Applied Soil Ecology 122 (2018) 22–41

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Applied field research article

# Humusica 1, article 2: Essential bases—Functional considerations☆

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ARTICLE INFO

*Keywords:*
Humus
Soil functioning
SOM
SOC
Litter
Biodegradation
Soil ecology
Humusica
Decomposition and temperature

ABSTRACT

Humusica 1 and 2 Applied Soil Ecology Special issues are field guides for humipedon classification. Contrary to other similar manuals dedicated to soil, the objects that one can describe with these guides are living, dynamic, functional, and relatively independent soil units. This is the reason to why the authors dedicated the whole article number 2 to functional considerations even before readers could go in the field and face the matter to be classified. Experienced lectors can overstep many of the sections reported in this article. If the titles of sections “1 A functional classification", "2 What is a humus system?"and "3 Energetic considerations in terrestrial systems” stimulate the reader’s curiosity, then we suggest to pass through them. Otherwise, only section “4 Climatic, plant litter, or nutritional constraints?” is crucial. Readers will understand how the soil works in terms of litter and Carbon accumulation, which one(s) among climatic, vegetational, or geological factors that intervene and strongly affect the formation processes of terrestrial (oxygenated) soils. The article concludes with a debate about a tergiversated question: can temperature influence humus decomposition? Preceding statements were used for explaining how the biological soil net can store in the soil a maximum of energy in the form of SOM, by raising a plateau partially independent of climatic conditions.

## 1. A functional classification

Classifying makes sense only if the established categories of objects correspond to a few references allowing us to better understand the observable real world (see also in Humusica 1, Article 1: Essential bases – Vocabulary and Article 7: Terrestrial humus systems and forms – Field practice and sampling problems). We have named these references Humus forms (= theoretical groups of humus profiles displaying the same series of diagnostic horizons) and Humus systems (= theoretical groups of humus forms sharing the same biological/functional properties).[1] If we want to use these references for understanding the real world, some well-known theoretical/practical principles have to be considered:

1- *Objects of the real world are organized in complex units made of smaller systems embedded in larger ones* (theory and examples in natural environments, papers in English, French or Italian: Odum, 1953, 1997; Johnson, 1998; Botkin, 1990; Zanella, 1995, 1996; Camaret et al., 2000; Saugier et al., 2001; Begon et al., 2005; few among many possible examples in forest ecosystems: Susmel et al. 1976; Susmel, 1980; Susmel and Viola, 1988; Oldeman, 1990; Zanella, 1994; Carletti et al., 2009; Nocentini, 2011; Mason and Zapponi, 2015). Concerning humus systems, we would like to classify humus profiles observing features detectable in the field by the naked eye or with a 10×-magnifying lens. This scale allows us to describe objects whose smallest dimension is 1/10 mm (when magnified 10 times with a lens it becomes 1 mm large, which is visible by the naked eye);

2- *Admitting a fractal structure of the soil, accepting that time and space are related to each other and scale depending* (Mandelbrot, 2004; Anderson et al., 1998; Young et al., 2008). In others words, this means that ecological processes at different scales are working in corresponding different times. Humus and soil specialists cannot exchange information and debate as well as expected (example: the discussion engaged in ResearchGate by Baveye P.: Should soil scientists stop using terms like “hmuus”, “humic”, or “humification”? https://www.researchgate.net/post/Should_soil_scientists_stop_using_terms_like_humus_humic_or_humification) because they are studying the same soil

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☆ Music while reading? Why? Anna RF (Alps): https://www.youtube.com/watch?v=YdXBWsFc-0U.

