Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Societa Botanica Italiana
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tplb20

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Accepted author version posted online: 09 Jun 2015.Published online: 10 Aug 2015.

To cite this article: P. Mendes, C. Meireles, C. Vila-Viçosa, C. Musarella & C. Pinto-Gomes (2015) Best management practices to face degraded territories occupied by Cistus ladanifer shrublands - Portugal case study, Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Societa Botanica Italiana, 149:3, 494-502, DOI: 10.1080/11263504.2015.1040483

To link to this article: http://dx.doi.org/10.1080/11263504.2015.1040483

Plant Biosystems, 2015
Vol. 149, No. 3, 494–502, http://dx.doi.org/10.1080/11263504.2015.1040483

Taylor & Francis
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ORIGINAL ARTICLE

Best management practices to face degraded territories occupied by *Cistus ladanifer* shrublands – Portugal case study

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Abstract
Land degradation in the Mediterranean Basin is clearly connected to the resilience of perturbed ecosystems, contributing to land abandonment, recurrent fires and biodiversity loss, with the prevalence of secondary shrublands that tend to occupy large areas. This is the case of *Cistus ladanifer* shrublands, one of the most widespread shrub communities in the Iberian Peninsula and a poor, uniform and resilient system. Here, we analyse the impact of several management practices in the recovery of territories largely occupied by this shrubland. We tested "non-intervention", "cut", "fire", "mechanical mobilisation" and "pasture" in 100-m^2 plots of *Cistus ladaniferus* L., in Central Portugal, and followed them from 1993. Flora were analysed using Braun–Blanquet's methodology and the plots were compared with hierarchical cluster analysis and principal component analysis. An analysis of variance was also performed to investigate differences in management practices, both between plots and between two periods of time. The results show that extensive grazing or continuous cut have a high impact on plant diversity and community structure, with extensive grazing being the best way to improve plant diversity in a short period of time, using fewer resources.

Keywords: *Landscape management,* Cistus ladanifer*, shrublands, fire, cut, grazing, Mediterranean ecosystems*

Introduction

The causes of land degradation on the Mediterranean Basin are not essentially dissimilar from those prevailing in other parts of the world; they are mostly driven by complex interactions of socio-economic, political, technological, natural and cultural factors (Brandt et al. 2002). The consequences are innumerous and include land abandonment (Antrop 2004; Caballero 2007), loss of many unique resources, such as soil and phytodiversity, damage of landscape values (Plieninger et al. 2006; Bagglea & Caria 2011) and increased fires, with respective consequences in plant species composition and soil degradation (Gómez-Limón & Fernández 1999; Valbuena et al. 2000; Gallart & Llorens 2004; Poyatos et al. 2003).

One of the most important aspects of land degradation concerns the resilience of perturbed systems (Cammeraat & Imeson 1999). For example, in the Mediterranean, land abandonment repeatedly associated with recurrent fire leads to the presence and maintenance of secondary shrublands that tend to occupy large areas. Those shrublands are associated, either directly or indirectly, to soil denudation in areas which, as their topography, slope, geological substratum and soils, are erosion-prone.

In Portugal, the environmental conditions, associated to severe historical anthropogenic pressures, also had major impact on landscape causing, ultimately, a general reduction of land productivity (Brandt & Thornes 1996; Puigdefábregas & Mendi-

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zabal 1998). Amongst the most prominent pressures are cycle forest fires, which, in the last 25 years, burned 2,702,979 ha (ICNF, available at http://www.icnf.pt/portal/florestas/dfci/inc/estatisticas) in the Portuguese mainland, including forest, shrublands and semi-natural grasslands. As a consequence, throughout the territory, abandoned areas have been occupied by several kinds of shrub communities that are "perpetuated" by short fire cycles. This is the *Cisto-Lavanduletea* Br.-Bl., 1940 shrublands case, which are dominated by *Cistaceae* (e.g. *Cistus ladanifer*.) and *Labiatae* (e.g. *Lavandula* Sect. *Stoechas*). Those are secondary shrub communities, mainly resulting from fire destruction of natural potential sclerophyllous forests, as well as wood cuttings and subsequent upper layer soil erosion (Rivas-Martínez 1979; Díaz-González et al. 1989). Currently, they are one of the most widespread shrub systems of the western half of the Iberian Peninsula (Núñez-Olivera et al. 1995), covering large areas of central and southern Portugal. They are especially present in drier and warmer biotopes, usually living in poor or scarcely evolved soils (Lousã et al. 2009). One of the biggest problems of this large area dominated by *Cistus ladanifer* is the fact that they are normally very poor in species and do not tend to develop positively to mature vegetation stages. This is a degraded state of soil, which limits the installation of autochthonous tree species (Meireles et al. 2005), but also of the well-known allelopathic action of *Cistus ladanifer*, which lies on the ground of phytotoxic active compounds, inhibiting the development of other plants (Alias et al. 2006; Sosa et al. 2010).

