: ***LDHm – Moerhydromullmoder***
    b. No O-horizons > 2 cm: *Mineral mullmoder* → *32*
32. Hydromorphic properties (no pseudogley)
    a. < 25 cm and without podzol (even deeper than 40 cm) *Hydromullmoder* → 33
    b. Not within 25 cm or with a podzol (may be a depth > 40 cm): *Xeromullmoder* → 39
33. Dominant organic horizon group
    a. Ectorganic horizons(F + H): ***LHDb - Boshydromullmoder***
    b. Root mats (M + AMh) → 34
34. Topsoil affected by brackish or sea-
    a. Yes → 35
    b. No → 36
35. Loam content
    a. < 20 % (or clay < 8%): ***LDHq - Wadhydromullmoder***
    b. ≥ 20 % (or clay ≥ 8%): ***LDHi - Slikhydromullmoder***
36. Depth to calcareous material
    a. 0 – 40 cm → 37
    b. ≥ 40 cm → 38
37. Loam content < 20 % (or clay < 8%): ***L DHc - Vlakhydromullmoder***
    a. ≥ 20 % (or clay ≥ 8%): ***LDHn - Kleihydromullmoder***

38. Thickness AMh-horizon
    a. < 2 cm: ***LDHs - Schraalhydromullmoder***
    b. ≥ 2 cm: ***LDHw - Wormhydromullmoder***
39. (32) Upper A-horizon
    a. Aa- or Ap-horizon: ***LDXa - Akkerxeromullmoder***
    b. Ah-horizon > 2 cm, may overly Aa- or Ap-horizon → 40
40. Depth to calcareous material
    a. 0 – 40 cm without AE-horizot: ***LDXc - Vlakxeromullmoder***
    b. 20 – 40 cm with AE-horizon: ***LDXd - Duinxeromullmoder***
    c. ≥ 40 cm → 41
41. Dominant organic horizon group over Ah-horizon
    a. M-horizonen → 42
    b. F- and H-horizonen → 43
42. Podzol (AE-, E-, B-, or BC-horizon) within 40 cm depth.
    a. Present: ***LDXh - Heidexeromullmoder***
    b. Absent: ***LDXs - Schraalxeromullmoder***
43. Loam content
    a. < 20 % (or clay < 8%): ***LDXz - Zandxeromullmoder***
    b. ≥ 20 % (or clay ≥ 8%): ***LDXl - Leemxeromullmoder***

Moder

44. (3) Ectorganic horizons (F-, H-)
    a. > 2 cm: ***DEb - Boseerdmoder***
    b. Absent, or ≤ 2 cm → 45
45. Thickness O-horizons
    a. < 15 cm: ***DEv - Vaageerdmoder***
    b. ≥ 15 cm → 46
46. Dominant O-horizon
    a. Oh → 47
    b. Og: ***DEm - Meereerdmoder***
    c. Od: ***DEg - Gliedeeerdmoder***
    d. OAh: ***DEo - Moereerdmoder***
47. Organic matter content Oh-horizon
    a. < 70 %: ***DEf - Beekeerdmoder***
    b. ≥ 70 %: ***DEn - Veeneerdmoder***
48. (4) Ectorganic horizons(F-, H-)
    a. Present: ***DHb - Boshydromoder***
    b. Absent → 49
49. Topsoil affected by brackish or seawater
    a. Yes → 50
    b. No → 51
50. Loam content
    a. < 20 % (or clay < 8%): ***DHq - Wadhydromoder***
    b. ≥ 20 % (or clay ≥ 8%): ***DHi - Slikhydromoder***
51. Depth to calcareous material
    a. 0 – 40 cm → 52
    b. ≥ 40 cm → 53
52. Loam content
    a. < 20 % (or clay < 8%): ***DHc - Vlakhydromoder***
    b. ≥ 20 % (or clay ≥ 8%): ***DHn - Kleihydromoder***
53. Thickness AMh-horizon
    a. < 2 cm: ***DHs - Schraalhydromoder***
    b. ≥ 2 cm: ***DHw - Wormhydromoder***

54. (6) Podzol (AE-, E-, B-, or BC-horizon) within 40 cm depth.
    a. Present: ***DXh - Heidexeromoder***
    b. Absent: ***DXs - Schraalxeromoder***
55. (7) Wood fragments in F-horizon
    a. Present: ***DXl - Lignoxeromoder***
    b. Absent → 56
56. Thickness Fz-horizon
    a. ≥ 5 cm, H-horizon ≤ 2 cm: ***DXr - Ruwxeromoder***
    b. < 5 cm → 57
57. Thickness H-horizon
    > 2 cm → 58
    a. ≤ 2 cm → 59
58. Sum of thicknesses of F2- and H-horizon
    a. < 5 cm: ***DXu - Humusxeromoder***
    b. ≥ 5 cm: ***DXt - Holtxeromoder***
59. Thickness Ah-horizon
    a. ≥ 2 cm: ***DXw - Wormxeromoder***
    b. < 2 cm or absent: ***DXv - Vaagxeromoder***

Mormoder

60. (7) Wood fragments in F-horizon
    a. Present: ***RDXl - Lignoxeromormoder***
    b. Absent → 61
61. Thickness Fa-horizon
    a. ≥ 5 cm and F2 and H together < 5 cm: ***RDXr - Ruwxeromormoder***
    b. 2 - 5 cm → 62
    c. Absent or < Hh→ 63
62. Thickness F2- and H together
    a. < 2 cm: ***RDXv - Vaagxeromormoder***
    b. 2 - 5 cm: ***RDXu - Humusxeromormoder***
63. Thickness Hh-horizon
    a. < 2 cm and F2 and H together ≥ 5 cm:: ***RDXb - Bosxeromormoder***
    b. ≥ 2 cm and F2 and H together ≥ 5 cm: ***RDXt - Holtxeromormoder***

Mor

64. (3) Dominant O-horizon
    a. Of-horizon in oligotrophic peat (Peat moss, Hair moss): *Veenmosmor* → 65
    b. Om-, or OAm-horizon, or Of-horizon in mesotrophic peat (e.g. Sedge peat) → 67
65. Thickness peat layer (O-horizons)
    a. < 15 cm: ***RVv - Vaagveenmosmor***
    b. ≥ 15 cm → 66
66. Total thickness earthy peat layers (Od- and Om-horizons)
    a. < 10 cm: ***RVp - Rauwveenmosmor***
    b. 10 – 20 cm: ***RVe - Eerdveenmosmor***
67. (64) Ectorganic horizons (F- and H)
    a. < 2 cm: ***RMb - Bosmesimor***
    b. ≤ 2 cm or absent → 68
68. Thickness peat layer (O-horizons)
    a. < 20 cm: ***RMv - Vaagmesimor***
    b. ≥ 20 cm → 69
69. Dominant O-horizon

a. OAh: ***RMo - Moermesimor***
b. Om → 70

70. Root mat (M-horizon)
  a. Present: ***RMh - Heidemesimor***
  b. Absent → 71
71. Irreversible dessicated Om-horizon
  a. Present: ***RMx - Turfmesimor***
  b. Absent → 72
72. Thickest O-horizon, apart from Om- and mesotrophic Of-horizon
  a. Oh 10 – 20 cm: ***RMe - Eerdmesimor***
  b. Od 10 – 20 cm: ***RMg - Gliedemesimor***
  c. Of in oligotrophic peat veen (Peat moss, Hair moss) 10 – 20 cm: ***RMp - Rauwmesimor***
  d. No other O-horizon > 10 cm → 73
73. Organic matter content Oh-horizon
  a. < 70 %: ***RMf - Beekmesimor***
  b. ≥ 70 %: ***RMn - Veenmesimor***
74. (7) Wood fragments in F-horizon
  a. Present: ***RXl - Lignoxeromor***
  b. Absent → *75*
75. H-horizon
  a. Hr-horizon > Fm-horizon: ***RXb - Bosxeromor***
  b. Hh-horizon > Fm-horizon: ***RXt - Holtxeromor***
  c. < Fm-horizon or absent: ***RXr - Ruwxeromor***

