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Effects of haying on vegetation communities, taxonomic diversity and sward properties in mediterranean dry grasslands: A preliminary assessment

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ABSTRACT

In the last years, the use of haying is increasing in Southwest Iberia. However, information on its effects on grassland diversity or productivity is missing for Mediterranean dry environments. We examined the short-medium term effects of haying in Alentejo region, South Portugal. Our hypotheses were: (1) haying influences plant taxonomic diversity, floristic composition, herbage productivity and quality; (2) haying effects act both at the field and surrounding of a field levels, and depend on yearly weather conditions and on the type of hay produced. Floristic inventories were conducted from 2012 to 2015 (121 fields). Vegetation samples were collected from 2012 to 2014 (130 fields) and analyzed in laboratory for determination of above-ground biomass and crude protein content. GLMMs and model averaging were used to model the relationship between vegetation parameters and grassland management variables. Redundancy analysis was used to analyse compositional changes with a special focus on the species with agronomical interest. Annual variation and land use were generally better predictors of vegetation parameters than haying management variables, with the exception of β-diversity. Fields with higher area of haying in forage crops in the previous years presented significantly lower γ-diversity and in less extent, lower α-diversity, β-diversity and leguminous richness. β-diversity was positively influenced by haying in fallow land in the surrounding of the field. Leguminous richness and proportion were lower in fields with higher area of haying in fallow land in the previous years. Crude protein content depended on the interaction between year and area of haying in fallow land. In general, communities tended to be highly similar in their species composition, but most species of agronomical interest were negatively influenced by haying. We conclude that haying has an overall moderate effect in Mediterranean dry grasslands, and that it is difficult to design management practices that simultaneously conciliate plant diversity, leguminous richness/proportion and herbage quality.

1. Introduction

Dry grasslands of Western Europe are mostly secondary and anthropogenic (Suárez et al., 1991). Their origin and maintenance are mostly linked to forest clearing and subsequent low-intensity agricultural management such as cultivation, mowing, grazing by domestic livestock and even fire (Coupland, 1979; Pott, 1995; Suárez et al., 1991). Nowadays, European grasslands are being increasingly transformed into improved (intensive) grasslands by artificial fertilization, increased mowing frequency or stocking rates and frequent re-sowing (Hejcman et al., 2010; Peach et al., 2013; Stevens et al., 2010).

In Portugal, grasslands are mostly distributed south of Tagus River, and are particularly common in Alentejo region. Contrasting with other European countries, the surface occupied by grasslands showed a considerable increase since 1989, representing in 2009 about 63% of the utilized agricultural area in Portugal and 68% in the Alentejo region (permanent plus temporary grasslands; INE, 2015a). This was mostly associated to an increase in cattle numbers on specialists' beef cattle farms, but also due to the conversion of dairy cattle farms in beef cattle farms (Huyghe et al., 2014). In Alentejo region, bovine numbers more than doubled between 1989 and 2013 (INE, 2014). Conversely, sheep numbers decreased by about 39% (INE, 2014). Following these trends, and supported by new infrastructures and technological solutions (irrigation perimeters, new fertilizers and more effective agriculture machinery), mowing for hay, haylage or silage production became more frequent in Iberian dry grasslands. Haying provides a feeding alternative in periods where grassland biomass production in farms is insufficient to ensure livestock feeding needs. In Iberian dry grasslands

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haying occurs both on cereal/legume forage crops and semi-natural grasslands. Under adequate soil and hydrological conditions these land uses can yield moderate to high primary production for hay or silage (Carpintero et al., 1991; Hernández et al., 1994; Rodríguez et al., 2006; San Miguel, 2009).

Unlike grazing, whose effects on vegetation are patchier in space and time (Klimek et al., 2007; Rook et al., 2004), mowing is non-selective, and hence results in lower sward heterogeneity. In addition, the removal of grass reduces the amount of organic matter returned to the soil (Vickery et al., 2001). Early and frequent destruction of above-ground plant organs or a generally low ability to resprout (which is particularly critical in dry environments), results in a rapid decline of sensitive species and enrichment of more disturbance-tolerant ruderal taxa (Grime, 2001). Whereas high levels or the absence of disturbance usually lead to a decline in species richness (Huston, 1994), low intensity mowing imposes moderate degrees of disturbance and nutrient stress that usually enhance species diversity in grasslands.

Iberian dry grasslands support a wide range of indigenous species of plants, invertebrates and birds, and thus have high nature conservation value. In this context, haying practices (e.g. dates and number of cuttings, the type of hay, machinery used or fertilizer application) may directly or indirectly affect the spatial variability of plant diversity or productivity, and in turn overall biodiversity levels. Although some information is available for the effects of haying in the grasslands of Iberian mountain areas (López-Mariño et al., 2000; Prince et al., 2012), reliable information on this subject is missing for Iberian Mediterranean dry environments. In this study, we assess the short-medium term effects of haying in floristic composition, diversity and sward properties in dry grasslands of Alentejo region (South Portugal). Our hypotheses are: (1) haying management (expressed as the proportion of area mown in the previous years and last haying) influences plant taxonomic diversity, floristic composition, herbage productivity and sward quality; (2) haying management influences the occurrence of plant species with agronomical interest (legumes) and; (3) haying management acts on the previous vegetation parameters both at field and surrounding of a field levels, depending on weather conditions in each year and on the type of hay produced.