The question that currently stands is to realise which is the best way to recover these territories, from edaphic and phytocoenotic viewpoints, in order to increase landscape and species diversity and, ultimately, land productivity. Several works have been developed to study the structure, dynamic and floristic composition of these shrublands (Braun-Blanquet et al. 1964; Rivas-Martínez 1979; Gavilán & Fernandez-González 1997; Pérez-Latorre et al. 1997; Vila-Viçosa et al. 2013). However, only a few have compared the long-term effects of management practices (Núñez-Olivera et al. 1995; Tárrega et al. 1995; Calvo et al. 2002).

Based on the floristic composition and species relative abundance, we aim to analyse the effects of several management practices, applied to *Cistus ladanifer* shrublands, over 20 years. The final goal was to understand which method can improve phytodiversity and consequently the phytocoenotic value of traditional landscapes in territories mainly occupied by this shrubland.

Methodology

Study area

The case study was developed in Central Portugal (Idanha, Castelo Branco district). This is a thermo-meso-Mediterranean territory, dry to sub-humid (Monteiro-Henriques 2010) and biogeographically inserted in the Lusitan-Extremadurean Subprovince, more concretely in the Beirensean Sector (Rivas-Martínez 2007). It is dominated by soils derived from Palaeozoic siliceous materials, mainly schists or granites (Costa et al. 1998). Human activities led to the almost non-existence of climatophilous woods in this territory, locally dominated by Cork Oak (*Quercus suber* L.) and Holm Oak (*Quercus rotundifolia* L.), comprehending the associations *Smilaco asperae–Quercetum suberis* Pinto-Gomes, Alvarez-Ladero, Gonçalves, Mendes & Lopes (2003); Cano et al. (2007b) and *Pyro bourgaeannae–Quercetum rotundifoliae* Costa, Aguiar, Capelo, Lousã & Neto (1998).

At present, open woodlands dominate this territory, mostly associated with eroded schistose soils. The prevailing shrublands headed by *Cistus ladanifer* and belonging to *Genisto hirsutae–Cistetum ladaniferi* Rivas Goday, 1955, almost all of the local landscape is overwhelmed by this shrubland, with or without punctual and scattered *Quercus* spp. trees (Figure 1).

Sampling

Since 1993, having had a starting point of shrublands of *Cistus ladanifer* L. as a serial regression stage, several plots of 100 m^2 were exposed to different management regimes according to the next explanation: five were abandoned and had no management (NM); five were exposed to grazing, with extensive and traditional systems (using sheep's; shrubs were initially cut; grazing along 20 years; about 2–3 livestock units per hectare) (*G*); five were exposed to shrub cutting in the first year of the project (*C*); three suffer continuous shrub cut in each 2 years (CC); five were burned once in 1997 (*F*) and five were exposed to soil mobilisation with harrows in the beginning of the experiment and then abandoned (*M*). Despite having initially contemplated five areas with continued cutting (CC), this was not possible due to budget reasons. Therefore, we present here only the results of three plots with this type of management. We also removed one of the mobilisation plots (*M*) because the owner tilled it once more than expected.

The treatments were selected in order to represent the most common management forms that can be observed in the territory. The exposed areas have similar biophysical conditions, including

Figure 1. Study area.

the same soil type (schist), a similar altitude (around 300 m) and a similar exposition (North Quadrant). The flora and vegetation of the entire study area were studied and reported before management in 1993, after management in 2003 (10 years) and again in 2013 (20 years). The before-management results were represent with a "*Z*". All plant species and respective covers, applying the Braun-Blanquet cover-abundance scale, were recorded at the beginning of spring. Species determination followed the proposals of Castroviejo et al. (1986–2012), Franco (1971–1984) and Franco and Rocha-Afonso (1994–2003), while sintaxonomic nomenclature followed Rivas-Martínez et al. (2011).