Phases

A series of phases has been defined that reflect relevant characteristics not included in the humus form classification at higher level. These phases are described below and are indicated by means of suffixes that are placed before the humus form code.

phase	code	description
marine	m	Stratified as a result of inundation by seawater
flood	o	With flood mark
brackish	z	Brackish
tidal	t	Under influence of fresh water tide
inundated	l	Alternating layers of loam, sand and peaty material, resulting from inundation
fluvial	f	Stratification resulting from inundation by fresh water
wet	n	With hydromorphic properties within 25 cm depth or with mean highest groundwater level of 0-25 cm
Iron rich	y	Iron (and manganese) concretions or layers
earthy	h	With earthy layer
peaty	d	With peaty subsoil within 40 cm depth
silted	k	Top layer of clay <20 cm on sand or peat
raw	r	Thin layer of acid, oligotrophic plant debris
poor	s	Tending towards M, AMh or OM
ecto	c	With ectorganic F- or H-horizon < 2cm
bleached	e	With some bleaching in A horizon
drifted	u	With e.g. buried A- of AC horizons and thin C-horizons
vague	v	Weakly developed, thin or vague
stony	i	With massive, stony layer of basalt blocks (dikes)
sod cut	a	Sod cut profile
disturbed	g	Completely disturbed and mixed by man or animal
ploughed	p	Ploughed
burned	b	Burned ectorganic layer and/or top soil

Literature

The list below comprises publications that are referred to in the text. Part of the Alterra publications is available as PDF-file. For these, go to http://www.humusvormen.wur.nl. Most publications are Dutch, some in French or German. Publications marked with ☒ are English.

Literature

Baize, D. , M.C. Girard, coord., 1995. Réfèrential Pédologique. INRA

Bakker, H. d. en J. Schelling, 1989. *Systeem van bodemclassificatie voor Nederland; de hogere niveaus.*, Wageningen, Pudoc.

Bakker, J. W., 1991. "Hoofdstuk 12: Luchthuishouding (Synopsis)" p. 173-176. In: W. P. Locher and H. d. Bakker (redactie). *Bodemkunde van Nederland; Deel 1, Algemene bodemkunde*. Den Bosch, Malmberg.

Brouwer, F., S. P. J. van Delft en R. H. Kemmers, 2002. *Landinventarisatie en ruimtelijke systeemanalyse van het herinrichtingsgebied De Vechtstreek, fase 2 : resultaten van een bodemgeografisch onderzoek*, Wageningen, Alterra, Research Instituut voor de Groene Ruimte. Alterra-rapport 379

☒ Brussaard, L. 1996 Soil fauna, guilds, functional groups and ecosystem processes. Applied Soil Ecology 9:123-153, 1996

Buis, E. en S. P. J. van Delft, 2003. *Handleiding Humusvormen 1; Een programma ter classificatie van humusvormen vanuit de Ecologische Bodemtypering*, Wageningen, Alterra. Alterra-rapport 708.

de Waal, R. W., 1999. *Humus als abiotische parameter : een haalbaarheidsstudie*, Wageningen, IKC Natuurbeheer [etc.]. Werkdocument / IKC Natuurbeheernr. W-173

☒ FAO-Unesco, 1988. Soil Map of the world. Revised legend. Rome

☒ Green, R. N., R. L. Trowbridge en K. Klinka, 1993. "Towards a Taxonomic Classification of Humus Forms", *Forest Science Monograph 29, p.*

Hegnauer, R. 1973. Chemotaxonomie der Pflanzen . Band 6. Birkhäuser. Basel Stuttgart

Hennekens, S. M., J. H. J. Schaminée en A. H. F. Stortelder, 2001. *Synbiosys, een biologisch kennissysteem ten behoeve van natuurbeheer, natuurbeleid en natuurontwikkeling*, Wageningen, Alterra.

Hommel, P. en R. de Waal, 2003. "Rijke bossen op arme bodems; Alternatieve boomsoortkeuze verhoogt soortenrijkdom ondergroei op verzuringsgevoelige gronden", *Landschap 20(4), p. 193-204.*

Hommel, P. W. F. M., T. Spek en R. W. de Waal, 2002. *Boomsoort, strooiselkwaliteit en ondergroei in loofbossen op verzuringsgevoelige bodem : een verkennend literatuur- en veldonderzoek*, Wageningen, Alterra, Research Instituut voor de Groene Ruimte. Alterra-rapport509

Jabiol, B., et al., 1995. *L'Humus sous toutes ses formes*, Nancy Cedex, École Nationale du Génie Rural, des Eaux et des Forêts.

Jansen, B. H., P. van der Sluijs en H. R. Ukkerman, 1990. "Hoofdstuk 8: Organische stof" p. In: W. P. Locher and H. de Bakker (redactie). *Bodemkunde van Nederland; deel 1, Algemene bodemkunde*. Den Bosch, Malmberg.

Jansen, P. C., R. H. Kemmers en P. Mekkink, 1994. *Eco-hydrologische systeembeschrijving van het landgoed "De Wildenborch"*, Wageningen, DLO-Staring Centrum. Rapport / DLO-Staring Centrum296

Kemmers, R., R. de Waal, B. van Delft en P. Mekkink, 2002. "Ecologische typering van bodems : Actuele informatie over bodemkundige geschiktheid voor natuurontwikkeling", *Landschap 19(2), p. 88-103.*

Kemmers, R. H., 1996. *De dynamiek van strooisellagen : voordrachten tijdens de themamiddag georganiseerd door DLO-Staring Centrum, Wageningen, 6 oktober 1995*, Wageningen, SC-DLO. Rapport / DLO-Staring Centrum438

Kemmers, R. H. en R. W. de Waal, 1999. *Ecologische typering van bodems : Deel 1 Raamwerk en humusvormtypologie*, Wageningen, Alterra. Alterra-rapport 667-1.

Kemmers, R. H., R. W. de Waal en S. P. J. van Delft, 2001a. *Ecologische typering van bodems : Deel 3 Van typering naar kartering*, Wageningen, Alterra Research Instituut voor de Groene Ruimte. Alterra-rapport 352.

Kemmers, R. H., P. Mekkink en R. W. de Waal, 2000. *Humusprofielen in de bosreservaten Hollandse Hout en Houtribbos : basisprogramma bosreservaten*, Wageningen, Alterra, Research Instituut voor de Groene Ruimte. Alterra-rapport175

Kemmers, R. H., S. P. J. van Delft en P. C. Jansen, 2001b. *Productiviteit van korte vegetaties en beperkende factoren in relatie tot voedselrijkdom en vochttoestand van natuurterreinen : basisonderzoek voor* *ecologische nutriëntenmodellen*, Wageningen, Alterra, Research Instituut voor de Groene Ruimte. Alterra-rapport 257.

☒ Klinka, K., R. N. Green, R. L. Trowbridge en L. E. Lowe, 1981. *Taxonomic Classification of Humus Forms in Ecosystems of British Columbia; First Approximation*, Province of British Columbia, Ministry of Forests.

☒ Marinissen, J. C. Y., 1995. *Earthworms, soil-aggregates and organic matter decomposition in agro-ecosystems in The Netherlands.*, Wageningen, Wageningen Agricultural University. Department of Soil Science and Geology

Pulleman, M.M., M.J. Kooistra, P.W.F.M. Hommel & R.W. de Waal, 2005. *Strooiselafbraak onder verschillende loofboomsoorten op de stuwwal bij Doorwerth. Micromorfologisch onderzoek van de humusprofielen.* Rapport 1052 Alterra, Wageningen.

