Humusica 1, article 5: Terrestrial humus systems and forms - Keys of classification of humus systems and forms

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ABSTRACT

This article is an as simple as possible key of classification of terrestrial (aerobic, not submerged) topsoils (organic and organic-mineral series of soil horizons). Based on the introduction exposed in Humusica 1, article 1, and using vocabulary and definitions listed in article 4, a classification is proposed for better understanding the biological functioning of the soil, partially disclosing the process of litter digestion. Five types of terrestrial topsoils, called terrestrial humus systems, are described and illustrated with the help of photographs. Within each humus system, 3–4 humus forms are also revealed, corresponding to similar series of soil horizons generated in a relatively homogeneous environment whose range of ecological factors is not so large to overstep and cause

the genesis of another different humus system. The article ends with a figure that shows the relationship between Tangel and Amphi humus systems, and a dichotomous key of classification that one can easily print and bring in the field for practicing humus classification.

Foreword

Even if published as an independent article, if you are not accustomed to soil or humus field classification, this paper lacks of basic information you can find in:

Humusica 1, article 1: Essential bases – Vocabulary (Soil and humus profiles and horizons, Humus systems and forms classifications, historical overview…);

Humusica 1, article 3: Essential bases – Quick look at the classification (for beginners);

Humusica 1, article 4: Terrestrial humus systems and forms – Specific terms and diagnostic horizons.

Humusica recovers keys of classification published in preceding works (Zanella et al., 2011a, b; Jabiol et al., 2013), which are still valid but incomplete. Here an enlarged group of authors updated the old units, created few new references and better illustrated the whole.

1. Key of classification of humus SYSTEMS

On a morpho-functional basis, Terrestrial humipedons are subdivided in five systems (Mull, Moder, Amphi, Mor and Tangel), hereafter identified and described based on diagnostic features.

Essential legend (complete definition in Humusica 1, article 4): biomacro A = biomacrostructured A horizon; biomeso A = biomesostructured A horizon; biomicro A = biomicrostructured A; zoOF or OF = zoogenic OF horizon; nozOF = non zoogenic OF horizon. OH= implied zoOH (zoogenic OH) and/or possible szoOH (slightly zoogenic OH) horizons.

Caution: “and” written at the end of a phrase means that the exposed preceding diagnostic criteria are not sufficient and need to be completed with others; “or” reported between criteria allows to select among them. The sign “;” is used between two sentences and indicates that the process of classification is not finished.

1.1 Mull

To be identified as Mull, a topsoil must display the following properties:

1) absence of any OH horizon; and

2) presence of biomacro A;

or

2) Presence of biomeso A and at least two of the following:

- presence in the A horizon of living earthworms or their casts, except in frozen or desiccated soil;
- presence of a very sharp transition (< 3 mm) between organic and organic-mineral horizons;
- pH_{water} of the A horizon ≥ 5.

Correct lecture/interpretation for Mull:

1) must be without OH horizon; and

2) must show biomacro

or

2) biomeso A horizon and two of the listed three criteria.

1.2 Moder

To be identified as Moder, the topsoil must display the following properties:

1) presence of an OH horizon (even if sometimes discontinuous); and

2) absence of nozOF; and

3) absence of biomacro A; and one of the following:

- no sharp transition OH/A horizon (transition ≥ 5 mm);
- pH_{water} of the A horizon < 5;

or

3) presence of biomeso A or biomicro A, or A single-grain or (rare, in case of intergrades to Mor) A massive, and one of the following:

- no sharp transition OH/A horizon (transition ≥ 5 mm);
- pH_{water} of the A horizon < 5.

1.3 Amphi

To be identified as Amphi, the topsoil must display the following properties:

1) simultaneous presence of OH and biomacro or biomeso A horizons; and

2) absence of nozOF; and

3) thickness of A horizon ≥thickness of ½ OH horizon; and

4) absence of massive or single-grain A; and

5) presence of biomacro A and one of the following:

- living earthworms in the A horizon;
- sharp transition between A and OH;
- pH_{water} of the A horizon ≥ 5,

  or

5) presence of biomeso A and one of the following:

- living earthworms in the A horizon;
- no sharp transition between OH and A;
- pH_{water} of the A horizon ≥ 5.

1.4 Mor

To be identified as Mor, the topsoil must display the following properties:

1) never biomeso or biomacro or biomicro A horizon; and

2) presence of nozOF and one of the following properties:

- pH_{water} of E or AE or A horizon < 4.5;
- A absent, or massive A, or single-grain A,

  or

2) presence of OH horizon in very sharp (< 3 mm) transition to A, AE or E horizon and one of the following properties:

- pH_{wate}r of E or AE or A horizon<4.5;
- A absent, or massive A, or single-grain A.

1.5 Tangel

To be identified as Tangel, the topsoil must display the following properties:

1) Organic zoogenic horizons present and thick (zoOF + OH)>10 cm; and

2) nozOF absent; and

3) Hard limestone and/or dolomite rock fragments in or at the bottom of the humus profile; and

4) A horizon absent or present. If present:

4) Biomeso A; and A < 1/2 OH

or

4) Massive A horizon and both the following:

- A<1/2 OH;
- pH_{water} of A ≥ 5

The name of a humus system is always written with capital letters, or with a beginning capital letter.

Example: TANGEL or Tangel, never tangel.

2. General character and distribution of the humus SYSTEMS

It is very useful to associate an ecological frame of genesis and development to each humus system. It allows beginners to avoid serious errors of classification. We reported main ecological conditions, dominant actors of biodegradation, actors' actions, pH_{water} of the A horizon, key diagnostic horizons and, sometimes, concise dynamic considerations. An entire paper (Humusica 1, article 8) has been written for describing/illustrating the biological activities of humus systems.

2.1. General characters and distribution of Mull

- ecological conditions: temperate or tropical climate and/or nutrient-rich siliceous or calcareous parent material and/or easily biodegradable litter (C/N < 30) and/or no major environmental constraint;
- dominant actors of biodegradation: anecic and large endogeic earthworms, bacteria; actors' action: fast biodegradation and rapid disappearance of litter from the topsoil (≤ 3 years), carbon mainly allocated in the A horizon;
- pH_{water} of the A horizon: generally ≥ 4.5;
- key diagnostic characters (morpho-functional result of specific biological activities): OH never present, biomacro or biomeso A, very sharp transition (< 3 mm) between organic and organic-mineral horizons.

Nota Bene: Even if a very low soil pH is observed (≤ 4.5) in the equatorial zone, temperature and moisture compensate for unfavourable soil conditions (Sanchez et al., 2003) and a very active Mull humus system occurs in all this area (Lavelle et al., 1993), except in white sand or inselberg sites (with very low base content), where Mor and Moder dominate, respectively (Hartmann, 1970; Klinka et al., 1981; Coomes and Grubb, 1996; Kounda-Kiki et al., 2008). The equatorial Mull shows a large number of roots at its surface (it is often a Rhizo Mull), which can absorb the nutrients thanks to mycorrhizal symbiotic partners (Nasto et al., 2014). Nitrogen fixing bacteria ensure a good amount of nitrogen in the soil and compensate for the leaching effect due to intense rainfall. On the contrary of temperate and boreal soils which often lack nitrogen, tropical soils are frequently poor in phosphorus. Despite their acidity, equatorial soils may be very fertile. Their fertility depends on a closed nutrient cycle between living biomass and topsoil. This biological phenomenon explains the relative fragility of the equatorial Mull systems when the growing biomass is exported by deforestation, letting a humus system that rapidly lacks essential nutriments and collapses…

2.2. General characters and distribution of Moder

- ecological conditions: mild to moderately cold climate, frequently on acidic substrate;
- dominant actors of biodegradation: arthropods, epigeic earthworms and enchytraeids; fungi;
- actors' action: slow biodegradation (2–7 years), carbon stocked in both organic and organic-mineral horizons;
- pH_{water} of the A horizon: generally < 4.5;
- key diagnostic characters: OH always present (presence includes discontinuous presence too), nozOF never present, biomicro A, massive or single grain A, gradual transition (≥ 5 mm) between organic and organic-mineral horizons.

