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Humus forms in relation to altitude and forest type in the Northern mountainous regions of Iran

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ABSTRACT

This study focuses on the morphological and chemical development of humus forms as a function of altitude and forest type in the Northern Iran. Terrestrial humus forms related to European Humus Group proposal (EHGP) were evaluated under six common forest types, *i.e. Alnus subcordata* (AS), *Acer velutinum* (AV), *Fagus orientalis - Carpinus betulus* (FC), *Carpinus betulus* (CB), *Fagus orientalis* (FO) and *Fagus orientalis - Carpinus betulus - Parrotia persica* (FCP) stands with different topographic conditions. Within 61 permanent plots, organic (OL, OF, OH), organic-mineral (Ah) and mineral (soil A 0–15; first 15 cm under Ah) layers were collected for identification and chemical analyses. Our results support the idea that altitude and species composition were the two major factors controlling the presence of the different humus forms and their chemical characteristics. While mull was mainly observed at the lowest altitude under AS, moder was usually present at middle altitude under FC and FCP and mor dominated at the highest altitude under FO and FC. Moreover, organic layer thickness also increased with altitude and was higher in the case of mor. On the contrary, the organic-mineral layer thickness was higher at the lowest elevations in the case of mull. The chemical composition of humus layers also differed among forest types. PCA analysis showed that AS and AV forest types were closely related with mull and amphi humus forms, pH, macro nutrients and soil C and N, while FO, FC, and FCP forest types were closely related with moder and mor humus forms, C:N ratio, slope and altitude.

1. Introduction

Humus forms integrate site physical, chemical and biological properties and have been used as good indicators of present and past climate (Ponge et al., 2010; Zanella et al., 2011a; Labaz et al., 2014) as well as of site quality/fertility and tree growth (Ponge et al., 2002; Andreetta et al., 2016). In fact, humus morphology strongly depends on the combination of both environmental (i.e. slope, altitude, climate, parent-rock, soil) and biological factors (i.e. tree species composition and forest management) (Seeber and Seeber, 2005; Labaz et al., 2014; Andreetta et al., 2016), even though the effect of altitude and tree species has been previously shown to be determinant in mountainous areas (Ponge et al., 2014; Labaz et al., 2014; Andreetta et al., 2016). Many authors contributed to the development of different humus form classifications, mainly based on the key role of living components in the topsoil. The most prominent contributions are those of Hesselmann (1926), Hartmann (1944), Kubiëna (1953), Babel (1971), Delecour (1983), Green et al. (1993) and Zanella et al. (2011) (Ponge et al., 2011; Jabiol et al., 2013; Ponge et al., 2014). Among all the different classification systems, the methodologies developed by Green et al. (1993) and Zanella et al. (2011), called the Canadian and European classification methods, respectively, have been largely used in several research activities in the last decade (Waez-Mousavi and Habashi, 2012; Ponge et al., 2014; Andreetta et al., 2016). Both classifications are based on the use of some diagnostic horizons but, while the Canadian classification recognizes three different humus form orders (i.e. mulls, moders and mors), the European classification refers to five different orders (i.e. mulls, moders, mors, amphis and tangels), further divided into more detailed sub-categories (Jabiol et al., 2013).

The Caspian Hyrcanian ecoregion, with its heterogeneous topography and soil characteristics, includes some of the oldest mixed forests in Asia and in the Northern hemisphere (Sagheb-Talebi et al., 2014). The natural forest vegetation, often classified using altitude (Salehi et al., 2007; Naqinezhad et al., 2013), is mainly represented by temperate mixed deciduous stands

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including beech (*Fagus orientalis* Lipsky), oak (*Quercus castaneifolia* C.A.M. *macranthera* F. & M.), hornbeam (*Carpinus betulus* L.), maple (*Acer velutinum* Boiss., *Acer cappadocium* Gled.), ash (*Fraxinus excelsior* L.), alder (*Alnus subcordata* C.A.M., *Alnus glutinosa* Gaertn.), elm (*Ulmus glabra* Huds.), wild cherry (*Prunus avium* L.), chequer tree (*Sorbus torminalis* Crantz.), and lime tree (*Tilia platyphyllus* Scop.). These forests appear to be very similar to broadleaf stands in central Europe, northern Turkey and the Caucasus (Adel et al., 2014). In these stands, the 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 (Waez-Mousavi and Habashi, 2012). In infertile soils, this role is even stronger as all the plant available nutrients originate only from plant debris (Sluiter and Smit, 2001). Thus, different humus forms develop within the topsoil throughout the process of biotransformation of dead organic matter (Waez-Mousavi and Habashi, 2012).

In Iran, the first morphological study on humus forms in the Hyrcanian ecoregion was performed by Sajedi et al. (2004) in pure and mixed beech forests using the Canadian classification (Green et al., 1993). Their results showed that mull and moder were the dominant orders in the studied forest types. A more recent survey applying both the Canadian and the European classifications to an unmanaged mixed beech stand confirmed that mull was the dominant order in such a forest (Waez-Mousavi and Habashi, 2012). However, nobody has investigated how humus forms change under different tree canopy composition along altitudinal gradients on homogeneous parent materials and general soil-forming processes. Due to the presence of tree species in Caspian region similar to other forests in the world (i.e. *Alnus*, *Acer*, *Carpinus*, *Fagus*), the present research aims to establish relationships among altitude zones, composition of tree species and humus forms. Thus, we applied the European humus classification (Zanella et al., 2011b; Jabiol et al., 2013; Ponge et al., 2014) under different deciduous forest types in the Hyrcanian ecoregion and we described the morphological and chemical features of the organic, organic-mineral and mineral soil layers in the different stands.

