Flora 206 (2011) 433–443

Contents lists available at ScienceDirect

Flora

journal homepage: www.elsevier.de/flora

Plant communities of mountain grasslands in a broad cross-section of the Eastern Alps

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ARTICLE INFO

Article history:
Received 2 March 2010
Accepted 27 July 2010

Keywords:
Land-use types
Land-use intensity
Site factors
Meadows
Pastures
Abandoned areas

ABSTRACT

Apart from forests, the landscape of the Alps is dominated by grasslands, where they account for up to 40% of the agricultural area. This study focuses on the main man-made grassland plant communities of the Eastern Alps, shows their current spatial distribution and examines how strongly the influence of land use and site factors determines the communities. Discriminant analysis was used to harmonize the phytosociological classification of 1502 vegetation relevés from the literature and 375 own recorded inventories from Western Austria and Northern Italy. Land-use intensity, altitude, slope and pH were also recorded, in order to assess the impact of the factors to plant communities, as calculated in nonmetric multidimensional scaling. We identified 39 plant communities and generated a table with the main ecological and floristic parameters as well as a map showing their present spatial distribution. Contrary to the literature, the pasture communities Crepido-Festucetum commutatae, Deschampsio cespitosae-Poetum alpinae and Rumicetum alpini occur also in fertilized meadows. On the other hand we found meadow communities occurring in pastures, such as the Angelico-Cirsietum oleracei, the Pastinaco-Arrhenatheretum, the Ranunculo repentis-Alopecuretum pratensis and the Trisetetum flavescentis. The most species-rich communities – the Caricetum ferruginei and the Seslerio-Caricetum sempervirentis – occur in unfertilized meadows above calcareous bedrock. Further species-rich communities – the Campanulo scheuchzeri-Festucetum noricae, the Gentianello anisodontae-Festucetum variae, the Pulsatillo alpinae-Festucetum noricae, the Trifolio thallii-Festucetum nigricantis and the Hypochoerido uniflorae-Festucetum paniculatae – are endangered: they are regionally restricted and depend on the absence of fertilizer and on mowing once annually or every second or third year. Therefore agri-environmental measures should focus on unfertilized mountain meadows, in order to conserve these rare grassland communities.

Introduction

Grasslands represent one of the most diverse man-made landscape formations in the Alps (Ellenberg, 1996; Kremer, 1991; Maurer et al., 2006). The percentage of meadows and pastures in the subalpine-alpine belt lies between 5% and 40% of the agriculturally used area, depending on the region (Tasser et al., 2009). Generally, due to the shorter growing season, the unfavourable climate and topographic conditions, farmers have tended very early to a marginal use of these areas (Niedrist et al., 2008).

Alpine grasslands are mainly used as summer pastures (Ellenberg, 1996), but a small proportion are meadows, usually unfertilized and mown annually or every second to third year. Generally only the easily accessible meadows are fertilized and allow two cuts of hay in one year. Depending on land use, typical plant communities have become established over the past centuries and millennia (Dullinger et al., 2003; Liira et al., 2008; Marcos et al., 2003; Oomes, 1992; Tasser et al., 2003; von Arx et al., 2002). On the alpine belt meadows typically support a large percentage of herbs as well as dwarf-shrubs (Ellenberg, 1996; Ellmauer, 1996; Marini et al., 2007) and show a pronounced species-richness (Grabherr and Mucina, 1993; Mucina et al., 1993).

Besides land-use management, small changes in site factors (altitude, slope angle and soil pH) increase ecosystem diversity (Kampmann et al., 2007; Marini et al., 2007). This is demonstrated impressively over large areas in alpine pastures, where animals are left more or less unattended (Tasser et al., 2003). Grazing animals prefer the gentle slopes of the pastures with their dry and undisturbed soils. Depending on topsoil pH, communities develop with *Nardus stricta* on acid soil and with *Sesleria albicans* on neutral to

Abbreviations: DA, discriminant analysis; NMS, nonmetric multidimensional scaling; a.s.l., above sea level.

