Evaluating humus forms variation in an unmanaged mixed beech forest using two different classification methods

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Humus is an important part of terrestrial ecosystems and can be considered as an indicator of th ecosystem functioning status. The application of morphological methods is an inexpensive and easy way to study humus forms. Two morphological methods were adopted in a beech stands of the Hyrcanian forest in order to assess their applicability in the study of these ecosystems. An unmanaged beech stand was selected and 320 humus profiles were considered. In each profile the humus form was determined as to suborder level according to the above morphological methods. The results showed that the average thickness of organic and organo-mineral horizons (OL, OF, OH and Ah) in the study site was 2, 0.6, 0.3 and 3.6 cm, respectively. Moreover, the two different morphological methods used in the study site had different functions and outputs. According to both methods the Mull order was the dominant humus form in the study site. The number of humus suborders found in the study site was different in the two methods and indicates their different ability in describing humus forms in the study site.

Keywords: Humus Classification, Mixed Beech Forests, Hyrcanian Forest, Organic Horizons

Introduction

Decomposition of organic matter plays a vital role in nutrient cycling, driving the mineralization of organically bound nutrients, and making them available for plant uptake. In infertile soils the role of decomposition processes becomes even more significant in nutrient cycling, since almost all plant available nutrients in these ecosystems originate from plant debris (Sluiter & Smit 2001). Different types of humus forms develop within the top-soil throughout the process of biotransformation of dead organic matter. Climatic conditions, soil characteristics and vegetation types are among the main factors affecting this process (Green et al. 1993). Humus forms have been considered as one of the principal components of terrestrial ecosystems (Sajedi et al. 2004). Since humus forms develop at shorter time scales than soil types, they have to be classified independently (Graefe & Beylich 2006). Humus forms are indicators of ecosystem functioning and characteristics, providing useful information on site conditions such as availability of moisture, soil acidity, nutrient status (Van Delft et al. 2006) and decomposition rates (Ampe & Langhor 2003). Humus represents the complex organic substances resulted from the decomposition of plant and animal fragments. These materials are more stable, colloidal, and mostly in connection with the mineral component of the soil. Humus forms commonly are comprised of organic and organic-enriched mineral horizons at the soil surface, and are considered as natural bodies such as the underlying soils (Green et al. 1993). The morphological study of humus forms has begun since the 19th century (Ponge 1999) and until now many morphological methods of classification have been developed worldwide (Babel 1971, Green et al. 1993, Brethes et al. 1995, Van Delft et al. 2006, Zanella et al. 2009, 2011). The morphological study of humus forms, in comparison to chemical methods, is inexpensive, easier to manage on the field and can easily be instructed to forest staffs.

Hyrcanian forests, covering about 1.9 million ha, are broad-leaved deciduous forests forming a green belt along southern and south-western coasts of the Caspian Sea. They are unique in genetic variation, biodiversity, commercial productions and many other environmental services (Sagheb-Talebi et al. 2004, Poorzady & Bakhtiari 2009, Pourmajidian & Rahmani 2009, Behjou et al. 2009). The first morphological study on humus forms in Hyrcanian forests was done by Sajedi et al. (2004). They classified the humus forms in a pure beech forest using a Canadian grid by Green et al. (1993). Their results showed that Moder was the dominant humus form in the studied stands. In a second report, Waez-Mousavi (2010) applied a European humus classification method (Zanella et al. 2009) to the study of humus forms in some mixed beech stands of Hyrcanian forests. The author found that humus forms belonging to the Mull group were dominant in this area. The present study aimed to compare the two morphological methods of classification which have been applied in beech stands of Hyrcanian forest and to assess their applicability for the ecological characterization of these ecosystems.

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Received: Dec 04, 2011 - Accepted: Sep 27, 2012

Citation: Waez-Mousavi SM, Habashi H, 2012. Evaluating humus forms variation in an unmanaged mixed beech forest using two different classification methods. iForest 5: 272-275 [online 2012-10-24] URL: http://www. sisef.it/iforest/contents?id=ifor0632-005

Communicated by: Alberto Santini

Materials and methods

Study site

This investigation was carried out in parcel 32 of compartment 1 in Shast Kalate (Bahram Nia) forest, experimental forest of Gorgan University of Agricultural Sciences and Natural Resources, a virgin mixed deciduous forest covering an area of about 3 716 ha and located in the north of Iran (36°41´ to 36°45′ N and 54°20′ to 54°24′ E), with an average annual precipitation of about 650 mm, and an altitude ranging from 100 to 1000 m a.s.l. The mentioned parcel, with an area of about 80 ha and an altitude of about 900 m a.s.l., is mostly covered by *Fagus orientalis Lipsky* (oriental beech) mixed with *Carpinus betulus* L. (common hornbeam) and *Parrotia persica* (DC.) C.A. Mey (Persian ironwood tree). The aforementioned parcel is a permanent plot for long term studies, established on brown forest soil with mostly sandstone as bedrock.

