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From Landsat to leafhoppers: A multidisciplinary approach for sustainable stocking assessment and ecological monitoring in mountain grasslands

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ABSTRACT

We present a case study illustrating a multidisciplinary approach for characterizing, mapping and monitoring the bio-ecological properties of Mediterranean mountain grasslands in extensive grazing systems. The approach was developed to provide the basis for the management plan of a cluster of Natura 2000 special conservation areas in the Central Apennine mountains, Italy (with a total area of 79,500 ha, including 22,130 ha of grasslands). It includes a novel methodology for estimating sustainable stocking rates of different plant communities, at a detailed spatial scale over large areas, based on the integration of: (i) a classification of grassland types, based on physical habitat stratification and vegetation sampling; (ii) a forage-value assessment of each grassland type, obtained from field sampling of botanical composition and corrected with remote-sensing information on pasture microtopography; (iii) an estimate of primary productivity at a detailed spatial scale, obtained from the remote-sensed Normalized Difference Vegetation Index (NDVI) calibrated with biomass field data. Additionally, to obtain a bioclimatic characterization of the grasslands and to determine the optimal grazing season for each grassland type, intra-annual phenological signatures were obtained from the Enhanced Vegetation Index (EVI). Given the inherent limitations in the sustainable stocking rates concept, and the particular susceptibility of dry grasslands to changes in grazing regimes, we tested two biological indicators, the Auchenorrhyncha quality index (AQI) and the Arthropod-based biological soil quality index (QBS-ar). These indicators take into account above- and below-ground arthropod diversity, respectively, and are applied here for the first time to the specific purpose of monitoring grazing load effects on ecological quality and biodiversity of Natura 2000 dry grasslands. We conclude that: (i) it is possible to effectively integrate biomass estimates, obtained from publicly available satellite data, with a relatively simple field sampling of botanical composition, to achieve a detailed spatialization of sustainable stocking rates; (ii) within the same Natura 2000 habitat type there can be a large spatial heterogeneity in both sustainable stocking rates and optimal stocking season: thus, grazing should be kept under careful human control to maintain the habitats in the desired conservation status; (iii) while plant species richness was not correlated to grazing intensity, both AQI and QBS-ar had a significant negative correlation to grazing levels and can thus be useful for monitoring the actual "sustainability" of livestock loads on different aspects of grassland ecosystems.

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1. Introduction

In Europe and in the Mediterranean, wild species of conservation concern are often dependent on agro-ecosystems created by traditional, low-intensity farming (Benton et al., 2002; Kleijn et al., 2009; Lasanta et al., 2015; Maurer et al., 2006). In this respect, secondary grasslands are particularly important (Habel et al., 2013): they are semi-natural habitats originated and maintained by anthropogenic disturbance such as mowing or livestock grazing, in areas that would be potentially covered by forest vegetation (Dengler et al., 2014). Many types of secondary grasslands are listed in Annex 1 of the EU Habitats Directive (European Union, 1992) among the habitat types whose conservation requires the designation of special areas of conservation, forming the "Natura 2000" network. Within these conservation areas, EU Member States are required to adopt management plans meeting the ecological requirements of the protected habitats and maintaining them in a "Favourable Conservation Status", while accounting for economic, social and cultural issues (European Union, 1992). The conservation status of semi-natural grassland habitats is considered as threatened because of the abandonment of low-intensity agricultural practices such as extensive grazing (European Commission, 2014; Ostermann, 1998).

Grasslands have an inherently dynamic nature, and spatial-temporal heterogeneity plays a crucial role in their stability, productivity and response to grazing (Laca, 2009; Schwinning and Parsons, 1999): their properties are thus difficult to quantify, and research teams should be "as diverse as the pastures they hope to measure" (Kallenbach, 2015). In this paper, we discuss a multidisciplinary approach aimed at mapping, characterizing and monitoring the bio-ecological properties of grassland ecosystems, that was developed for the management plan for a cluster of Natura 2000 areas in the Central Apennine mountains, Italy (Fig. 1). Here, secondary dry grasslands occupy a large proportion of the landscape, and contribute to the habitat of two endangered large mammals: the endemic Apennine chamois (*Rupicapra pyrenaica*

