Humus forms as a synthetic parameter for ecological investigations. Some examples in the Ligurian Alps (North-Western Italy)

DOI:10.1016/j.apsoil.2017.04.008

Humus forms as a synthetic parameter for ecological investigations. Some examples in the Ligurian Alps (North-Western Italy)

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Abstract

In the Ligurian Alps, a wide range of site conditions that influence soil development and may affect humus variability are present. In this work, we wanted to evaluate the potentialities of humus forms as a synthetic indicator of both chemical properties of the humic episola and site conditions in the upper Tanaro Valley (NW Italy). Vegetation affected the C/N ratio of the least transformed organic horizons, but the effect disappeared in mineral ones, where the pH was related to the soil parent material. All terrestrial humus forms were found in the area and their distribution well reflects the interactions between vegetation, lithology, elevation that shape soil properties and affect the degradability of litter and its actual degradation by microorganisms and soil fauna. Humus forms were thus able to capture the ecological conditions, providing additional information with respect to soil classifications.

Highlights

- The Ligurian Alps represent a transition between the Mediterranean and the temperate climate.
- All humus systems are present and Amphis are relatively abundant
- Humus forms reflect the interaction between site and soil conditions

- Humus forms were able to capture the ecological variability and synthesize it in a single parameter

Keywords: forest cover, soil parent material, climate, soil organic matter

1. Introduction

In the Ligurian Alps, the Mediterranean and temperate climatic regimes merge, giving rise to unique environmental conditions in the geographical Alpine area. Vegetation distribution reflects micro-environmental conditions, shaped by the influence of marine breezes, atmospheric humidity and thick, though often transient, snow cover during wintertime (Jefferson, 2011). In a relatively small area, soils vary from poorly developed Regosols to desaturated Alisols, from Podzols to Terra Rossa soils, depending on present or past climatic conditions, geomorphology, vegetation and lithology and their interactions (Catoni et al., 2016; D'Amico et al., 2015).

Humus forms are useful and inexpensive indicators of the complex interactions between the soil forming factors (such as climate, vegetation, relief, and geology) and the soil environment (Ponge et al., 2014). Vegetation has indeed a direct effect on litter degradability and transformations (e.g. Bonifacio et al., 2008), while climate and parent material have a major influence on soil biological and microbiological activity (e.g. Ponge et al., 2011). The description of humus forms may thus help in elucidating ecological conditions in complex environments adding therefore to the information provided by soil classifications.

The aim of this work is therefore to show how the humus forms can be used as a synthetic indicator of environmental variable interactions in a valley of the Ligurian Alps.

2. Materials and Methods

The upper Tanaro Valley, at the border between Piemonte and Liguria Regions, in Italy, was the object of an extensive soil survey in the last years, that encompassed the villages of Ormea, Briga Alta, Caprauna, Garessio and Triora, with an area of approximately 280 km^2. Thanks to a low anthropogenic pressure and a generally low altitude, the area is mainly covered by forests. The most common forest species is beech (FS, *Fagus sylvatica* L.), covering around 30% of the forest surface. Chestnut (CS, *Castanea sativa* Mill.), Scots pine (PS, *Pinus sylvestris* L. or *Pinus montana* Mill.) and hornbeam-ash associations (FO, *Fraxinus ornus* L. and *Ostrya carpinifolia* Scop) represent approximately 10-15% of forest surface each, while a lower percentage of the area (around 5%) is occupied by larch (LD, Larix decidua Mill) and silver fir (AA, *Abies alba* Mill.) forests.

Twenty sites were selected as examples amidst a much larger (70) number of observations to describe humus forms that represent the most common forest cover and lithology types in the area. Seven sites were under FS, 4 under PS, 3 under CS, 2 in LD- and FO-dominated sites, and 1 under AA. From the geological point of view, all sites were located on either the Ligurian Briançonnais domain (quartzite or metamorphic quartzitic porphiroids, QTZ, or limestone-dolostone, LIM) or the Helminthoides Flysch units (FLY). The sites range in elevation from 800 to 1730 m a.s.l. At all sites, pits were opened and soil profiles were described, analyzed and classified according to the WRB (IUSS Working Group WRB, 2014). Humus forms were described following Zanella et al. (2011).

