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Patterns of variability in soil properties and vegetation cover following abandonment of olive groves in Catalonia (NE Spain)

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ABSTRACT

Understanding patterns and processes involved in changes in soil and vegetation after agricultural abandonment is a key issue for management policies leading to land restoration and reclamation in Mediterranean semiarid environments. We selected a number of active and abandoned fields in two regions of olive groves in Catalonia (NE Spain), in order to analyze changes in certain soil properties and vegetation cover variables, as well as their interrelationships. The soil chemical properties considered, summarized into a single PCA axis, showed significant spatial (regional) differences and no temporal (successional) pattern, indicative of the strong influence of the parent rock material. The soil physical variables examined also showed significant regional variability, but such differences could be partially explained by successional changes. The variability at the landscape level and the observed successional trends for soil physical properties are interpreted as a result of both the influence of the bedrock and contrasting management practices prior to abandonment in each region. Although we did not find significant regional or successional variability in a global measure of plant cover, we did find significant and different patterns of variability for each of the main plant functional groups considered. Regional and post-agricultural variability in soil physical properties seem to be the prime factors determining the abundance of the main plant functional groups.

1. Introduction

The Mediterranean region has experienced profound changes in landscape structure during the last century, mainly determined by changes in land use (Debussche et al., 1996). These changes are the result of increased extension of urban areas and the progressive abandonment of agricultural practices. Consequently, large areas formerly devoted to agriculture have been transformed into a dynamic mosaic of crop fields, abandoned fields of different successional stages, thickets and forests (Debussche et al., 1996). Understanding spatial and temporal patterns and processes after abandonment of agricultural practices is a key issue for the management, preservation and restoration of natural communities.

Together with environmental conditions, such as climate or the influence of the bedrock, historical factors associated

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to agricultural practices prior to abandonment, such as tillage and crop rotation, generally lead to changes in soil properties and processes (Fraser et al., 1994). Soils under a long-term regime of tillage usually suffer from losses in organic matter, increased nitrification, and loss of soil structure (Elliott, 1986; Koerner et al., 1997). Furthermore, and under harsh conditions, soil physical properties related to agricultural practices have a significant effect on nutrient flow and above-ground plant distribution (Maestre and Cortina, 2002). Lipiec and Stepniewski (1995) showed how soil compaction resulting from tillage systems affected nutrient transformations and uptake through changes in soil hydraulic, aeration, and diffusive properties, as well as by its effect on root growth and configuration. After abandonment, changes in vegetation structure and composition may also affect soil chemical and physical properties (e.g., James et al., 2003).

The past agricultural land use may also have a strong and persistent influence on both the plant community composition (Foster, 1992; Koerner et al., 1997; Dupouey et al., 2002) and the pathway of succession (Bonet, 2004), although such effects have also been shown to be highly variable at a regional scale (Flinn and Vellend, 2005). According to both theoretical and empirical grounds, re-colonisation of abandoned fields occurs through a process of succession whereby the pioneer vegetation characteristic of cultivated fields is replaced by post-cultural plant communities. Re-colonization begins from the seed bank or adjacent seed sources of early-colonizing species, mainly annual forbs, which are replaced by perennial forbs and grasses after two to three years (Wilcox, 1998). In general, successional changes in abandoned fields have been interpreted in terms of competitive ability mediated by resource availability, particularly light and nutrients (Gleeson and Tilman, 1990; Tilman, 1994). However, as suggested by Passioura (2002), plants might respond to soil conditions in ways that can not be readily explained by current nutrient availability, but rather by the soil's physical conditions, i.e. soils becoming too dry or too hard, or having a limited soil volume. From this point of view it is clear that any cultural and tillage practice is likely to have marked consequences on individual plant growth and performance, as well as on overall vegetation development (Zanin et al., 1997; Bonet, 2004).

Moreover, and particularly in Mediterranean communities, some studies have reported a close relationship between soil physical properties (e.g., physical crusts, rock fragments) and aboveground plant cover distribution (Kosmas et al., 2000; Maestre and Cortina, 2002). Re-vegetation in these ecosystems, and particularly the development of plant cover, has important consequences for soil biodiversity and conservation. At these sites, biodiversity in the soil below plants is greater than in the adjacent exposed soils, suggesting that patches of plant cover serve as ''resource islands'' providing higher organic matter pools and higher rates of ecosystem processes such as mineralization (Symstad et al., 2003).

In spite of numerous studies on regional and successional dynamics following field abandonment in European Mediterranean landscapes, information about the patterns of covariation in soil properties and vegetation is quite scarce. Studies on vegetation changes have been mainly focussed on analysing changes in plant species composition and abundance (Debussche et al., 1996; Ne'eman and Izhaki, 1996; Bonet and Pausas, 2004 and references therein), while few studies have been concerned with edaphic processes (Ruecker et al., 1998) or the relationship between soil and vegetation (but see Bonet, 2004).

In the present paper we investigate the effects of tillage practices on soil properties and vegetation cover after abandonment in two agricultural landscapes in NE Spain. The main objectives are: (1) to determine the effects of agricultural practices on spatial and temporal variability in soil physical and chemical properties; (2) to asses the early successional patterns of change in plant cover; and (3) to test whether the impact of agricultural practices on soil properties can significantly influence plant cover development and alter the pathway of succession.

2. Methods

2.1. *Study areas and land use*

The study was carried out in two typical Mediterranean agricultural landscapes of NE Spain (Catalonia), characterized by a mosaic of managed and abandoned olive groves of different ages (Fig. 1).

The first landscape is located in the region of Garrigues (41°28′ N, 1°0′ W), Lleida province, at 500 m a.s.l. The region has a Mediterranean climate with a continental trend. Mean annual temperature is 12.5 °C, mean annual rainfall is 530 mm, and mean annual potential evapotranspiration is ca. 800 mm (Digital Climatic Atlas of Catalonia, Ninyerola et al., 2000). The predominant soils are Lithic Xeric Torriorthents developed on carbonate-rich lutites, highly influenced by the bedrock (Porta and Julià, 1983). Tillage practices in this area are conducted in a conventional way, that is, annual removal of vegetation by ploughing and moderate application of fertilizers. Management of olive trees includes manual clipping of sprouts arising from the base of the trunk.

The second landscape is located in the region of Montsià (40°43′ N, 0°23′ W), Tarragona province, at 400 m a.s.l. This zone has a Mediterranean maritime climate, with a mean annual temperature of 17 °C, mean annual rainfall of 580 mm, and mean annual potential evapotranspiration of ca. 800 mm (Digital Climatic Atlas of Catalonia, Ninyerola et al., 2000). The predominant soils in the area are Calcic Haploxeralfs, developed on quaternary sediments composed by carbonate-rich gravels and clays (Porta and Julià, 1983). Management of olive groves involves soil compaction prior to mechanical olive harvesting, application of postemergence herbicides (Gil-Ribes, 2001), and the combination of manures and mineral fertilizers.

Both landscapes harbour a rich assemblage of species. A complete account of species composition at Garrigues can be found in Sans (1990). Species richness in a single abandoned field may reach values as high as 120 species, many of them annual forbs. Some of the most abundant forbs species in both landscapes are *Anacyclus clavatus* (Desf.) Pers., *Chenopodium album* L., *Medicago minima* (L.) L., *Leontodon taraxacoides* (Vill.) Merat and *Diplotaxis erucoides* (L.) DC., and among grasses