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What plant traits tell us: Consequences of land-use change of a traditional agro-forest system on biodiversity and ecosystem service provision

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ABSTRACT

Traditional agro-forest systems (TAFS) link the two ecosystems forest and grassland and are an attractive, species-rich land-use type in the European cultural landscape. In the past decades, particularly in mountainous regions, socio economic changes have resulted in their abandonment or intensification of use. Our study employed plant traits to analyze and understand the consequences that abandonment and intensification have on plant species diversity, functional diversity and the provision of ecosystem services of larch (*Larix decidua*) grassland, a TAFS in the European Alps. By applying commonly used traits such as growth form and pollination agent, together with less used traits such as flower color and edible or healing plants, we found highest plant species diversity in traditionally managed larch meadows and larch pastures, while functional diversity was seen to be high also in abandoned larch grasslands. We further show that provision of the ecosystem services scenic beauty and pollination is best in traditionally managed larch meadows and larch pastures. Regarding the provision of edible or healing plants, the largest species pool was found in traditionally managed larch meadows, while the highest species coverage was found in intensively managed larch meadows. Summarizing our results, we deduce that both the abandonment and intensification of larch grasslands result in a loss of plant diversity and a decrease in provided ecosystem services. Consequently, enhancement of our knowledge through further investigation of TAFS is essential for the maintenance and conservation of these valuable cultural ecosystems.

1. Introduction

Grasslands with trees, or wood pastures, were once widespread from the Mediterranean region to boreal Europe (Bergmeier et al., 2010). Fragments of those traditional agro-forest systems (TAFS) can still be found in several countries, e.g. the Spanish Dehesa, the German Hutewald or the Finnish wood pastures. Another remnant of such TAFS is found in the larch grasslands of the Alps, scattered with the European larch (*Larix decidua*). These wooded hay-meadows or pastures evolved since the Bronze Age (Gobet et al., 2004) between 1000 and 2000 m.a.s.l. Each year the hay is gathered or the land pastured, and in times of need individual larches are cut and the precious larch wood sold. Aside from socio-economic aspects, these traditional ecosystems have a long history in the European cultural landscape and harbor a high biodiversity (Maurer et al., 2006; Bastian, 2013). Similar to other TAFS, larch grasslands should also support a high biodiversity due to the various niches provided by the mixture of the two ecosystem types forest and grassland, regular disturbance from mowing or pasturing, and the special climatic conditions in the Alpine area.

However, the widely documented increase in land-use change throughout Europe (Mottet et al., 2006; Tasser et al., 2007;

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Castro et al., 2010) also affected mountain areas. The agricultural industrialization after the Second World War, the increase in production costs, and the evolution from full-time to part-time farming are identified as the main reasons for land-use change in rural areas (Krausmann et al., 2003; Streifeneder et al., 2007). Furthermore, the reduction in European household size has decreased the available manpower on farms (Ogden and Hall, 2012), resulting in a decline in traditional land-use systems and extensive farming practices that require significant manual labor (Bergmeier et al., 2010; Zimmermann et al., 2010). Consequently, TAFS have decreased rapidly since the 1950s, often being abandoned on steep, remote sites or converted into more intensive land-use systems on flat and easily accessible sites (Tasser et al., 2007; Fontana et al., 2013). Hence, the current area of larch grasslands in South Tyrol, our study area, has diminished to approx. 30 km^2, which is around a third of the original area.

Both management changes, namely abandonment and intensification, are known to result in a change in species cover and plant species composition (Dullinger et al., 2003; Peco et al., 2005). In this context species and functional diversity, i.e. plant and plant trait occurrence and abundance in a community, are useful for the determination of changes in biodiversity (Díaz et al., 2007; Vandewalle et al., 2010). It has been shown that plant responses to disturbance or changes in land use are reflected in vegetation structure and can be assessed by measurements of simple biological traits (Díaz et al., 2001; Peco et al., 2005). Those biological or functional traits allow the description of important underlying properties of ecosystems and have thus been identified as useful indicators in ecosystem service assessments (Kremen, 2005; de Bello et al., 2010; Lavorel and Grigulis, 2012). The concept of ecosystem services, a framework describing the benefits of nature to humankind (MEA, 2005; TEEB, 2010), has become a popular instrument for the assessment and valuation of ecosystems and their functions. The growing consensus that biodiversity plays a significant role in the provision of ecosystem services (Balvanera et al., 2006; Díaz et al., 2007; de Bello et al., 2010; Pla et al., 2012) implies the integration of plant functional diversity measurements into ecosystem service assessments (Quetier et al., 2007; Lavorel and Grigulis, 2012). However, there is a lack of studies analyzing services such as cultural services, because they are difficult to measure and thus the number of their indicators is still low (Feld et al., 2009; TEEB, 2010). Consequently, beside the traits life strategy, growth form, mowing tolerance and dominance in situ, which capture basal structural changes, our study focuses on rarely used traits in order to deduce the provision of aesthetic value, cultural-historical value, and pollination value. Furthermore, we assessed the conservation value using the Red List. We analyzed vegetation data from mown or pastured, abandoned, and intensified larch grassland to compare the impact on plant species and functional diversity.