☒ Richards, B. N., 1974. *Introduction to the soil ecosystem*, London, Longman Group Ltd.

Schaminée, J. H. J., A. H. F. Stortelder en E. J. Weeda, 1996. *De Vegetatie van Nederland; Deel 3. Plantengemeenschappen van graslanden, zomen en droge heiden.*, Uppsala/Leiden, Opuluspress.

Schaminée, J. H. J., A. H. F. Stortelder en V. Westhof, 1995a. *De Vegetatie van Nederland; Deel 1. Inleiding tot de plantensociologie - grondslagen, methoden en toepassingen.*, Uppsala/Leiden, Opuluspress.

Schaminée, J. H. J., A. H. F. Stortelder en V. Westhof, 1995b. *De Vegetatie van Nederland; Deel 2. Plantengemeenschappen van wateren, moerassen en natte heiden.*, Uppsala/Leiden, Opuluspress.

Schaminée, J. H. J., E. J. Weeda en V. Westhof, 1998. *De Vegetatie van Nederland; Deel 4. Plantengemeenschappen van de kust en van binnenlandse pioniermilieu's.*, Uppsala/Leiden, Opuluspress.

Scheffer, F., P schachtschabel, H.P. Blume, K.H. Hartge & U. Schwertmann, 1982. *Lehrbuch der Bodenkunde*. Enke, Stuttgart.

Schipper, P. C., 2002. *Catalogus vegetatietypen. In: Staatsbosbeheer: Catalogi Bedrijfssturing; natuur, bos, receatie en landschap. Tabblad 4 en 5. Versie maart 2002.*, Driebergen, Staatsbosbeheer.

☒ Sival, F. P., H. J. Mücher en S. P. J. van Delft, 1998. "Management of basiphilous dune slack communities in relation to carbonate accumulation and hydrological conditions", *Journal of Coastal Conservation 4, p. 91-100.*

Steur, G. G. L., 1991. "Hoofdstuk 27: Indeling van de Nederlandse gronden" p. 71-80. In: H. d. Bakker and W. P. Locher (redactie). *Bodemkunde van Nederland; Deel 2, Algemene bodemkunde*. Den Bosch, Malmberg.

Stortelder, A. H. F., P. W. F. M. Hommel en R. W. de Waal, 1998. *Broekbossen*, Utrecht, KNNV Uitgeverij. Bosecosystemen van NederlandNatuurhistorische bibliotheek66

Stortelder, A. H. F., J. H. J. Schaminée en P. W. F. M. Hommel, 1999. *De Vegetatie van Nederland; Deel 5. Plantengemeenschappen van ruigten, struwelen en bossen.*, Uppsala/Leiden, Opuluspress.

ten Cate, J. A. M., A. F. van Holst, H. Kleijer en J. Stolp, 1995. *Handleiding bodemgeografisch onderzoek; Richtlijnen en voorschriften; Deel A: Bodem*, Wageninegn, SC-DLO. Technisch document 19A.

van Delft, B., R. Kemmers en R. de Waal, 2002. "Ecologische typering van bodems onder korte vegetaties : Het humusprofiel als graadmeter voor standplaatsontwikkeling", *Landschap 19(3), p. 152-164.*

☒ van Delft, S. P. J., 1997. *Decomposition of organic matter in grassland ecosystems : effects of litter quality and earthworm activity*, Wageningen, Wageningen Universiteit. Bodemkunde en Geologie

van Delft, S. P. J., 2001. *Ecologische typering van bodems; Deel 2 Humusvormtypologie voor korte vegetaties*, Wageningen, Alterra, Research Instituut voor de Groene Ruimte. Alterra-rapport 268.

van Delft, Bas van, 2004. *Veldgids Humusvormen; Beschrijving en classificatie van humusprofielen voor ecologische toepassingen.* Wageningen, Alterra, Research Instituut voor de Groene Ruimte.

Waal, R. W. d. en R. J. Bijlsma, 2003. *Bossen van de keileemgronden; Betekenis van stagnerend grondwater voor de ontwikkeling van humusprofiel en vegetatie*.

Appendix 1 Glossary

This glossary concerns concepts and terms that are not familiar to part of the readers or may be wrongly understood by people having a background in other sciences (vegetation, soil biology, eco-hydrology, etc.). For more extensive descriptions, reference is made to the literature listed above

Accumulation Accumulation of organic matter in or on top of the soil, because of retarded decomposition and lack of homogenisation (turbation)

Aerobic *'Containing air'* Soil in which gasses freely diffuse between the soil air and the atmosphere (Bakker, 1991). For many organisms such free diffusion is essential for their adequate supply with oxygen and removal of carbon dioxide produced. Soil organisms that depend on the soil atmosphere for their respiration are described as 'aerobic' (See also anaerobic)

Aggregate Structural element in the soil, composed of mineral and organic particles that are bound together. Soil fauna and flora plays an important role in the development of aggregates through the production of humic substances and slimes and the growth of an intricate network of (hair)roots and fungal hyphea (Steur, 1991). Particularly earthworms contribute to aggregation by consuming soil material and through this mixing of organic and mineral particles with sticky excretion products (mucus) (Marinissen, 1995, van Delft, 1997). Based on their size distinction is made microaggregates (0,05 – 0,5 mm), small macro aggregates (0,5 – 2 mm) and large macro aggregates (> 2 mm).

Anaerobic Opposite of aerobic (see aerobic). When anaerobic, the exchange of gasses (by diffusion) between the soil air and the atmosphere is hampered by a dense soil structure (low porosity) or saturation with water, filling the pores and thus limiting diffusion. Aerobic organisms that for their respiration depend on the soil air, die back or are seriously hampered in their functioning. Under such conditions, microbial processes are limited to those by anaerobic organisms that are capable of reducing soil compounds. These include, with increasing redox potential: $O_2 \rightarrow CO_2$, $NO_3^- \rightarrow NH_4^+$, $Mn^{4+} \rightarrow Mn^{2+}$, $Fe^{3+} \rightarrow Fe^{2+}$, $SO_4^{2-} \rightarrow S^{2-}$, $CO_2 \rightarrow CH_4$. As a result of these reduction processes the redox potential decreases and a reduced soil is formed. Of many plants the root respiration depends on the availability of oxygen and thus the redox potential in the root zone. Marsh plants are adapted to anaerobic conditions having root channels that conduct air, thus allowing for gas exchange with the atmosphere.

Association In soil surveys an interrelated group of two or more soil units, which cannot be separately indicated at the scale that is used are described as an association. We use this term also for combinations of humus forms, such as in a forest with a varied structure and age distribution. In such forest under old trees humus forms may differ distinctly from those under young saplings. An example of associations at even finer scale is that in tussock grasslands of *Molinia caerula* where humus forms under the clumps of grasses differ strongly from those in the intertussock lows. In vegetation science such association is described as a mosaic.

Bioturbation Mixing of soil by soil fauna (particularly earthworms)

Brown pigment Compounds formed in leaf tissues upon their die back, by reactions between tannin and proteins (Jabiol, et al., 1995), and giving the leafs a brown colour. Only few organisms are capable of breaking down these compounds (earthworms and fungi).