The C and N contents of all samples from the humic episolum were analyzed with an element analyzer (NA2100, CE Instruments, Rodano, Italy) and pH was determined in water.

Differences in chemical properties related to vegetation or parent material were evaluated through analysis of variance (oneway ANOVA) using IBM SPSS Statistics 23. In case of significance of the ANOVA model, differences among groups were assessed through the Duncan test.

Table 1 provides a summary of the site characteristics and soil types at sampling points.

3. Results and Discussion

Despite the variability in site factors, the pH values had a quite narrow range, particularly in the OL and OF horizons (from 5.1 to 6.5), while the variability increased in the mineral horizons of the episolum (from 4.8 to 7.3, Table 2), where a significant effect of soil parent material was found (7.3 ± 0.99 on LIM and 4.84 ± 0.96 on QTZ, $p<0.01$). In the OL horizons, the C contents did not differ significantly with vegetation types ($p=0.268$), but a forest cover effect was visible in the N contents ($p<0.05$), with the lowest values under pine (Table 2), and consequently in the C/N ratio ($p<0.01$). The highest C/N ratio in OL layers was found under Scots pine (60.6), but it was above 40 also in fir (48.2) and beech (42.3). The effect of vegetation was less visible in OF and OH horizons, where only the C/N ratio was significantly different ($p<0.01$ in OF and $p<0.05$ in OH, Table 2), and almost disappeared in the mineral horizons ($p=0.047$). This is in agreement with the complexity of the system controlling organic matter and its interactions with the mineral phase in the soils of the area that sharply affect its degradability (Catoni et al., 2016).

All Humus systems were found in the study area without, as expected, any clear dependence on vegetation cover nor on soil parent material as single influencing variables (Table 3). Amphis were common, in agreement with the diffusion of this humus form in Italy pointed out by Andreetta et al. (2016).

In the case of Scots pine stands (PS), humus forms illustrated quite well the interaction between vegetation and lithology: the low degradability of pine litter, related to its low N contents, originated Pachyamphi forms on limestones, where a higher pH favored biological activity. At the same elevation, a Dysmoder developed on quartzitic rocks (Figure 1) and, where higher elevation added to the poor degradability of pine litter and acidity of the parent material, a Hemimor formed (Figure 2). Humus forms thus mirrored the variability of ecological conditions when the lack of specific pedogenic processes and the limited soil development originated soils belonging to the same WRB group (Cambisols on both LIM and QTZ at around 1200 m, Table 1). The potentiality of humus forms as ecological indicators of interactions between site and soil properties was emphasized in the beech stands (FS, Figure 3a). Amphi forms were present on limestones where a good biological activity was coupled with the low degradability of beech litter. Biological activity allowed the development of biomacro A horizons and Leptoamphi humus forms at the lowest elevation (830 m a.s.l.), while biomeso A were present at 1200-1400 m, with Eumesoamphi and Pachyamphi forms (Figure 3b). Beech litter is well known for having a high lignin/N content, coupled with relatively low contents of basic cations and N (Jacob et al., 2010; Lagenbruch et al., 2012), and its ability to acidify the soil may be even comparable to that of conifers (Augusto et al., 2002). This effect was clearly visible from humus forms in the study area: Podzols with well developed E horizons were found in beech stands on quartzite, where humus belonging to the Mor system were present. Similar situations were observed in the chestnut stands (CS), with the shift from Oligomull and Eumesoamphi (at ~ 900-1000 m a.s.l.) to Hemimoder (1100 m a.s.l.) with increasing elevation and acidity of the soil parent material. In forests belonging to the hornbeam-ash associations (FO), humus forms seemed to reflect more the litter characteristics than other site or soil factors, such as lithology or soil pH. At 800-900 m, Amphiforms with biomacro A horizons were present both on calcareous and acidic rocks, with only slight differences in OH thickness. Larch forests (LD) were used as pasture in the study area, particularly in the past, and were thus characterized by abundant grass cover. The high degradability of herbaceous litter, coupled with limestones, was likely the determinant factor for the occurrence of Mull forms, despite the high elevation of the two sites (e.g. 1640 and 1670 m). At approximately the same elevation, on the same parent material, a Hemimoder humus developed under silver fir (AA) (Table 3).

