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Humus forms as tool for upscaling soil biodiversity data to landscape level?

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The relation between humus forms and general features of the soil faunal community is well founded knowledge in soil science and soil biology. As the direct exploration of soil communities is limited to the local scale, mapping of humus forms can be a tool for upscaling and prediction of soil biodiversity at regional or landscape scales. Existing inconsistencies in classification systems that hamper an easy translation of humus forms into soil biodiversity are addressed.

Soil life is essentially connected to the humus layer and the topsoil, forming together the humus profile. This uppermost part of the soil profile, classified as humus form, is immediately affected by environmental impacts such as land use, eutrophication, acidification, heavy metal input and climate change. As humus forms develop at shorter time scales than soil types, both do not always coincide in a regular way and therefore need to be classified independently (Fig. 1).

The function of soil animals in humus forming processes is a focal issue in soil ecology (e.g. *Bal*, 1982; *Belotti* and *Babel*, 1993; *Ponge*, 2003). Current classification systems of humus forms (e.g. *Green* et al., 1993; *Jabiol* et al., 1995) recognize the role of soil animals by using observable signs of their activity for the description of humus horizons. The series Mull, Moder, Mor is understood as sequence of decreasing soil animal activity and soil biodiversity (Fig. 2).

Figure 2 illustrates a recent proposal from the "European humus research group". The group seeks to find common rules for the classification of humus forms at the European level (*Jabiol* et al., 2004). The main types correspond well to general lines of the soil faunal community. Only the separation of Mor and Moder is somewhat problematic from a zoological point of view, since both bear a largely similar species composition. Investigations on soil fauna using specific extraction methods often reveal even at Mor sites an astonishing mesofaunal abundance that cannot be detected macroscopically (*Graefe*, 1994, 2004). According to *Baritz* (2003) transitional forms between Mor and Moder have become the most abundant forest humus forms in northern German lowlands due to the high nitrogen deposition and resulting levelling effects on the soil chemical condition. This may be another reason not to separate Mor and Moder at the highest hierarchy level.

A further approach, based on discussions after the second meeting of the European humus research group, differentiates between Mull and "Non-Mull" and introduces semi-terrestrial humus forms at a second axis (Fig. 3). Problematic is the designation of peat as humus form, because this would include also deeper organic horizons that have developed at historical time scales and do not reflect actual processes and functioning. Drained and fertilised peat soil (Histosol), on the other hand, can have an aeromorphic mull-like topsoil with an animal community which is not very different from that of a Mull in mineral soil (*Graefe*, 1993).

The dichotomy between Mull and Non-Mull is justified because of the distinctive role anecic and endogeic earthworms play by incorporating and mixing organic matter into the topsoil and thus creating the biologically active A horizon that is typical of Mull. The occurrence of these functional earthworm groups is largely limited to pH-values above 4.2. Below this value most organisms that live in close contact to the soil solution avoid the mineral soil because of its toxic properties (*Graefe* et al., 2002).

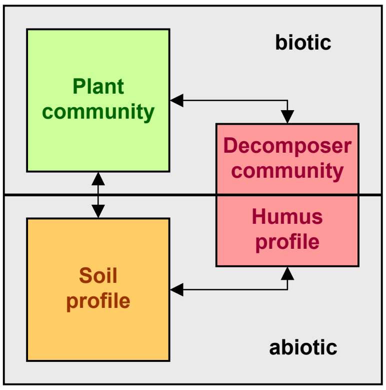

Figure 1: Ecosystem components of high complexity that are subjects of separate classifications.

While the species composition of earthworm communities does abruptly change close to pH 4.2, which is the borderline between the aluminium and the exchanger buffer range, only minor changes along the gradient of soil reaction occur on either side of this threshold (*Graefe* et al., 2002; *Sommer* et al., 2002). A similar behaviour is shown also by enchytraeids, but their species changeover is more gradual (Fig. 4).