Calcareous material Material that contains calcium carbonate (lime). In the field its presence can be assessed with diluted hydrochloric acid (10 % HCl): no effervescence = non-calcareous (< 0,5% $CaCO_3$); audible effervescence = slightly calcareous (0,5-2 % $CaCO_3$); visible effervescence = calcareous (> 2 % $CaCO_3$). Apart from $CaCO_3$ other carbonates may occur in the soil that react with HCl, such as $MgCO_3$ and $FeCO_3$. The provenance of the carbonates is highly diverse. Marine sediments and those of larger rivers are often calcareous, due to the presence of shell fragments (primary carbonates). In brook valleys and other landscape elements with seepage, secondary carbonates may occur formed by precipitation from seepage water that was charged with dissolved carbonates while percolating through the subsoil (see photograph at page 50). Such precipitation may occur in the unsaturated zone where CO_2 escapes to the atmosphere (Sival, et al., 1998).

Clay-humus complex Organo-mineral complexes in which organic matter and clay minerals are intimately bound largely through electrostatic and van der Waals forces (Jansen, et al., 1990). In such complexes decomposition of organic matter is strongly retarded.

Dominant horizon(group) Horizon(group) that most prominently reflects the actual status of the organic matter cycle in the humus form concerned. See chapter *'Classification, page. 55* (Buis en van Delft, 2003).

Droppings Excrements of mesofauna that consist of small spheroids in between the litter or in the soil (moderhumus, see photograph page 18). (Jansen, et al., 1990)

Ecological soil typology Ecologically relevant classification system of soils. The description and interpretation of humus forms constitutes part of such system (Kemmers en de Waal, 1999, Kemmers, et al., 2001a, van Delft, 2001, van Delft, et al., 2002, Hommel en de Waal, 2003).

Ectorganic The organic part of the humus form that consists of decomposing litter, accumulated on top of the mineral soil (L-, F-and H-horizons).

Endorganic The part of the humus form in which organic matter is present as a result of homogenisation (A horizons) or was formed in situ (M-, en O-horizons).

Eutrophic peat Peat consisting of residues of plants that grew under eutrophic (nutrient rich) conditions. Examples are reed peat and brook peat of which the nutrient status is further enhanced by sedimentation of fine mineral material (mostly clay).

Fibric "Fibrous", term used for peat or root material that is hardly decomposed and consists of easily recognizable plant residues. See Of-horizon (page 44) and Mf-horizon (page 42).

Gleyic properties See hydromorphic properties.

GPS (Global Positioning System) Satellite navigation system allowing for the establishment of topographic coordinates of observation sites by a hand held receiver with a high accuracy.

Homogenization Mixing of mineral and organic material by soil fauna (mostly earthworms: bioturbation) and man (by soil labour, e.g. ploughing), particularly of decomposing litter with the mineral subsoil.

Horizon Soil layer with specific characteristics and properties that differ from those of the layers above and/or below; in general a horizon is more or less parallel to the soil surface.

Humic Humified organic matter such as in Oh and Mh horizons (page 44 and 42). Plant residues are decomposed beyond recognition.

Humus See *'Organic matter'*

Humus form That part of a soil in which organic matter occurs, associated with the current soil surface. It comprises the organic horizons L, F, H, O and M, but also mineral horizons that contain organic matter as a result of biological (rooting and bioturbation) or physical processes (A-, E- and B-horizons). The concept 'humus form' is comparable with the 'soil pedon' and it commonly constitutes the upper part of a pedon. See also chapters 'Introduction' and 'Horizon subdivision'.

Humus form description Description of all relevant characteristics of a humus form profile. It includes at least the thickness and the code of all humus horizons present, as well as their major properties such organic matter content, loam content and carbonate content.

Humus form Class Based on a humus form classification (or humus form typology) a humus form is assigned to a humus form class. This resembles the classification of a soil profile as belonging to a certain soil unit (see also the chapter *'Classification'*

Humus profile cutter or Wardenaar sampler Tool for cutting a humus form profile and sample with fixed section (see chapter 'Profile description'). Such cut is very practical for describing a humus form profile and sampling a fixed volume of specific horizons.

Hydromorphic properties Phenomena resulting from periodical saturation by water of the soil, comprising bleaching, rust and reduction mottles and a completely reduced (greyish) zone. In soils with shallow groundwater described as gley or gleyic properties, while in soils with periodical saturation resulting from stagnation on a dense layer they are described as pseudo- or even stagnogleyic properties.

Irreversibly desiccated peat Peat that after being desiccated develops more or less prominent hydrophobia (water repellence) and therefore cannot be rewetted to its original state. This phenomenon causes peat that is composed of peat moss to change into turf.

Litter Dead organic material, a.o. leafs, needles, twigs, branches, fruits and roots (below soil surface), but also remains of dead animals. Litter input can be both above and below ground surface. Litter forms the input of organic matter in the soil and the starting point of the recycling of nutrients by decomposition.

Litter horizon Horizon consisting of aboveground litter. Often several litter layers can be distinguished, based on the stage of decomposition of the litter. The uppermost layer generally consists of fresh litter (L-horizon), while in deeper layers decomposition increases (F- and H-horizons). See also the chapter *Horizons (page 35)*.

Loam content Content of mineral material < 50 µm expressed as mass percentage of the total mineral soil material. This includes both the clay and silt content. In the humus form classification, distinction is made between soils low in loam with < 20% loam and loamy soils with > 20% loam. This boundary of 20% proved to be ecologically more relevant than the 17,5% boundary that is used in the Dutch soil classification system.

Mesic Partly decomposed organic matter in Om- and Mm-horizons (see pages 44 and 42). See also fibric en humic.

Mesotrophic peat Peat that is composed of residues of plants that grew under mesotrophic conditions (moderately high in nutrients). Examples are sedges and alder brooks.

Micromorphology The study of structure and spatial patterns in soils with the aid of diverse microscopical techniques (Carmiggelt and Schulten, 2002). Usually an undisturbed soil sample is impregnated in synthetic resin from which a very thin cross-section is made (thin section approx. 25 µm thick) and studied with microscopical techniques. This provides much information about spatial distribution and nature of organic and mineral components in the soil. Such information can be of great importance for interpretation of the humus form studied. For examples, see photographs on page 15 and 20.

Moder (humus form) Humus form that is marked by accumulation of organic matter. Decomposition largely by mesofauna. Humus largely as *moder humus (droppings)*. Dominant horizons are Oh, Og, Od, OAh, Mh, AMh or Hz. Fz is the dominant F-horizon.

Moder humus Humus that consists of excrements of mesofauna (droppings). See photograph at page 18

Mor (humus form) Humus form that is marked by accumulation of organic matter. Decomposition and homogenisation proceed very slow. Decomposition largely by fungi. Dominant horizons are Of, Om, OAm or Mf. Fm is the dominant F-horizon.

Mormoder (Humus form) Transitional between moder and mor (see these terms). Decomposition by soil fauna and fungi. The dominant organic horizon is the Mm, while the Fa is the dominant F-horizon. In case that a F-horizon is absent, a Hr or Hh dominates.

Mull (humus form) Humus form determined by a rapid decomposition of organic matter and strong homogenisation as a result of an active soil fauna. No accumulation of organic matter in the form of an ectorganic layer, a root mat or peat layers. The profile is marked by the presence of an Ah-horizon or an (A)C-horizon in very recent soils that lack significant soil formation.

Mullmoder (Humus form) Humus form with some accumulation of ectorganic material. Transitional between Mull and Moder (see these terms). The total thickness of the ectorganic horizons is always less than that of the Ah-horizon.

Oligotrophic peat Peat that is composed of residues of plants that grew under oligotrophic conditions (nutrient-poor, often acid). Examples are peat moss peat and hair moss peat.

Organic matter All living and dead material in the soil that is organic in origin. Largely of plant origin and ranging from living organic matter such as roots to plant residues in various stages of decomposition. The more or less stable end product of the litter breakdown by soil fauna and flora is described as humus (sensu stricto). However, for the description of humus profiles a much wider definition of humus is employed, including all stages of decomposition and transformation of the litter.

