Towards an European Classification of Terrestrial Humus Forms

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1 Introduction

Humus plays an important role in the functioning of ecosystems. It acts as a link between above- and below-ground ecosystem compartments. The fall and decomposition of organic matter return minerals and energy to the soil biota, and the depth or depth ratio of different humic horizons is indicative for the velocity and mode of turnover and carbon storage in forests.
But, since classification and description of humus forms is a valuable tool, a scheme of unified European humus classification could contribute towards compatibility of national ecosystem analyses.
In Europe as well as in North America a multitude of humus taxonomies exists starting with early approaches in the late 19th century. Due to the variety of sites throughout Europe, different methodological approaches were used, thus resulting in different classification systems.
The Canadian (Green et al. 1993) and French (Brêthes et al. 1998) classification systems are frequently used in an international context, but don’t cover all site conditions of European forest ecosystems. Throughout the last decade, new national classification systems were developed in Austria, Germany, and the Netherlands.
Basic concepts of most national European classification systems are similar along general lines. Nevertheless there are differences in parameters used for description and classification of humus forms as well as in scaling these parameters. This results in incompatibility of classifications on the lower levels of the systems. So, i.e. regional humus forms cannot be described and compared as similar designations of humus forms often having differing contents, and similar contents having differing names.
The present paper gives a general outline of a concept on a classification system of humus forms at the European level. As a first step, the classification is outlined for terrestrial (aerobic) humus forms.

2 Common bases

A simplified comparison between four European classification systems is presented in table 1.

Table 1. Simplified comparison between the first levels of national classification of humus forms in 4 European countries **(***From R. Baritz 2003; modified).*

	FRANCE (1), ITALY (2)	GERMANY (3)	AUSTRIA (4)
MULL	EUMULL	A-MULL	
	MESOMULL	typical L-MULL	
		typical F-MULL	typical
MULL			
	OLIGOMULL		
	DYSMULL	moderartiger F-MULL	
			Moder-like
MULL			
	AMPHIMULL		
		Rhizo L-Mull	
		Rhizo F- Mull	
MODER			
	Hémimoder		
		Mullartiger Moder	Mull-like
Moder			
	Eumoder		calcicModer
		typischer Moder	typical Moder
	Dysmoder		Acid Moder
		Rhizomoder	Rhizomoder
		Typischer Tangel	AlpenModer
			(Tangel-Mor)
MOR	(Hémimor)	Moderartiger-Rohhumus	mor-like Moder
	Mor (Eumor)	Typischer Rohhumus	typical Mor
			inactive Mor
			Rhizomor
			active Mor
	Tangel	Mächtiger-Tangel	Tangel-Mor

(1) Brêthes and al. 1998, (2) Zanella and al. 2001, (3) AK Standsortskartierung,1996, (4) Nestroy and al. 2000.

As we can see, most national classifications have at the first common level the humus forms Mull, Moder and Mor. Despite of this identity in terminology, there is marked discrepancy in diagnostic parameters and/or thresholds used.

For instance, the impact of the structure of the A horizon is very strong in the French model (an A biomacrostructurated defines the mull forms); in the German system the absence of the OH horizon links to the mull forms. The juxtaposition A horizon links to the moder forms in the French system and doesn't exist in the other systems…

So a common definition for the diagnostic horizons has to be proposed before classifying humus forms.

3 Propositions

3.1 Definitions of main horizons of terrestrial humus forms

Terrestrial: organic layers consist mainly of debris of terrestrial plants. All humus-horizons are well aerated for most of the year. Thus aerobic decomposition dominates.

Organic master horizons:

- The following organic (O) master horizons are distinguished: OL, OF, OM, OH. These horizons are formed entirely (> 17% organic Carbon = 30% organic matter) from dead organic matter, mainly from leaves, needles, twigs, roots and, under certain circumstances, moss and lichens. They do not include a living moss layer.
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- OL (Litter, Förna): this organic horizon is characterised by an accumulation of mainly leaves/needles, twigs and woody materials. Most of the original biomass structures are easily discernible. Leaves and/or needles may be discoloured and slightly fragmented. Organic fine substance (in which the original organs are not recognisable with naked eye) amounts to less than 10 % by volume.
- Sub-horizons: OLn..new OLv..slightly altered (vetus, verändert, old).
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- OF (fragmented and/or fermented): this organic horizon is characterised by an accumulation of partly decomposed (i.e. fragmented, bleached, spotted) organic matter derived mainly from leaves/needles, twigs and woody materials. The proportion of organic fine substance is 10 % to 70 % by volume. Depending on humus form, decomposition is mainly accomplished by soil fauna (mull, moder) or cellulose-decomposing fungi (mor). Slow decomposition is characterised by a partly decomposed matted layer, permeated by hyphae.