Nota Bene: When erosion bring away organic horizons, or in case of evolution from Moder toward Mull and absence of OH horizon, it is necessary to focus on the structure of the A horizon and/or to observe equivalent humipedons in areas not altered by erosion.

2.3. General characters and distribution of Amphi

- ecological conditions: strongly seasonal climate conditions (dry summer or winter frost), generally on calcareous and/or dolomitic or nutrient-rich substrate; an artificial substitution of vegetation, with a consequent shift from rich and palatable broad-leaf litter (C/N < 20) to recalcitrant coniferous litter (C/N>40), leads generally to a transformation of the original Mull into Amphi (this dynamic process can also generate a Moder on acidic substrates or in cold climate conditions);
- dominant actors of biodegradation: endogeic and/or anecic earthworms in the organic-mineral horizon; arthropods, enchytraeids and epigeic earthworms in the organic horizons; fungi;
- actors' action: slow biodegradation (2–7 years), high carbon content in both organic and organic-mineral horizons;
- pH_{water} of the A horizon: generally ≥ 5;
- key diagnostic characters (morpho-functional result of specific biological activities): OH always present, nozOF never present, thickness of A horizon ≥ ½ OH; biomacro A and sharp

transition (< 5 mm) between organic and organic-mineral horizons, or biomeso A (biomicro A possible in addition to biomeso A) and no sharp transition (≥5 mm) between organic and organic-mineral horizons.

2.4. General characters and distribution of Mor

- ecological conditions: cold climate, and/or very nutrient-poor siliceous substrate (mostly sand or sandstone), poorly degradable litter (rich in resins and/or phenols, thick cuticle, C/N > 40);
- dominant actors of biodegradation: fungi (mostly mycorrhizal) and other non-faunal processes;
- actors' action: very slow biodegradation (> 7 years), highest carbon content in organic horizons;
- pH_{water} of E or AE or A horizon < 4.5;
- key diagnostic characters (morpho-functional result of specific biological activities): nozOF (always present but sometimes difficult to recognize especially in wet conditions), E horizon or massive A or single-grain A, very sharp transition (< 3 mm) between organic and organic-mineral (or mineral) horizons.

2.5. General characters and distribution of Tangel

- ecological conditions: mountain humid climate (subalpine or upper montane belts) on hard limestone and/or dolomite rock/rock fragments;
- dominant actors of biodegradation: epigeic earthworms, enchytraeids and arthropods within organic horizons; fungi;
- actors' action: very slow biodegradation (> 7 years), carbon stocked mainly in organic horizons;
- if presence of A horizon: pH_{water} of the A horizon ≥5;
- key diagnostic characters (morpho-functional result of specific biological activities): nozOF never present but thick organic horizons [(zoOF +OH) > 10 cm], if presence of A horizon: thickness of A horizon < ½ OH; A biomeso or A massive.

In Table 1, the main diagnostic horizons and their specific features are synthetically associated to the main Terrestrial humus systems.

3. Key of classification of humus FORMS

In this new version of the key of classification of humus forms, we added a Tangel form and the names of the three Tangel forms were changed in order to fit with the corresponding forms of an Amphi system. The prefix “Dys” (reminiscent of poor nutrient availability) was abandoned because not suited for a humus form that can be even calcareous.

Terrestrial humus forms correspond to the topsoil never submerged and/or water saturated, or only for a few days per year, having:

Step 1

1) Organic zoogenic horizons present and thick (zoOF + OH)> 10 cm; and

2) nozOF absent; and

3) Hard limestone and/or dolomite rock fragments in or at the bottom of the humus profile; and

4) A horizon absent or present. If present:

4) Biomeso A; and A < 1/2 OH

or

4) Massive A horizon and both the following:

- A < 1/2 OH;
- pH_{water} of A ≥ 5

TANGEL (Fig. 1), and either:

a) thickness of organic horizons (zoOF + OH)>50 cm: **Pachytangel** (Fig. 2);

b) thickness of organic horizons (zoOF + OH) comprised between 15 and 50 cm: **Eutangel** (Figs. 3a and b)

c) thickness of organic horizons (zoOF + OH) < 15 cm: **Leptotangel** (Fig. 4).

OR

Step 2

1) never A biomeso or biomacro or biomicro; and

2) presence of nozOF and one of the following:

- pH_{water} of E or AE or A horizon < 4.5;
- A absent, or A massive, or A single grain,

or

2) presence of OH horizon in very sharp (< 3 mm) transition to A, AE or E horizon and one of the following:

- pH_{water} of E or AE or A horizon < 4.5;
- A absent, or A massive, or A single grain.

MOR (Fig. 5) and either:

a) nozOF continuous, OH absent: **Eumor** (Fig. 6),

b) nozOF continuous, OH present and continuous: **Humimor** (Fig. 7),

c) nozOF discontinuous and OH present and continuous: **Hemimor** (Fig. 8),

OR

Step 3

Other topsoils, never submerged and/or water saturated, or only for a few days per year, having:

1) OH horizon present (even if sometimes discontinuous); and

2) nozOF absent; and

3) Biomacro A horizons absent; and

4) Biomeso or biomicrostructured, or massive, or single grain A horizon present, and one of the following:

- Gradual transition OH/A horizon (transition ≥ 5 mm); or
- pH_{water} of the A horizon < 5

MODER (Fig. 9) and either:

a) Biomeso A absent, OH horizon continuous and ≥ 1 cm, **Dysmoder** (Fig. 10),

b) Biomeso A absent, OH horizon continuous and < 1 cm, **Eumoder** (Fig. 11),

c) Massive or single grain A absent, OH horizon discontinuous or in pockets, **Hemimoder** (Fig. 12),

OR

Step 4

Other topsoils, never submerged and/or water saturated, or only a few days per year, having:

1) nozOF horizon absent; and

2) Thickness of A horizon> ½ that of OH horizon;

and either:

3) OH and biomeso A horizons present; and one of the following:

- Living earthworms (or freshly deposited earthworm faeces) in the A horizon; or
- Gradual transition (≥5 mm) between A and OH horizons; or
- pH_{water} of the A horizon ≥ 5;

AMPHI (Fig. 13) and either:

a) OH horizon ≥ 3 cm, **Pachyamphi** (Fig. 14),

b) OH horizon < 3 cm, **Eumesoamphi** (Fig. 15),

or

3) OH and biomacro A horizons present; and one of the following:

- Living earthworms (or freshly deposited earthworm faeces) in the A horizon; or
- Sharp (< 5 mm) transition between OH and A horizons; or
- pH_{water} of the A horizon ≥ 5

AMPHI and either:

c) OH horizon ≥ 1 cm, **Eumacroamphi** (Figs. 16a and b),

d) OH horizon < 1 cm, **Leptoamphi** (Fig. 17),

OR

Step 5

Other topsoils, never submerged and/or water saturated, or only a few days per year, having:

1) OH horizon absent; and

2) Biomacro A horizon present; or

2) Biomeso A horizon present and at least two of the following:

- Presence in the A horizon of living earthworms or their casts, except in frozen or desiccated soil;
- Presence of a very sharp transition (< 3 mm) between organic and organic-mineral horizons;
- pH_{water} of the A horizon > 5

MULL (Fig. 18) and either:

a) OF horizon present and continuous, **Dysmull** (Fig. 19),

b) OF horizon missing or discontinuous and vOL horizon continuous and thick, **Oligomull** (Figs. 20a and b),

c) OF horizon missing and vOL horizon present but discontinuous, **Mesomull** (Fig. 21),

d) OF and vOL horizons missing, **Eumull** (Figs. 22a and b)

The name of a humus forms is written in a single word, beginning with a capital letter. Example: Eumull, not Eu Mull, not Eu-Mull, not Eu-mull, not eumull.