Peat layer Layer composed of peaty material.

Peaty material Soil with an organic matter content > 15% (at 0% clay) to > 30% (at 70% clay). Class boundaries at intermediate clay contents can be found in the so-called organic matter triangle (Jansen, et al., 1990)

Peaty layer (horizon) Layer (horizon) that consists of peaty material.

Physiographic unit Highest level of ordination within the ecological soil typology (Kemmers, et al., 2001a, Hommel en de Waal, 2003). Within the Netherlands, eight physiographic units are distinguished based on the parent material and the (hydrological) position in the landscape: 1) Limestone and loess soils, 2) Calcareous sandy soils, 3) Holocene clay soils, 4) Pleistocene clay soils, 5) Recent floodplains, 6) Moors and Mires, 7) Poorly drained sandy soils fed by seepage, 8) Sandy soils fed by precipitation water. See also figure on page 12 and table on page 81.

Physiotope Second level of ordination within the ecological soil typology (Kemmers, et al., 2001a, Hommel en de Waal, 2003). Landscape unit that is homogeneous with respect to a combination of primary factors, such as a slope or spring. See also http://www.synbiosys.alterra.nl/. On page 81 an overview is given of all physiotopes that are currently recognized within the Netherlands.

Podzol profile Soil profile that is marked by the presence of podzol horizons, notably a bleached eluvial E-horizon and illuvial Bh and/or Bs horizon.

Pseudogley Hydromorphic properties that are caused by temporary stagnation of water on a slowly permeable layer.

Root horizon Horizon marked by the abundant presence of (dead) roots, such as AMh- and M-horizons. See also chapter Horizon classification.

Root mat Mat of (dead) roots on top or in the upper part of the mineral soil (M-horizon). See also chapter *'Horizon classification'*.

Sandy soil fed by precipitation water Physiographic unit that consists of sandy soils where soil forming processes are driven by infiltrating rainwater. Eluviation of basic cations, minerals (a.o. Fe and Al) and organic matter is a dominant soil forming process, resulting in development of podzol soils. (Kemmers, et al., 2001a, Kemmers, et al., 2002).

Sandy soils fed by seepage Physiographic unit comprising sandy soils in which seepage controlled the soil forming processes (Kemmers, et al., 2001a, van Delft, 2001, van Delft, et al., 2002). Top soils in these areas are often enriched with basic cations (mainly Ca) and iron(hydr)oxides. Examples of such soils are *beekeerd soils*.

Saprophagous/Saprophytic Soil organisms that feed on dead organic matter. ***Semiterrestric*** Sites that are strongly affected by (ground)water. Apart from peats and peaty soils these include mineral soils with gley within 25 cm depth, or a mean highest groundwater level < 25 cm or a mean lowest groundwater level < 60 cm. Humus forms that formed under these conditions are defined as *´semiterrestric humus forms´*. See also the chapter *'Classification'*.

Sesquioxides Iron and aluminium (hydr)oxides.

Soil fauna Animals that live in the soil (see page 15).

Soil organisms Organisms that during at least part of their active stadia live in the soil (Richards, 1974, Steur, 1991). Animals that hibernate in the soil, that passively stay in the soil as egg, grub or nymph, or that use the soil as temporary refuge, are excluded.

Soil profile Vertical section of the soil, composed of a succession of soil horizons (see page 55).

Substratum Medium for bacteria.

Successional series Series of humus forms that represent successive developmental stages from an initial phase onwards, or in connection with specific changes in environmental conditions (desiccation, acidification; see page 33). These series are analogue to successional seres or vegetation types. By linking humus forms to developmental series insight can be obtained regarding future ecosystem development as a result of 'natural succession' or as a result of degradation. Examples of such series are discussed in (van Delft, et al., 2002)

Terrestric Sites that do not meet the criteria for semiterrestric sites and are associated with *´terrestric humus forms´*. See also chapter *'Classification'*.

Thin section See micromorphology

Tool kit See chapter 'Introduction': Metaphor for the criteria, properties and characteristics used in the ecological soil typology in which, depending on the question and nature of the area, various 'tools' may be selected.

Wardenaar sampler See *Humus profile cutter*

Wood residues Residues of tree and shrub branches and stems in the litter layer. Based on their occurrence, subgroups with the prefix 'Ligno-' are distinguished (see chapter 'Classification').

Appendix 2 Profile description form

On the next page a reduced version is presented of the form for profile description that is used by Alterra. The original can be downloaded from the website of Alterra (www.humusvormen.wur.nl. For more information reference is made to the preface.

ALTERRA

RESEARCH INSTITUUT VOOR DE GROENE RUIMTE

Administrative data				
Site	AlphaCode	Date	Surveyor	Project
Topmap	Volgno CPF	X-coordinate	Y-coordinate	Height
Land use	Management	Sod cutting year	Humus profile	Soil profile
Remarks concerning the site				

Landscape					
Physiogr. unit	Physiotope	Geomorphology	Microrelief	Slope	Expo

Vegetation type:	Class	Order	Alliance	Ass	Sub

Hydrology										
System	MHW	MLW	MSW	GWL	Inun. period	Inun.type	addition .Gt	Gt	pH	EC

Profile data					
Pre	Sub	Number	Lime	Behind	Disturbed
Code 1 : 50 000	Humus form class		Rootable depth	Effective Rootable depth	Spread

Layer			Depth		Bound		Mixed	Humus			Mineral						Mottles			Various			Roots			
Nr	Horizon	HorBIS	U	L	s.	size	A:B	%	A	VS	2□	50□	M50	Lime	Ripe	pH	A	Hue	V/C	Geo	Stru	Fauna	Num	Size	Orient	Remarks
1																			/							
2																			/							
3																			/							
4																			/							
5																			/							
6																			/							
7																			/							
8																			/							
9																			/							
10																			/							
11																			/							
12																			/							
13																			/							

mandatory	mandatory in BIS

Appendix 3 Classifications and codes used in humus form profile descriptions

Heading data

Administrative data

Site Name of the site. It is preferred to record the name of the management unit as given by the site manager, such as *'Boswachterij Ommen'*.

Alphacode Unique alphanumerical code by which the location can be indicated.

Date Date on which the profile description was made.

Surveyor Code or name of the surveyor that produced the description.

Project Project number or title of the project for which the data have been recorded.

Topmap Map sheet number of the 1 : 25.000 map on which the site is located.

Volgno CPF Unique number for the **B**odemkundig **I**nformatie**S**ysteem (BIS) of Alterra.

X-coordinate & Y-coordinate RD coordinates of the site. To be established by GPS or from the topographic map.

Height Height of soil surface in meters above reference level, if known.

Land use Code for land use according to the Alterra system

Code	Description
	Arable land
AA	Arable land, potatoes
AB	Arable land, beets
AG	Arable land, cereals
AK	Arable land, bare
AM	Arable land, maize
AO	Arable land, unspecified
AX	Arable land, other crops
	Forest and woods
BK	Tree nursery
BL	Deciduous forest
BN	Coniferous forest
BO	Forest, unspecified
BX	Forest, mixed stand
	Orchard
FG	Green orchard (with grass underneath)
FO	Orchard
FZ	Orchard with arable land underneath
	Grassland (inclusive nature)
GO	Grassland, unspecified
GR	Grassland, permanent
GX	Grassland, other (recently sown)
	Other terrains (rest)
RO	Other terrains (rest)
RP	Public garden
RS	Sport fields
RX	Others (building locations etc.)