  Sub-horizons:
  - OFz = zoogenous (decomposition mainly by soil fauna, mostly macro- and mesofauna, thus faunal droppings are easily recognisable).
  - OFzm=intermediate between OFz an OFm.
  - OFm or OFnoz = not zoogenous = mycogenous (decomposition mainly by fungal activity; fungal hyphae are easily recognisable; faunal droppings sparse to absent).
  - OFr..felt of roots/rhizomes.
  -
- OM: designates more or less living moss layers or matted grass-rhizomes on top of the humus profile, where the difference between living and dead organic matter is not easily possible and the distinction between OL, OF or OH is hampered.
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- OH (humus, humification): OH is an organic horizon characterised by an accumulation of decomposed organic matter. The original structures and materials are not discernible. Organic fine substance amounts to more than 70 % by volume. OH differs from the OF horizon by showing a more advanced humification due to the action of soil organisms. The OH-horizon is either sharply delineated from the mineral soil where humification is dependent on fungal activity (mor), or partly incorporated into the mineral soil (moder).

- Sub-horizons:
- OHz = zoogenous; droppings of soil fauna (epigeic earthworms, arthropods, etc.) dominate. A fine structure (less than 3 mm) is typical.
- OHm = mycogenous; this horizon is weakly structured and shows interwoven fungal hyphae.
- OHnoz = no zoogenous properties, but fungal hyphae are not discernible
- OHzm = combines properties of OHz and OHm or OHnoz
- OHr = felt of roots/rhizomes.

Humic mineral soil horizons:

The A-horizon is a master mineral soil horizon formed near the soil surface and characterised by an accumulation of organic substances. The content of organic carbon in the soil fraction < 2mm is less than 17 % by mass.

- Az = biomacrostructured A horizon: dark coloured clay-humus complexes are formed. Significant action of anecic and endogeic earthworms create a typical crumb structure.
- Ajz: the transition from the OH horizon to the mineral soil is gradual; the transition from the Ajz to the B horizon is distinct. Biogenous intermixing (by Arthropods or Enchytreids; juxtaposition of faecal pellets or particular organic matter with mineral particles) dominates over infiltration of humic substances
- Aze: The humus is mainly infiltrated, the horizon shows a weak podzolisation (diffuse bleached spots). While the Aze horizon is sharply delineated from the OH horizon the transition to the B-horizon is gradual. The structure is compact (coherent), sometimes platy.
- Ae: The Ae horizon is podzolised, the colour of the bleached parts is greyish sometimes with a violet hue. The structure is in transition from coherent (minerals cemented with humic substances) towards loose single grain, structureless conditions (when podzolisation is well developed)

3.2 The concepts of the main humus forms and ecology of humus forms

The first level of classification is built around the activity of biological key actors in the decomposition processes and, as a consequence, on the resulting horizons and their morphology (tab. 2).
The characters of the A and OH horizons allow to class the top soil in four humus forms. Some transitional forms appear when the horizons become very thin or discontinuous.
The concept of “amphi” was originally developed by Hartmann F. 1952 (“twin” humus) and was elaborated by Brêthes et al. 1998 for the French classification system (amphimull). In Italy these forms were recognised by Zanella et al. 2001 in several prealpine beech forests. In these forms both A biomacrostructurated and OH zoogenic are present and reflect dominating zoogenic turn over in periodical drought soil-climate conditions.
The difficulty of classifying the OHm horizon is avoided using the definition of “not zoogenic” horizon, since it is easier to recognise the absence of zoogenic activity (macroscopic characteristics) in the field than the presence of fungal activity (fungi are always present, though they may be only observed on macroscopic scale during certain seasons). The anecic/endogeic worm droppings are very different to the epigeic worms, Arthropods and Enchitreids. The size of the first rounded crumb structures (clay-humus complexes) are often more than 5 mm, the faecal pellets of the other group of animals are cylindrical, like “little sausages”, often holorganic, and their dimensions less than 3 mm. The A “not biogeneous” is

transitional to an E horizon, containing infiltrated (transported by percolating water) humus substance.

Table 2. Actors of biodegradation and diagnostic horizons.

