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Landscape mosaic for enhancing biodiversity: On what scale and how to maintain it?

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SUMMARY – Successional processes in Mediterranean woodlands are often considered to diminish plant species richness. We investigated the relative importance of both woody and open patches for enhancing plant species diversity and how their effects are scale-dependent and grazing-dependent. Our study site is located in Israel, within a Mediterranean ecosystem characterized by mosaic of shrubs and herbaceous patches. Shrub removal was used to assess the impact of open patches on plant species diversity. The impact was investigated with and without goat grazing and in two spatial scales: cluster of shrubs and 1000 m^2 plot. Shrub removal increased plant species richness on a small scale but on a larger scale it resulted in a reduction of species richness. Grazing, however, did not affect species number on both scales. In order to preserve high biodiversity it is advised to remove woody vegetation at small patches while preserving a matrix of intact woody patches. Goats can help in maintaining the desired landscape mosaic without reducing species richness.

Keywords: Goat grazing, coppicing, Mediterranean ecosystem, diversity, species composition, patchiness.

RESUME – *"Paysage en mosaïque pour améliorer la biodiversité - A quelle échelle et comment le maintenir ?". Nous avons étudié l'importance respective des terrains boisés et des champs ouverts dans l'accroissement de la diversité des espèces végétales, et comment leurs effets dépendent de leur étendue et du pâturage. Le défrichage des arbustes fut employé afin d'estimer l'impact des champs ouverts sur la diversité des espèces de plantes. L'impact fut étudié avec ou sans pâturage de chèvres ainsi que dans deux dimensions spatiales : des bosquets d'arbustes et des terrains de 1000 m^2. Le défrichage des arbustes accrut la richesse en espèces de plantes à petite échelle mais sur une plus grande échelle il en a résulté une réduction de la richesse en espèces de plantes. Le pâturage, par contre, n'a pas affecté le nombre des espèces, dans aucun des cas. Afin de conserver une haute biodiversité il est conseillé de défricher la végétation boisée des petites parcelles tout en conservant intacte une configuration de champs boisés. Les chèvres peuvent aider à maintenir la mosaïque de paysages désirée sans réduire la richesse en espèces.*

Mots-clés : *Pâturage de chèvres, défrichage, écosystème méditerranéen, diversité, composition en espèces.*

Introduction

Mediterranean landscape is characterized by heterogeneous structure, composed of mosaic of shrubs, trees and open patches, with herbaceous vegetation scattered among them. Successional processes in the Mediterranean woodland result in domination of woody vegetation and decline in number and area of open patches (Naveh, 1982). In Mediterranean woodland, woody vegetation affects negatively plant species diversity, due to competition on light and water or by inhibiting seed arrival and germination. Therefore, increasing woody cover can exclude herbaceous species, and reduce species diversity in the landscape (Milton *et al*., 1997). This process leads conservationists to consider intervention (active management) in order to reduce woody vegetation cover and promote higher species richness (McIntyre *et al*., 2003). Mediterranean ecosystems have been grazed by small ruminants, mainly sheep and goats, for more than 5000 years (Perevolotsky and Seligman, 1998) and coppiced for firewood and fuel even longer. In fact, Mediterranean woodlands have evolved under pressure of human exploitation (Blondel, 2006) and therefore applying grazing and wood cutting as management tools may be legitimate for enhancing biodiversity.

Effects of coppicing and grazing on plant species diversity can be examined on different spatial scales (De Miguel *et al*., 2005). We are looking at two spatial scales: the smaller scale is individual

patch (cluster of shrubs or open patches between them), and the larger scale is the landscape unit -a mosaic of woody vegetation and open patches. Shrub removal was used to assess the impact of open patches on plant species diversity in comparison with closed woody patches, in the two spatial scales. In addition, we examine the effect of goat grazing on plant species richness at both scales, and in the two different patch-types. Such experimental design can promote our understanding of the impact of management treatments on species diversity, and how this effect changes with different spatial structure (different mosaic of open and woody patches).

Materials and methods

The study site is located in the southern tip of Mt. Carmel, at Ramat Hanadiv Park (32º30' N, 34º55' E, 120 m) where precipitation is ~600mm. The bedrock is dolomite and limestone; vegetation form is evergreen Mediterranean garigue with sclerophylous trees and shrubs and herbaceous patches. The dominant woody species is *Phillyrea latifolia* (Oleaceae), accompanied by *Calicotome villosa* (Fabaceae), *Pistacia lentiscus* (Anacardiaceae) and *Sacropoterium spinosum* (Rosasea). *Phillyrea latifolia* is a branched and dense evergreen shrub, its height is 2-4 m and it is common in Israel in the Mediterranean lowlands (up to 800 meters) (Feinbrun-Dothan and Danin, 1998).

