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Functional response traits in relation to land use change in the Montado

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ABSTRACT

The socio-economic changes of the last decades have resulted in changes in traditional land uses with consequent abandonment of large farmland areas in the Mediterranean region. We assessed the response of species richness and composition, and species functional traits to decreasing land use intensity in a Montado system, an agro-pastoral system characteristic of the Alentejo, Southern Portugal. Additionally, we investigated whether plant functional types can be established based on the response to decreasing land use intensity in these systems. Consistent with previous studies, species richness decreased sharply after land abandonment, and this was associated with a strong turnover in species composition from grazed to abandoned sites as the vegetation changed from herbaceous to shrub dominated communities. Pronounced differences in functional traits were found for different successional stages. Therophyte life form, short plant height, high specific leaf area (SLA), low leaf dry matter content (LDMC) and small seeds with dispersal structures were dominant in grazed plots. Within abandoned plots, chamaephytes dominated in plots abandoned for 10–15 years and decreased in favour of nanophanerophytes in plots abandoned for 20–30 years. Plant height, LDMC and seed mass increased with abandonment time while SLA decreased. Functional response groups sufficient to describe vegetation change were identified combining life form and SLA. Therophytes with medium SLA were the dominant functional group in grazed areas, while nanophanerophytes with medium or low SLA were associated with later phases of abandonment. At intermediate stages of succession the dominant group was chamaephytes with medium SLA but functional diversity was highest as all the groups, except hemicryptophytes with medium SLA, were represented. These changes in functional composition can be translated into effects on key ecosystem properties. The increase in LDMC indicates an increase in flammability while trends in both LDMC and SLA suggest decreased decomposition, and thereby carbon and nutrient cycling. These will need to be considered in combination with consequences for other ecosystem properties for future management.

1. Introduction

Vegetation change has traditionally been described by changes in species composition. However, the need to predict the effects of climate and land use change on vegetation structure and ecosystem functioning at regional and global scale has lead to an ongoing effort to identify plant functional traits and types that relate to climate and land use change (Díaz and Cabido, 1997; Lavorel et al., 1997). By now, the approaches to classify species range from expert knowledge (Noble and Gitay, 1996) to multivariate techniques based solely on trait attributes of species, *e.g.* 'emergent groups' (*e.g.* Kleyer, 1999) with a subsequent testing of the functionality with correlation techniques. While the first approach is not reproducible, the second is criticised for potentially leading to functional groups with low predictive power, because the response of the species to the environment is ignored (Nygaard and Ejrnaes, 2004). So far, no classification method has been accepted as a standard procedure (Nygaard and Ejrnaes, 2004). Here we use a classification approach which forms functional response groups based on both the similarity of traits and their response to the environmental conditions.

For a local biota, the regional species pool consists of a specific set of species that represent the outcome of history, biogeography and evolutionary processes (Naeem and Wright, 2003). Considering that species differ in their response to environmental factors and effects on ecosystem functioning, and that important changes may occur as a result of land use changes it is important to

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understand the consequences of such land use changes, particularly in areas with a long history of human management. In this study we aimed to describe species compositional changes, assess changes in species functional traits, and identify plant functional response groups with respect to abandonment in the Montado. The Montado is an agro-pastoral system specific to the region of Alentejo, Southern Portugal that comprises an open formation of cork and holm oaks in varying densities, combined with rotation of cereal crops and fallow, uncultivated areas often used as pastures. The Montado ecosystem is therefore the result of the interaction of a long history of anthropogenic disturbances (cultivation, grazing, timber and fuel wood) with natural disturbances (such as fire, floods and extreme droughts) and a variable climate (Lavorel and Richardson, 1999; Gallego-Fernández et al., 2004). As a consequence of the rapid industrial and socio-demographic changes of the last decades, the characteristic extensive land use practices of these systems are being gradually abandoned and the consequences are still little understood.

Traits such as life form, plant height, dispersal mode, clonal growth, and seed mass have been shown to respond to grassland disturbance, and especially grazing (*e.g.* Fernández-Alés et al., 1993; Lavorel et al., 1999; Peco et al., 2005; Díaz et al., 2007). Since the ecological response of plant communities may be linked to structural traits of species in vegetation that is or has been subjected to such types of disturbances (Lindborg and Eriksson, 2005), these traits provide a good starting point to find response traits to abandonment. Plant height and leaf traits associated with resource economy, such as specific leaf area (SLA) and leaf dry matter content (LDMC), have been shown to respond to grazing abandonment and to succession (Prach et al., 1997; Díaz et al., 2001; Kahmen and Poschold, 2004; Louault et al., 2005). Plant height can also be related to competition and has generally been reported to increase during succession (*e.g.* Prach et al., 1997; Kahmen and Poschold, 2004), while small-stature plants seem to be favoured by grazing (Díaz et al., 2007). Clonal growth has been shown to respond to grazing (*e.g.* Klimesova et al., 2008). However, this response varies with environmental factors and seems to be more relevant in moist than arid environments (De Bello et al., 2005). The association between small seeded species and disturbance, as well as the increase of seed mass in response to abandonment has been previously demonstrated for Mediterranean (*e.g.* Fernández-Alés et al., 1993; Lavorel et al., 1999) and non-Mediterranean areas (Kahmen and Poschold, 2004).