Data analysis

In order to support field observations, we performed a statistical analysis using XLSTAT software (version 2013.6). For the joint comparison of all plots, a cluster analysis was first carried out using the algorithm unweighted pair-group arithmetic mean method and a Bray–Curtis dissimilarity matrix. In this process, all Braun-Blanquet's abundance indexes were converted to the scale of 0–9 proposed by Van der Maabel (1979), enabling statistical analysis. Succeeding, we characterised plots according to a set of easily measured variables: (1) total cover; (2) species richness; (3) leguminous richness; (4) leguminous total cover; (5) gramineous richness; (6) gramineous total cover; (7) shrub richness; (8) shrub total cover; (9) *Querceteailicis* species richness and (10) *Quercetea ilicis* species total cover.

For the *Quercetea ilicis* variables, we considered all of the characteristic species up to the alliance level of *sintaxa*. These variables were selected because we considered that they can express different levels of land recovery and biological richness. In order to detect general changes in plant composition across the management types, we submitted the final matrix to a principal component analysis (PCA) based on a Pearson correlation matrix of all variables from the total number of plots. Finally, we used an analysis of variance (ANOVA) to determine significant differences between management procedures, repeating the procedure for the results of 10 and 20 years.

Results and discussion

Twenty years later, most of the plots were again covered by *Cistus ladanifer* and found to have a similar floristic composition, as they had in 1993 (*Z* plots). The only exceptions are the plots that experienced continuous management (*G* and CC), which showed an important reduction of shrub dominance and the entrance of several plants, especially *Poaceae* and *Fabaceae*. This can be perceived in the dendrogram plots (Figure 2), which show three main clusters (I, II and III). In the first left sub-branch lies Cluster I, with an approximate truncation level of 0.85 plots, completely branching the continuous management plots, from the others.

We believe this is due to the positive impact of cattle in this species, once they consume the inflorescences, during the autumn and spring, consisting of an extra supply of nutrients from Clusters II and III, gathering plots with no management (NM) and plots with non-continued management (*M*, *F* and *C*). In the right sub-branch are Clusters II and III, which include plots from pasture (*G*) and continued cutting (CC), respectively. The grazing plots are differentiated by the great presence of leguminous and gramineous species, especially those belonging to *Poetea bulbosae* Rivas Goday & Rivas-Martínez in Rivas-Martínez, 1978 (e.g. *Poa bulbosa* L., *Trifolium subterraneum* L., *Erodium botrys* (Cav.) Bertol, *Trifolium glomeratum* L., *Trifolium tomentosum* L.). It is also interesting to note the presence of *Lavandula sapaioana* Rivas Mart., T.E. Díaz & Fern. Gonz in some of these plots, which could be justified by grazing activity (Barroso et al. 1995) which simultaneously helps with seed dispersal. The CC plots are also very different from the rest of the plots and are particularly characterised by perennial grasslands of *Centaureo coutinhoi–Dactyletum lusitanici* Pinto-Gomes et al. (2010), especially *Dactylis hispanica* subsp. *lusitanica* (Stebbins & D. Zohary) Rivas Mart. & Izco.

The PCA of the selected variables also confirms the singleness of the grazed areas (Figure 3). The first axis (F_1) explains almost 47% of the variance and was identified as an axis, especially linked to species diversity. At the higher end of F_1 are plots with more plant species, especially *Poaceae* and *Fabaceae*. Those plots correspond to grazing. Authors like Celaya and Osoro (1997) emphasise how grazing management has a significant effect on vegetation, enhancing plant richness. The results can be explained by plant growth under herbivory and improvements in soil fertilisation connected to animal excretions, as well as to higher light irradiation in the deeper vegetation layers. The grazers can also contribute to seed dispersion and the provision of adequate conditions for their germination (Tallowin et al. 2005; McEvoy et al. 2006; Casasús et al. 2007). For example, species like *Poa bulbosa* L. are zoochory plants and therefore favoured by grazers, namely by sheep (Kleyer et al. 2008). At the other end of the axes, basically at the same position in F_2, all other kinds of managements can be found, except CC plots, which are in an intermediate position in the F_1 axis, but are closer to the *G* plots. PCA axis 2 (F_2) accounted for a further ca. 30% of the total variance, and appear to be related with more shrub cover and *Quercetea ilicis* species. We can see that there is a slight tendency for plots, analysed 20 years after the intervention, being arranged on the top of F_2. However, this is not the role, suggesting that the system needs much more time to evolve, corroborating system resilience.

