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Short communication

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 is 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 soil pH was related to the parent material. All terrestrial humus forms were found in the area and their distribution well reflected the interactions between vegetation, lithology, elevation that shaped soil properties and affected the degradability of litter and its actual degradation by microorganisms and soil fauna. Humus forms were thus able to capture the ecological conditions, integrating the information provided by soil classifications.

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 complementing and integrating 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, 4 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

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

Vegetation[a]	Lithology[b]	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)

[a] 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.
[b] FLY: Helmintoides Flysch Unit; LIM: limestone and/or dolostone; QTZ: quartzite or porphiroids.

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.

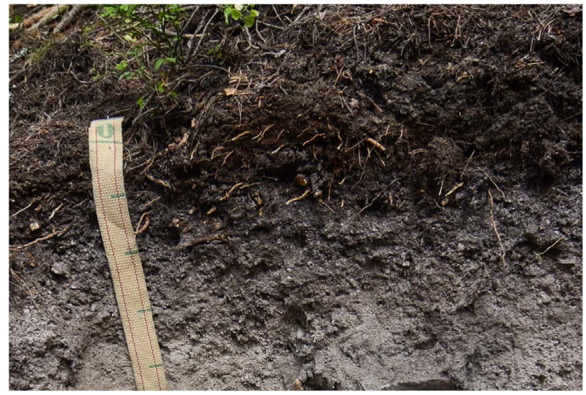

Fig. 1. Dysmoder under Scots pine on acidic parent material.

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). 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

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 (g ± kg^{-1})	N (g ± kg^{-1})	C/N
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.