The interactions among site factors are summarized in Figure 4, where a clear gradient towards less biologically active humus forms with increasing climatic or soil fertility limitations is visible.

4. Conclusions

In the Ligurian Alps, the distribution of humus form seems to be shaped by the concomitant action of vegetation, lithology, and elevation that drives the degradability of litter and affects its actual decomposition by microrganisms and soil fauna. Although in some cases one of the factors dominates, more frequently humus forms well reflect the complex interactions between site and soil factors. Humus forms represent therefore a synthetic and inexpensive indicator for the interpretation of ecological conditions in the forest ecosystems of the Ligurian Alps.

5. Acknowledgements

This work was supported by the POR-FESR 2007/2013 program (Poli innovazione-Regione Piemonte) (grant number 186-153C).

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Table 1. Forest cover, lithology, elevation and soils at sampling points

Vegetation[†]	Lithology[‡]	Soil types
PS	LIM	Folic Cambisol (1200 m)
	FLY	Cutanic Alisol (1320 m)
	QTZ	Haplic Cambisol (1230 m), Ortsteinic Albic Podzol (1730 m)
FS	LIM	Calcic Chernozem (840 m), Cutanic Luvisol (1230 m), Haplic Cambisol (1410 m)
	FLY	Haplic Regosol (1310 m)
	QTZ	Albic Podzol (1300 m), Haplic Regosols (1020, 1240 m)
CS	FLY	Haplic Regosols (880, 1030 m), Cutanic Luvisol (970 m)
	QTZ	Cutanic Escalic Luvisol (1100 m)
LD	LIM	Haplic Cambisol (1640 m), Haplic Regosol (1670 m)
AA	LIM	Haplic Regosol (1610 m)
FO	LIM	Calcic Kastanozem (800 m)
	QTZ	Haplic Cambisol (890 m)

† PS: *Pinus sylvestris* L. or *Pinus montana* Mill.; FS: *Fagus sylvatica* L.; LD: *Larix decidua* Mill. associated with grassland; AA: *Abies alba* Mill., FO: *Fraxinus ornus* L. and *Ostrya carpinifolia* Scop. association; CS: *Castanea sativa* Mill.

‡ FLY: Helmintoides Flysch Unit; LIM: limestone and/or dolostone; QTZ: quartzite or porphiroids.

Table 2. Chemical characteristics of the horizons of the humic episola (average ± standard deviation) in the different forest sites. Different letters indicate significant differences among vegetation types ($p<0.05$, Duncan test)