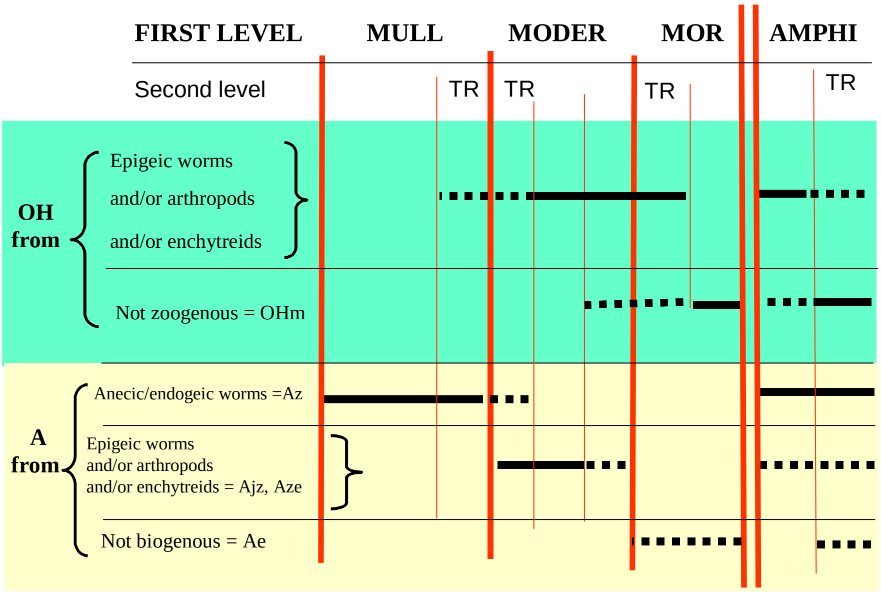


Table 3. Typical and transitional forms in essential definition, presence/absence of diagnostic horizons.

Typical forms (Eu) and Horizons
TR = transitional forms

	MULL	TR	MODER	TR	MOR	AMPHI	TR
OL	yes/no	→					
OF	no	yes	→				
OHz	no →		yes →		no	yes	no
OHnoz, OHm	no →				yes	no	yes
Az	yes	yes	no	→		yes →	
Ajz, Aze	no	yes	yes	yes	no	yes	no
Ae	no →			yes →		no →	

Table 3 presents a key using the diagnostic horizons to classify the major humus forms. In addition to the mull, moder and mor forms, which are classified in all the national systems, the concept of amphi humus forms and a varying number of transitional forms are given. The transitional forms from mull to moder result from the fact that the OF horizon, which is not typical for the pure mull form, is already encountered in the transitional forms while an OH horizon is still missing. Discrimination of different transitional forms can be done by the thickness of the newly encountered horizon (less active mull in figure 1). The transitional forms from moder to mor are characterised by a zoogenic OH horizon which is typical of a moder form in combination with no zoogenic Ae horizon typical of a mor.

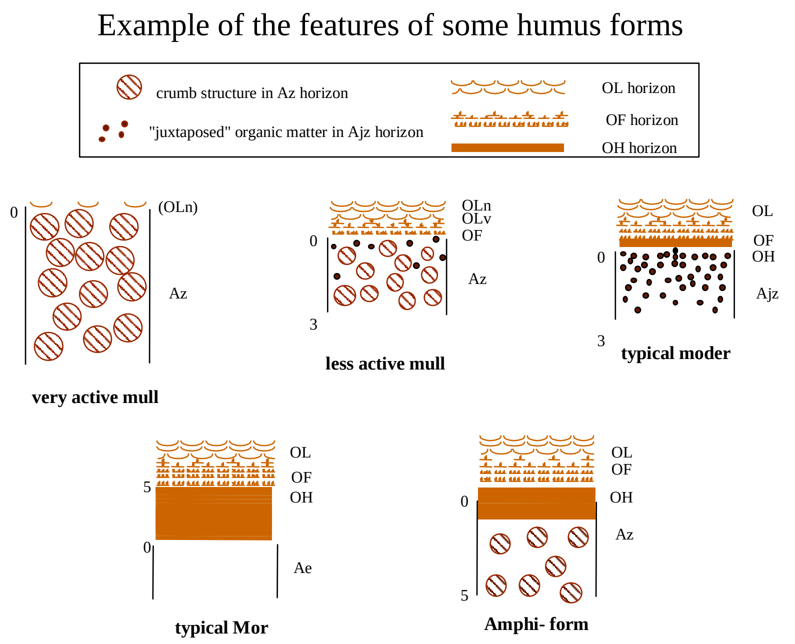


Figure 1. The main humus forms in picture.