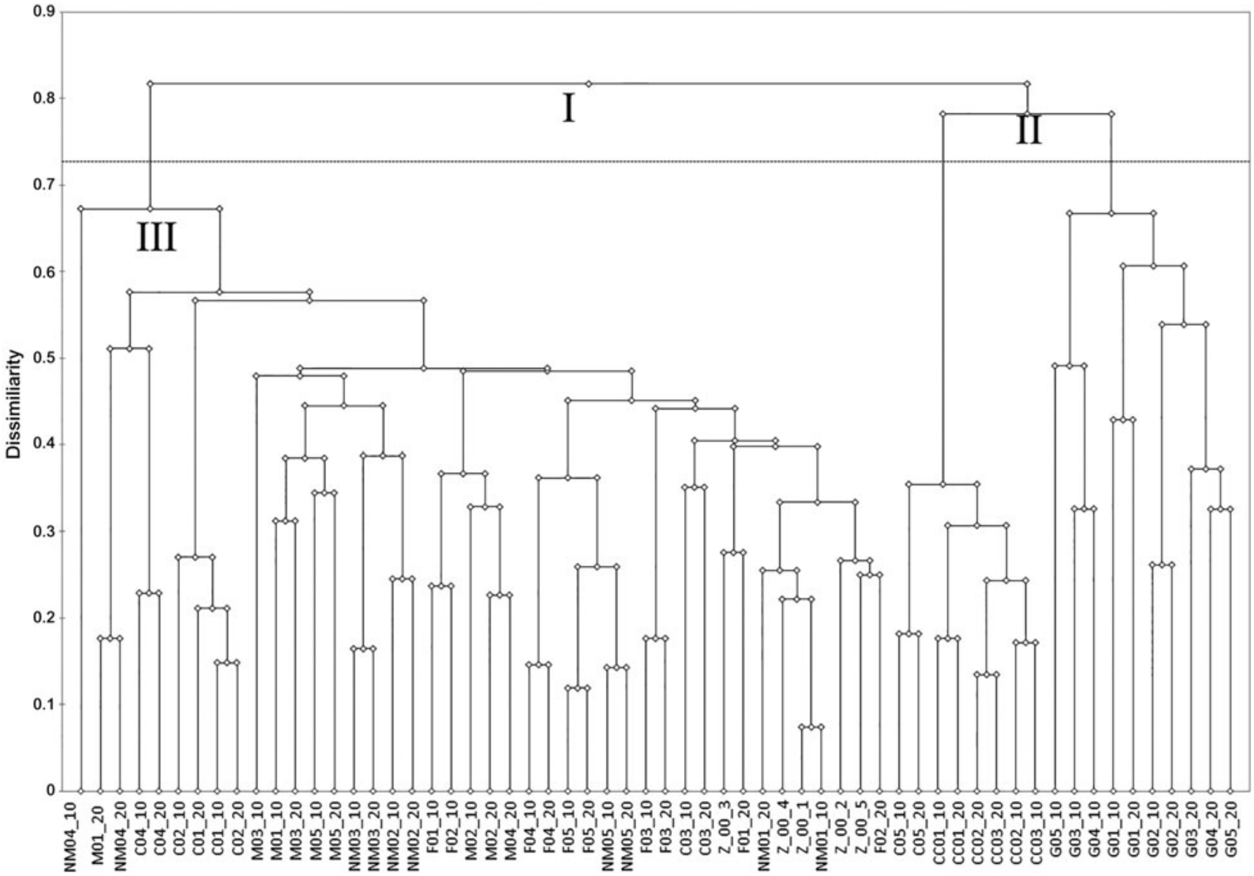

Figure 2. Hierarchical cluster dendrogram of the plots under different management treatments (NM, no management; *C*, cut; *F*, fire; *M*, mechanical mobilisation; CC: continuous cut; *G*, grazing; *Z*, the plots before management intervention).

