

TerrHum: An iOS Application for Classifying Terrestrial Humipedons and Some Considerations about Soil Classification

A. Zanella*

Univ. di Padova
Dip. TESAF
Viale Dell Univ.
16, 35020 Legnaro, Italy

K. Katzensteiner*

Univ. of Natural Resources and Life Sciences Vienna
Dep. of Forest and Soil Sciences
Peter Jordanstr. 82
1190 Vienna, Austria

J.-F. Ponge

Muséum National d'Histoire Naturelle
57 Rue Cuvier
75005 Paris, France

B. Jabiol

AgroParisTech
14 Rue Girardet
54000 Nancy, France

G. Sartori

Museo di Scienze Naturali
Corso del Lavoro e della Scienza, 3
38122 Trento, Italy

E. Kolb

Technische Univ. München
Wissenschaftszentrum Weihenstephan
Hans-Carl-von-Carlowitz-Platz 2
85354 Freising, Germany

R.-C. Le Bayon

Univ. de Neuchâtel
Lab. d'écologie fonctionnelle
Institut de biologie
Rue Emile-Argand 11
2000 Neuchâtel, Switzerland

M. Aubert

Univ. de Rouen
Lab. Ecodiv URA IRSTEA/EA 1293
SFR SCALE 4116, Bâtiment IRESE A
place E. Blondel UFR Sciences et
Techniques
F-76821 Mont Saint Aignan cedex
France

J. Ascher-Jenull

Univ. of Innsbruck
Institute of Microbiology
Technikerstr. 25d
A-6020 Innsbruck, Austria

M. Englisch

Federal Research and Training
Centre for Forests
Natural Hazards and Landscape
Dep. of Forest Ecology and Soils
Seckendorff-Gudent-Weg 8
1131 Vienna, Austria

H. Hager

Univ. of Natural Resources and Life Sciences Vienna
Dep. of Forest and Soil Sciences
Peter Jordanstr. 82
1190 Vienna, Austria

The name *TerrHum* is an abbreviation of the words “Terrestrial” (not hydro-morphic, not submerged) and “Humipedon” (organic and organic-mineral humus horizons). With this application, it is possible to describe and classify terrestrial forest and grassland topsoils in a system published as a Special Issue entitled “Humusica 1– Terrestrial Natural Humipedons” in the journal *Applied Soil Ecology*. The iOS application *TerrHum* allows the storage of the main content of *Humusica 1* on a cellular phone. Images, diagrams and simplified tables of classification may be recalled with a few touches on the screen. Humus forms, representing five humus systems, are classified based on the vertical arrangement of diagnostic horizons and their attributes. *TerrHum* allows accessing specific figures that are stored in a virtual cloud and can be downloaded the first time the user recalls them. Once all figures have been opened in the device, the application is ready to use, without any further internet connection. The application is in continuous evolution.

Core Ideas

- A common humus classification system improves communication among soil scientists.
- A cellular phone application can be used for global soil mapping and monitoring purposes.
- The humus classification can be combined with different soil classification systems.

In 2003, 26 soil scientists gathered in Trento, Italy to standardize methods and rules for classifying the biologically most active upper part of the soil. For doing so, it was essential to develop a common terminology and to exchange data on soil carbon dynamics and its relation to morphological characteristics of

Soil Sci. Soc. Am. J. 83:S42–S48

doi:10.2136/sssaj2018.07.0279

Received 30 July 2018.

Accepted 18 Mar. 2019.

*Corresponding authors (augusto.zanella@unipd.it; klaus.katzensteiner@boku.ac.at).

© 2019 The Author(s). Re-use requires permission from the publisher.

organic and organic-mineral topsoil. The definitions of organic and organic-mineral horizons of the soil, for example, diverged a lot. These scholars came from nine different European countries and immediately realized that the task was not an easy one because each country had its own historical classification systems, often incompatible in-between. It took more than 5 yr of meetings and discussions to publish, on behalf of a part of the members of the “European Humus Group”, then simply “Humus Group”, a first synthesis (Zanella et al., 2009).