2. Methods

2.1. Study area

The study area is located in Évora, south Portugal (Fig. 1). Climate is generally dry, with average annual temperatures ranging from 9.6 °C in winter to 24.1 °C in summer and annual rainfall average of 586 mm (1981–2010 period; IPMA, 2015a). Soils are mostly acidic, with low-average fertility (own unpublished data). The most frequent land uses are pastures with extensive livestock grazing (mostly cattle), fallow land and rotational hay crops (cereal, leguminous or mixed crops). Cereal crops for grain are nowadays less common due to recent conversion of farms for beef production or irrigated crops (e.g. olive, tomato). Irrigated pastures are also common in this region, although marginal in area compared to dry grasslands. The mean field size in the study area is around 70 ha.

There are no official mowing statistics for the region of Évora and therefore the only data available refer to the fields monitored by our team from 2012 to 2015 (Table 1). Mowing in all the fields during that period was done for hay production. Both rainfall and temperature were very different between years (Table 1), potentially affecting the entire process of haying and plant species occurrence (2012 and 2015 were dry years, whereas 2013 and 2014 were wet years).

2.2. Data collection

Vegetation sampling comprised two tasks: (1) floristic inventories and (2) above-ground vegetation biomass and crude protein content determination. Floristic inventories were conducted in May during four consecutive years. We selected “eligible farms” according to the dominant types of grassland (temporary or permanent), widely distributed around the city of Évora, both in the north and the south plains. Farms predominantly used for intensive/irrigated uses or with moderate to high tree density (cork/green oak forests: “Montados”) were not considered in this study. Following this farmland stratification, we randomly selected 14 farms. Then, sampling fields were randomly selected within these farms (Fig. 1). The main land uses in these grasslands, and specifically the fields used for haying, were not concentrated in any particular sector of the study area. Most of the fields were sampled for two or more years, resulting in a cumulative total of 121 fields sampled over the four years of sampling (31 fields in 2012, 37 in 2013, 38 in 2014 and 15 in 2015). The information on floristic composition was obtained at two random sites per field; sites within a field were 200 m apart from each other. At each site, we registered the occurrence of each plant species in four sampling replicates (50 × 50 cm squares). These replicates were disposed around the central location of the sampling site (forming a 10 m-side square).

Aboveground biomass and crude protein content were determined between 2012 and 2014 also in May, in a cumulative total of 130 fields (44 fields in 2012, 42 in 2013 and 44 in 2014). Aboveground biomass vegetation samples were collected using a portable cutter within a square of 50 × 50 cm at each of the two sites within each field. Samples were dried in laboratory (65 °C for 48 h) in the day of collection. Then, the samples were weighted using a precision balance, milled (Wiley mill, 1 mm sieve) and homogenised in order to ensure accurate determinations. Crude protein content (in grams per 100 g of dry matter) was determined through the nitrogen combustion method (method AOAC 990.03).

Information on land management was mostly collected during field work or provided by land managers (when necessary, the area mown in each field was corrected using the aerial photos of the region). This information was organized in 6 land management variables: (a) two variables describing haying management at the field level in the previous three-year period: *HCF3* for the extent of haying in hay crops, and *HFF3* for the extent of haying in fallow land; (b) one variable describing the timing of haying, *LHay*; (c) two variables describing haying extent in the previous year in the surroundings of a field (within a buffer of 300 m from the limit of field): BHayC for haying in hay crops and *BHayF* for haying in fallow land and; (d) one variable describing the land use in the field in the year of sampling, *LUse*, including hay crops, fallow land and grazed land. Table 2 contains a detailed description of these variables. Both hay crops and fallow land were managed during winter and spring for haying using livestock exclusion. Most hay crop fields received soil fertilization, but this was uncommon in fallow land. The use of these vegetation types for haying or alternatively for grazing depended mostly on rainfall between September and March (more rain means more fields mown and less fields grazed). At the time of haying the two habitats were fairly similar in sward structure, presenting tall and dense vegetation and absence of woody plants.

2.3. Data analyses

2.3.1. Taxonomic diversity and sward quality versus land management

We calculated taxonomic diversity (γ-, α- and β-diversity) for each field to examine the effects of grassland management and inter-annual variability across scales. Specifically, α-diversity was calculated as the average diversity (species richness) of the sampling replicates in each field, and γ-diversity as the total diversity of all the sampling replicates of the field. β-diversity, the proportion of γ-diversity due to the differences between sampling replicates, was calculated as follows:

$$\beta\text{-diversity} = (\gamma\text{-diversity} - \alpha\text{-diversity})/\gamma\text{-diversity}$$

Thus, α- and β-diversities summarize the amount of within- and