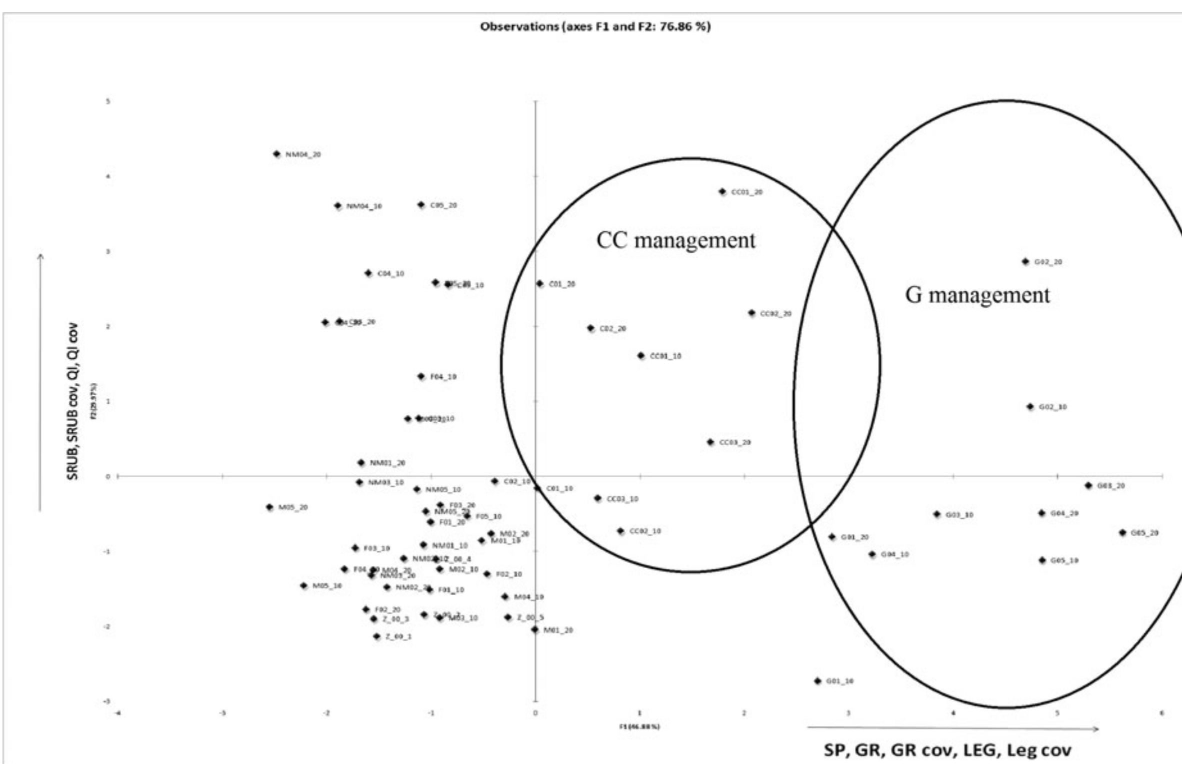

Figure 3. PCA of the plots under different management treatments (NM, no management; *C*, cut; *F*, fire; *M*, mechanical mobilisation; CC, continuous cut; *G*, grazing; *Z*, the plots before management intervention).

Table I. ANOVA results for 10 years.

	Cov	SP	GR	GRcov	LEG	LEGcov	SRU	SRUcov	QI	QIcov
R^2	0.134	0.884	0.753	0.742	0.692	0.726	0.417	0.606	0.359	0.307
F	0.679	33.669	13.396	12.654	9.905	11.633	3.152	6.772	2.469	1.949
Pr > F	0.644	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	0.027	**0.001**	0.064	0.127

Notes: Cov, total cover; SP, species richness; GR, gramineous richness; GRcov, gramineous total cover; LEG, leguminous richness; LEGcov, leguminous total cover; SRU, shrub richness; SRUcov, shrub total cover; QI, *Quercetea ilicis* species richness; QIcov, *Quercetea ilicis* species total cover.