We strongly suggest adding survey date and geographic coordinates to the name as minimum information in a dataset.

Example July 2016 − Eumull − long +44.28.59; lat +09.41.25.

3.1. Tangel status and comparison with thickness of Amphi diagnostic horizons

It is sometimes difficult to distinguish Amphi and Tangel. They gradually pass the one into the other. Subjectively, it was decided to consider the relative thickness of A and OH horizons (Fig. 23) for distinguishing a system (Amphi) with strong biological activity in both organic-mineral (A) and organic (OH, OF, OL) horizons, from another system (Tangel) with strong activity only in the organic horizons. Amphi is generated even at low altitude, in Mediterranean climates; Tangel develops only at high altitude, in alpine or subalpine climates. We think that the low temperatures of these mountain climates (and the consequent low rate of rock weathering) does not allow the formation of mineral soil, resulting in a lack of habitat for large anecic earthworms (which live in depth during the bad season) and the evolution of the Tangel toward an Amphi humus form. Considering that temperature could be of minor importance in soil development with respect to rainfall, an alternative explanation could be that Tangels develop on carbonates and therefore on parent material that are easily dissolved, but because of their chemical composition (theoretically no Si and Al), soil minerals can only form from the impurities contained in calcite or dolomite.

3.2. Field dichotomic key of classification

This field key (Fig. 24) is elaborated starting from a French classification (Jabiol et al., 2007), completed with Amphi and Tangel forms (Zanella et al., 2011a, 2011b), updated with new codes horizons and slight modifications (R.-C. Le Bayon, unpublished), completed in September 2016 by A. Zanella, J.F. Ponge, B. Jabiol and M. Auber considering Histo and Para systems, pedofauna features and presence/absence of A diagnostic horizons.

In general, the criteria for humus system classification are assimilated by heart after few utilisations of the indications reported in Section 1. It is a good habitude to control whether the detected systems fit the main criteria reported in Section 2. If incoherence between systems classified with Section 1 and described in Section 2, a second attempt of classification may be necessary. Each humus system is shared in a few humus forms which range in intergrades and create bridges between systems. A doubtful situation can be solved using two names of humus forms and evaluating the surface occupied by each of them. The faster way for recognizing a humus form is to pass through the key of Section 3, at the level of the right humus system, or go straight to the tables with annexed photographs (Section 3).

The dichotomic field key (Fig. 24) is built considering even essential biological data. It is cautious to use biological criteria after acquiring some experience in the field, following the instructions of an expert. In Humusica 1, article 8, curious autodidacts may find supplementary information about pedofauna, droppings and other biological features related to each terrestrial humus system. The dichotomic field key is a very efficient mean for a rapid and sure field classification of humus systems and forms.

Authors' contributions

A. Zanella, J.-F. Ponge, B. Jabiol, G. Sartori, E. Kolb, J.-M. Gobat, R.-C. Le Bayon, M. Aubert, R. De Waal: redaction of the text and elaboration of the key of classification.

Other authors: re-lecture and correction of the text, participation to researches and meetings, field investigations, discussions for improvements of the content of key and article.

Not cited author of photographs: A. Zanella.

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Figure captions

Fig. 1. Tangel system and forms. Table: diagnostic horizons in line, sequence as in real profile; humus forms in columns: Pachytangel, Eutangel, Leptotangel. Profile: Typic Tangel diagnostic horizons with very thick OF and OH horizons. Earthworms generating an A horizon may be present at the bottom in contact with the bedrock or between rock blocks (photograph of the humus profile: E. Kolb).

Fig. 2. Pachytangel or Bryo Pachytangel considering the moss carpet (refer to Humusica 2, article 13 for a detailed description of Bryo humus systems and intergrades to Terrestrial humus systems). Thickness of OF + OH horizons > 50 cm (photograph, E. Kolb).

Fig. 3. Eutangel. Thickness of OF + OH horizons about 30 cm, less than 50 cm. a) OF and OH horizons directly on hard calcareous bedrock; b) OF and OH horizons within a loose accumulation of dolomitic rock.

Fig. 4. Leptotangel or Bryo Leptotangel considering the moss carpet (refer to Humusica 2, article 13 for a detailed description of Bryo humus systems).

Fig. 5. Mor system and forms. Table: diagnostic horizons in line, sequence as in real profile; humus forms in columns: Hemimor, Humimor, Eumor. Profile: Typic Mor diagnostic horizons with sharp transition between organic OH and mineral E horizons. Common on Podzols, as in this picture.

Fig. 6. Eumor or Bryo Eumor, considering the overlying moss carpet (see chapter 2.2 in Humusica 2, article 13). nozOF (with yellow fungal hyphae) is dominant in the organic layer; sharp transition with an E mineral horizon at the bottom.

Fig. 7. Humimor. Presence of a thick organic layer with a thick black nozOH horizon; sharp transition with the mineral light grey horizon of a Podzol.

Fig. 8. Hemimor. Sharp transition between a thin organic nozOH and a mineral clear E horizon.

Fig. 9. Moder system and forms. Table: diagnostic horizons in line, sequence as in real profile; humus forms in columns: Hemimoder, Eumoder, Dysmoder. Profile: Typic Moder diagnostic horizons with gradual transition between organic OH and organic-mineral A horizons. Common on Luvisols, as in this picture.

Fig. 10. a) Dysmoder. Alpine, between the dark brown OH and clear E horizons it is possible to notice the presence of a black organic-mineral A horizon, in gradual transition with the above OH horizon. b) Dysmoder. Brown organic OH horizon in gradual transition with a clearer organic-mineral A horizon in a Mediterranean forest ecosystem.

Fig. 11. Eumoder. Thin continuous OH horizon over a thin organic-mineral biomicrostructured A horizon, in a Mediterranean forest ecosystem.

Fig. 12. Hemimoder. Discontinuous OH horizon laying over an organic-mineral biomicrostructured A horizon. a) Earthworms can consume all the OH horizon which becomes discontinuous; b)

two types of A horizons are often possible: dark and thin at the soil surface, clearer und thick in contact with the mineral part of the soil profile.

Fig. 13. Amphi system and forms. Table: diagnostic horizons in line, sequence as in real profile; humus forms in columns: Leptoamphi, Eumacroamphi, Eumesoamphi, Pachyamphi. Profile: Typic Amphi diagnostic horizons with biological organic OH and organic-mineral A horizons.

Fig. 14. Pachyamphi. Thick brown zoOH horizon in gradual transition to an organic-mineral biomesostructured A horizon, (unfortunately the structure is not visible on the picture) in a Mediterranean forest ecosystem.

Fig. 15. Eumesoamphi. Thick but < 3 cm black organic zoOH horizon in gradual transition to a brown-grey thick organic-mineral biomesostructured A horizon; In an Alpine pure spruce forest, on calcareous lithopedon.

Fig. 16. Eumacroamphi. Large aggregates in a grey organic-mineral biomacrostructured A horizon, overlaid by a black OH horizon. a) In a broadleaf and coniferous forest, b) in a beech forest, both in the Alps on calcareous lithopedon.

Fig. 17. Leptoamphi. Like a Mull, but with a thin OH horizon covering the biomacrostructured A horizon. In an Alpine beech forest.

Fig. 18. Mull system and forms. Table: diagnostic horizons in line, sequence as in real profile; Humus forms in columns: Names of humus forms in Mull system: Eumull, Mesomull, Oligomull, Dysmull. Profile: Typic Mull diagnostic horizons, absence of OH horizon, gradual change in the colour of the A horizon, darker at the top.