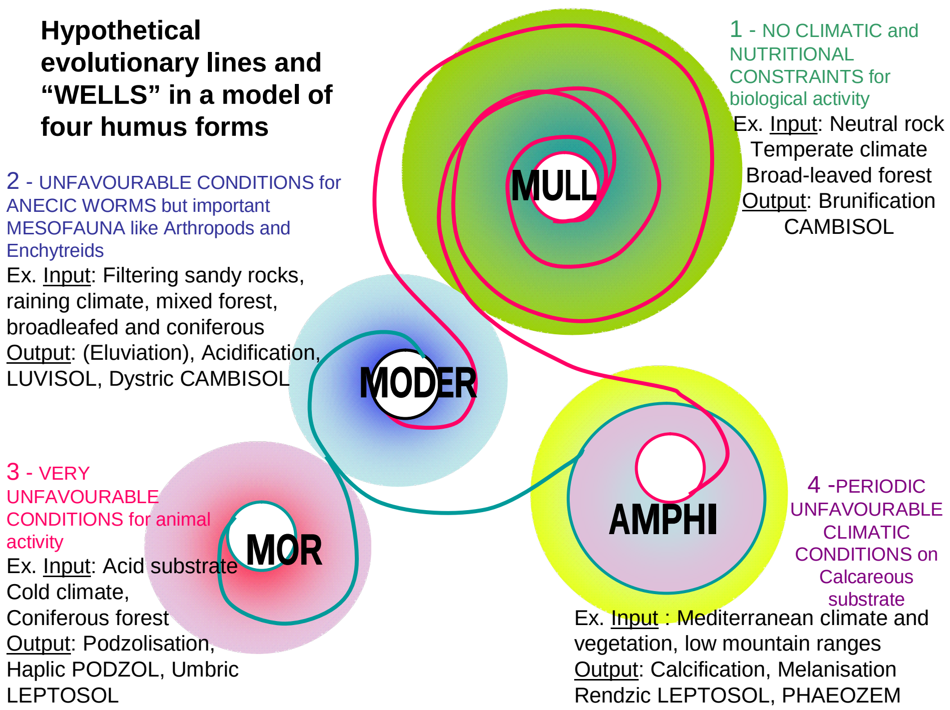


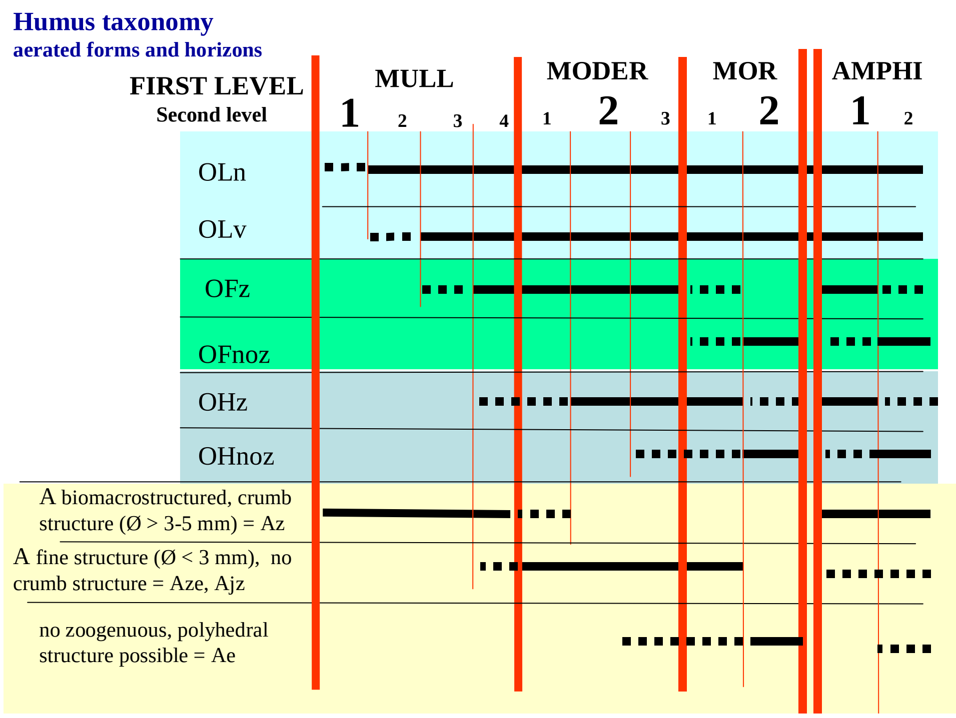
Figure 2. Hypothetical evolutionary lines and "wells" in a model of four humus forms.