The PCA also shows a general agglomeration of plots in the lower end of F_1 and F_2, mostly joining *F* plots (made in 1993), and *M* and *Z* plots (from 2003 and 2013). This result shows how sporadic fire or mobilisation do not have a long-term impact in this particular community.

ANOVA, which was applied to the first 10 years of data (Table I), reflected the existence of significant differences (considering a significance level of 0.01) between management types in relation to number of species, gramineous and leguminous richness (Figure 4). The same result was observed for shrub cover but not for shrub richness. This can probably be due to the tendency of *Cistus ladanifer* L. to occupy great covers in the plots and simultaneously deterring the establishment and proliferation of other shrubs, due to both soil erosion and *Cistus ladanifer* L. allelopathic effect (Chaves & Escudero 1997). Total cover did not differ much from the beginning of the experiment in all of the plots because *Cistus ladanifer* returned and dominated the majority of them. The exceptions were CC and *G* plots, where *Cistus ladanifer* was replaced by herbaceous species that were also capable of covering the majority of the plot areas. The inexistence of significant differences in *Quercetalia ilicis* species and cover can also be explained with the difficulty of species establishing in this territory. However, when analysing average results for each kind of management (Figure 4), we observed that *F* and *M* are the plots with the lowest average of *Quecertalia ilicis* species and richness.

Comparing the ANOVA for 10 years (Table I) with the data after 20 years (Table II), we can see no important changes. Twenty years later, *Quercetalia ilis* species variability is not influenced by management but has results that are close to significant. This is being improved by CC, and *C* cutting revealed that this method in the long term could be the best way to improve this species group (Figure 5).

The results also support the assumptions made by phytosociological methodology, assumed in the natural sintaxonomic scheme, which establishes hierarchic vegetation units. The assumed premises, inherently describes vegetal dynamics, supported by land use and ecological gradients. The collected data support the serial dynamics of *Pyro bourgaeannae–Quercetum rotundifoliae* Rivas Martínez, 1987 and