The main problem was not the existing classifications, but the fact that for bringing together the existing pieces of knowledge to form a frame compatible with all points of view, it was necessary to enlarge the picture, and also to understand what the different classifications had not considered individually. As an example, there were some humus forms called “humus gemellare” (twin humus) by an Italian classification. In France, these forms were considered as “double” forms, but rather classified as Mulls (Amphimull) because of their thick and impressive crumbly organic-mineral horizon (Jabiol et al., 1994). In other countries, these same forms were classified as Moder, because of their very thick OH horizon (Broll et al., 2006). Because of all these disparities, it was then proposed to bring all these “double” forms together into a new category called “Amphi”. This decision caused a rift between (i) those who had seen and supported the existence of such forms of humus, and (ii) those who instead preferred to stick to the current classification systems without considering such forms, because they were not very common in their respective countries. The issue was solved only after a workshop in San Vito (2005, Italy), with field trips to see “Amphi” and comment on it. Elsewhere, a German member of the Humus Group published an article explaining to his compatriots the existence of such forms in Germany, also highlighting that they could become more frequent and therefore be used as indicators of ongoing global warming (Graefe, 2007).

However, the story went on. When members of the Humus Group came together to see these Amphi forms in Vienna (2004, Austria), other humus forms already described many years before did not match this category, and then fell more or less in oblivion (Hartmann, 1952, 1965; Kubičena, 1953). So are Tangel forms (sometimes called “Alpenmoder” by local forest managers), found at high altitude on calcareous substrates, while corresponding Mor humus forms, with different morphological and chemical properties, are related to siliceous bedrock and acidic soils. The fact opened a diatribe concerning differences between Mor and Tangel that lasted for years and was solved only recently (Kolb and Kohlpaintner, 2018; Meynier and Brun, 2018). To clarify the situation, we decided to set up a classification linked to the soil forming substrate (only if it influences the topsoil: Amphi and Tangel on calcareous substrates, Moder and Mor on “acidic” ones, with Mull in-between in neutral or nearly neutral situations). All members of the Humus Group were then in agreement with this solution, except supporters of “Mor rather without pedofauna” (French point of view) and others who wanted instead “Mor with rather relevant pedofauna” (German supporters who described Mor as extreme Moder forms).

One day, inevitably, the discussion on classification became bogged down on the definition of soil (Zanella et al., 2018a, 2018g; Zanella and Ascher-Jenull, 2018) a point of contention for more than 2 yr. For some of us, abiotic factors predominate pedogenesis, while for others, biotic factors outshine the abiotic. When the soil was proposed as a “digestion system”, a “belly”, with living organisms having it inside (in their belly), the group started to crumble. It spread to individual members when the idea came out that soil binds life and death (for many soil scientists, philosophy should remain separated from what they call “real science”, “numbers”, “mathematical evidence”, even if all of us—as living beings—are destined to die an incalculable day coming). Against all odds, however, the group remained united, but encountered very often many other difficulties, for example when the various humus forms were arranged on a global scale (Zanella et al., 2018f, 2018h). It was then necessary to introduce the concept of “humus system”, comprising ecologically and functionally similar humus forms as well as creating new systems for collecting strange, unusual or never surveyed humus forms (Zanella et al., 2018f) or for those in water (Zanella et al., 2018b, 2018c, 2018d) and in strongly anthropogenics-shaped environments (Zanella et al., 2018l).

Nevertheless, there are still many questions that may be resolved in the near future. New methods at the frontier of science in soil biology can answer issues linked to co-evolution of soil and organisms, biogeography of soil organisms, soil biodiversity etc. Anyway, all these questions give a huge importance to the soil and may be reflected in its morphological characteristics. Humans need to better know the soil, but what about “humus”? Recently it has been suggested to abandon the use of this term, because “humus” cannot be clearly characterized from a chemical point of view (Lehmann and Kleber, 2015). We strongly suggest to keep the term and to speak of “humus” when organic particles and accompanying biota are present.

HOW DOES TERRHUM WORK?

Let us consider a user facing a soil profile to be classified. A cubic hole (50 × 50 × 50 cm) dug into the ground is generally sufficient for studying humus systems and forms in a forest environment, while a larger hole or many well-distributed small holes are necessary for a representative survey of a heterogeneous area (Zanella et al., 2018k). A detailed description of the main actors of soil biodegradation and their relationships with the horizontal and vertical distribution of humus horizons is reported in (Zanella et al., 2018e).