		n	pH	C	N	C/N
				g kg^{-1}	g kg^{-1}	
PS[†]	OL	3	5.1 ± 0.3	463.3 ± 40.2	7.8 ± 1.1 b	60.6 ± 12.6 a
	OF	3	5.5 ± 0.7	356.6 ± 91.9	10.8 ± 2.2	32.6 ± 2.2 a
	OH	3	5.2 ± 1.2	327.4 ± 50.0	9.6 ± 1.8	34.3 ± 1.5 a
	A or E	4	5.2 ± 1.7	60.7 ± 23.2	2.2 ± 1.1	29.5 ± 8.7 a
FS	OL	7	5.7 ± 0.4	435.6 ± 28.0	10.6 ± 1.9 ab	42.3 ± 7.6 b
	OF	7	6.1 ± 0.6	366.2 ± 67.7	13.4 ± 1.7	27.2 ± 2.0 b
	OH	4	6.2 ± 1.1	266.0 ± 66.0	11.7 ± 2.1	22.7 ± 3.5 b
	A or AE	7	5.9 ± 1.4	62.4 ± 37.9	3.8 ± 2.5	17.8 ± 4.3 ab
CS	OL	4	4.9 ± 0.6	454.0 ± 17.2	13.0 ± 2.0 a	36.0 ± 5.7 b
	OF	3	5.8 ± 0.2	255.0 ± 59.0	11.4 ± 3.0	22.5 ± 0.8 c
	OH	1	5.9	262.7	10.0	26.3
	A	4	4.8 ± 0.6	24.5 ± 6.4	1.8 ± 1.1	17.6 ± 9.0 ab
LD	OL	2	5.5 ± 1.0	340.4 ± 173.9	12.4 ± 1.4 a	26.9 ± 11.1 b
	OF	1	5.6	359.7	14.8	24.4
	A	2	5.9 ± 0.4	81.3 ± 3.8	5.9 ± 0.9	13.8 ± 1.5 b
AA	OL	1	6.5	416.9	8.7	48.2
	OF	1	6.1	258.3	8.6	30.1
	A	1	7.2	82.7	3.2	25.9
FO	OL	2	5.8 ± 0.4	426.2 ± 13.2	13.7 ± 3.3 a	32.1 ± 6.8 b
	OF	1	6.3	372.6	14.3	26.1
	OH	1	7.1	349.1	16.3	21.4
	A	2	7.1 ± 1.1	35.4 ± 19.7	2.8 ± 2.2	14.7 ± 4.5 b

[†] PS: *Pinus sylvestris* L. or *Pinus montana* Mill.; FS: *Fagus sylvatica* L.; LD: *Larix decidua* Mill. associated with grassland; AA: *Abies alba* Mill., FO: *Fraxinus ornus* L. and *Ostrya carpinifolia* Scop. association; CS: *Castanea sativa* Mill.