2. Materials and methods

2.1. Site description

Six different forest types (AS, AV, CB, FCP, FC and FO) representing the main species mixtures in the Hyrcanian ecoregion (Table 1) were selected at the Experimental Forest Station of the Tarbiat Modares University in the Mazandaran province, Iran (36°29′23″–36°32′56″N and 51°43′20″–51°47′39″E) (Fig. 1). The most important species in these stands were *Fagus orientalis* Lipsky, *Carpinus betulus* L., *Alnus subcordata* C.A.M., *Parrotia persica* C. A. Meyer, *Acer velutinum* Boiss, *Acer cappadocium* Gled and *Fraxinus excelsior* L. At the experimental site, temperatures range between 3.8 °C (January) and 28.9 °C (August) with a mean annual precipitation between 920 and 1594 mm (Maximum and minimum monthly precipitation occurs in October (243.5 mm) and July (33.1 mm), respectively (data refer to Noushahr city meteorological station, which is 10 km far from the study area, from 1977 to 2010) (Daryaei and Sohrabi, 2016). According to the USDA Soil Taxonomy, soils can be classified as silty-clay-loam Alfisols (Kooch et al., 2012a), developed on dolomite limestones and belonging to the upper Jurassic and lower Cretaceous period. Sixty-one permanent sample plots (20 m × 20 m) were distributed in the different forest types in 2015 (Table 1). A detailed description of each stand is reported in Bayranvand, 2015.

2.2. Sampling of topsoil horizons and humus form classification

Topsoil sampling was carried out at the end of the growing season after tree leaf fall. Before sampling, elevation and slope of each plot were recorded using a Garmin model GPSMAP 60Cx. Aspect values were assigned to three categories (i.e. North, East and West as South aspect was never present) using angles from 0 to 360° given by a pocket compass. Within each of the 61 permanent plots, diameter at breast-height (DBH, 1.3 m) and total height (>1.3 m) of all living trees were measured with a diameter tape and Impulse 200 Laser Hypsometer, respectively. Organic (OL, OF, OH), organic-mineral (AH) and mineral (first 15 cm under AH) layers were collected for the further laboratory analyses within five 30 × 30 cm metal frames located at the four corners and at the center of each plot, thus resulting in a total of 305 humus profiles. Before collecting the soil samples, thicknesses of the diagnostic horizons were also measured and the earthworm ecological groups (i.e. epigeic, anecic and endogeic) were identified by eye or with a 5–10 X magnifying hand lens (Bohlen, 2002). Each humus profile was classified according to the European Humus Group Proposal (EHGP; Zanella et al., 2011) on the basis of the morphological characteristics of the organic and/or organic-mineral diagnostic horizons.

2.3. Laboratory analyses

All the collected samples were air-dried and 2 mm sieved. Fine roots (<2 mm diameter) were removed from each sample and dried at 70 °C to a constant mass (Neatrour et al., 2005). Sieved samples were then mixed per plot and horizon and subsamples were sent to the laboratory for the chemical analysis described as follows. The pH was measured in water with a glass electrode using a 1:5 and 1:2.5 soil: water weight ratio for the organic and organic-mineral horizons, respectively (Qian and Klinka, 1995). Organic carbon (C) in the organic horizons was determined by dry combustion (Kooch et al., 2012b), while the modified Walkey-Black extraction technique (wet oxidation) was used for the organic-mineral horizons (Jackson, 1973). Total nitrogen (N) was measured using a semi micro-Kjeldahl technique (Bremner and Mulvaney, 1982). Available phosphorous (P) was determined according to the Olsen

Table 1
Forest types and site topographic characteristics.

Forest type	Tree species composition (%)	Number of plots (micro plots)	Aspect	Slope (%)	Elevation (meter above sea level)
AS	57.31 *Alnus subcordata* C.A.M., 19.41 *Fraxinus excelsior* L., 12 *Carpinus betulus* L., 6.78 *Parrotia persica* C. A. Meyer, 4.50 *Acer velutinum* Boiss.	9 (45)	N-NE	6	457
AV	35.34 *Acer velutinum* Boiss., 25.38 *Parrotia persica* C. A. Meyer, 19.29 *Fagus orientalis* Lipsky, 12.12 *Carpinus betulus* L., 7.88 *Fraxinus excelsior* L.	6 (30)	N-NE	37	595
CB	57.10 *Carpinus betulus* L., 25.70 *Parrotia persica* C. A. Meyer, 8.53 *Acer cappadocium* Gled., 8.07 *Fagus orientalis* Lipsky, 0.59 *Fraxinus excelsior* L.	13 (65)	N-NW and W-SW	43	649
FCP	69.95 *Fagus orientalis* Lipsky, 18.14 *Carpinus betulus* L., 11.24 *Parrotia persica* C. A. Meyer, 0.68 *Fraxinus excelsior* L.	11 (55)	N-NE, N-NW and E	27	682
FC	72.05 *Fagus orientalis* Lipsky, 27.95 *Carpinus betulus* L.	8 (40)	W-SW, W and W-NW	20	777
FO	99.53 *Fagus orientalis* Lipsky, 0.47 *Acer velutinum* Boiss.	14 (70)	N-NW and N-NE	28	720