Fig. 19. Dysmull. Presence of a continuous OF horizon overlying a biomacrostructured A horizon.

Fig. 20. Oligomull. a) Presence of a discontinuous OF horizon overlying a biomesostructured A horizon. b) Oligomull. Presence of pockets of OF horizon.

Fig. 21. Mesomull. Absence of any OH and OF horizons. Presence of a continuous OL horizon (grass leaves in this case) and a discontinuous vOL horizon.

Fig. 22. Eumull. a) absence of OH, OF and vOL horizons, presence of a discontinuous nOL and a crumby maA horizon visible even at the surface. b) Presence of a biomacrostructured maA horizon. The horizon is generally darker at the surface because the numerous anecic earthworms living in this humipedon progressively integrate the litter in the underlying soil by moving vertically through the soil profile. c) typical biomacrostructure of a Mull A horizon.

Fig. 23. Amphi and Tangel. Amphi and Tangel can be distinguished considering the relative thickness of A and OH horizons. Amphi =thickness A ≥ OH/2; Tangel = thickness OH > 2 x A. Tangel can also be without an A horizon.

Fig. 24. Dichotomic key of classification of Terrestrial Humus systems and Forms. The first bifurcation shares (or separates) Terrestrial from Histic, Aqueous and Para systems. Specific articles have been prompted for these hydromorphic or specialized complex systems, which are collected in Humusica 2, articles 9, 12 and 13, respectively. Slightly different from the keys reported in

the text of this article, this simplified Terrestrial field key requires some field experience but allows a faster, equivalent, correct classification. Legend: zo= zoogenic; noz = non zoogenic; szo =slightly zoogenic. Example: nozA corresponds to a non-zoogenic A horizon, which groups msA (massive A) and sgA (single grain A). For rigorous definitions of all diagnostic horizons and criteria of classification, please refer to Humusica 1, article 4, in which pictures and tables solve a large number of doubts raised during field activities of humipedon classification.

Table 1
Diagnostic horizons and features of the five Terrestrial humus systems (five references = biological activity types). In the table, the adjectives "active" or "inactive" refer to the presence or absence of living organisms in the diagnostic horizons.

Diagnostic horizons		MULL	MODER	AMPHI	MOR	TANGEL
OL		possible	present	present	present	present
OF		possible, zoogenically transformed	present, zoogenically transformed, active, with living organisms	present, zoogenically transformed, active, with living organisms	not zoogenically transformed always present even if sometimes discontinuous; zoogenically transformed possible (accompanied), inactive or partially active	present, zoogenically transformed, active, with living organisms
OH		absent	present, active, sometimes discontinuous	present, active, thick (but ≤ 2 times thickness of A)	present or absent, if present: inactive or partially active	present, inactive or partially active, thick (> 2 times thickness of A)
Transition O/A or O/AE or O/E		very sharp (< 3 mm)	not sharp (≥ 5 mm)	if A biomacro: sharp (< 5 mm) if A biomeso: not sharp (≥ 5 mm)	very sharp (< 3 mm)	Not discriminant
A		biomacro or biomeso	biomeso or biomicro or single grain or massive	biomacro or biomeso, biomeso accompanied by biomicro possible	absent (= E) or present, if present: not zoogenic or discontinuously biomicro.	absent or: present. If present : massive or biomeso
Horizon of dominant faunal activity		A (anecic and endogeic earthworms)	OF (feeding) OH (accumul. droppings)	OF (feeding) OH (accumul. droppings) A (earthworms)	OH (weak or traces of old activity)	OF (feeding) OH (feeding and accumulated droppings)
Earthworms	Organic horizons	Epigeic and Anecic	Epigeic	Epigeic	Epigeic absent or rarely present	Epigeic possible
	Organo-mineral horizon	Endogeic and Anecic	absent	Endogeic and/or Anecic	absent	Endogeic possible

DIAGNOSTIC HORIZONS Trans: O-A		TANGEL		
HYDRO	(typical)	Leptotangel	Eutangel	Pachytangel
gOL, gOF posble not sufficient, gOH sufficient for Hydro prefix	nOL	possible and not discriminant		
	vOL			
	nozOF			
	zoOF	OF+OH < 15 cm OH > 2A	OF+OH = 15-50 OH > 2A	OF+OH > 50 cm OH > 2A
	szoOH			
	zoOH			
Transition O-A (mm)		not discriminant		
gAE, gnozA, gzoA (gmaA, gmeA, gmiA) sufficient for Hydro prefix	AE, EA			
	nozA	possible msA < OH/2 (*)		
	miA			
	meA	OR possible meA < OH/2		
	maA			