Code	Description
Horticulture	
TG	Horticulture, green houses
TO	Horticulture
TV	Horticulture, open air
Nature (Uncultivated)	
WD	Dry vegetation (a.o. drift sands)
WH	Heathland
WN	Wet vegetation a.o. marshes, wet sands and muds
WO	Nature, unspecified
WX	Nature, other

Management Short description of the management. Classes distinguished are as follows:

Code	Management	Description
BE	Grazing (light)	Large grazers at a low density
BI	Grazing (intensive)	Agricultural grazing or grazing at high density in grasslands in nature reserves
BO	Forestry	Active silviculture, including thinnings
MA	Mowing (agricultural)	Several cuts a year, for fodder production
MN	Hay making (nature)	1 or 2 cuts a year, possibly combined with light grazing; aiming at nutrient poor conditions
NI	Nothing	No active management
ON	Unknown	Unknown

Sod cutting year Year in which the sod was cut (if relevant). This provides an indication for the rate at which a new humus form developed in the system concerned.

Humus profile/Soil profile Serves to indicate whether a humus profile or soil profile is described.

Remarks concerning the site Place to record remarks about the site. More extensive remarks can be added on the back of the form.

Landscape

Physiographic unit Indication for the physiographic unit to which the site belongs according to the framework for ecological soil typology (Kemmers, et al., 2001a, Kemmers, et al., 2002). Physiographic units are related to units from the soil map and include:

Nr	Physiographic unit	Units Soil map of the Netherlands
1	Limestone and loess soils	BL, EL, L, MA, MK, MZ, FG, FK, KM, KK, KS, ABI, AH
2	Calcareous sandy soils	EZA, pZgA, ZnA, ZdA, ZbA, AD, AZW, Sn
3	Holocene clay soils	MOo, MOb, ROo, ROb, pMn, Mv, Mo, Mn, Rn, AZW, BK, EK, pMv, pMo, pMd, pRv, pRn, Aem, Rd, kZ…A, kWp, kWz, Abk, Afk, AM, Ro, AAK, Aep, AO, AR, kZAK, Alu, AWZ, Rv, Wo, Wg, EK, pMd, Mo, gMn, Md, Agm, Aek, Amm, Awg, Awo, EK, Awv, kV, pV
4	Pleistocene clay soils	PKRn, KRn, KT, KX
5	Recent floodplains	all units in floodplains
6	Moors and Mires	hV, hEV, aV, aEV, Vo, V, AP, Avk, vWz, uWz, vWp
7	Poorly drained sandy soils fed by seepage	zWz, pZg, pZn, Abz, Afz, L
8	Sandy soils fed by precipitation	Y, Hn, Hd, Zn, Zd, Zb, G1, ABH, AS, AZ1, tZd, cY, cHn, cHd, BZ, cZn, tZd, zWp, zV, iV, AAP, Abv, iWp, iWz, EZg, zEZ, bEZ

Physiotope Indication for the physiotope to which the site belongs (Hennekens, et al., 2001), http://www.synbiosys.alterra.nl/. The classification used by Alterra is employed in various projects. It concerns a hierarchical system with 6 *'Ecoregions'* at the highest level, subdivided into *'Ecoseries'* and *'Physiotopes'*.

Ecoregion / Ecoseries / Code	Physiotope
Hills	
plateaus and plateau borders	
hl1a	Plateaus with residual limestone and loess soils
hl1b	Plateau remnants and borders with terrace deposits
hl1c	Residual chert plateaus and –plateau borders
Slopes	
hl2a	Limestone slopes and ridges
hl2b	Dry highly calcareous slopes
hl2c	Slightly to non-calcareous slopes in limestone
hl2d	Slightly to non-calcareous loess and greensand slopes
Valleys	
hl3a	Springs and seepage dominated valley heads
hl3b	Cleft like valleys (grubben)
hl3c	Brook valleys and colluvial valleys
hl3d	Brooks
Sandy soils in Pleistocene areas	
Glacial areas	
hz1a	Loamy textured ice pushed ridges
hz1b	Sandy textured ice pushed ridges and fluvioglacial fans
hz1c	Boulder clay outcrops
Drift sand areas	
hz2a	Inland dunes
hz2b	Residual drift sand plateaus and overblown depressions
hz2c	Drift sand depressions
Cover sand areas	
hz3a	Dry, non-loamy cover sands

Ecoregion			
	Ecoseries		
		Code	Physiotope
		hz3b	Loamy cover sands and cover sands on loams
		hz3c	Old fields
		hz3d1	Moist cover sand depressions
		hz3d2	Groundwater fed pools
		hz3e	Rainwater fed pools
		hz3f	Dry, non-loamy cover sands
	Raised bogs		
		hz4a	Raised bog remnants
		hz4b	Raised bog
		hz4c	Transitional bog
		hz4d	Peatland canals
	Brook valleys		
		hz5a	Springs and seepage dominated valleyheads
		hz5b	Wet brook valleys
		hz5c	Parched brook valleys
		hz5d	Isolated brook valleys
		hz5e	Lower courses of brook valleys
		hz5f	Natural levees and low river dunes in brook valley systems
		hz5g	Brook channels
		hz5h	Loamy former floodplains
Riverine areas			
	Dynamic floodplains		
		ri1a	River channels
		ri1b	Point bars
		ri1c	Low natural levees and sandy, ridge-shaped channel fills
	Other floodplains		

Ecoregion			
	Ecoseries		
		Code	Physiotope
		ri2a	Swales and dike breach scour pools
		ri2b	Low floodplains
		ri2c	High floodplains
		ri2d	High natural levees and river dunes
		ri2e	River dikes
	Reclaimed floodplains and terraces		
		ri3a	High reclaimed floodplains and terraces
		ri3b	Backswamps
		ri3c	Former clay pits (reclaimed floodplain)
		ri3d	Abandoned river channels
Coastal dunes			
	Young coastal dunes		
		du1a	Beaches
		du1b	Fore dune
		du1c	Former arable lands and dune meadows
		du1d	Dry highly calcareous coastal dunes
		du1e	Slightly to non calcareous coastal dunes
		du1f	Sheltered tidal flats
		du1g	Moist dune slacks
		du1h	Dune lakes and marshes
		du1k	Reclaimed tidal flats
	Old coastal dunes		
		du2a	Beach ridges
		du2b	Moist inland tidal flats
Lowland fen area			
	Fenlands		
		lv1a	Fresh water fenlands
		lv1b	Brackish fenlands

Ecoregion			
	Ecoseries		
		Code	Physiotope
		lv1c	Transitional peatlands
	Marshes		
		lv2a	Peatland lakes and excavation ditches
		lv2b	Fresh water peat banks
		lv2c	Brackish peat banks
		lv2d	Peatland baulks and peatland remnants
Marine clay area			
	Reclaimed land		
		zk1a	Clay-marshes
		zk1b	High calcareous clay polders
		zk1c	Slightly calcareous clay polders
		zk1d	Brackish clay polders
		zk1e	Sandy polders
		zk1f	Mounds and dikes
	Creeks		
		zk2a	Pools and creeks
		zk2b	Creek banks and former clayey shoals
		zk2c	Sandy shoals and tidal levees
	Closed estuaria		
		zk3a	Creek banks and shoal edges
		zk3a	Sandy shoals
	Fresh water tidal area		
		zk4a	Low fresh water tidal banks
		zk4b	Fresh water banks with moderate tidal influence
		zk4c	Fresh water banks with slight tidal influence
		zk4d	Fresh water tidal depressions
Salt water tidal area			
		zg1a	Low clayey shoals
		zg1b	Low sandy shoals
		zg1c	High clayey shoals
		zg1d	High sandy shoals
		zg1e	Shoal edges

Geomorphology Fill in a brief indication for the geomorphological position such as ‘top of cover sand ridge’ or ‘valley shaped depression’.

Microrelief Code for short range relief:

Slope Slope in degrees.