Figure 1: Dysmoder under Scots pine on acidic parent material

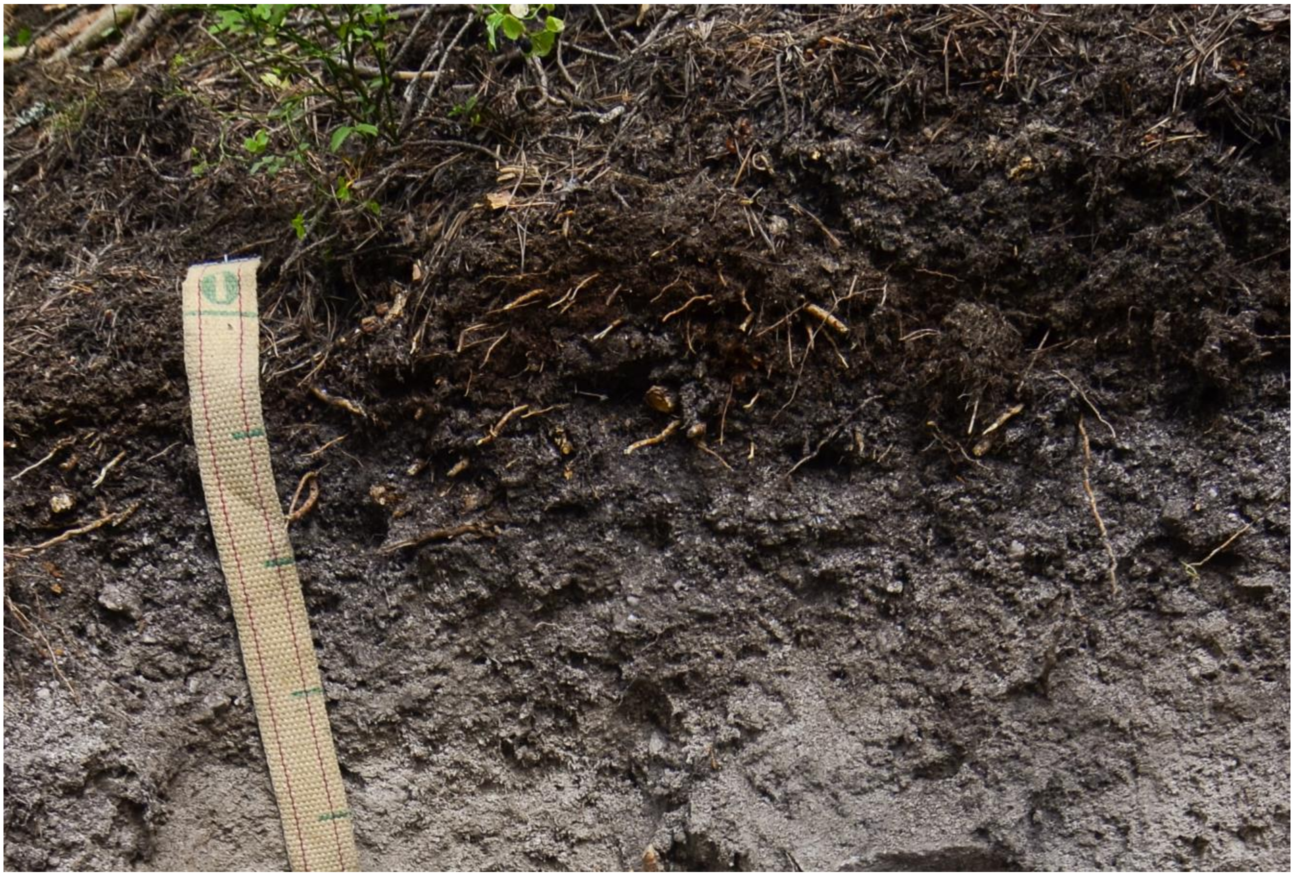

Figure 2: Hemimor in pine forest at high elevation

Figure 3: A beech stand at 1200 m a.s.l in the Ligurian Alps (a) with Pachiamphy humus form (b)

Figure 4: Distribution of humus forms in the Ligurian Alps under the influence of vegetation, lithology and elevation. Vegetation types have increasing C/N ratio from left to right, site conditions become harsher from top to bottom and, for each species, with increasing color saturation. Number in parentheses are pH and C/N ratio of the mineral horizon.

	LD		*FO*		*CS*		*FS*			*AA*	*PS*		
elevation (m asl)	**LIM**		**LIM**	**QTZ**	**FLY**	**QTZ**	**LIM**	**FLY**	**QTZ**	**LIM**	**LIM**	**FLY**	**QTZ**
800			EumeA (7.9-11.5)				LeptoA (8.1-14.8)						
900				LeptoA (6.3-17.9)	OliMu (5.7-11.3)								
1000					EumeA (4.4-10.9)				DysMu (5.7-14.8)				
1100						HeMd (4.6-18.0)							
1200							PachyA (7.4-15.4)		HeMd (4.6-16.9)		PachyA (7.7-22.0)		DysMd (4.2-42.0)
1300								OliMu (5.7-15.7)	HuMor (4.1-26.9)			HeMd (4.8-25.9)	
1400							EumeA (5.4-19.0)						
1500													
1600	OliMu (6.2-12.7)									HeMd (7.2-25.8)			
1700	DysMu (6.1-15.7)												HeMor (4.0-28.0)

PS: *Pinus sylvestris* L. or*Pinus montana* Mill.; FS: *Fagus sylvatica* L.; LD: *Larix decidua* Mill. associated with grassland; AA: *Abies alba* Mill., FO: *Fraxinus ornus* L. and *Ostrya carpinifolia* Scop. association; CS: *Castanea sativa* Mill. - FLY: Helmintoides Flysch Unit; LIM: limestone and/or dolostone; QTZ: quartzite or porphiroids – OliMu: Oligomull, DysMu: Dysmull, LeptoA: Leptoamphi, EumeA: Eumesoamphi, PachyA: Pachyamphi, HeMd: Hemimoder; DysMd: Dysmoder; HuMor: Humimor, HeMor: Hemimor