(*) Mandatory in Tangel: pHwater of nozA = msA ≥ 4.5

Possible hydromorphic (g) terrestrial diagnostic horizons

Terrestrial diagnostic horizons

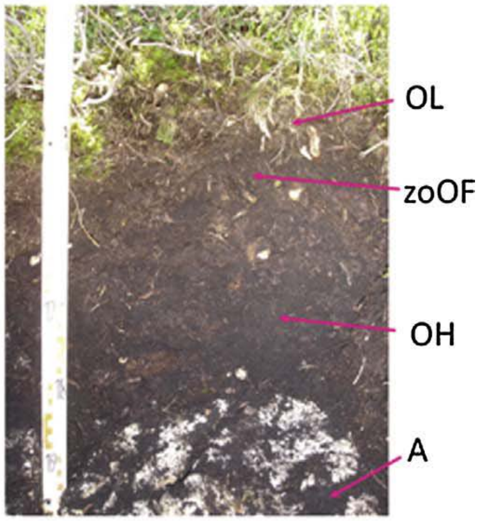


Fig. 1

Fig. 2

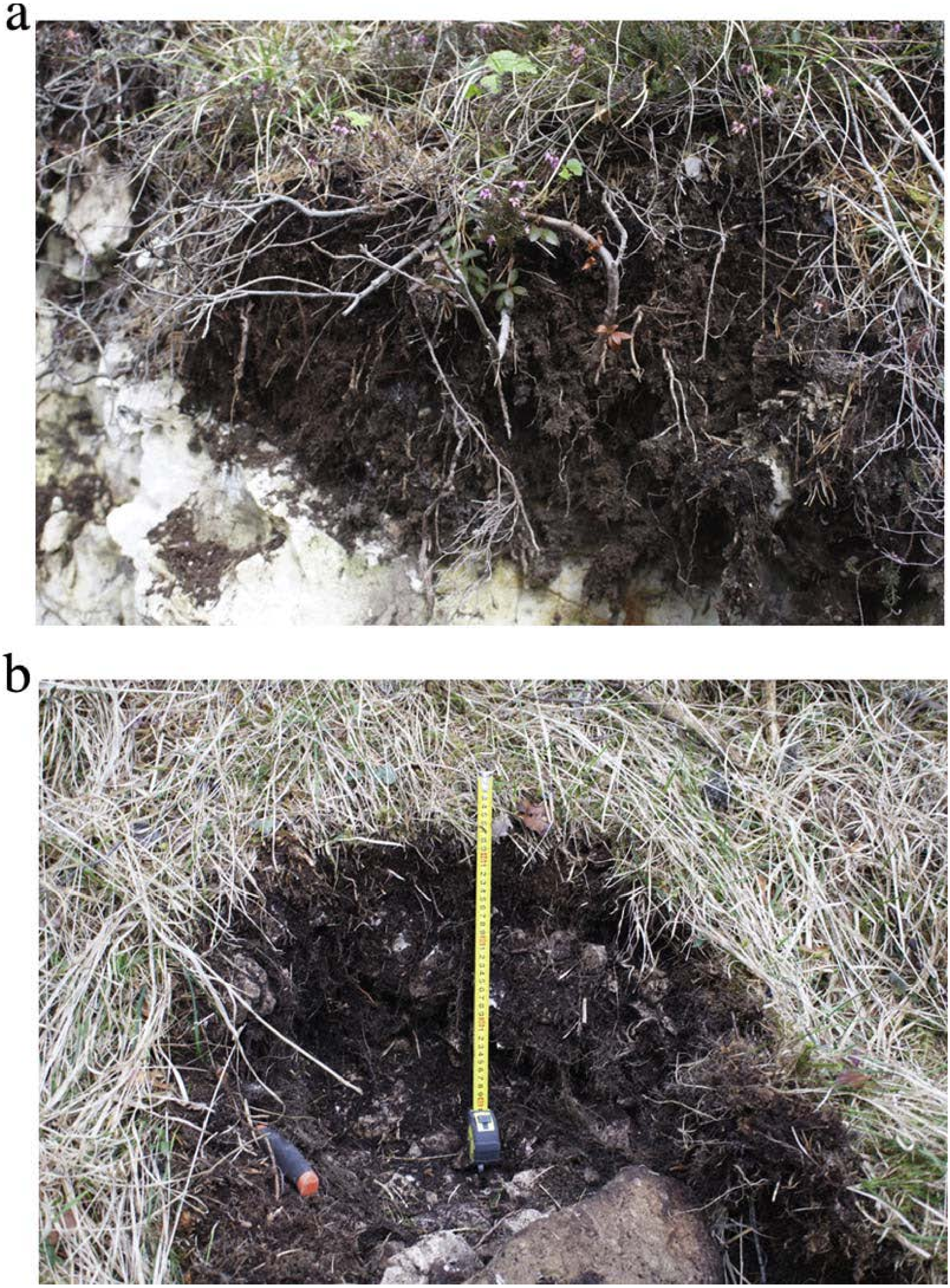


Fig. 3

Fig. 4

DIAGNOSTIC HORIZONS Trans: O-A		MOR		
HYDRO	(typical)	Hemimor	Humimor	Eumor
gOL, gOF posble not sufficient, gOH sufficient for Hydro prefix	nOL	possible and not discriminant		
	vOL			
	nozOF	disc pock		
	zoOF	possible		
	szoOH			possible
	zoOH	possible		
Transition O-A (mm)		< 3 mm (*)		
gAE, gnozA, gzoA (gmaA, gmeA, gmiA) sufficient for Hydro prefix	AE, EA	OR		
	nozA	A absent OR sgA, OR msA		
	miA			
	meA			
	maA			

(*) mandatory < 3 mm

disc pock = discontinuous or in pockets

Possible hydromorphic (g) terrestrial diagnostic horizons

Terrestrial diagnostic horizons

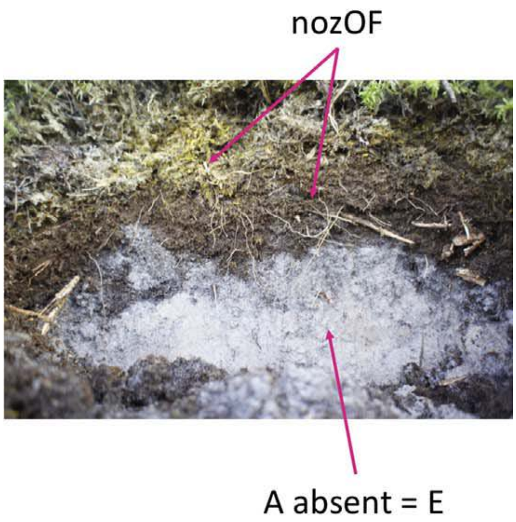


Fig. 5

Fig. 6

Fig. 7

Fig. 8

DIAGNOSTIC HORIZONS Trans: O-A		MODER		
HYDRO	(typical)	Hemimoder	Eumoder	Dysmoder
gOL, gOF posble not sufficient, gOH sufficient for Hydro prefix	nOL	possible and not discriminant		
	vOL			
	nozOF			
	zoOF			
	szoOH			possible
	zoOH	disc pock	≤ 1 cm	> 1 cm
Transition O-A (mm)		≥ 5 mm (*)		
gAE, gnozA, gzoA (gmaA, gmeA, gmiA) sufficient for Hydro prefix	AE, EA			OR
	nozA		sgA, msA	
	miA		OR	
	meA	OR		
	maA			