Exposition Exposition in compass degrees relative to the North if the site is on an inclined surface.

Vegetation type Vegetation type, indicated at the lowest level possible. If this is impossible, use a higher level (Class, Order, Alliance, Association or Sub association). For current vegetation typologies reference is made to the literature. The vegetation of the Netherlands has been described by (Schaminée, et al., 1995a, 1995b, Schaminée, et al., 1996, Schaminée, et al., 1998, Stortelder, et al., 1999). The State Forestry uses a classification that differs from these aforementioned systems for a number of types (Schipper, 2002).

Code	Description
VL	Smooth, few local differences
GO	Wavy; local differences << mutual distance
ON	Irregular; local differences < mutual distance
ZO	Very irregular: local differences ≥ mutual distance
	Undefined

Hydrology

Hydrological system Brief characterization of the hydrological system based on the classification below.

Code	Hydrological System
WZ	Infiltration area
WR	Infiltration area, border zone
KZ	Seepage area, fresh water
KD	Seepage area, drained
KB	Seepage area, brackish
GG	Isolated area
KR	Scraw system

MHW Estimated mean highest groundwater level (in cm from the surface). The MHW is estimated a.o. on the basis of the presence of hydromorphic properties (depth at which rust mottling starts), but also on knowledge about terrain conditions, data from nearby gauging tubes and the groundwater level in the borehole at the site concerned. It is important to realize that rust mottles often reflect past conditions since more recent human interference may have led to a considerable lowering of the actual MHW. This MHW (and MLW) is estimated at multiples of 5 cm if such accuracy can be reached. If the MHW is above the soil surface a negative value should be given (e.g. – 10).

MLW Estimated mean lowest groundwater level (in cm from the surface). The MLW is estimated a.o. on the basis of the presence of hydromorphic properties (depth at which complete reduction starts), but also on knowledge about terrain conditions, data from nearby gauging tubes and the groundwater level in the borehole at the site concerned. If the MLW does not occur within augering depth, an estimate should be given rounded of at 5 cm if such accuracy can be reached. The last cipher must be a 2 to indicate that the value is an estimate (e.g. 252). If no estimation is possible, 1 is added as the last cipher (e.g. 151) to indicate that the value is deeper than augering depth.

MSW Estimated mean spring groundwater level (in cm from the surface). This requires careful estimation, based on terrain knowledge (what groundwater level is usual around April 1). In case that gauging tube data are available, spring levels can be compared with the GHG. A rule of thumb is: GVG = GHG + 15 cm for soils with limited seasonal fluctuations and for other soils GVG = GHG + 25 cm.

GWL Groundwater level in the auger hole. In case that GHG, GLG and the current groundwater level at a nearby gauging tube are known, the groundwater level in the auger hole may serve to estimate the GHG and GLG. If the hole is also used to establish water quality parameters (e.g. pH and EC), or a water sample is taken, it is important to establish at what depth the water is sampled. For a reliable estimate the water level in the auger hole must be in equilibrium with the groundwater level. In permeable sandy soils a few minutes may be sufficient to reach such equilibrium and the level can be adequately measured after completion of the description. In less permeable soils, such as clayey soils and some peats, up to one day or more may be required for equilibrium to be reached.

Inundation period Estimation of the mean inundation period in month, rounded off at ½ month. This estimate is based on field experience and may be derived from data on nearby gauging tubes.

Inundation type In case that the inundation period is > 1 month, the type of water can be indicated. Types distinguished are

Code	Inundation type
SA	Stagnation of (rain)water in depressions
ST	Stagnation of rainwater on slowly permeable layer
KZ	Seepage water (fresh)
KB	Seepage water (brackish)
OW	Surface water
ZW	Seawater
ON	Unknown

Addition Gt Qualitative addition to groundwater step (before code)

Code	Description
w	water above land surface for a continuous period of more than 1 month in winter (only for soils that are embanked)
b	Non-embanked soils that are periodically flooded
s	Apparent groundwater tables; the level of the GHG is determined by periodical stagnation on (a) slowly permeable layer(s)
ws	Combination of w and s

Gt Groundwater step. Steps are derived from the MHW and MLW as indicated in the table below.

	MHW (cm below surface)				
MLW (cm below surface)	**< 25**	**25 - 40**	**40 - 80**	**80 - 140**	**> 140**
< 50	Ia	Ic			
50 – 80	IIa	IIb	IIc		
80 – 120	IIIa	IIIb	IVu	IVc	
120 – 180	Vao	Vbo	VIo	VIIo	VIIIo
> 180	Vad	Vbd	VId	VIId	VIIId

pH and EC Field estimations of pH and EC (electric conductivity in mS/m) of the water in the borehole. Such information may help to identify the type of groundwater.

Profile data

Pre, Sub, Number, Lime, Behind, Disturbed These fields together represent the standard point code used by Alterra to characterize soils at a given site. This provides more detailed information than the mapping unit on the soil map, since soils within such unit cover a certain range. For these codes reference is made to (ten Cate, et al., 1995). In many cases the code as indicated on the soil map 1 : 50 000 will suffice (see below).

Code Soil map 1 : 50 000 Map unit of the soil map 1 : 50 000 to which the soil profile described belongs. For further information reference is made to the literature (Bakker en Schelling, 1989, Steur, 1991, ten Cate, et al., 1995).

Humus form class The code and/or name of the humus form (see chapter *'Classification'*).

Rootable depth Depth to which the profile may be rooted, estimated on the basis of profile characteristics, including soil acidity, aeration, and penetrability of the soil. This depth may exceed the depth to which roots are actually observed (ten Cate, et al., 1995).

Effective rootable depth Depth to which most roots reach, which is generally less than the rootable depth.

Spread in profile characteristics In case that profile characteristics are highly variable within short distance, this field serves to register the extent of variability.

Layer data

Layer

For each horizon one line is used to record its characteristics. Layers are numbered.

Horizon The horizon is coded according to the classification presented in the chapter 'Horizon classification'.

- This code is preceded by a number to indicate the order in which various parent materials occur (litter, sand, peat, clay, loam).
- In case that 2 successive horizons would receive the same code they are distinguished by a serial number placed after the code.
- For a reworked layer codes are used of the layers from which it is derived, separated by a slash such as A/Cg (see photograph at page 51).

- All layers observed while augering are described, inclusive of C-horizons that do not belong to the humus form.
- ***HorBIS*** The horizon code as used in soil profile descriptions (Bakker en Schelling, 1989, ten Cate, et al., 1995). This code generally conforms to the horizon code in the first column. Only for peaty and peat layers (O-horizons) deviating codes are used. To store the descriptions consistently in BIS (Soil Information System, see www.bodemdata.nl) in addition the Alterra standard codes are used.

Depth

U and L Upper and lower boundaries of the layer in cm. In case of thin horizons a mm scale can be used. The mineral soil surface is used as the zero level, implying that the depth of ectorganic horizons is indicated with negative values. A S-horizon is considered to be an ectorganic horizon.

Boundary

shape and size In these columns, codes for shape and size of the boundary between two horizons are recorded. These parameters reflect the extent of homogenisation. If boundaries are sharp transport of organic matter between horizons will be very limited. The shape is recorded using the following classes:

Code	Description
IR	Irregular, pockets deeper than wide
SM	Smooth, nearly flat
WA	Wavy, pockets wider than deep
BR	Broken, discontinuous

The thickness of the boundary is recorded using the following classes:

Code	Description
AB	Abrubt, < 5 mm
CL	Clear, 5 - 10 mm
DI	Diffuse, 11 - 20 mm
GR	Gradual, > 20 mm

Mixed

A:B For mixed horizons the contribution of individual horizons is indicated by their ratio, such as an A/C horizon with a mix of 1:3.

