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Vegetation, soils, and humus forms of Sardinian holm oak forests and approximated cross-harmonization of vegetation types, WRB Soil Groups and humus forms in selected Mediterranean ecosystems

Andrea Vacca[a,*], Gianluca Serra[b], Riccardo Scalenghe[c]

[a] Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Cagliari, Via Trentino 51, 09127 Cagliari, Italy
[b] Professional Forester, Via Prinetti 9, 08030 Genoni, OR, Italy
[c] Dipartimento di Scienze Agrarie e Forestali (SAF), Università degli Studi di Palermo, Viale delle Scienze 13, 90128 Palermo, Italy

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ABSTRACT

Five plant communities, related to elevation above sea level and geological substrata, are recognized in the holm oak forests of Sardinia (Italy). These forests show a considerable inhomogeneous structure due to present day and past uses. Coppice management prevails, influencing the quantity and quality of organic horizons. Most frequent mineral soils are Cambisols, Leptosols, and Regosols. Regarding the humus forms, Moder and, with less extent, Amphi, are prevailing. Furthermore, the paper presents a synoptic table giving a rough picture of the relationships between vegetation types, WRB Soil Groups and humus forms in selected Mediterranean ecosystems.

1. Introduction

Holm oak (*Quercus ilex* L.) is a typical broadleaf evergreen sclerophyllous tree, widely distributed in the Mediterranean Basin, whose traditional management has led to a diversity of forest types differing in structure and maturity (Aguillaume et al., 2017). In Sardinia (Italy), 38% of about 5760 km^2 of woodlands is dominated by holm oak (Camarda et al., 2015). Consequently, holm oak forests represent a very important ecosystem for Sardinia.

Regarding the mineral soils, the climax of the holm oak formation is the brown Mediterranean soil (Mancini, 1955; Duchaufour, 1970), characterized by a black A horizon and a brownish-red Bw horizon, corresponding to the Cambisols and the Umbrisols of the World Reference Base for Soil Resources (IUSS Working Group WRB, 2015). Anyhow, the holm oak forests of Sardinia are often far from their climax because cutting, fire, pork pasture, and consequent erosion have modified the original soil profile to a Regosol (Giordano, 2013).

In Mediterranean eutrophic environments, where humification is not complete due to a seasonal water deficit, Mull humus forms under forests are rare (Zaiets and Poch, 2016), while the main forms are Amphi (Brêthes et al., 1995; Bottner et al., 2000; Andreetta et al., 2011, 2016; Zanella et al., 2011), with a slow turnover rate. Amphi might result, as a response to a Mediterranean climate, from the co-evolution of periodically dried Mull and Moder humus types (Ponge et al., 2014).

This study aims to present a synthesis about vegetation, soils and humus forms of holm oak forests of Sardinia. The relationships between soils, substrata, and climate are summarized, and prevailing humus forms are listed. Furthermore, a synoptic table giving a rough picture of the relationships between vegetation types, WRB Soil Groups, and humus forms in some Mediterranean ecosystems is presented.

2. Plant communities of Sardinian holm oak forests

Holm oak (*Quercus ilex* L.) forests in Sardinia (Italy) are found from sea level to 1400 m above sea level (asl) in different landscapes and soils. Five plant communities are recognized (Bacchetta et al., 2004): (i) *Pyro amygdaliformis-Quercetum ilicis* (in the thermomediterranean phytoclimate, on clayey substrata with mixed calcicolous-silic matrix in alluvial plains), (ii) *Prasio majoris-Quercetum ilicis* (in the upper thermomediterranean and the lower mesomediterranean phytoclimatic planes, from 60 to 340 m asl, on various substrata), (iii) *Galio scabri-Quercetum ilicis* (in the upper mesomediterranean and supramediterranean phytoclimatic planes, from 580 to 1030 m asl, calcifugous series, on basalts, rhyolites, granitic and metamorphic rocks) (Fig. 1), (iv) *Saniculo europaeae-Quercetum ilicis* (in the upper mesotemperate and the lower supratemperate phytoclimatic planes, above 800 m asl, on acid substrata), and (v) *Aceri monspessulani-Quercetum ilicis* (with phytoclimatic optimum in the lower supramediterranean plane, on calcareous,

* Corresponding author.
E-mail addresses: avacca@unica.it (A. Vacca), lserra@tiscali.it (G. Serra), riccardo.scalenghe@unipa.it (R. Scalenghe).