(*): or pH of A < 5

disc pock = discontinuous or in pockets

Possible hydromorphic (g) terrestrial diagnostic horizons

Terrestrial diagnostic horizons

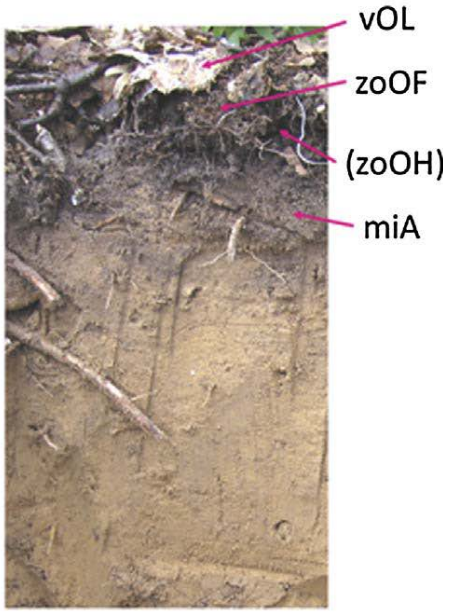


Fig. 9

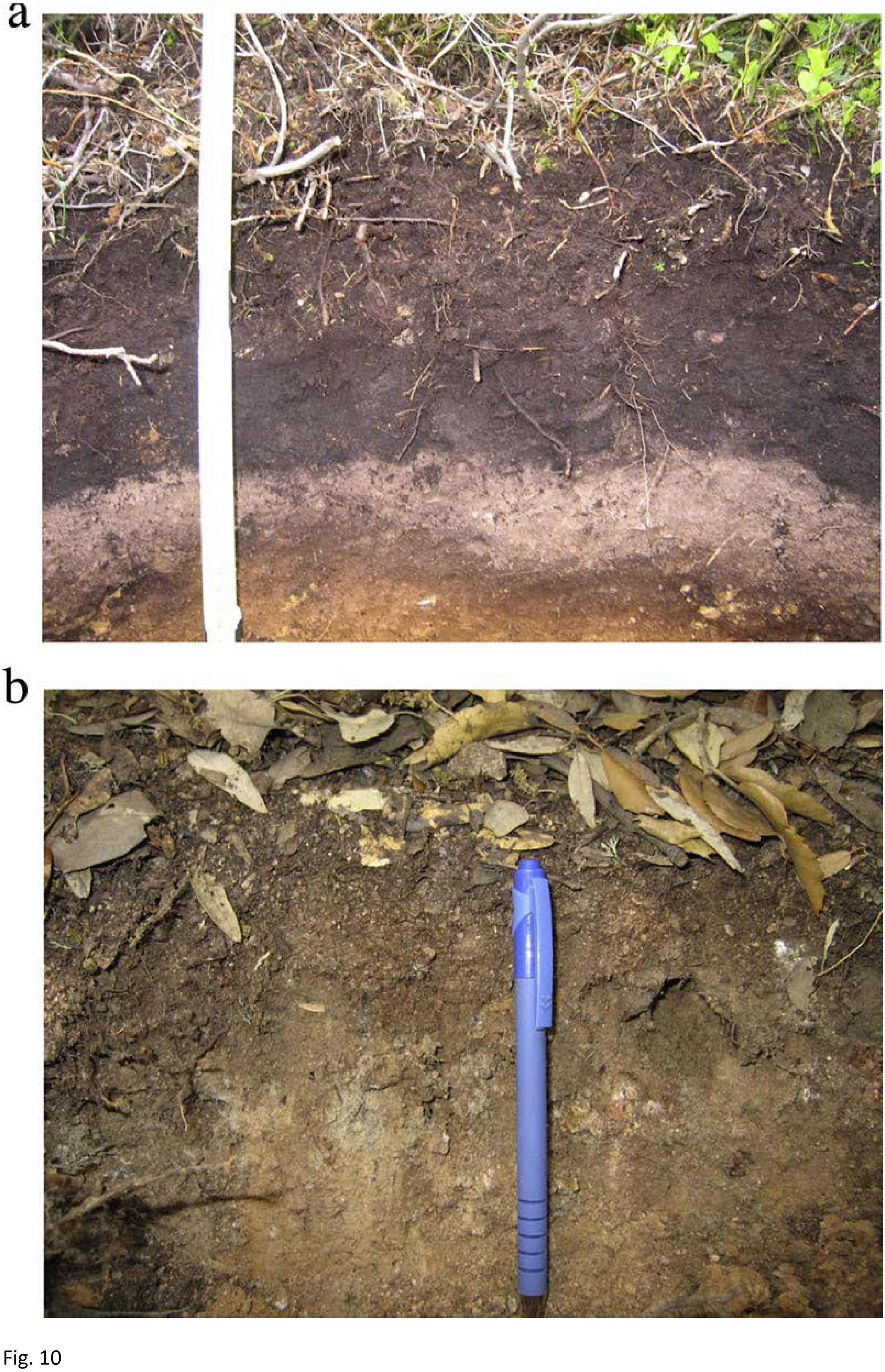


Fig. 10

Fig. 11

Fig. 12

DIAGNOSTIC HORIZONS Trans: O-A		AMPHI			
HYDRO	(typical)	Leptoamphi	Eumacroamphi	Eumesoamphi	Pachyamphi
gOL, gOF posble not sufficient, gOH sufficient for Hydro prefix	nOL	possible and not discriminant			
	vOL				
	nozOF				
	zoOF				
	szoOH				possible
	zoOH	< 1 cm or disc	≥ 1 cm	< 3 cm	≥ 3 cm
Transition O-A (mm)		< 5 (*)		≥ 5 (**)	
gAE, gnozA, gzoA (gmaA, gmeA, gmiA) sufficient for Hydro prefix	AE, EA				
	nozA				
	miA			miA AND meA ≥ OH/2	
	meA			OR ONLY meA ≥ OH/2	
	maA	A ≥ OH/2			

(*) or living earthworms (or freshly deposited earthworm faeces) in the A horizon; or pHwater of the A horizon ≥ 5.

(**) or living earthworms (or freshly deposited earthworm faeces) in the A horizon; or pHwater of the A horizon ≥ 5.

disc = discontinuous

Possible hydromorphic (g) terrestrial diagnostic horizons

Terrestrial diagnostic horizons

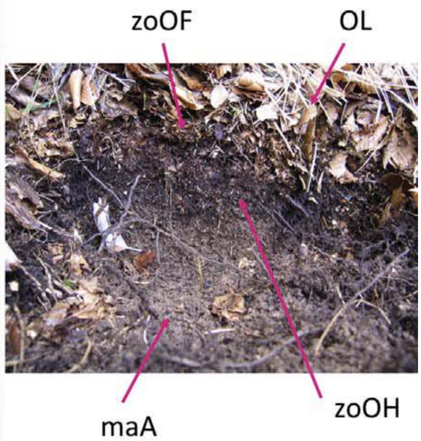


Fig. 13

Fig. 14

Fig. 15

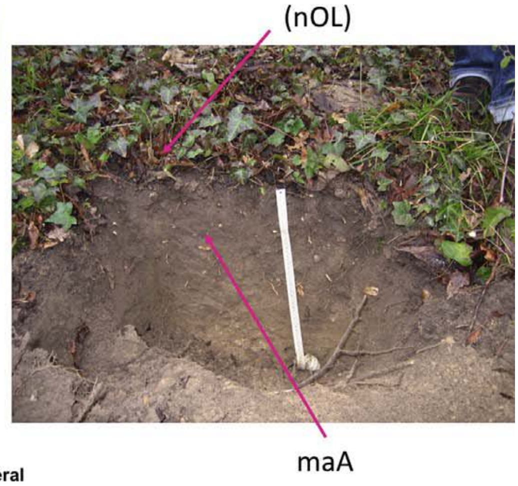
a

b

Fig. 16

Fig. 17

DIAGNOSTIC HORIZONS Trans: O-A		MULL			
HYDRO	(typical)	Eumull	Mesomull	Oligomull	Dysmull
gOL, gOF posble not sufficient, gOH sufficient for Hydro prefix	nOL	disc pock			
	vOL		disc pock		
	nozOF				
	zoOF			disc pock	
	szoOH				
	zoOH				
Transition O-A (mm)		< 3 (*)			
gAE, gnozA, gzoA (gmaA, gmeA, gmiA) sufficient for Hydro prefix	AE, EA				
	nozA				
	miA				
	meA			OR	
	maA				



(*) at least two of the following:

1) Presence of a very sharp transition (< 3 mm) between organic and organo-mineral horizons;

2) Presence in the A horizon of living earthworms or their casts, except in frozen or desiccated soil;