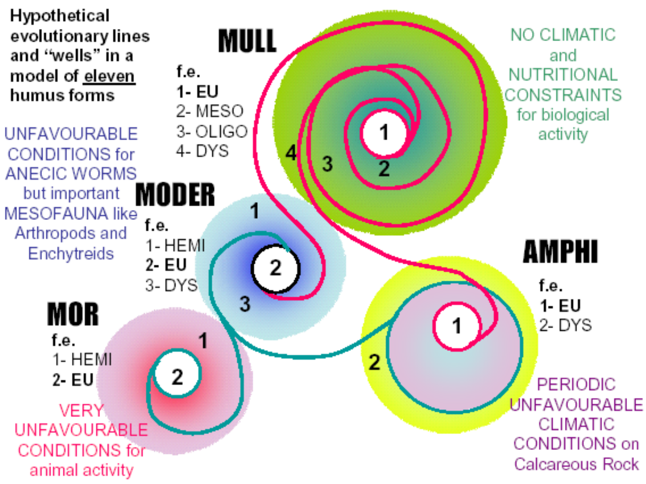

Figure 2: First approach to a classification of humus forms at the European level (from *Jabiol* et al., 2004).

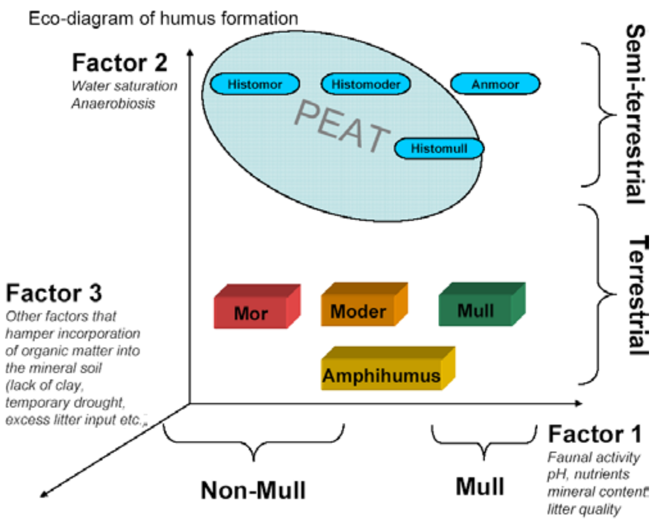

Figure 3: Second approach to a classification of humus forms at the European level (from *Englisch* et al., 2005).

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It thus appears that, referring to the model of ecological resilience (*Peterson* et al., 1998; *Brand*, 2005), there are two “basins of attraction” at the community level, where presence and abundance or absence of anecic and endogeic earthworms are the driving forces, which basically organize the structure of the soil community (Fig 5.). In terms of humus forms they correspond to Mull and Moder/Mor respectively. Press disturbances such as acid rain or liming (*Bengtsson*, 2002) may shift the species composition (Fig. 6) gradually within the range of a domain (humus form) or may push it into a new domain surpassing the threshold of ecological resilience.

More detailed insights into humus forming processes are obtained by relating humus horizons to activity profiles either of microorganisms or of the mesofauna (e.g. *Baritz* 2003; *Ponge*, 1999; *Graefe*, 2004). Figure 7 shows a generalized scheme of horizons and humus forms in which Moder forms are separated according to different gradients of biological activity in the profile. F-Moder corresponds to a low activity in the OH horizon, which is often referred to as Mor. The organic matter is almost completely humified and can have a very old date of origin.

The scheme is also used to describe the main occurrence of single species in the continuum of humus horizons and humus forms (Fig. 8). Practically all species prefer or are restricted to specific horizons. Their ranges indicate comparable ecological conditions. An A horizon structured by endogeic earthworms supports a similar combination of species whether it belongs to a soil in forest, grassland or arable land (A-Mull).