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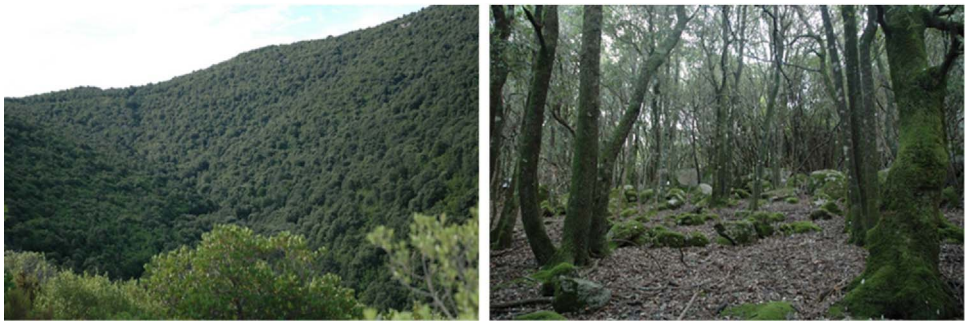

Fig. 1. Mesomediterranean coppice holm oak forest (*Galio scabri-Quercetum ilicis*) (Monti dei Settefratelli, south-eastern Sardinia, Italy).

calcareous-dolomitic and metacalcareous substrata) (Fig. 2).

Widely used for firewood production (or charcoal, in the past), the current silvicultural aspect of Sardinian holm oak forests shows a considerable inhomogeneous structure. Coppice forests, characterized by notable cultural differences and with largely variable density and degree of cover, prevail (Fig. 3). These differences do not produce sensible changes in the floristic composition but they affect lighting conditions and microclimate that, in their turn, influence the quantity and quality of organic horizons (Vacca et al., 2017). Moreover, holm oak forests rarely develop with closed and monospecific structures, whilst they are generally mixed to species of the pre-forest *maquis*, such as *Arbutus unedo*, *Erica arborea,* and *Phyllirea latifolia*.

3. Mineral soils of Sardinian holm oak forests

Most frequent mineral soils are Cambisols, Leptosols, and Regosols (sensu IUSS Working Group WRB, 2015). Leptosols are mostly present on steep slopes on hard rocks (such as limestones, dolomites, basalts, granitic, and metamorphic rocks). Cambisols and Regosols prevail on gentle slopes where, in areas with high density and degree of cover, Phaeozems (at lower elevation) or Umbrisols (at higher elevation) may be present as well. Regosols are also present on Holocene slope deposits, while Luvisols and Alisols are found on Pleistocene slope deposits. Luvisols are also present on Paleozoic and Mesozoic dolomitic limestones.

Fig. 4 shows some typical soils found in holm oak forests in Sardinia classified according to WRB (IUSS Working Group WRB, 2015). These soils are:

A Endoleptic Regosols on a slope deposit derived from metamorphic rocks, in thermomediterranean phytoclimate;
B Dystric Cambisols on Paleozoic metamorphic rocks, in mesomediterranean phytoclimate;
C Haplic Umbrisols on gray phyllites of the Gennargentu mountain, in supramediterranean phytoclimate;
D Haplic Umbrisols on granitoids of the Gallura area, in mesomediterranean phytoclimate;
E Eutric Regosols on granitoids of the Sulcis area, in mesomediterranean phytoclimate;
F Eutric Regosols (Humic) on metavulcanites of Monte Santa Vittoria area, in mesomediterranean phytoclimate;
G Haplic Luvisols on Paleozoic metalimestones, in mesomediterranean phytoclimate;
H Mollic Umbrisols (Pachic) on Mesozoic dolomitic limestones, in supramediterranean phytoclimate.

4. Humus forms of Sardinian holm oak forests

Humus forms in Sardinian holm oak forests show relatively homogenous features and belong mostly to the Moder and, with less extent, the Amphi forms (Serra, 2007). Anyhow, according to the current state of knowledge, it is not possible to clarify, with respect to the plant communities, where Amphi humus forms are most frequent. Indeed, these were found in all five detected plant communities, mostly associated with Cambisols, Regosols, and Umbrisols. Moder and Amphi humus forms are characterized by the presence of a OF horizon, generally friable, reflecting the predominance of zoogenic decomposition. This OF horizon is manly made by partially decomposed vegetal residues, which have been fragmented by the soil fauna and vaguely reorganized in a feltry structure similar to that of micogenous OF horizons, which, however, is not compact. The feltry structure may sometimes be due to the abundance of very fine roots. Moreover, the OF horizon is very rich in coprolites, easily visible in the field by using a magnifying lens. The most common soil fauna include arthropods, mites, isopods, and various insects' larvae. This soil fauna is very active both in the decomposition of vegetal residues (with the excavation of

Fig. 2. Supramediterranean holm oak forest (*Aceri monspessulani-Quercetum ilicis*) with tall trees (Marganai, south-western Sardinia, Italy) and centuries-old holm oak (Montarbu, central Sardinia, Italy).