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Factors affecting plant species richness of grasslands enclosed by forest in the Pesio Valley

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Abstract. European mountain regions have been dominated by semi-natural ecosystems, where natural and anthropogenic disturbance regimes have interacted for thousands of years. In the western Italian Alps, traditional practices, such as silvo-cultural intervention and grazing regimes, have created a heterogeneous mosaic of open areas, as well as sparse and dense forests. Throughout the last decades, a trend of abandonment of marginal areas has caused a natural reforestation of former grassland patches enclosed by forest with a consequent loss of grassland plant diversity. The study was conducted to assess the effect of ecological, topographic, management, and landscape features on current patch species richness. All vascular plant species were recorded within each grassland patch of the Pesio Valley. Grassland species richness was calculated and used in GLMs as dependent variables. On the whole, the soil reaction and the soil nutrient content emerged to be the most important ecological factors affecting grassland species richness. The conservation of suitable ecological factors is strictly related to mowing and grazing practices, thus management practices appear to be essential instruments to preserve plant diversity of grasslands enclosed by forest.

Keywords. Generalized linear models – Grassland patch – Plant diversity.

Les facteurs déterminant la richesse de la végétation dans les prairies entourées par la forêt dans la vallée de Pesio

Résumé. *Les régions de montagne européennes ont été dominées par les écosystèmes semi-naturels, où les perturbations naturelles et anthropiques ont interagi pendant des milliers d'années. Dans l'ouest des Alpes italiennes, les pratiques traditionnelles ont créé une mosaïque hétérogène de forêts et de zones ouvertes. Au cours des dernières décennies, l'abandon des zones marginales a provoqué une reforestation naturelle des anciennes zones ouvertes, avec une perte de la diversité végétale. Cette étude a donc évalué l'effet des facteurs écologiques, topographiques, de management et du paysage sur la richesse en espèces des prairies. La totalité des espèces de plantes vasculaires a été déterminée au sein de chaque prairie ouverte. Les richesses spécifiques de toutes les espèces ont été calculées et utilisées dans comme variables dépendantes dans un modèle d'analyse GLM. La réaction du sol et la teneur des éléments nutritifs dans le sol semblent être les facteurs écologiques les plus influençant la richesse en espèces. La conservation des facteurs écologiques est strictement liée aux pratiques de gestion, qui sont les meilleurs instruments pour préserver la diversité végétale des prairies entourées par la forêt.*

Mots-clés. *Models linéaires généralisés – Prairies entourées par la forêt – Diversité de la végétation.*

I – Introduction

In European mountain regions the complex variability of plant species richness has been intensely influenced by land-use patterns (Garbarino *et al*., 2013). In particular, agro-pastoral activities have significantly increased plant diversity in the mountain and sub-alpine belts of the Alps (Strebel and Bühler, 2015). However, throughout the last decades the abandonment of marginal agro-pastoral lands has caused a steady decline in the regularity of land-use practices in many Italian alpine ar-

eas (Probo *et al*., 2013). As a consequence, secondary succession has led to the reduction of meadow and pasture communities. For these reasons, most of the remaining grasslands located below the treeline have been reduced and fragmented into a system of small patches enclosed by forest, which have been increasingly subjected to management abandonment (Orlandi *et al.*, 2016). The high species richness of semi-natural grasslands is mainly dependent on the combination of different ecological, topographic, management, and landscape factors, which relative importance has to be thoroughly analysed.

II – Materials and methods

1. Study area

The study was conducted in the upper Pesio valley (44°13' N; 7°40' E), which is located within the Marguareis Regional Park in the Piedmont Region (Italy). The elevation ranged from 850 to 2600 m a.s.l., the average temperature in the bottom of the valley (935 m a.s.l.) was 9.1°C (APAT, 2007). The average annual rainfall was 1367 mm, with two peaks in May and November (APAT, 2007).

To assess the location of grassland patches, aerial photograph of 2012 were used for photo interpretation in a GIS environment, using the GIS software ESRI® ArcMapTM 9.3. Grassland patches were defined as polygons wider than 0.1 ha, larger than 10 m and with a tree density lower than 20% (Sitzia and Trentanovi, 2011).

Total plant species richness was measured for each grassland patch from the beginning of June to the end of August. Each patch was walked through and all vascular plant species were recorded. The time spent at each patch was approximately 30 min per ha (Sitzia and Trentanovi, 2011). The phytosociological optimum was attributed to each plant species at the class level, according to Aeschimann *et al*. (2004).

2. Factors affecting grassland patch vegetation

Different ecological, topographic, management, and landscape features were considered as factors affecting plant species within grassland patches. The following ecological indicator values of Landolt *et al.* (2010), ranging from 1 to 5 and related to the optimal habitats of species, were attributed to each plant species: light (L); soil moisture (F); soil reaction (R); and nutrient value (N). The unweighted mean and the standard deviation of each indicator value were calculated to determine the mean and the variation of ecological conditions affecting grassland species within each patch. Bare ground and rock layers percentage cover were visually estimated for each grassland patch. The average soil depth was assessed by randomly inserting a 1 m pole 5 times for each patch, measuring the height of the insertion.