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[1] Supplementary information in: Humusica 1, art. 8: Terrestrial humus systems and forms – Biological activity and soil aggregates, space-time dynamics; Humusica 3, many articles or short communications about pedofauna, symbioses, roots, biodiversity… and functioning (driving factors, carbon storage, humeomics…), particularly Berg B.: “Decomposing litter; Limit values; Humus accumulation, locally and regionally”; and Kõlli R.: “Dynamics of annual falling debris decomposition and forest floor accumulation”.

http://dx.doi.org/10.1016/j.apsoil.2017.07.010
Received 22 November 2016; Received in revised form 3 July 2017; Accepted 7 July 2017

system at different time-space scales. “Humus” scientists analyse litter biodegradation and biological molecules implementation in the topsoil during days to decades of years, in cubic millimetres or meters of soil volumes; soil scientists work on rock transformation and soil genesis, considering decades or hundred to thousand years of history and larger soil volumes (regional surfaces and metres of soil depth). Examples will facilitate our purposes. Humus specialists consider a Mull system strongly influenced by large earthworms. Simplifying their view, it is possible to write that the higher the number of earthworms, the better the soil quality (for data, refer to Cluzeau et al., 1987, 2012, 2014). However, this soil quality does not depend directly from the number of individuals of earthworms but from the quality and quantity of the organic matter these animals are able to store in their droppings, which depends on the type of soil exploitation (e.g. use of pesticides, organic or mineral fertilisation, irrigation, type of culture. Recent review in Bertrand et al., 2015). Even worse, to free the potential energy and nutrients content in the organic matter that earthworm activity could have stored in the soil, it is necessary to wake up microbial communities, purposely fed by plant exudates or even stimulated by a complex interaction with other organisms (Fitter and Garbaye, 1994; Blouin et al., 2013; Kardol et al., 2016). Earthworms are organisms working at a scale observable by the naked eye, and their numbers change following seasonal variations; bacteria occupy microscopic spaces and respond to changes at a space-time scale that can be independent from earthworms’ cycle of life. On a different scale, and in the same parcel, soil scientists could measure pH, nutrients contents, texture, distinguishing substrate (R), mineral (C, B, E, etc.) and ploughing layers. Depending on the needs of specific crops, they would try to perpetuate the exploitation, watering and feeding soil and plants. It is well known on one side (Stevenson, 1972, 1985, 1994; Gobat et al., 1998; Janzen, 2006; Legros, 2007) that the stability of the content in bases depends of the capacity of exchange (CEC) of the soil, which takes place at the level of organic macromolecules, edge of mineral microstructures; on the other side (Schulten and Schnitzer, 1997; Leinweber and Schulten, 1998; Piccolo, 2001; van Heerwaarden et al., 2003; Kelleher and Simpson, 2006; Lehmann et al., 2008; Kleber et al., 2011) nutrients may take place between organic-mineral aggregates made by earthworms and microorganisms, or even be attracted by electrostatic forces of organic molecules generated by them. Finally, the functioning of the soil may be summarized by a multitude of processes, each one at a given limited space-time scale, interconnected and influenced by each other at a larger scale.

Humus and soil scientists should accentuate their collaboration. Together they could traslate complex realities (made of a multitude of coevolving processes) into understandable "models" human “brain-models”, and take practical decisions. For instance, following different simplified functional models of sustainable agriculture, humus scientists may promote the biological quality (example: a higher number of earthworms), soil scientists the mineral quality (high quantity of crops nutrients) of a same field. Both decisions are interconnected on a functional plan and need consultation for finding the right soil-plant system harmony;human “brain-models”

3- *The process of comprehension needs to play with the scale of phenomena.* It has to start from a large-scale model, easy to understand, and in a second step to include more detailed information at a finer resolution, until reaching the limit of a personal (historical) knowledge. The inverse way has to be taken too, from smaller to larger scales, and the movement, in both directions, has to find a final relative harmony in a functional model that could be observed at the same time at both large and small scales. A detective feeling comes along with this harmony in progress [examples for forest management in Zanella et al. (2001, 2003, 2008); Cavalli and Mason (2003); Scattolin et al. (2004a, 2004b); Corona et al. (2005); Ciancio and Nocentini (2005); Ciancio et al. (2014); pedofauna and soil interactions in: Salmon et al. (2006); Galvan et al. (2006, 2008); ecology and evolution in: Barot et al. (2007); relationships between soil biology and climate/land use in: Ascher et al. (2012); Blouin et al. (2013); Spurgeon et al. (2013); Sverdrup-Thygeson et al. (2014a); Sverdrup-Thygeson et al. (2014b); Clause et al. (2014); Nielsen et al. (2015); Fusaro (2015).