Only few studies have examined plant trait responses in the Montado or similar systems (*e.g.* Fernández-Alés et al., 1993; Lavorel et al., 1999; Peco et al., 2005). In systems like the Montado shrubs sprout frequently and are kept at low frequencies by herbivore pressure or clearing (Pereira and Fonseca, 2003). Therefore, and in accordance with other studies addressing post-disturbance succession in Mediterranean areas (*e.g.* Debussche et al., 1996; De Bello et al., 2005; Peco et al., 2005), we expect that life form dominances will strongly shift in response to decreasing land use. If this is the case, the result will be the replacement of Mediterranean annual grassland communities, where the soil is open for colonization every autumn, with shrub communities, where less space and light are available. It is hypothesised that seed weight and the role of animal dispersal increase during succession. Disturbed sites provide more opportunities for recruitment and, species that produce a large number of small seeds, in opposition to a smaller number of larger seeds, will be more successful in taking advantage of these recruitment opportunities. Additionally, small seeds tend to survive more in the seed bank (Peco et al., 2003), which can be advantageous in the unpredictable rainfall patterns of Mediterranean systems, and are better adapted to endozoochory than larger ones, which is considered an important dispersal mechanism in Mediterranean grasslands (Azcárate et al., 2002). The seed mass increase hypothesis is likely to be true because larger seeds provide more assimilate for seedling growth (Turnbull et al., 1999), which may give an advantage to species with larger seeds as succession advances, and space and light availability decrease. Animal dispersal is affected by the availability of dispersal vectors and diaspore characteristics of the species colonizing each successional stage, and tends to gain relevance as the climax vegetation is approached (Guitián and Sánchez, 1992). The hypothesis that the role of animal dispersal increases during succession may not hold for sites where later stages of succession are dominated by early successional species.

It is hypothesised that abandonment leads to replacement of species with high SLA and low LDMC with species of opposite traits. Species with fast acquisition of resources (high SLA, low LDMC) tend to be favoured by disturbance, which generally creates conditions of higher availability of light and nutrients (Grime, 2001). If disturbance is removed, species with a resource conservation strategy (lower SLA, higher LDMC), which are more adapted the poor soils and drought characteristic of these Montado areas are expected to be more successful in establishing and persisting. This should also be reflected in the change of these traits at the community level. Recently there has been a growing interest in using trait values at the community level as means to link to ecosystem processes. Plant functional traits such as SLA and LDMC are thought to be associated with ecosystem properties that are key to the provision of services to local stakeholders: flammability, primary productivity and nutrient cycling (Garnier et al., 2004; Saura-Mas and Lloret, 2007; Fortunel et al., 2009).

Summarizing, our main objectives in relating species traits to the time since abandonment were to identify changes in (1) vegetation composition and structure, (2) species traits, (3) functional response groups, and (4) community functional properties (Violle et al., 2007) associated to key ecosystem properties.

2. Methods

2.1. Study area

The study site, with an area of 198.44 ha, is located in the Southeast of Portugal, at about 37°48′21.72″N and 7°40′44.96″W. It used to be under a traditional management scheme of rotation of crops/fallow/pasture. In the rotation system, the farm is divided into fields and each field is under different phases of the rotation cycle, creating a mosaic of fallow and cultivated fields. For 2 years a field is under cereal cultivation (wheat, oat), after which land is left fallow for a period of 2 years. During fallow vegetation is allowed to grow from natural sources and animals, usually sheep, are allowed to feed on this vegetation. In the last decades large areas have been abandoned from cropping or both cropping and grazing. At the study site cropping stopped gradually so it is possible to find a range in time since cropping stopped that goes from 5 to 7 years to more than 20 years. We selected three areas within this range: grazing, intermediate succession and advanced succession. Grazing, where cropping stopped more recently, is currently used for extensive grazing by sheep (0.99 CU/ha). The herd visits the area twice a year, at the end of winter and beginning of summer. The two others, intermediate succession and advanced succession, were abandoned from cropping 10 to 15 years and 20 to 30 years ago, respectively. Time of abandonment estimates was based on aerial photographs and land cover maps (Van Doorn and Pinto-Correia, 2006), interviews to landowners and management plans or reports, when available. As no data was available for cessation of grazing it was not possible to determine when intermediate and advanced succession were last used for grazing, it is only possible