Data collection

In 2009, 320 humus profiles were randomly examined within old-growth mixed beech-dominated stands in the parcel. In each profile humus classification units and subunits were determined according to Canadian (Green et al. 1993) and European (Zanella et al. 2009) methods mentioned above. Both classifications are based on morphological characteristics of organic (L, F, H or OL, OF and OH, respectively) and organo-mineral (Ah or A, respectively) horizons, such as their presence or absence, thickness, structure, animal or fungal acti-

Tab. 1 - Organic and organo-mineral horizon thickness.

Parameters	N	Range (cm)	Mean (cm)	SD
L=OL	320	0-7.5	2.0	0.90
F=OF	320	0-3	0.6	0.57
H=OH	320	0-3.5	0.3	0.55
Ah=A	320	0-15	3.6	2.36

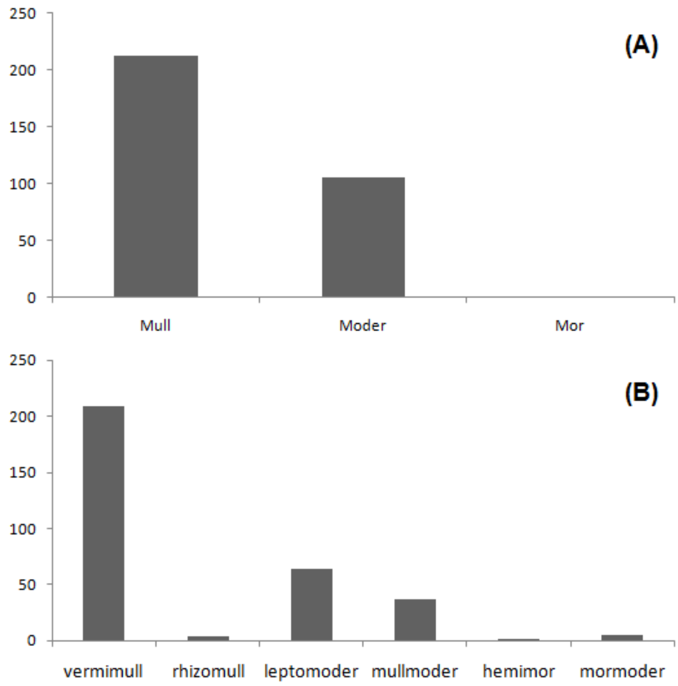

Fig. 1 - Abundance of humus main references (a) and subunits (b) according to Green et al. (1993).

vity, *etc*., among which horizon thickness and structure were the most important. The thickness was measured as to the nearest mm and the structure was assessed to the naked eye or with a 5-10x magnifying hand lens.

Results

The average thickness of organic and organo-mineral horizons (OL, OF, OH and A) in the study site was 2, 0.6, 0.3 and 3.6 cm, respectively (Tab. 1).

Using the key by Green et al. (1993) Mull was the dominant humus form unit, with 213 of all 320 studied profiles (66.5%), Moder followed with 106 profiles (33.12%) and only 1 profile belonged to Mor (Fig. 1a). Six humus form subunits were observed: vermimull was the most dominant humus suborder (209 samples, 65.3%), while hemimor was the rarest one (1 sample). Other subunits found in the study site were leptomoder (64 samples, 20%), mullmoder (37, 11.56%), mormoder (5, 1.56%) and rhizomull (4, 1.25% - Fig. 1b).

Using the classification of humus forms by Zanella et al. (2009), Mull was the most widespread humus form unit, with a frequency of 226 (70.62% of all samples) in the study site. Amphi and Tangel showed a frequencies of 92 (28.75%) and 2 (0.62%), respectively. Nine subunits were found in the study site: dysmull, with 121 samples (37.1%) and eumull, with 92 samples (28.75%), were the commonest humus form subunits, while pachyamphi and eutangel with 2 samples each (0.62%) were the rarest humus form subunits in the study site (Fig. 2).