Humus

% Estimation of the organic matter content in %.

A Nature of the organic matter in humic sandy topsoils

Code	Description
1	Brown
2	Black (mild)
3	Black (raw)

VS Type of peat, only for peaty layers

Code	Description
BA	Slush
BE	Eutrophic forest peat
BM	Mesotrophic forest peat
C	Sedge peat
CR	Sedge-reed peat
D	Moulded or weathered peat
DK	Moulded or weathered peat, relatively clayey
DV	Moulded or weathered peat, other
DZ	Moulded or weathered peat, relatively sandy
OV	Other types of peat
R	Reed peat
RC	Reed-sedge peat
S	Other peat moss peat
SP	Dense peat moss peat
VV	Detrital peat
J	Young, oligo-fibrous peat
B	Forest peat
GL	Sandy muck
GY	Gyttja
L	Litter

Mineral

2µ Clay content (%).

50µ Loam content (% of mineral parts < 50µ). For the classification of humus forms the loam content is particularly relevant (smaller or larger than 20%).

M50 Median of the sand fraction

Lime Class established by hydrochloric acid (10 %). The depth at which the soil is calcareous is important for the classification of humus forms (see chapter '*Classification*'). In acid soils (non-calcareous sandy soils, many peaty soils) the carbonate content needs not to be checked. The class should only be indicated if based on the test, or if it is certain that the soil is non-calcareous. Clayey fluvial and marine deposits as well as soils with seepage should always be tested.

Code	Description
1	Non-calcareous, no effervescence
2	Slightly calcareous, audible effervescence;
3	Calcareous, visible effervescence

Ripening For clayey soils, indicate the degree of ripening using the codes in the table below

Code	Class	Consistency
1	Totally unripe	Very soft, runs between the fingers
2	Nearly unripe	Soft, upon kneading easily runs between the fingers
3	Partially ripe	Moderately soft, upon kneading runs well between the fingers
4	Nearly ripe	Moderately firm, can be forced to pass between the fingers by steady kneading
5	Ripe	Firm, cannot be forced to pass between the fingers

pH pH-value of the horizon, estimated in the field using indicator sticks. The sticks provide values that correspond to the pH-KCl estimation in the laboratory. The path of soil acidity with depth provides clear information on the extent of acidification of the soil profile. To estimate the soil reaction, the pH-stick needs to be put in wet soil material for several minutes. This can easily be achieved by an oblique knife cut at the required depth and subsequent wetting of the soil with dematerialized water using a siphon.

After some minutes the stick can be sprayed clean and the pH determined by comparison with the added colour scale. Commonly in the upper part of the profile a strong pH-gradient occurs for which reason it might be useful to establish the pH for each individual layer. Deeper down pH estimated can be at larger distances.

Mottles

A Number of rust mottles according to the code below:

Code	Description
o	None
w	few: 0 - 2% of the surface
m	moderate: 2-20% of the surface
b	many, variegated: > 20%, but variegated
h	many, heterogeneous: > 20%, but heterogeneous

Hue and V/ C Codes for the colour of mottles (Hue, Value, Chroma) according to the Munsell colour scale.

Various

Geo Code of the geological formation as used by Alterra for soil profile descriptions.

Code	Description
	Peaty material
110	Peaty material, without identifiable plant residues such as moulded or strongly weathered peat.
120	Eutrophic forest peat
130	Sedge peat, reed-sedge peat, mesotrophic forest peat
140	Reed peat, sedge-reed peat
150	Peat moss peat
151	Young, oligo fibrous peat
152	Other peat moss peat

Code	Description
160	Sedimentary peat (a.o. sandy muck, gyttja, detritus)
170	Litter layer
171	Litter layer of deciduous trees
172	Litter layer of coniferous trees
190	Other peat types (a.o. Scheuchzeria peat); also used for root mats
	Marine deposits (Holocene)
210	Tidal deposit: saline-brackish
211	Recent tidal deposit: saline-brackish (Dunekirke deposits; incl. sand)
212	Old tidal deposit: saline-brackish (Calais deposits; incl. sand)
220	Tidal deposit; fresh water
230	Deposits in permanent water
	Fluvial deposits
310	Very recent deposits in flood plains
320	Holocene deposits of Rhine or Meuse
321	Holocene deposits of Rhine
322	Holocene deposits of Meuse
330	Pleistocene deposits of Rhine or Meuse
331	Late- Pleistocene deposits of Rhine or Meuse (Formation of Kreftenheye)
332	Mid- and Early Pleistocene deposits of Rhine or Meuse (not ice-pushed)
340	Deposits of other rivers or brooks (e.g. Vecht, Berkel, Roer)
390	Other fluvial deposits (e.g. Formation of Enschede)
	Aeolian and fluvioperiglacial deposits
410	Cover sands
411	Young cover sands
412	Old cover sands

Code	Description
413	Fluvioperiglacial
420	Loess
421	Loess cover
422	Loess in local depressions (e.g. ’Brabant loam’)
430	Coastal dune sands
431	Young coastal dune sands
432	Old coastal dune sands
440	River dune sands
450	Inland dune sands (e.g. drift sands)
490	Other aeolian and fluvioperiglacial deposits (e.g. aeolian premorenal sand)
	Glacial and fluvioglacial deposits
510	Moraine (loam)
520	Moraine (sand)
530	Melt water deposits
531	Melt water deposits; sand
532	Melt water deposits; (‘warven’) clay
533	Melt water deposits; “potklei”
	Other deposits
610	Slope deposits incl. of fan deposits (at the foot of dry valleys)
620	Secondary loess (e.g. colluvium)
630	Ice-pushed deposits
631	Ice-pushed deposits; Rhine, Meuse
632	Ice-pushed deposits; Eastern rivers
633	Ice-pushed deposits; deposits of Tertiary age
691	Other geogenic deposits (e.g. limestone, Tertiary clay)
692	Antropogenic homogeneous (e.g. plaggen soil)
693	Antropogenic heterogeneous (e.g. sand + peat)
699	Unknown, not differentiated

Stru Structure of organic horizons according to the following classes:

Code	Description
BL	Blocky; Faces rectangular and flattened; vertices sharply angular
CM	Compact matted; Materials arranged along horizontal planes with evident compaction
GR	Granular; Spheroidal and characterized by rounded or subrounded vertices
MA	Massive; A coherent mass showing no evidence of aggregation
NM	Non-compact matted, Materials arranged along horizontal planes with no compaction
RE	Recumbent; Materials in recumbent (reclining) position
SP	Single particles, An incoherent mass of individual particles (may be of various sizes) with no aggregation
WO	Woven, mostly roots, hard to tear apart
ER	Erect, Materials in vertical position

Fauna Soil fauna observed or traces of soil fauna such as wormholes

Roots

Number Number of roots expressed in number per 1 inch^2 = 6.25 cm^2) in the following classes:

Code	Description
AB	Abundant; > 30 per 6,25 cm2
PF	Plentiful; 21 - 30 per 6,25 cm2
CO	Common; 11 - 20 per 6,25 cm2
FE	Few; 3 - 10 per 6,25 cm2
VF	Very few; 0 - 3 per 6,25 cm2
NO	None; 0 per 6,25 cm2

Size Thickness of roots in mm. In case that thicknesses of roots are varied, the dominant thickness class is recorded.

Code	Description
VF	Very fine; < 1mm
FI	Fine; 1 - 2 mm
ME	Medium; 3 - 10 mm
CO	Coarse; 11 - 25 mm
VC	Very Coarse; > 25 mm

Orientation Dominant orientation of the roots:

Code	Description
RA	Random
HO	Horizontal
VE	Vertical
OB	Oblique

Remarks Remarks on the layer described.