C. R. Biologies 337 (2014) 717–724

Contents lists available at ScienceDirect

Comptes Rendus Biologies

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Biodiversity/Biodiversité

Contrasting land uses in Mediterranean agro-silvo-pastoral systems generated patchy diversity patterns of vascular plants and below-ground microorganisms

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ARTICLE INFO

Article history:
Received 18 July 2014
Accepted after revision 23 September 2014
Available online 24 October 2014

Keywords:
Cork oak forests
Grass covered vineyards
Grazing
Hay crops
Secondary grasslands
Tilled vineyards

ABSTRACT

The aims of this paper were (i) to define how contrasting land uses affected plant biodiversity in Mediterranean agro-silvo-pastoral-systems across a gradient of disturbance regimes: cork oak forests, secondary grasslands, hay crops, grass covered vineyards, tilled vineyards; (ii) to determine whether these patterns mirrored those of below-ground microorganisms and whether the components of γ-diversity followed a similar model. The disturbance regimes affected plant assemblage composition. Species richness decreased with increasing land use intensity, the Shannon index showed the highest values in grasslands and hay crops. Plant assemblage composition patterns mirrored those of *Basidiomycota* and *Ascomycota*. Richness in *Basidiomycota*, denitrifying bacteria and microbial biomass showed the same trend as that observed for vascular plant richness. The Shannon index pattern of below-ground microorganisms was different from that of plants. The plant γ-diversity component model weakly mirrored those of *Ascomycota*. Patchy diversity patterns suggest that the maintenance of contrasting land uses associated with different productions typical of agro-silvo-pastoral-systems can guarantee the conservation of biodiversity.

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1. Introduction

Agro-silvo-pastoral systems are recognized as crucial for maintaining the viability of rural areas in Europe and have particular significance for resource and nature conservation [1]. However, they are endangered by the dramatic changes towards intensification and abandonment that are occurring in the agricultural and agroforestry systems of many areas in the world, which in the long run can result in a general change of biodiversity and consequently of functionality [2–6]. In the last decades, the European agricultural and environmental policies have started to recognize productive, environmental and societal services of these systems, but the formulation of effective management proposals to balance human activities and biodiversity conservation would greatly benefit from more detailed information on the patterns of diversity [7,8]. The growing concern for the conservation of agro-silvo-pastoral systems makes it relevant to fill the gaps in knowledge, particularly in the Mediterranean region, where the effects of land use

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http://dx.doi.org/10.1016/j.crvi.2014.09.005
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changes on the above- and below-ground biota have been traditionally investigated separately.

Mediterranean agro-silvo-pastoral systems are complex mosaics shaped over the long term by human activities based on multiple-use-oriented management [9] characterized by different levels of management practice intensity [10]. Each element of the mosaic is related to a cosmos of biota, potentially inter-linked, exhibiting different levels of diversity and providing different types and levels of ecosystem services [11–14].

The objective of this paper was to compare the diversity patterns of vascular plants with those of below-ground microorganisms under a gradient of land-use disturbances. We focused on five different land uses in the context of a long-term observatory representative of Mediterranean agro-silvo-pastoral systems under uniform environmental conditions [15,16]. In this long-term observatory, a number of multidisciplinary teams are analysing the relationships between land use, biodiversity and ecosystem services in the framework of different research projects (e.g. SOILSINK: http://soilsink.entecra.it/; ECOFINDERS: www.ecofinders.eu). Several pieces of information concerning the patterns of below-ground microorganisms of the long-term observatory have been already published by specialists of different taxonomic groups [17–21], but never compared with each other. Moreover, vascular plant patterns have not been assessed at all.

Starting from the general assumption that under the same ecological conditions, different land uses are relevant in shaping vascular plant biodiversity [22–25], we hypothesized that: (1) the land uses affected vascular plant diversity patterns, (2) the composition, richness and Shannon index patterns of vascular plants mirrored those of below-ground microorganisms, and (3) the relative importance of the components of γ-diversity, namely relativized species replacement, similarity and richness difference, presented similar patterns for plant and below-ground microorganisms under contrasting land uses.

To test the hypothesis, (1) we assessed and compared vascular plant composition, richness and Shannon index in the same sites that had been characterized for below-ground microorganisms; to test the hypothesis (2), we assessed the co-variation between plants and below-ground microorganism patterns; to test the hypothesis (3), we partitioned the γ-diversity of plants and below-ground microorganisms into the three additive components and compared their relative importance in shaping the biodiversity patterns of vascular plants and below-ground microorganisms.

2. Materials and methods

2.1. Study area and sampling sites

The field experiment was conducted at the Berchidda-Monti long term observatory located in Sardinia (Italy) (40°48'N; 9°17'E). The observatory includes private farm fields for which no specific permissions were required, as these fields are not located in protected areas and do not involve endangered or protected species. The observatory is representative of the Mediterranean agro-forestry systems of Gallura that are shaped by human activities practiced since centuries [26]. The area is included in the Meso-Mediterranean phytoclimatic belt (http://www.globalbioclimatics.org), characterized by an aridity index of 0.53, average annual precipitation of 632 mm with at least 70% of annual rain falling from October to May and average annual temperature of 14.2 °C. All the sampling sites were located on same soil type, *Typic Dystroxerept* [27], with the same morphology, on a granitic substratum [28]. The current Natural Potential Vegetation [29,30] of the area is represented by a *Quercus suber* forest, referable to the association *Violo dehnhardtii–Quercetum suberis* [31]. Nowadays, the forest is widely thinned and replaced by field crops or plant community successions [32].

The landscape is characterized by a variety of land uses related to different types of agro-silvo-pastoral activities, which are mainly represented by grape-growing (mostly the DOC vine cultivar "Vermentino di Gallura"), livestock farming, and cork extraction. Vineyards are conventionally managed applying annually one or rarely two inversion tillage treatments in spring to reduce the competition of the grass cover (tilled vineyards [TV]) or allowing the development of a permanent inter-row grass cover (grass covered vineyards [GV]).

Livestock farming is practiced in the area since centuries and hence it is frequent to observe fields that have been managed in the same way since over 50–60 years [15]. The main land uses related with livestock farming are secondary grasslands (GR) and hay crops (HC). GR in fact represent the grass covered fallow between two subsequent HC. In the study site, GR followed a less intensive rotation scheme than HC (e.g., five years of fallow grassland and one year of annual forage crop). HC has a complementary scheme of more intensive forage crop rotation (e.g., up to five years of cultivation and one year of fallow grassland). Cork extraction is operated in *Q. suber* forests (cork oak forests, CO) approximately every 10–11 years. Further details about the land use managements in the study area were reported by Bagella et al. [32].

2.2. Experimental design

The experimental sites were represented by fields of 1–4 ha, characterized by uniform management since at least 50 years, except for vineyards, which were planted 20 years before the survey was made. They were selected according to a gradient of increasing land-use intensity: CO → GR → HC → GV → TV [32]. A mono-factorial design considering land uses as fixed factors was applied. Four replicated sampling areas were randomly chosen within each field. Vascular plants and below-ground microorganisms were sampled in the same areas in May 2007.

2.3. Vascular plant sampling

Herbaceous communities (i.e. GR, HC, GV and TV) were sampled in spring 2007 using the linear transect methodology. Along each transect the presence/absence of each plant species over 100 vertical point quadrates at 1-m

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