The experiments involved treatments of grazing by goats and removal of shrubs. We used four combined treatments: (i) shrub removal + grazing; (ii) shrub removal + no grazing; (iii) no removal + grazing; and (iv) no removal + no grazing. Each treatment was replicated 5 times in 1000 m^2 plots (20 plots). Two patch types were defined in each treatment: (i) *woody* patches where ground surface is under the canopy of a *Phillyrea latifolia* shrub or had been so before its removal; (ii) *open* patches where woody vegetation did not cover ground surface before the beginning of the experiment. Removal of canopy took place in spring 2004 and was repeated in October 2005. Goat grazing has started, in spring 2004, and was carried out between spring and early winters. Sampling took place in spring 2006, two years after shrub removal. Sampling was randomly stratified to patch type. Each patch type was sampled by 48 quadrates of 20*20 cm^2 for identification of plant species. We used One-Way ANOVA and protected multiple comparisons (Tukey's HSD) to compare species richness between the patch types under each treatment combination. Multivariate community analyses were performed using PRIMER version 4.0 (Clarke and Warwick, 2001). Bray-Curtis similarity coefficients (Bray and Curtis, 1957), based on arcsine transformation of frequency of species, were used for constructing similarity matrices. Ordination of plots was conducted using non-metric multi-dimensional scaling (MDS). We used one-way analysis of similarity (ANOSIM; Clarke, 1993) to test for species composition similarities in patch types under different treatments.

Results

Open patches show no differences in species richness between the treatments (Fig. 1a). Likewise, no significant differences between species composition was noted under different treatments in the open patches (Table 1). This can be seen clearly in non-metric multidimensional scaling ordination, which presents similarities between samples from open patches in different treatment (Fig. 2a). On the other hand, species richness in woody patches increased after canopy removal, but not after grazing (Fig. 1a). Species composition in woody patches was significantly different after treatments comparing to untreated plots. In addition, species composition in shrub-removal plots (with and without grazing) showed significant difference compared to the grazing treatment (Table 1). While plant composition in open patches does not change substantially following treatments, in the woody patches a remarkable change occurred and it becomes more similar to the composition in open patches after grazing, and even more after shrub removal (Table 1, Fig. 2a). Although the number of species in woody patches increased after canopy removal, average species number at the plot decreased (Fig. 1b). Looking at each patch-type separately, species composition in open patches shows little change in response to grazing and shrub removal, while species composition in woody patches changed dramatically after shrub removal and grazing. At the whole plot scale, differences in species composition in untreated plots compared to shrub-removal and removal+grazing treatments are revealed but no significant difference when compared to grazing (Table 1, Fig. 2b).

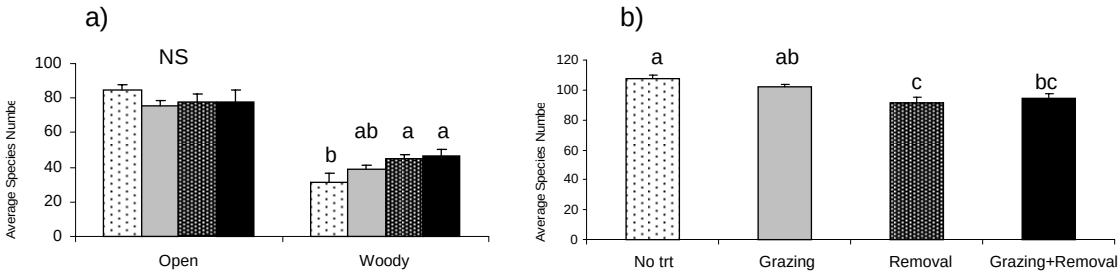

Fig. 1. Species number after treatments in the two patch-types (a) and in 1000m^2 plots (b). ⊡no removal + no grazing; ▒ grazing + no removal; ▩shrub removal + no grazing; ■ grazing + shrub removal. Letters sign significant differences in Tukey test. n=5.