Discussion

The abundance of Mull in the study site, 66% using the method by Green et al. (1993) and 71% using the method by Zanella et al. (2009), indicates a fairly fast decomposition rate and a rapid return of foliage nutrients into the soil (Ampe & Langhor 2003, Zanella et al. 2011). It also shows good habitat conditions for soil organisms such as suitable aeration, balanced moisture supply, nutrient-richness, proper temperature and an input of easily decomposable litter (Green et al. 1993).

A previous study by Sajedi et al. (2004) revealed that Moder was the dominant humus form in some pure beech stands of Hyrcanian forests, while the present study, realized in a mixed broadleaved part of Hyrcanian forests, shows the dominance of Mull humus forms. This difference is probably due to the difference in species composition of the canopy. The presence of Mull-forming tree species like hornbeam (*Carpinus betulus*) within a stand dominated by Moder-forming species such as beech (*Fagus orientalis*) has probably a positive impact on the forest floor decomposition rate and can facilitate the building of a Mull form. A similar impact of mixed canopies has already been observed by Brandtberg et al. (2000) and Aubert et al. (2006).

According to Green et al. (1993), Mull is a humus form in which organic matter is combined with the upper mineral soil instead of being accumulated on its surface as in Mor and Moder humus forms. Actually, the most common Mull subunit in the study site is vermimull, resulting from a high activity of large earthworms, which are able to incorporate organic matter and mineral particles, forming the topsoil crumby structure of Mull. This also suggests that trees in the stu-

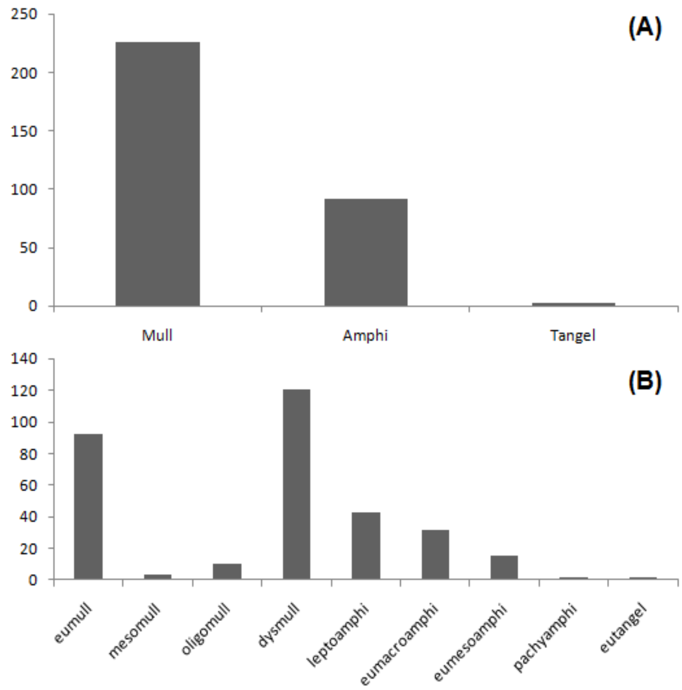

Fig. 2 - Abundance of humus main references (a) and subunits (b) according to Zanella et al. (2009).

died stands produce easily decomposable litter. The next most abundant humus subunits were leptomoder and mullmoder, both belonging to the Moder unit according to the above authors. The abundance of these two subunits suggests a rapid decomposition rate and a high soil faunal activity, though not high enough to completely decompose and vanishing the organic horizons, as occurring in the Mull unit (Green et al. 1993).

According to Zanella et al. (2009), Mull was the dominant humus form unit in the study site. Mull is an indicator of a temperate climate condition with high soil fauna activity and rapid decomposition rate (Ponge 1999, Sajedi et al. 2004, Zanella et al. 2011). This humus form occurs in stands that produce easily biodegradable litter with relative low C/N ratio and without serious environmental constraints. The pH_{water} of the A horizon in Mull order is often more than 5 (Zanella et al. 2011), in agreement with a pH ranging from 5.3 to 7.8 observed by Habashi (2007) in the same site.