As a humus form is made of superposed humus horizons, the application asks the user to indicate one by one which types of humus horizons are present in the observed profile. Organic horizons (OL, OF and OH, corresponding to USDA Oi, Oe, Oa) were clearly distinguished from organic-mineral ones (different types of A horizons) (Fig. 1).

In general, when in the field a horizon appears totally consisting of organic remains, it is classified as an organic horizon. It is well accepted that the organic matter (OM) composing such horizons amounts to more than 1/3 of the total weight,

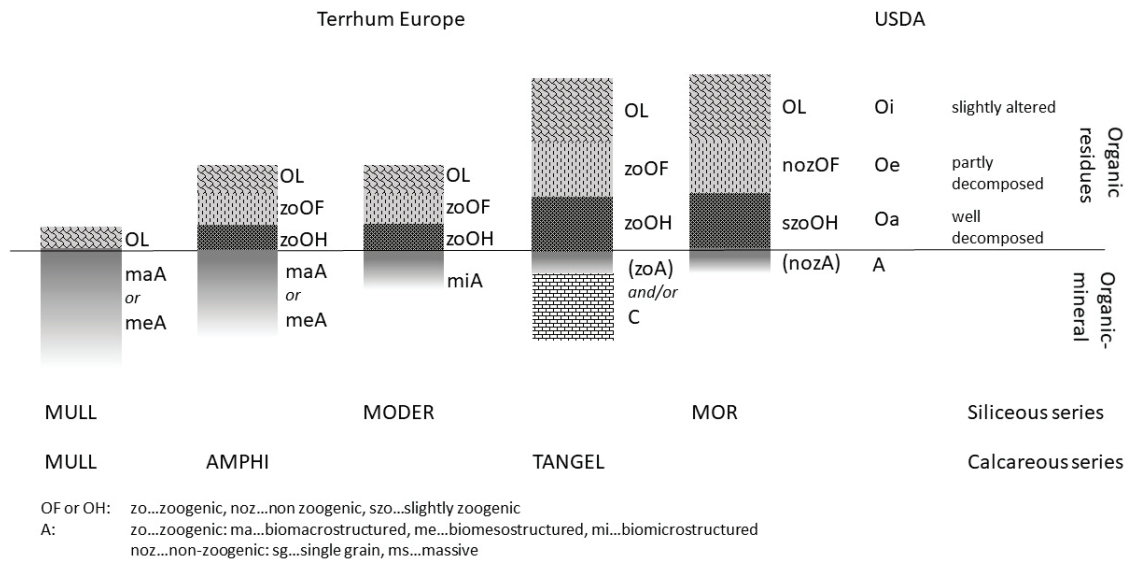


Fig. 1. Basic concept of humus classification and the designation of organic layers on forest floors (O-horizons) and organic-mineral soil horizons in the European classification of humus systems (TerrHum).

which corresponds to 20% or more organic carbon (OC). That allows the separation of organic and organic-mineral horizons in the field and the adjustment of the classification, if necessary, after laboratory analyses of the OC concentration in a horizon sample. The organic horizons are divided into OL, OF and OH following their decreasing content of “recognizable remains” (e.g., a leaf, a needle, a piece of bark...): more than 90% in OL, from 90 to 30% in OF, and less than 30% in OH.

Another diagnostic criterion is, if the process of litter transformation (decomposition) is accomplished mainly by animals or by microbes. Respectively, the process generates zoogenic zoOF or non-zoogenic nozOF horizons described in the application and

recognizable in the field. According to its structure and genesis, the organic-mineral A horizon is classified in zoogenic biomacro, biomeso and biomicro A horizons (maA, meA, miA), and in non-zoogenic massive and single-grain A horizons (msA and sgA). All these horizons are described and illustrated in the application.

The user is asked to answer a series of Yes/No questions in a dichotomous key; an example: “is OH horizon present”? (Fig. 2; Fig. 3a-d). Slightly differing from the application, the simplified key (Fig. 2) requires some field experience, but allows a faster, equivalent, correct classification. For detailed definitions of all diagnostic horizons and criteria of classification, refer to Zanella et al. (2018i, 2018j).