Table 1. One-way analysis of similarity for plant community under treatments in different patch-types. Analysis based on Bray-Curtis distance of species frequency. Significant effects are shown in *italics*. G-Grazing; R-Canopy Removal; GR- Grazing+Removal; No trt- No Grazing+No Removal

	Open		Woody		Plot	
	R Statistic	Significance Level	R Statistic	Significance Level	R Statistic	Significance Level
GR *vs* G	-0.06	0.683	0.864	*0.008*	0.336	*0.016*
GR *vs* R	-0.2	0.984	0.176	0.071	-0.14	0.944
GR *vs* No trt	0.112	0.238	1	*0.008*	0.412	*0.016*
G *vs* R	0.084	0.246	0.748	*0.008*	0.44	*0.016*
G *vs* No trt	0.296	0.056	0.416	*0.008*	0.264	0.063
R *vs* No trt	-0.016	0.444	0.972	*0.008*	0.38	*0.04*

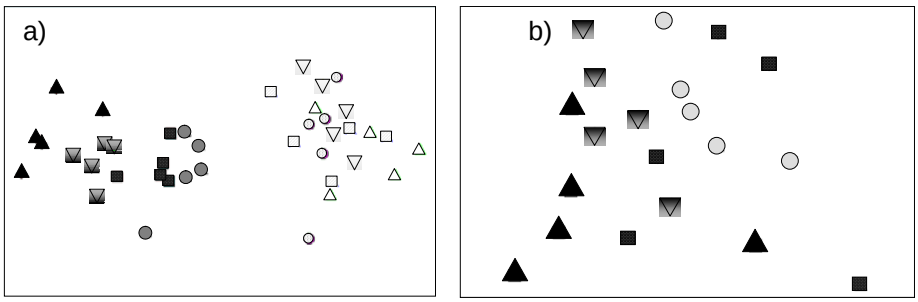

Fig. 2. Non-metric multidimensional scaling ordination showing species composition of woody and open patches (a) and plots (b) under different treatments. Full symbols represent woody patches, hollow symbols represent open patches. △= No treatment; ▽= Grazing; □= Removal; ○= Grazing+Removal.

Disscusion

Woody plants in the Mediterranean area have negative effect of understory plant species diversity mostly through competition for light, nutrients and water (Specht *et al.,* 1990). Hence, it was predicted that opening up the plots would encourage colonization of plant species that had been competitively suppressed by the woody vegetation (Bisteau and Mahy, 2005). This trend was observed in patches where shrubs were removed. New species colonized in the shrub-removed

patches and as a result, species richness increased. In addition, the occurrence of annual species, which were presented in low frequency under shrubs, increased in the patch after shrub removal.

However, the positive effect of shrub removal on species richness is not maintained in a larger scale (Fig. 1a,b); shrub removal has a negative effect on species richness at the plot scale. Previous studies in the Mediterranean region reported on positive effect of tree clear-cutting on species diversity (*Floret et al.,* 1992), thus permitting colonization by new species. In our study, common species frequencies did not change significantly after shrub removal, but frequencies of low-abundances species decreased. This decrease results in local extinction of the rare species from the plot and a consequent decrease in species richness.

Grazing can induce profound effects on herbaceous communities, changing species composition and structure (McIntyre *et al.,* 2003). In Mediterranean ecosystems, herbivores can increase or reduce plant diversity, depending on grazing intensity and grassland productivity. At intermediate grazing intensity plant diversity may increase due to the reduction of the cover of dominant species, favouring the survival of the less competitive species (Milchunas *et al.,* 1988). In our study, grazing affects plant species directly through consuming seeds and indirectly through its effect on plot properties, by soil trampling, and changing woody vegetation structure by browsing its foliage. Those effects change availability and flow of resources such as light and water, and movement of seeds in space. Although two years of intensive browsing and grazing altered significantly plots pattern and woody vegetation structure, it did not cause any significant change in species richness neither at plot level nor in patch-types (Fig. 1a,b). Despite the fact that species number did not changes, species composition at woody patches changed significantly after grazing (Table 1), Implying that grazing can affect plant community by altering landscape properties and not only by direct consumption.

Conclusions

Opening dense woody vegetation cover is necessary to preserve high values of biodiversity in Mediterranean woodland. Our research indicated that shrub removal yields better results in terms of biodiversity than grazing. However, the effectiveness of shrub removal as a tool for enhancing biodiversity is scale-dependent. Removal of woody vegetation should be carried out at small patches, while the matrix of intact woody patches should be maintained. Creating landscape mosaic composed of open and woody patches would ensure the existence of the many species that characterize open patches without losing species that appear only in woody-patches.

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