We have to accept that a proposed functional model could only represent a new starting point for further search. The final agreement should not be different from an anthropomorphic statement.

## 2. What is a humus system?

The humipedon – the upper part of a soil made of organic and/or organic-mineral horizons – is directly under the influence of the aboveground parts of an ecosystem. The humipedon constitutes an interaction system born to manage a functional transition between organic and mineral worlds. This humus system has the possibility to degrade structured organic matter and use it as a source of energy. Further, it may act as a sink and a source of energy. Due to the process of photosynthesis, plant activity produces organic matter, which feeds a complex system of consumers. On the other hand, living organisms lose mineralised compounds such as water, carbon dioxide, ammonia, nitrate, and organic matter (urine, organic waste products) in order to renew their structures, thereby creating a substrate rich in energy, which can be utilized by numerous interconnected decomposers. Both the process of production and that of mineralisation of organic matter are interdependent and can or cannot be well shared. All this activity is organized like a chain from the largest to the tiniest organisms. At each step, part of its energy is extracted from the substrate. Curiously, the result of the process of biodegradation is not the complete mineralisation of the previously built organic matter, but a new “body”, corresponding to functional organic, organic-mineral and mineral interacting “humus horizons” (Fig. 1). On one side this new structure is able to form and/or retain vital elements while on the other side it can release these elements both in mineral form and in more sophisticated molecules (e.g. humic acids, hormone like substances). This new substrate behaves like a biological matrix in which microorganisms as well as *meso*- and macro-organisms live and evolve in tight association. The result seems helpful for the producing photosynthetic system (aboveground), which finds in it water and nutrients in relatively equilibrated association all along its lifetime. We suggest that such systems of interactions between biotic and abiotic components taking place in the humipedon be called “humus interaction systems” or in short “humus systems”. They are designed to provide a name for still imperfectly known conditions for the common life and evolution of the immense variety of organisms which ensure, in a coordinated manner, the sustainability of terrestrial ecosystems. Since a limited number of strategies were selected in the course of Earth’s history, taking into account the variety of conditions (climate, nutrient availability, vegetation types) prevailing in terrestrial environments, several humus systems have been described, featuring the bulk of existing variation (Ponge, 2003).

## 3. Energetic considerations in terrestrial systems

The large-scale approach (point 2 of Section 1) has to consider the most important parameter while discussing ecosystem functioning: energy. No energy, no life. Sun sends high amounts of energy to Earth. Ignoring clouds, the average insolation for the Earth is approximately 250 W per square meter ($= 6\ \mathrm{kWhm}^{-2}\ \mathrm{day}^{-1}$). In fact, over the course of a year the average solar radiation arriving at the top of the Earth's atmosphere is roughly 1366 W per square meter of ground. Sun rays are attenuated as they pass through the atmosphere, thus reducing the insolation at the Earth's surface to approximately 1000 W per square meter for a surface at right angle to sun rays at sea level on a clear day. Then, taking into account the lower radiation intensity in early mornings and evenings, the sun angle at different seasons of the year and the fact that only half of the Earth spherical surface receives sun radiation – the other half being in night – the average insolation per square meter reduces itself to 250 W ($1\ \mathrm{W} = 1\ \mathrm{J\,s}^{-1}$). Still, this represents ($250 \times 60 \times 60 \times 24 = 21\,600\,000 = 21\ \mathrm{MJ\ day}^{-1}$) about twice the