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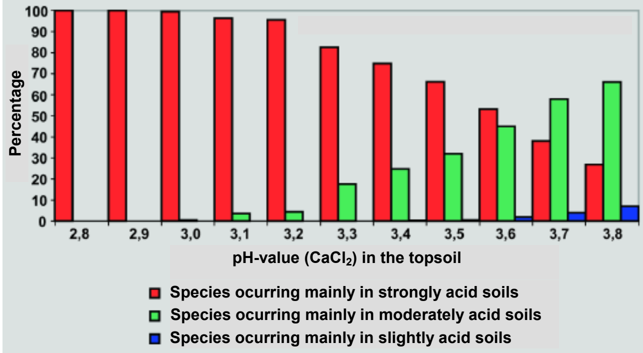

Figure 4: Effect of pH on the species composition of microannelids in forest soils. Data from monitoring sites in North Rhine-Westphalia (after *Landesumweltamt Nordrhein-Westfalen*, 2003).

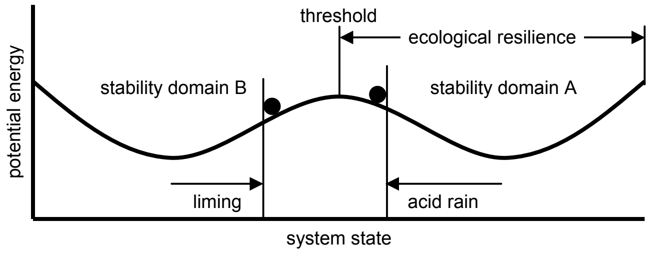

Figure 5: Stability landscape with two basins of attraction along the gradient of soil reaction. Press disturbances such as acid rain and liming may shift the soil community into another domain.

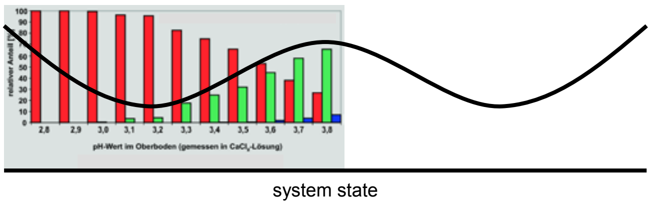

Figure 6: Placement of measured community parameters at soil monitoring sites over the model of ecological resilience with two basins of attraction along the gradient of soil reaction.

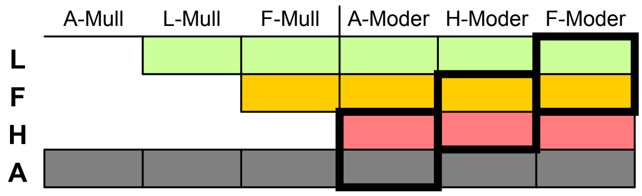

Figure 7: Scheme of the continuum of humus horizons and humus forms. Mull humus forms are termed according to the presence of horizons. Moder humus forms are termed according to the deepest biologically active horizon in which large proportions of the mesofauna and fine roots do concentrate.

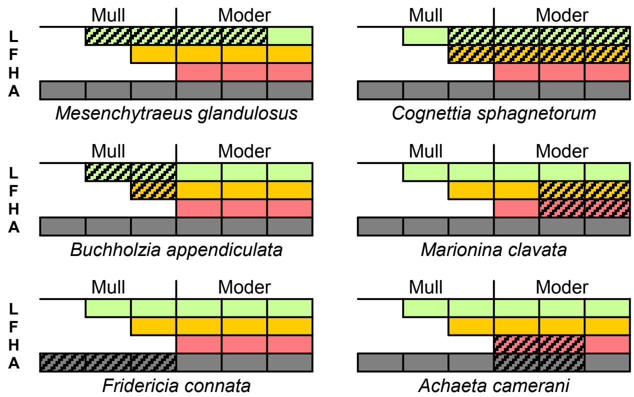

Figure 8: Examples of the occurrence of microannelid species (hatched) in the continuum of humus horizons and humus forms.