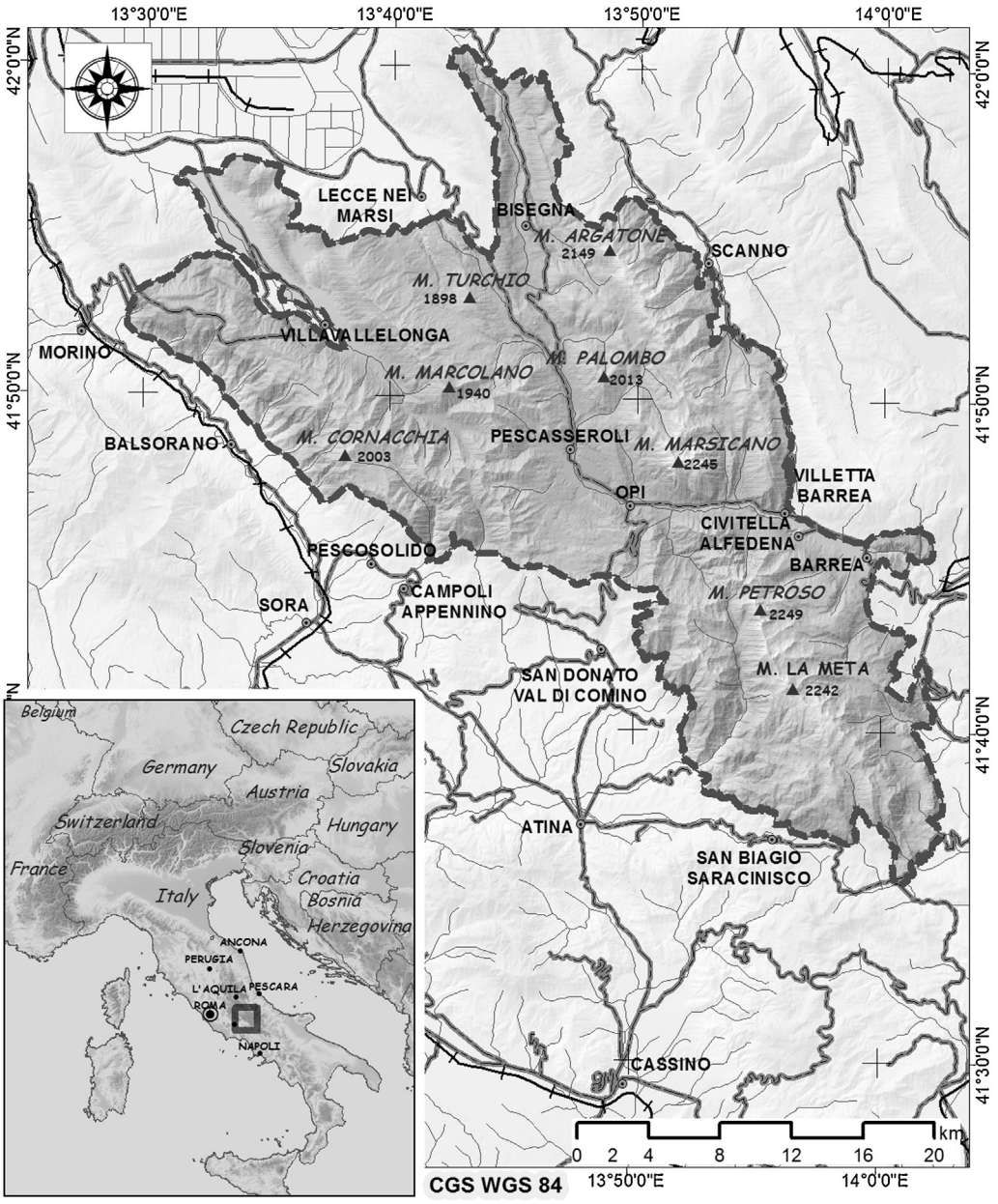

Fig. 1. Study area position (inset) and physiography (main map). Dashed line: study area boundary (Abruzzo Lazio e Molise National Park, and adjoining Natura 2000 sites).

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