Concerning terrestrial ecosystems, *i.e.*, those showing never or almost never submerged or water saturated soils, the employed keys of classification are able to identify 3 (Canadian: Mull, Moder and Mor) or 5 (European: Mull, Moder, Mor, Amphi and Tangel) main references. European Amphi, Tangel, Moder and Mor correspond to Canadian Moder or Mor. In fact, considering the influence of the substrate, the European classification shares calcareous and siliceous topsoils. On calcareous substrates Amphi corresponds to a twin humus form showing both characters of Mull (crumby organo-mineral horizon) and Moder (accumulated organic humus), due to a seasonal alternation between phases of high and low biological activity in strongly seasonal Alpine and Mediterranean environments (Ponge et al. 2010). Tangel expresses particular characters at high elevation and on hard calcareous rocks, where litter is out of reach of soil decomposer activity for most of the year and invertebrates cannot dig through the parent rock. In both European and Canadian classifications, starting from a neutral Mull, Moder and Mor correspond to a scale of decreasing nutrient availability and colder conditions, stemming in decreasing biological diversity and activity on acid substrates.

The above main references were further distinguished in a second level of 16 subunits in the Canadian or European classification as well. In the study area, 6 or 9 subunits were detected with Canadian (Green et al. 1993) or European (Zanella et al. 2009) keys respectively. The Green et al. (1993) reference comprises only 3 Mull subunits while the Moder and Mor enumerate 6 and 7 subunits respectively. This means that the Canadian key emphasizes Mor and Moder humus forms which are common in this country. On the other hand, the European key encompasses of 4 Mull, 4 Amphi, 3 Moder, 2 Tangel and 3 Mor subunits. Regarding the temperate climate condition of the investigated site, Mull, Amphi and Moder (or Mull and Moder in Green et al. 1993) are more expectable than Mor forms. Leptoamphi sub-unit in European method mostly correspond to vermimull and leptomoder sub-units in Canadian method, eumacroamphi correspond to leptomoder, vermimull and mullmoder, eumesoamphi correspond to leptomoder, pachyamphi correspond to hemimor, eutangel correspond to mormoder sub-unit in as well. This correspondence is mainly due to similar definition of these four units (Amphi, Moder, Tangel, Mor):

1. *Amphi or Moder.* According to the European classification Amphi order encompasses humus profiles in which there is "simultaneous presence of OH, A biomacro or A biomeso horizons, absence of OFnoz, thickness of A horizon ≥ thickness of ½ OH horizon, absence of A massive or single grain, presence of A biomacro and one of the following; living earthworms in the A horizon, sharp transition between A and OH, pH in water of the A horizon ≥ 5". While in Moder according to the aforementioned classification, the following characteristics are expected: "presence of OH horizon, absence of OFnoz, absence of A biomacro, absence of A biomeso and one of the following, no sharp transition OH/A horizon (transition ≥ 5 mm), pH in water of the A horizon < 5, presence of A biomicro". But Canadian classification does not mention neither an especial pH nor an A to OH transition condition for Moder order, and emphasize on the horizon thickness and zoogenous or fungal activities as the most important criteria to classify the humus profiles.
2. *Tangel or Mor*. According to the European classification a Tangel order must has the following characteristics: "presence of thick organic zoogenic horizons (OFzo + OH > 5 cm), hard limestone and/or dolomite rock/rock fragments at the bottom of the humus profile, cold climate (subalpine or upper montane belts), absence of OFnoz, presence of a thin (thickness < ½ OH) A massive or single grain or biomeso; or pH in water of the a thin (thickness < ½ OH) A horizon ≥ 5". In this study site only two Tangel orders were found in some rare stone outstanding (mostly sand stone) scattered out in the area. But Mor order is characterized by a mass accumulation of organic matter and a thick Fm (mycogenous F horizon) and zoogenous activity is very low (Green et al. 1993). In the study site only one humus profile was found having (almost) such characteristic, which is negligible.

Considering all above facts, it can be concluded that in comparison between two main humus classification methods, the European key classification reveals itself more precise and seems more suitable than the Canadian one for mixed oriental beech forests and similar ecosystems. The same category (such as Mull or Moder) did not gather an equal number of soil profiles with European or Canadian classification. This is due to the difference in definition of units and sub-units in the classifications. A soil profile may be considered as a Mull (dysmull) with the European method and as a Moder (mullmoder) with the Canadian, because the two methods emphasize different criteria for the definition of the main references and subunits. The European method emphasizes the structure of A, pH and H to A transition condition as critical criteria, while the Canadian method mostly stresses the horizons thickness more that other characteristics of humus profile.

As a conclusion, the European humus classification method (Zanella et al. 2009) is recommended for Hyrcanian mixed beech forests and similar ecosystems.

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