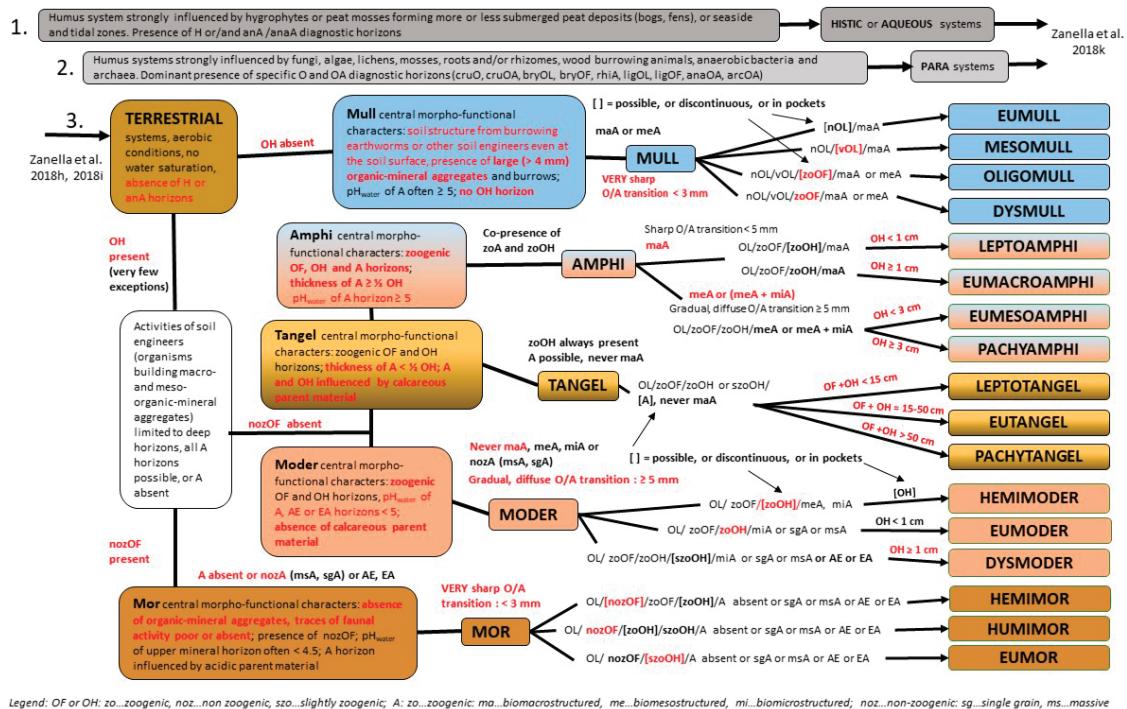


Fig. 2. Dichotomous key for identifying Terrestrial Humus systems and forms. The first bifurcation divides “3. Terrestrial” (described in TerrHum) from “1. Histic and Aqueous” or “2. Para” systems (1 and 2 are described in Zanella et al. 2018b and Zanella et al. 2018f, respectively).