Since research on functional diversity in TAFS is still rare (Castro et al., 2010), but strongly needed in order to manage and monitor those land-uses (de Bello et al., 2010; Peco et al., 2012), our principal aim was to understand the impact of land-use change on larch grasslands by testing the following hypotheses:

The abandonment or intensification of larch grasslands:

(1) decreases their plant species diversity, functional diversity and the number of Red List species, and thus lowers their conservation value;
(2) decreases their provision of the ecosystem services scenic beauty due to decreases in colorfulness, pollination capacity because of lower pollinator diversity, and cultural-historical value due to lower provision of healing and edible plants.

2. Materials and methods

2.1. Study region

The Autonomous Province of Bozen-Bolzano (South Tyrol) is located in the Eastern Alps, in the northernmost region of Italy. It covers an area of 7400 km^2, which extends within the longitudes 10°22′E and 12°28′E and the latitudes 46°13′N and 47°05′N. The mountain chains surrounding South Tyrol generate a subcontinental climatic condition in the Central Range with relatively mild temperatures (~4 °C) and relatively low precipitation (~1000 mm) for an Alpine environment (Fliri, 1962; Tasser et al., 2013). The southern part of the province is less subjected to the influence of surrounding mountains and is characterized by sub-Mediterranean aspects (~8.5 °C, ~800 mm, Tasser et al., 2013). The landscape is mainly shaped by mountains and almost 60% of the study region lies above 1600 m.a.s.l. (ASTAT, 2011). Space is a limited resource in the region, which influences land-use decisions in agronomy and forestry. South Tyrolean agronomy is divided into two main parts: advantaged valley regions where apple and viticulture dominate and less advantaged mountain regions where grassland and dairy farming prevails. The majority of agricultural operations is small-structured and owned by individual families. The agriculturally effective surface amounts to 2419 km^2, whereby 26.7% thereof is managed as meadow and 61.2% as pasture (ASTAT, 2011).

2.2. Investigated management types

2.2.1. Currently managed larch grasslands

Today's larch meadows and pastures in the study region are mostly managed in three different ways with varying intensities. Seen from a distance all three management types look similar and demonstrate comparably high scenic values. To maintain this characteristic scenery, and the biodiversity of this ecologically valuable habitat, they are financially supported by European and national funds (Autonome Provinz Bozen-Südtirol, 2007).

- *Traditionally managed larch meadows* (tra.l.meadows) constitute one of two original management forms. According to the requirements of the Subsidy Register (Autonome Provinz Bozen-Südtirol, 2007), traditionally managed larch meadows are mown at least every two years, but not more than twice per year, and fertilized with small amounts of stall manure (max. 30 dt ha^{-1} $year^{-1}$). Sparse grazing in autumn is allowed.
- *Larch pastures* (l.pastures) are the second original management form. Generally, they are neither mown nor fertilized and livestock includes cattle or horses. Grazing intensity is rather low, since grazing is usually practiced during a few weeks in late spring (June) and then again in early autumn (August–September).
- *Intensively managed larch meadows* (int.l.meadows) have developed in the last few decades. They are mown up to three times and fertilized twice per year with relatively large amounts of slurry or liquid manure (~100 dt ha^{-1} $year^{-1}$).

2.2.2. Abandoned larch grasslands

Successional stages (succ.stages) are the result of natural succession taking place on areas formerly managed as larch meadows or pastures. Information on the approximate time of abandonment was derived from historical land-use maps (Land Register of Emperor Francis I, 1861; vegetation map, Peer, 1980) and statements made by local forest rangers. None of the studied plots has been mown or pastured for 15–50 years and all are already colonized by saplings and/or trees (mainly *Picea abies*).

2.3. Sampling design

To select the study plots we used GIS (ArcMap 10) to analyze a distribution map of all larch grasslands in the study region (Autonome Provinz Bozen-Südtirol, 2011) for their mean slope, mean direction of exposure and mean altitude. Categories of mean slope, altitude and direction of exposure were defined as 8°–18°, 1400–1800 m.a.s.l., and SE-SW, respectively, and the ten areas (forest domains) with the largest amount of larch grasslands within those categories were selected as focus areas (Fig. 1). The individual study sites were randomly selected using GIS, and the position of the plot on those random larch grasslands or successional sites was subsequently set on site to allow the sampling of a homogeneous and representative area as required for phyto-sociological vegetation surveys (Braun-Blanquet, 1964). Within each focus area approximately four traditionally managed larch meadows, four intensively managed larch meadows and four larch pastures were sampled, with not more than one plot being surveyed in each grassland site. In six of the ten selected focus areas we sampled between five and 15 successional stages of former larch grassland. In total, we sampled 165 semi-randomly chosen plots (Fig. 1). The total number of plots per management type is shown in Tables 2 and 3.

2.4. Data collection

2.4.1. Vegetation data

Field sampling was conducted between May 2011 and September 2011. On circular plots with a radius of 10 m a phyto-sociological vegetation survey of all vascular plants in the herb layer was performed according to Braun-Blanquet (1964). The plot