Grazing intensity, obtained from a visual evaluation of forage consumption, was estimated using a scale ranging from 0 to 5. Moreover, the distance between each grassland patch and the nearest farm building was calculated as a proxy for management intensity. In each plot, forage pastoral value, a synthetic value summarizing forage yield and nutritive value, was attributed to grassland vegetation, according to Cavallero *et al*. (2007), and used as a proxy of forage quality. The number of mowing in each patch was recorded by direct interviews to farmers. The litter cover was visually estimated and classified in five groups.

Elevation, slope and southness were extracted for each patch from a Digital Elevation Model (DEM) with a 5X5 m cell size. A southness index was calculated as a linear transformation of aspect (southness = 180 – |aspect – 180|).

To assess grassland changes at a landscape level, the area and the shape index of grassland patches were calculated. The maximum nearest neighbour distance among grassland patches and all the other grassland patches within a 1-km radius was calculated. Within this distance the proportion of grassland area for every patch was calculated as an index of connectivity (Sitzia and Trentanovi, 2011).

3. Statistical analyses

Total plant species richness was used as dependent variables in stepwise analyses Generalized Linear Model (GLMs). In all GLMs, predictors were ecological, topographic, management, and landscape variables. Predictors were standardized (Z-scores) to allow for analysis of effect size by scrutinizing model parameters (β coefficients). A correlation analysis of predictor variable was used to exclude highly collinear predictors ($r > |0.80|$).

III – Results

A total of 61 grassland patches enclosed by forest were identified, the total area occupied by grasslands was 59.23 ha, with an average extension of 0.97 ha per patch. The total species richness of grassland patches consisted in 609 species.

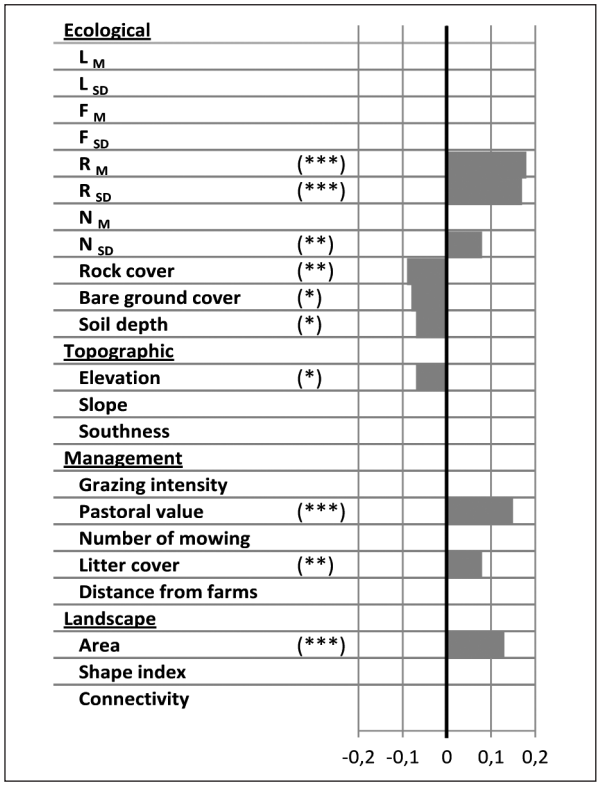

Fig. 1. Stepwise GLMs of Total species richness of grassland patches as dependent variable, and ecological (Landolt indicator values expressed as mean value "X_M" and as standard deviation "X_{SD}; rock cover; bare ground cover; soil depth), topographic (elevation, slope, southness), management (grazing intensity, pastoral value, number of mowing, litter cover, distance from farm buildings) and landscape features (patch area, shape index, connectivity) as predictors.

According to model parameters (i.e. |β| coefficients of significant variables), grassland vegetation was primarily affected by ecological and management factors and secondarily by landscape and topographic features (Fig. 1). The total patch species richness was mostly and positively influenced by the mean and the standard deviation value of soil reaction, while the bare ground cover, the rock cover, the soil depth and the elevation negatively affected the total number of plant species. Moreover, the pastoral value, the litter cover, and the area had a positive effect.

IV – Discussions

The positive effect of soil reaction at grassland patch level was in line with literature (Peter *et al*., 2009) and it was probably due to the unimodal relationship between species richness and pH, which has a peak of species richness at about pH 6-7 (Dengler *et al*., 2014). Moreover, according to the environmental heterogeneity hypothesis (Dengler *et al*., 2014), a wide soil nutrient content range was favorable for increasing species richness at patch and plot levels. This could be also related to the de-intensification or abandonment of traditionally managed areas, in which the co-existence of both residual nutrient-demanding species and stress-tolerant species can occur (Marini *et al*., 2007).

A strong influence of the pastoral value was detected, which is strictly related to management practices, such as the soil nutrient content (Marini *et al*., 2007).

Among landscape features, only grassland area was positively significant for species richness. Contrariwise, the importance of connectivity for plant species richness conservation has been already highlighted in alpine grasslands (Sitzia and Trentanovi, 2011). However, in our context the effect of ecological and management features were dominant, highlighting that isolated grassland patches could successfully be maintained by periodic anthropogenic disturbance.

V – Conclusions

Suitable management practices, adapted to specific species composition, were retained to be important tools for the maintenance or the restoration of suitable ecological parameters, such as light availability or soil nutrient content. A better comprehension of ecosystem processes involved in the population dynamics of plant species could help the identification of management activities, in order to prevent further closure of grassland patches.

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