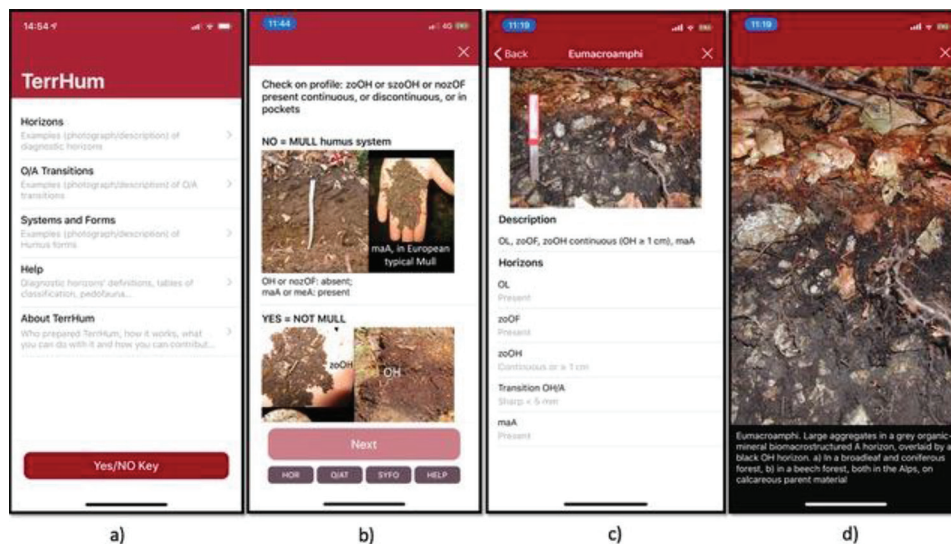


Fig. 3. *TerrHum* screens. (a) Initial screen. The main key of classification is accessible by touching the red button (“Yes/No” key). In addition, four options allow accessing to illustrations of humus horizons, forms, systems and types of transition between organic and organic-mineral horizons. The third option (“Systems and Forms”) allows opening specific tables containing helpful specific information for the classification (e.g., percentage of recognizable remains in different diagnostic horizons). The last option (“About *TerrHum*”) corresponds to a link to an external site, where the user may find a complete manual of the application; (b) A single click on the “Yes/No” key (red button) opens a new window where a Yes/No question is proposed to the user; touching the screen on either “Yes” or “No” keys and subsequently on the “Next” red button activates a series of further Yes/No questions; (c) At the end of the series of answers, a humus form is proposed as solution, along with the list of horizons chosen during the run/classification process; (d) By clicking on the proposed image it is possible to magnify the photograph and, in addition, to see other examples of the same humus form, in different environments.

A touch-button located at the bottom of the screen allows the user to recall at any time definition and photographs of each diagnostic horizon, allowing users to more accurately define the real horizon (Fig. 4a-d).

Other keys at the bottom of the screen allow retrieving examples of humus systems and forms (Fig. 5), as well as tables of composition and/or classification of humus horizons, or groups of animals and their droppings (Fig. 6). At the end of the classification process, a photograph of the target humus form appears, along with a list of the chosen horizons.

By touching the screen, each photograph may be magnified (Fig. 3d; Fig. 4b; Fig. 5b; Fig. 6b). A caption at the bottom of each picture provides access to the morpho-functional features of the soil profile and leads finally to the classification of the humus system.

Many examples of soil horizon features are documented in the application. Future updates of the application will include useful links to enriched external data banks. We are currently collecting information and photographs to further improve the classification of charcoal, charred mass and other dark-colored sublayers that can interfere with the definitions of standard

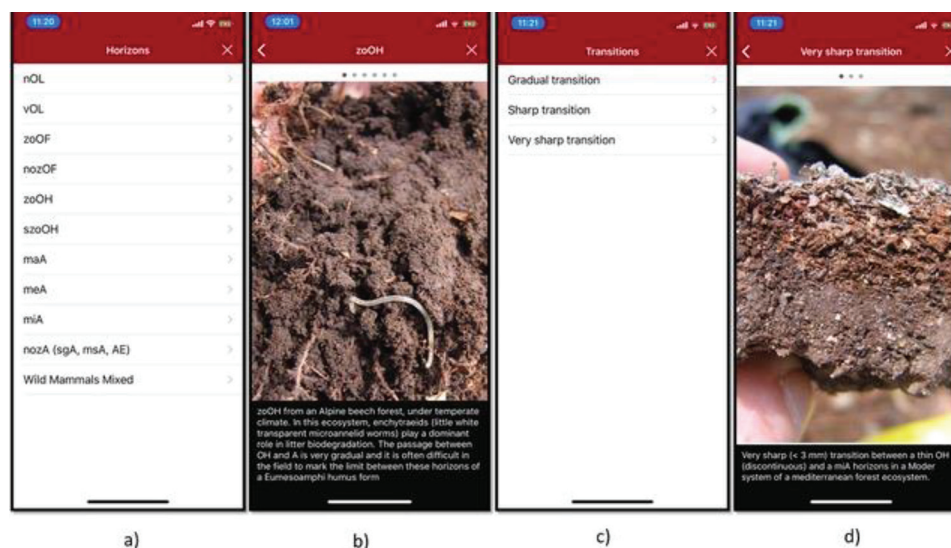


Fig. 4. *TerrHum* screens. (a) Clicking on the first touch-button “Horizons” (Fig. 3a) allows to see examples of diagnostic horizons; (b) Example of the result of clicking on “zoOH horizon”; (c) By clicking on the touch-button named “O/A transitions”, the user may display examples of passages between O and A horizons; (d) An example of a very sharp O/A transition.