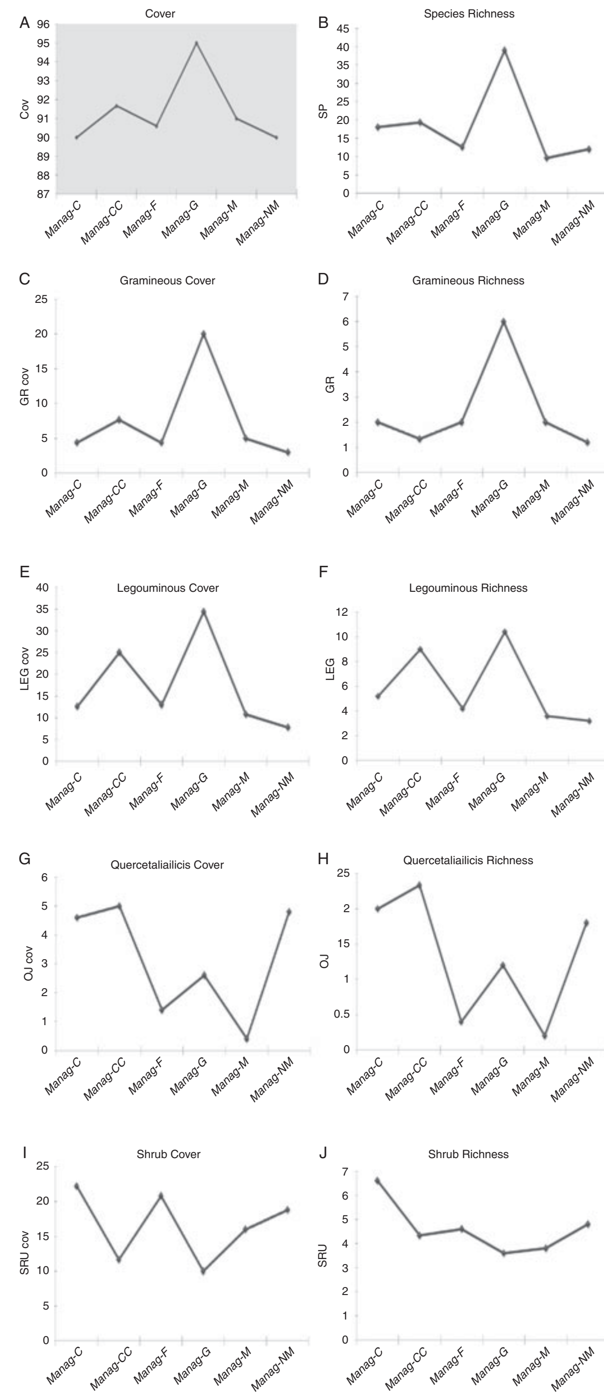

Figure 4. Variables average response to management, for 10 years (NM, no management; *C*, cut; *F*, fire; *M*, mechanical mobilisation; CC, continuous cut; *G*, grazing; *Z*, the plots before management intervention).

Table II. ANOVA results for 20 years.

	Cov	SP	GR	GRcov	LEG	LEGcov	SRU	SRUcov	QI	QIcov
R^2	0.466	0.880	0.700	0.798	0.851	0.832	0.401	0.439	0.441	0.376
F	3.836	32.293	10.268	17.332	25.138	21.835	2.941	3.440	3.469	2.646
Pr > F	0.012	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	0.035	0.019	0.018	0.051

Notes: Cov, total cover; SP, species richness; GR, gramineous richness; GRcov, gramineous total cover; LEG, leguminous richness; LEGcov, leguminous total cover; SRU, shrub richness; SRUcov, shrub total cover; QI, *Quercetea ilicis* species richness; QIcov, *Quercetea ilicis* species total cover.

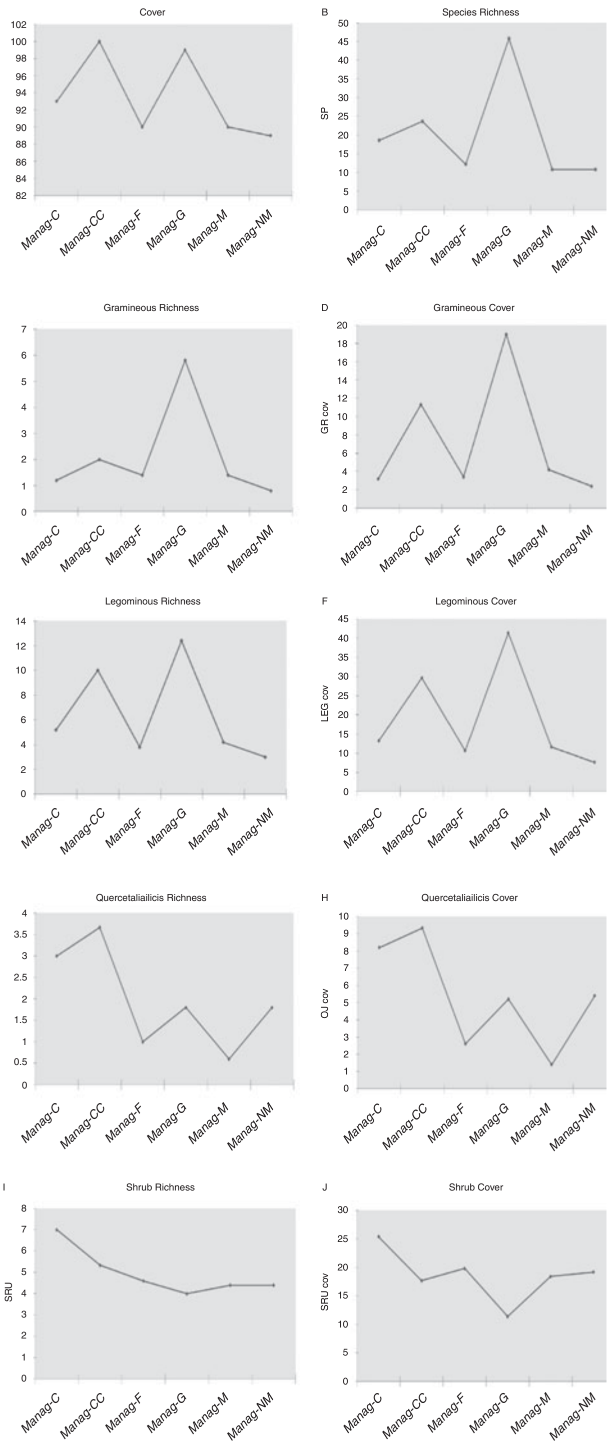

Figure 5. Variables average response to management, for 20 years (NM, no management; *C*, cut; *F*, fire; *M*, mechanical mobilisation; CC, continuous cut; *G*, grazing; *Z*, the plots before management intervention).