3) pHwater of the A horizon > 5

disc pock = discontinuous or in pockets

Possible hydromorphic (g) terrestrial diagnostic horizons

Terrestrial diagnostic horizons

Fig. 18

Fig. 19

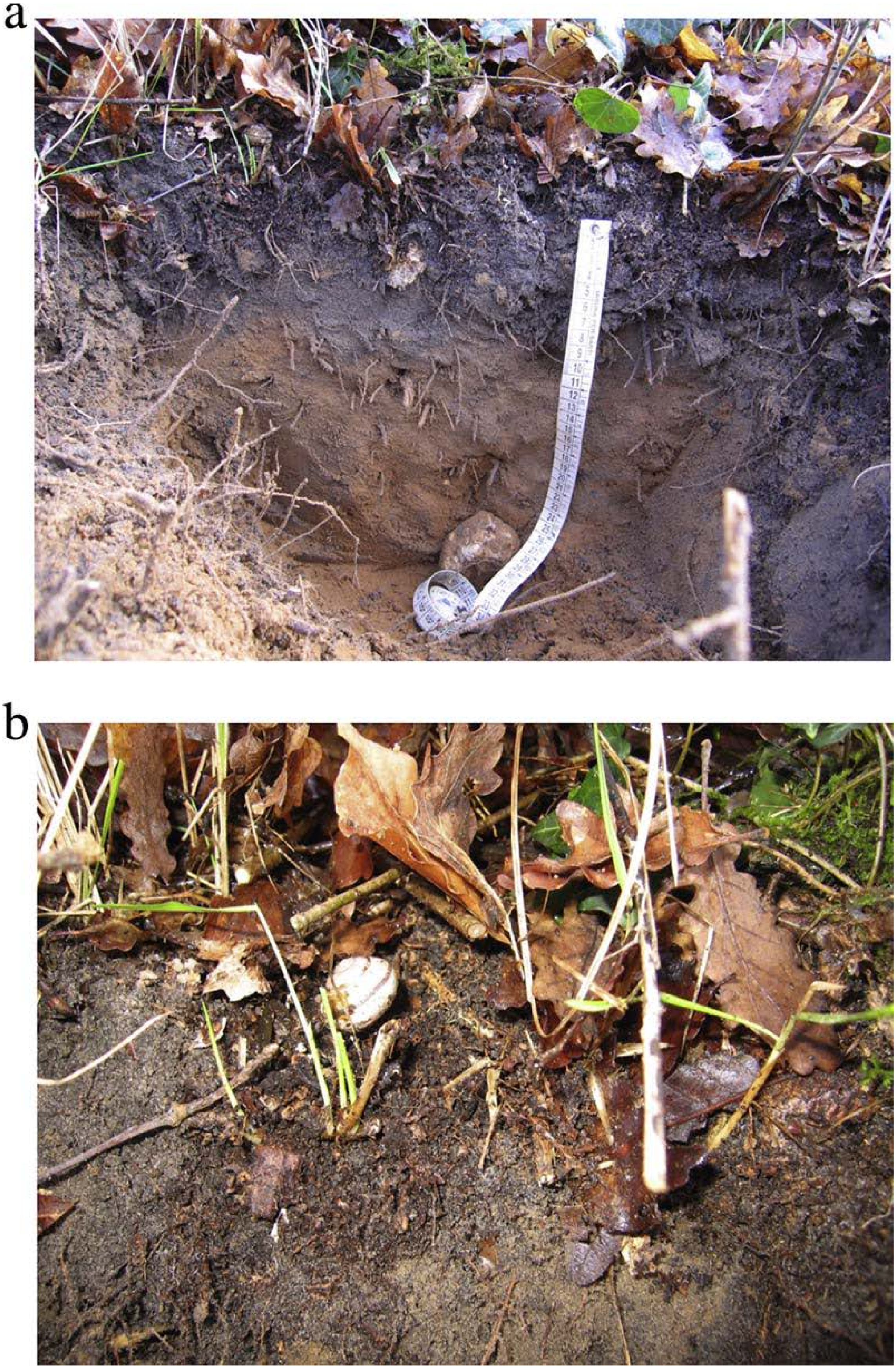


Fig. 20

Fig. 21

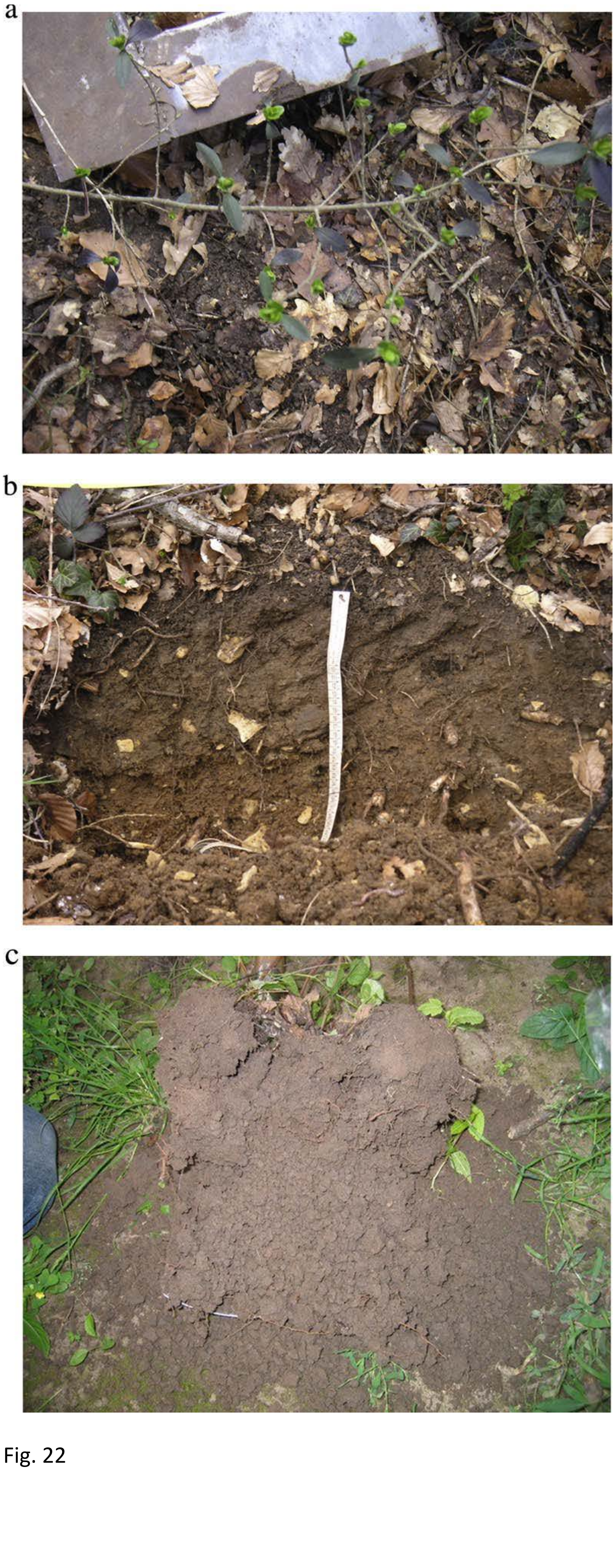


Fig. 22

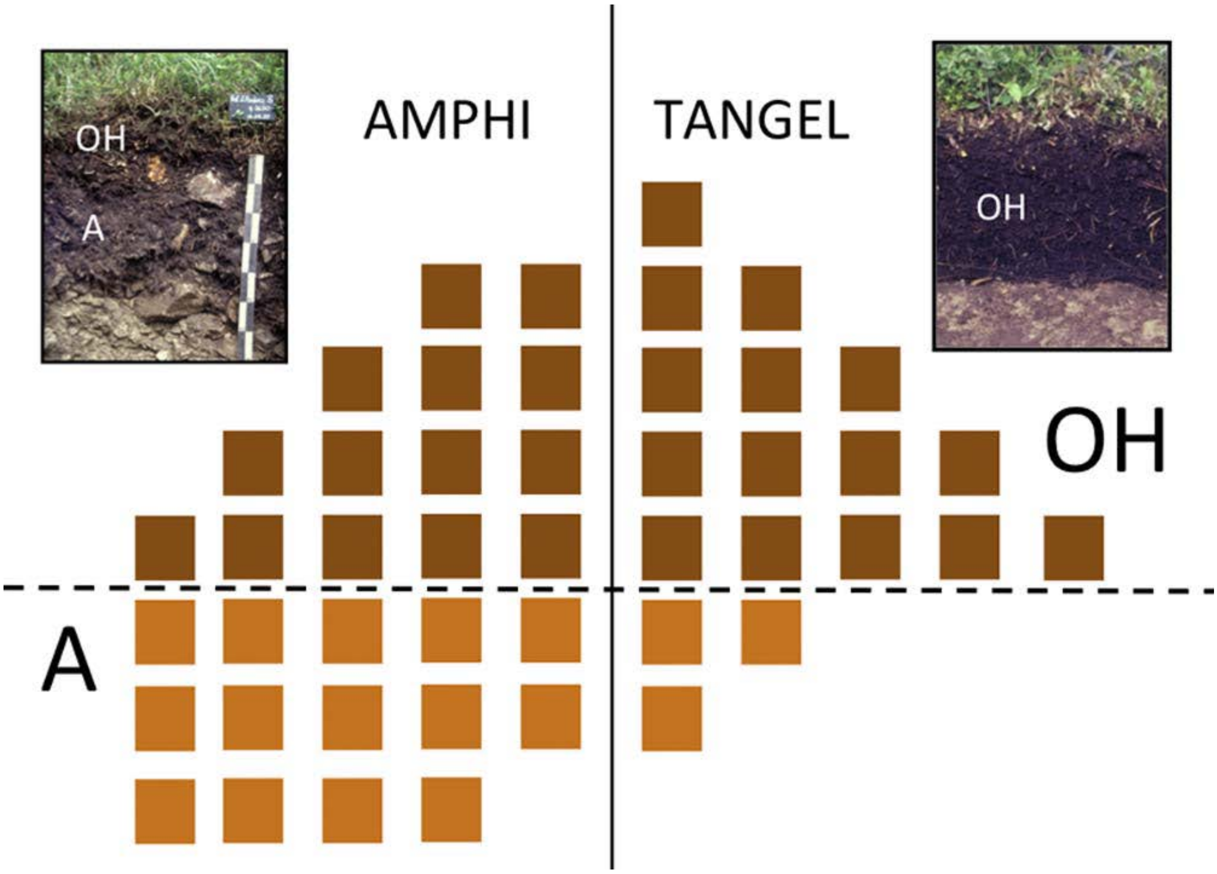


Fig. 23

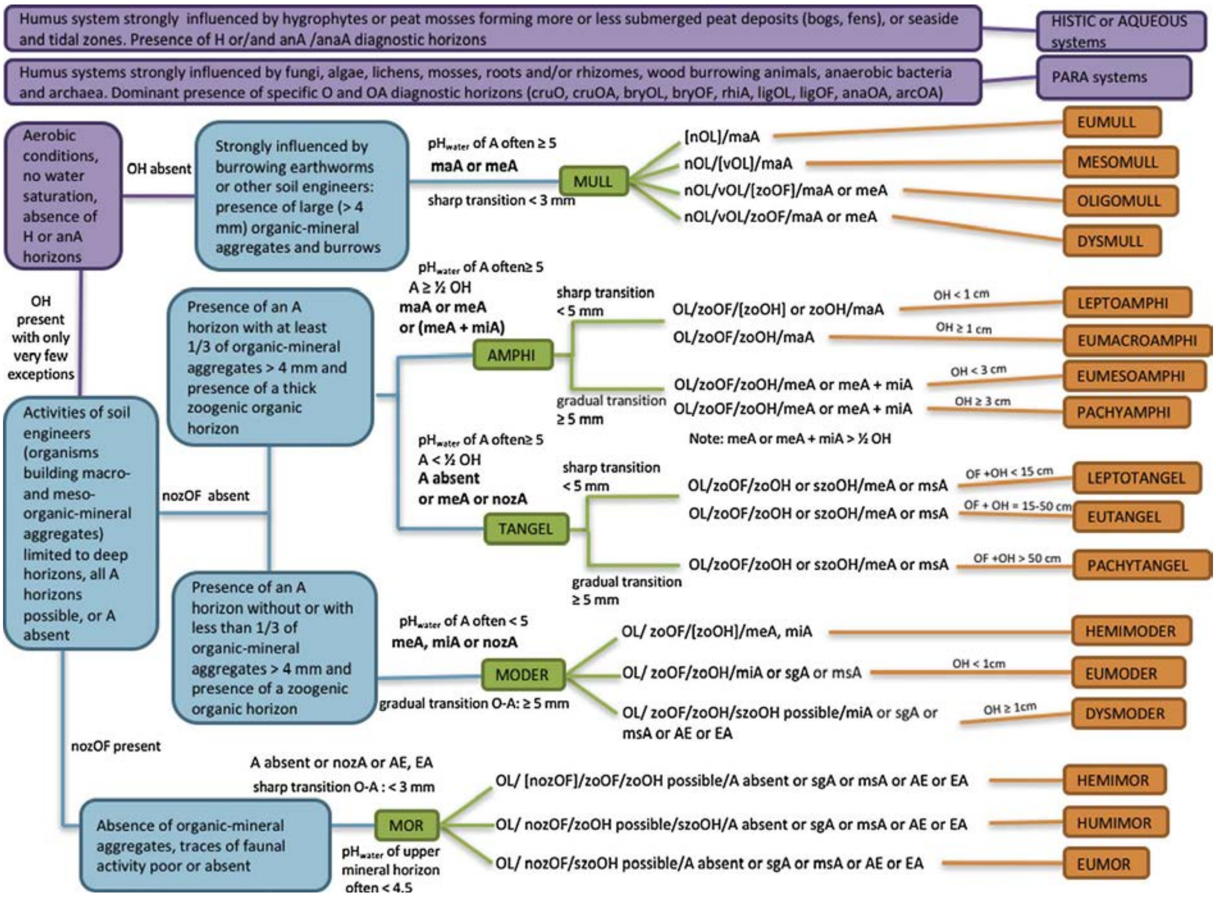

Humus system strongly influenced by hygrophytes or peat mosses forming more or less submerged peat deposits (bogs, fens), or seaside and tidal zones. Presence of H or/and anA /anaA diagnostic horizons
HISTIC or AQUEOUS systems
Humus systems strongly influenced by fungi, algae, lichens, mosses, roots and/or rhizomes, wood burrowing animals, anaerobic bacteria and archaea. Dominant presence of specific O and OA diagnostic horizons (cruO, cruOA, bryOL, bryOF, rhiA, ligOL, ligOF, anaOA, arcOA)
PARA systems
Aerobic conditions, no water saturation, absence of H or anA horizons
OH absent
Strongly influenced by burrowing earthworms or other soil engineers: presence of large (> 4 mm) organic-mineral aggregates and burrows
pHwater of A often ≥ 5
maA or meA
sharp transition < 3 mm
MULL
[nOL]/maA
nOL/[vOL]/maA
nOL/vOL/[zoOF]/maA or meA
nOL/vOL/zoOF/maA or meA
EUMULL
MESOMULL
OLIGOMULL
DYSMULL
OH present with only very few exceptions
Presence of an A horizon with at least 1/3 of organic-mineral aggregates > 4 mm and presence of a thick zoogenic organic horizon
pHwater of A often≥ 5
A ≥ ½ OH
maA or meA
or (meA + miA)
AMPHI