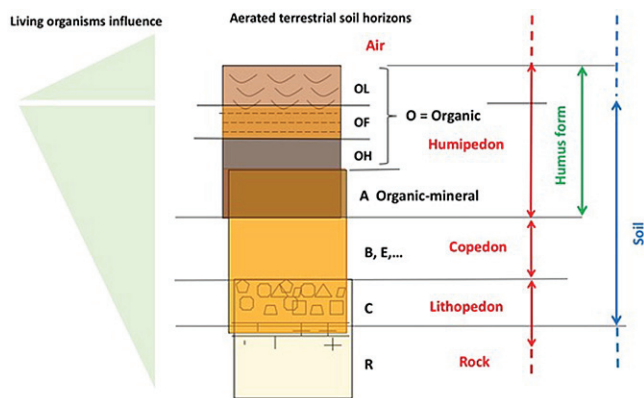


Fig. 7. Subdivision into strata of the soil profile. The biodiversity maximum value is not realized at the surface, but in the layer that separates the horizons OL and OF or in the horizon OF. The latter is a very protected horizon (in particular desiccation but also rain), which contains a large number of trophic resources (very transformed dead leaves, but also fungi and bacteria) and which, by its fragmentation, constitutes many refuges for species that would otherwise be in strong competition, all that is needed to have maximum biodiversity.

programmed to work on applications like this for Copedons and Lithopedons. Histosols are also considered as humus forms and will be later integrated in *TerrHum*. People interested in the project are kindly asked to contact the authors of this paper. Given Humipedons, Copedons and Lithopedons could then be associated to provide a full profile and name for each type of soil.

This is the reason we would like to widen the concept of soil. We would like to divide the soil profile into three parts, each of them being studied either separately or brought together to better understand the overall soil functioning (Fig. 7; Fig. 8). We know that this concept may hurt some among the pedologists, however, it is crucial to understand that each humus form functions relative to soil and vegetation but has also its own spatiotemporal scale of formation, functioning and dynamics (Bernier and Ponge, 1994).

The soil may be divided into three layers which may be described and classified relatively independent each from each other: Humipedon, Copedon and Lithopedon. The first depends mainly on the source of organic matter and animals and microorganisms that live in the soil: they generate the Humipedon composed of organic (OL, OF and OH) and organic-mineral (A) horizons (Hole, 1981).

Beyond these, in the most evolved soils, different mineral horizons like E and B can be distinguished. Their development, though linked to root dynamics and turnover of organic matter is strongly dependent on physical and chemical soil processes. As for those belonging to the Humipedon, there are different types of Copedon horizons, according to climate and parent material (Muhs et al., 2001).

The bottom of the profile completely depends on the original rock. These are the fragmented C horizons and the hard R rock layer. There are different types of Lithopedon (e.g., carbonatic, silicatic; all possible morpho-functional types or more or less transformed initial rocky basements). The Lithopedon is not always at the bottom of a well-differentiated

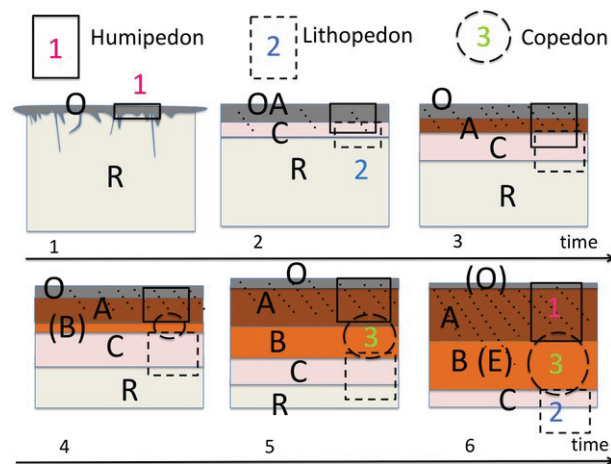


Fig. 8. Pedon sub-units: Humipedon, Copedon and Lithopedon in a theoretical series of soil development. Slightly modified from Zanella et al. (2018a, 2018e).

soil profile. A very young soil is just a thin “biofilm” laying on a Lithopedon, like in deglaciated environments (Wynn-Williams, 1996). Then Humipedon and Lithopedon are built-up, the soil profile evolving toward a complete sequence of Humipedon, Copedon and Lithopedon (Fig. 5). Occasionally the soil can either lose some of its more superficial parts by erosion (truncated soils; Desmet and Govers, 1995) or one part grows till taking all the place (e.g., Humipedon in submerged soils- Histosols, or Copedon in tropical Vertisols).