Smilaco asperae–Quercetum suberis forests, where the first regression steps and stages are maintained, under cyclical disturbances. In this way, shrublands of *Cisto-Lavanduletea*, typical from eroded soils, are maintained by recurrent fire cycles and soil mobilisations, as are the sub-nitrophilous terophytic grasslands of *Stellarietea mediae*, under frequent soil mobilisations and heavier livestock, also promoting the occurrence of ruderal species and communities. As an outmost result of the interaction between grazing and grasslands dynamics, *Poetea bulbosae* pastures are obtained by long-term and extensive grazing, namely by sheep, with gradual nitrate inputs, improving the trophic level and organic matter quantity and, consequently, changing the structural and floristic composition of the pasture.

Therefore, stepping-dependent species, and grazed-adapted herbs, with basal growth meristems, are able to benefit from the first few centimetres of the soil, where fertility from faeces is collected, developing a diverse and dense carpet, that is very productive and involves a high participation and diversity of perennial species (Blanco et al. 2005).

The applied management measures, such as extensive grazing and biomass cutting and incorporation, promote and ensure the maintenance of these *Poetea bulbosae* and *Stipo giganteae–Agrostietea castellanae* Rivas-Martínez, Fernández-González & Loidi, 1999 grasslands, throughout the indispensable supply of organic matter, even greater than that obtained by primary production. Several studies (Galan de Mera et al. 2000; Sánchez-Rodríguez et al. 2006; Cano et al. 2007a; Ribeiro et al. 2012) have already displayed the importance of livestock cattle on the development of theses pastures as well as their importance for conservational matters.

Conclusions

In this study, we concluded that extensive grazing and continuous cut are the management practices that lead to more obvious positive changes in vegetation cover and phytodiversity of territories previously occupied by *Cistus ladanifer* L. shrublands. In contrast, abandonment or occasional fire, mobilisation and cutting do not lead to long-term influence, maintaining the high resilience of the community. In this sense, both continuous cut and grazing seem to be effective ways to reverse land degradation and improve biodiversity in central Portugal and similar territories. Moreover, it has been demonstrated that optimal management should often include the restoration of traditional sheep management.

However, it should be noted that, comparatively, continuous cutting is extremely costly for the owner who does not have any benefits other than grazing. For example, in Portugal, continuous cuts cost an average of 300 euros/ha per year. However, in grazing, the associated management costs are nullified by the cattle incomes. These incomes are generally meat or secondary products such as cheese or wool. However, we cannot neglect the fact that extensive grazing has a range of other positive externalities, such regulation of the water cycle, soil conservation, carbon sequestration and biodiversity conservation and enhancement. These ecosystems services should be covered by EU policies, namely on CAP; furthermore, grazing could be of economic value to these vastly degraded areas, which could mitigate forest fires, depopulation and agricultural abandonment, whilst pair-wisely protecting and reconverting Council Directive Habitats such as the European priority habitat 6220* (Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*) and 6310 (Dehesas with evergreen *Quercus* spp.) and species from the Annexes as *Halimium verticillatum* (Brot.) Sennen, *Narcissus fernandesii* and *Narcissus cavanillesii* Barra & G. López (Annexes II and IV), as well as several endemisms and species with scarce and rare distribution as *Armeria pinifolia* (Brot.) Hoffmanns. & Link, and *Centaurea coutinhoi* Franco.

Also, this study, not only provides good and strong statistical data on essays, it also validates the assumptions made by phytosociologists in a wider and global region (Mediterranean Region), with major biogeographic value for conservation matters, assuming this methodology as an outstanding tool on land management for biodiversity and ecological valuation.

Notes

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