In figure 2 some hypothetical transitions among the different principal humus forms, acting as "wells", are elaborated. In order to express the ecological meaning of the humus forms, it also sketches the main ecological conditions determining the site and, as a consequence, the characteristic of organic matter turnover. The constraints increase from mull to mor in quite a continuous way; in case of amphi forms, the humification in the protected A horizon reflects the main humus form (i.e. mull), while turnover in the ectorganic layers is hampered by unfavourable climatic and/or stand species composition conditions and tends towards accumulation in these layers.

4. Humus forms : a second level of taxonomy?

Perhaps a second level of taxonomy could be introduced utilising subdivisions of master horizons (OLn and OLv, OFz and OFnoz, OHz and OHnoz, A…) and/or taking into consideration the appearance of discontinuous and later-on continuous horizons which are typical for the adjacent humus type (i.e. the OFz horizon in the mull subcategories 3 and 4 in table 4). Eleven subcategories are also determined, as you can see on table 4 and figure 3. These categories seem to be compatible with the concepts of the national classification schemes.

Table 4. A possible second level division of main humus forms.



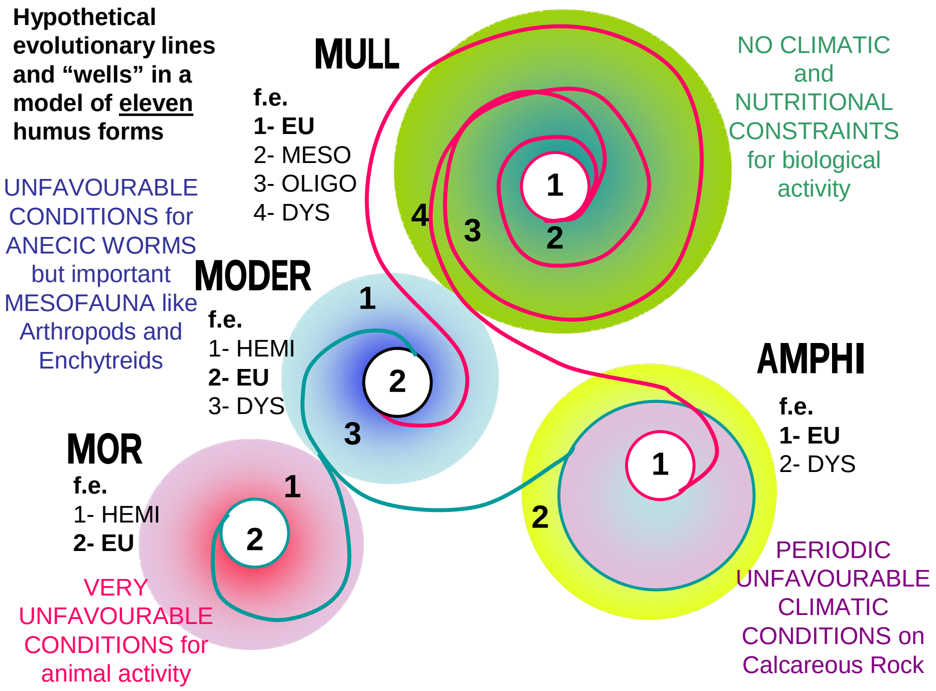


Figure 3. Position of the transitional forms in the continuum of the ecological factors.