sharp transition < 5 mm
OL/zoOF/[zoOH] or zoOH/maA
OL/zoOF/zoOH/maA
OL/zoOF/zoOH/meA or meA + miA
gradual transition ≥ 5 mm
OL/zoOF/zoOH/meA or meA + miA
Note: meA or meA + miA > ½ OH
OH < 1 cm
OH ≥ 1 cm
OH < 3 cm
OH ≥ 3 cm
LEPTOAMPHI
EUMACROAMPHI
EUMESOAMPHI
PACHYAMPHI
Activities of soil engineers (organisms building macro- and meso-organic-mineral aggregates) limited to deep horizons, all A horizons possible, or A absent
nozOF absent
pHwater of A often≥ 5
A < ½ OH
A absent
or meA or nozA
TANGEL
sharp transition < 5 mm
OL/zoOF/zoOH or szoOH/meA or msA
OL/zoOF/zoOH or szoOH/meA or msA
gradual transition ≥ 5 mm
OL/zoOF/zoOH or szoOH/meA or msA
OF +OH < 15 cm
OF + OH = 15-50 cm
OF +OH > 50 cm
LEPTOTANGEL
EUTANGEL
PACHYTANGEL
Presence of an A horizon without or with less than 1/3 of organic-mineral aggregates > 4 mm and presence of a zoogenic organic horizon
pHwater of A often < 5
meA, miA or nozA
MODER
gradual transition O-A: ≥ 5 mm
OL/ zoOF/[zoOH]/meA, miA
OL/ zoOF/zoOH/miA or sgA or msA
OL/ zoOF/zoOH/szoOH possible/miA or sgA or msA or AE or EA
OH < 1cm
OH ≥ 1cm
HEMIMODER
EUMODER
DYSMODER
nozOF present
A absent or nozA or AE, EA
sharp transition O-A : < 3 mm
Absence of organic-mineral aggregates, traces of faunal activity poor or absent
MOR
pHwater of upper mineral horizon often < 4.5
OL/ [nozOF]/zoOF/zoOH possible/A absent or sgA or msA or AE or EA
OL/ nozOF/zoOH possible/szoOH/A absent or sgA or msA or AE or EA
OL/ nozOF/szoOH possible/A absent or sgA or msA or AE or EA
HEMIMOR
HUMIMOR
EUMOR

Fig. 24