Once mastered this classification, things become simpler and easier to understand; and the definitive/detailed name of the soil could arise from combining the names given separately to the humipedon and the classification of the soil profile in any system.

REFERENCES

- Bernier, N., and J.F. Ponge. 1994. Humus form dynamics during the sylvo-genetic cycle in a mountain spruce forest. *Soil Biol. Biochem.* 26:183–220. doi:10.1016/0038-0717(94)90161-9
- Broll, G., H.J. Brauckmann, M. Overesch, B. Junge, C. Erber, et al. 2006. Topsoil characterization- Recommendations for revision and expansion of the FAO-Draft (1998) with emphasis on humus forms and biological features. *J. Plant Nutr. Soil Sci.* 169:453–461. doi:10.1002/jpln.200521961
- Desmet, P.J.J., and G. Govers. 1995. GIS-based simulation of erosion and deposition patterns in an agricultural landscape: A comparison of model results with soil map information. *Catena* 25:389–401. doi:10.1016/0341-8162(95)00019-O
- Graefe, U. 2007. Gibt es in Deutschland die humusform Amphi? (Can the Amphi humus system be found in Germany?) (In German.) Reports of the DBG 110:459–460. https://www.researchgate.net/profile/Ulfert_Graefe/publication/261286541_Gibt_es_in_Deutschland_die_Humusform_Amphi/links/00463533c43b6e792b000000.pdf.
- Hartmann, F. 1952. Forstökologie. (Forest ecology.) (In German.) Georg Fromme & Co., Vienna, Austria.
- Hartmann, F. 1965. Waldhumusdiagnose auf biomorphologischer Grundlage. (Forest humus diagnosis on a biomorphological basis.) (In German.) Springer-Verlag, Wien, Austria. doi:10.1007/978-3-7091-7925-3
- Hole, F.D. 1981. Effects of animals on soil. *Geoderma* 25:75–112. doi:10.1016/0016-7061(81)90008-2
- Jabiol, B., A. Brêthes, J.-J. Brun, J.F. Ponge, and F. Toutain. 1994. Une classification morphologique et fonctionnelle des formes d humus. Proposition du Référentiel Pédologique 1992. *Rev. For. Fr.* 46:152–156. doi:10.4267/2042/26527
- Kolb, E., and M. Kohlpaintner. 2018. Tangel humus forms - genesis and co-evolution with vegetation. *Appl. Soil Ecol.* 123:622–626. doi:10.1016/j.apsoil.2017.09.040