5. Space/time relationships

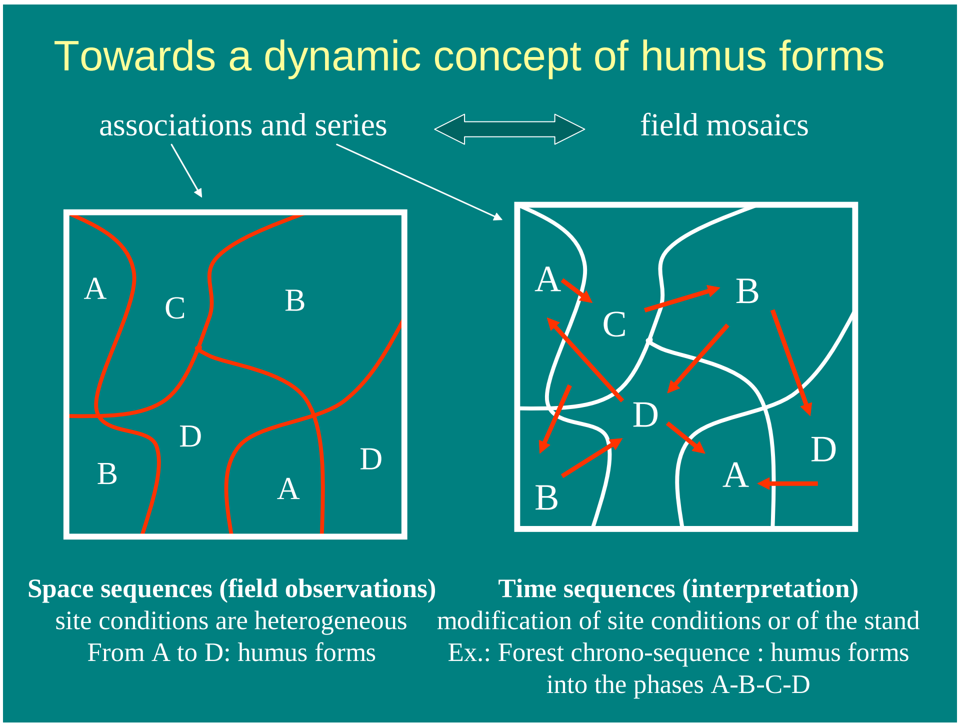
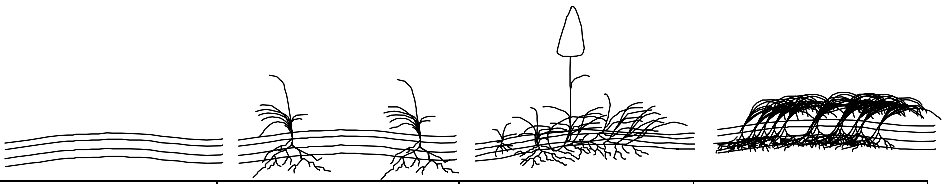


Figure 4. Space-time sequences

As it was pointed out several times throughout this text, humus forms are very valuable diagnostic tools for analysis of forest ecosystem status and dynamic behaviour. Thus a distinct humus form which is diagnosed on location and/or at a certain time in a forest ecosystem reflects the spatial and/or temporal pattern of exo- and endogenic factors, which determine or control the humification process. A certain spatial pattern of distribution of humus forms in the field may be either the product of spatial variability of site conditions, or tree species and canopy conditions, or it may be the product of temporal development stages or sucession stages of a certain forest ecosystem, which occur side by side (figure 4). This pattern may be investigated using a “false” time series approach.

Figure 5 gives important characteristics of a humus form pattern on a site on Hochwechsel, in Eastern Styria, Austria. The site is situated at an altitude of 1320 m on Wechselgneiss, potential natural woodland community being a Luzulo-Abietum typicum (Zukrigl, 1973). The four development phases which are shown in the figure reflect a “false” chronosequence of canopy densities in a rotational Norway spruce forest indicated by the establishment of the grass species Avenella flexuosa.



Development phase	Nudum	Establishment phase	Exploration phase	Final phase
Humus form*	mor	morlike moder	rhizomoder	morlike moder
Mass [$g.m^{-2}$]	7600	6400	3040	4690
C:N-ratio	23.2	23.2	19.5	26.9

** from Nestroy et al. 2000*

Figure 5. Chronosequence on Hochwechsel, in Eastern Styria, Austria.

6. Outlook

The importance of an harmonization in humus forms concepts, methods of description and classifications led the authors to invite last year some personalities of 8 European countries to a meeting in Italy. The result was the constitution of an European working group whose mission statement has been defined:

- Normative actions: to present an harmonized humus description and classification system in the different regions of Europe,
- To see the humus profiles in a dynamic context,
- To strengthen understanding of ecosystem dynamics in the soil compartments
- To apply knowledge from humus studies in management: decisions in land management (i.e. in respect to carbon sequestration or consequences of climate change) or support to decisions in forestry…

Five sub-groups were created, focussed respectively on: the concept of humus forms, methods of studying or describing, harmonized classification, communication and education, humus form and society. The labour of these groups has continued during the year by the way of e-mail or field trips, and a new meeting is planned for next year to progress in the aim of harmonization.

The question of the definition of diagnostic horizons or units of classification is yet open: new opinions have to be taken into account, some complements have to be added, and situations of some humus forms in time sequences have to be précised, i.e.: humus forms of high elevations, humus forms with sequestration of organic carbon in A horizons, initial humus forms…

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