- Kubišna, W.L. 1953. The soils of Europe: Illustrated diagnosis and systematics. Allen & Unwin, Madrid, London.
- Lehmann, J., and M. Kleber. 2015. The contentious nature of soil organic matter. *Nature* 528:60–68. doi:10.1038/nature16069
- Meynier, S., and J.-J. Brun. 2018. Humus forms pathways in low-elevation cold scree slopes: Tangel or Mor? *Appl. Soil Ecol.* 123:572–580. doi:10.1016/j.apsoil.2017.10.017
- Muhs, D.R., E.A. Bettis, J. Been, and J.P. McGeehin. 2001. Impact of climate and parent material on chemical weathering in loess-derived soils of the Mississippi River Valley. *Soil Sci. Soc. Am. J.* 65:1761–1777. doi:10.2136/sssaj2001.1761
- Ponomarenko, E., D. Anderson, and E. Gregorich. 2018. A recommendation for a new descriptor for pyrogenic soil horizons in the Canadian Soil Classification System. North American Forest Soils Conference and International Symposium on Forest Soils 2018. 10-16 June 2018, Quebec City, Quebec, Canada.
- Wynn-Williams, D.D. 1996. Response of pioneer soil microalgal colonists to environmental change in Antarctica. *Microb. Ecol.* 31:177–188. doi:10.1007/BF00167863
- Zanella, A., and J. Ascher-Jenull. 2018. Editorial. *Humusica 1*– Terrestrial natural humipedons. *Appl. Soil Ecol.* 122:1–9. doi:10.1016/j.apsoil.2017.11.029
- Zanella, A., C. Bolzonella, J. Lowenfels, J.-F. Ponge, M. Bouché, et al. 2018a. *Humusica 2*, article 19: Techno humus systems and global change– Conservation agriculture and 4/1000 proposal. *Appl. Soil Ecol.* 122:271–296. doi:10.1016/j.apsoil.2017.10.036
- Zanella, A., R. De Waal, B. Van Delft, J.-F. Ponge, C. Ferronato, et al. 2018b. *Humusica 2*, article 10: Histic humus systems and forms– Key of classification. *Appl. Soil Ecol.* 122:154–161. doi:10.1016/j.apsoil.2017.06.035
- Zanella, A., R. De Waal, B. Van Delft, J.-F. Ponge, B. Jabiol, et al. 2018c. *Humusica 2*, article 9: Histic humus systems and forms– Specific terms, diagnostic horizons and overview. *Appl. Soil Ecol.* 122:148–153. doi:10.1016/j.apsoil.2017.05.026
- Zanella, A., C. Ferronato, M. De Nobili, G. Vianello, L. Vittori Antisari, et al. 2018d. *Humusica 2*, article 12: Aqueous humipedons– Tidal and subtidal humus systems and forms. *Appl. Soil Ecol.* 122:170–180. doi:10.1016/j.apsoil.2017.05.022
- Zanella, A., B. Jabiol, J.-F. Ponge, G. Sartori, R. De Waal, et al. 2009. Toward a European humus forms reference base. *Stud. Trentini di Sci. Nat.* 85:145–151. <http://www2.muse.it/pubblicazioni/18/85/15.pdf>.
- Zanella, A., J.-F. Ponge, and M.J.I. Briones. 2018e. *Humusica 1*, article 8: Terrestrial humus systems and forms– Biological activity and soil aggregates, space-time dynamics. *Appl. Soil Ecol.* 122:103–137. doi:10.1016/j.apsoil.2017.07.020
- Zanella, A., J.-F. Ponge, I. Fritz, N. Pietrasiak, M. Matteodo, et al. 2018f. *Humusica 2*, article 13: Para humus systems and forms. *Appl. Soil Ecol.* 122:181–199. doi:10.1016/j.apsoil.2017.09.043
- Zanella, A., J.-F. Ponge, J.M. Gobat, J. Juilleret, M. Blouin, et al. 2018g. *Humusica 1*, article 1: Essential bases– Vocabulary. *Appl. Soil Ecol.* 122:10–21. doi:10.1016/j.apsoil.2017.07.004
- Zanella, A., J.-F. Ponge, H. Hager, S. Pignatti, J. Galbraith, et al. 2018h. *Humusica 2*, article 18: Techno humus systems and global change– Greenhouse effect, soil and agriculture. *Appl. Soil Ecol.* 122:254–270. doi:10.1016/j.apsoil.2017.10.024
- Zanella, A., J.-F. Ponge, B. Jabiol, G. Sartori, E. Kolb, et al. 2018i. *Humusica 1*, article 4: Terrestrial humus systems and forms– Specific terms and diagnostic horizons. *Appl. Soil Ecol.* 122:56–74. doi:10.1016/j.apsoil.2017.07.005
- Zanella, A., J.-F. Ponge, B. Jabiol, G. Sartori, E. Kolb, et al. 2018j. *Humusica 1*, article 5: Terrestrial humus systems and forms– Keys of classification of humus systems and forms. *Appl. Soil Ecol.* 122:75–86. doi:10.1016/j.apsoil.2017.06.012
- Zanella, A., J.-F. Ponge, and M. Matteodo. 2018k. *Humusica 1*, article 7: Terrestrial humus systems and forms– Field practice and sampling problems. *Appl. Soil Ecol.* 122:92–102. doi:10.1016/j.apsoil.2017.05.028
- Zanella, A., J.-F. Ponge, S. Topoliantz, N. Bernier, and J. Juilleret. 2018l. *Humusica 2*, article 15: Agro humus systems and forms. *Appl. Soil Ecol.* 122:204–219. doi:10.1016/j.apsoil.2017.10.011