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doi:10.1016/j.flora.2010.11.007

alkaline soils (Grabherr and Mucina, 1993; Mucina et al., 1993; Myklestad and Sætersdal, 2004). Plane places are used as animal resting places, where the increase in local nutrient load leads to the development of typical trodden swards. On steep pastures, the free range style of grazing in the Alps greatly reduces the frequency of use by grazing cattle and thus the level of nutrient deposition. The resulting vegetation covers exhibit a dwarf-shrub invasion or typical high alpine gramineous-rich communities.

In the Alps land use combined with site factors results in a large variety of plant communities (Pykälä, 2000) and creates a landscape with high diversity (Tappeiner et al., 2008). Hence, this region is a 'hot spot' of biodiversity in Europe (World Wildlife Fund, 2004). Unfortunately, traditional land-use practices have become less important over the last few decades in the Alps (Streifeneder et al., 2007; Tasser et al., 2003). About 20% – in some areas even much more – of the agricultural land has been abandoned (Macdonald et al., 2000; Tappeiner et al., 2008; Tasser et al., 2007). The crucial factor here is that steep areas and small plots create higher production costs, thus mountain agriculture is hardly competitive on national and international markets. Consequently marginal productive areas in the Alps have been increasingly abandoned since 1950.

However, the severity of this decline varies significantly, depending on the region (Tasser et al., 2007, 2008): in the region 'Südtiroler Unterland/Überetsch' – one of the most productive regions of the Alps – only 6% of formerly used agricultural areas are currently abandoned, while in the region 'Innsbruck-Land' they amount to 37%, and in the region 'Carnia' even to 67%. On the other hand, an intensification of land use can also be observed (Krausmann et al., 2003; Mottet et al., 2006), due to the massive extension of forest roads and farm tracks, which leads to a higher accessibility, mechanisation and manuring of agricultural areas in the alpine and subalpine altitudinal belt (Liira et al., 2008; Pavlů et al., 2005; Stöcklin et al., 2007). All these changes lead to a reduction of semi-natural grasslands (Bakker and Berendse, 1999; Lavorel et al., 1998; Tappeiner et al., 1998), and an old and invaluable cultural landscape is gradually disappearing.

Several studies exist on grasslands in the Eastern Alps (Bischof, 1981; Kohler et al., 2004; Maurer et al., 2006; Tasser and Tappeiner, 2002; Vonlanthen et al., 2006; Zimmermann and Kienast, 1999) as well as numerous diplomas and Ph.D. theses (see Appendix) containing field relevés of grasslands. However, they often refer only to small regions and are not related to one another. Unfortunately, their descriptions of plant communities do not focus on form and intensity of land use, even though plant communities are predominantly the result of differences in land-use management (Burnside et al., 2007; Studer, 2001). It is therefore about time that an inventory which characterizes the remaining grassland plant communities is created, in order to have a database for prospective decisions.

With a huge and unique data set of vegetation relevés in the Eastern Alps, the present study aims at (1) providing a general overview of the man-made grassland plant communities and their distribution with a focus on montane to alpine regions, (2) clarifying how land use and site factors affect their establishment and (3) find out the most species-rich communities and how to maintain them.

Materials and methods

Research area

To obtain a cross-section of meadows through the Eastern Alps, vegetation relevés were taken from Tyrol (Austria) and South Tyrol (Italy) together with a number of further relevés from western Vorarlberg, eastern Salzburg (both Austria) and northern Trentino (Italy). The location of the region lies between 47°36′–46°02′ N and 10°08′–12°45′ E (Fig. 1). Average annual precipitation ranges from 700 mm to 2000 mm, with maximum rainfall observed from June to July (Fliri, 1998). Mean annual temperature ranges from 0 °C to 9 °C. Strong climatic distinctions are caused by the fact that relevés were taken from 650 m to 2680 m a.s.l. and that two climatic regions – Continental and Atlantic climate – affect the vegetation in the research area (Fliri, 1998). The bedrock of the research area is comprised of calcareous sedimentary rocks in the northern and the southern regions and of primary rocks in the central massive, sometimes with superimposed calcareous isles (Bögel and Schmidt, 1976). The pH of the topsoil (0–10 cm), which ranges from 3.7 to 7.8 (Niedrist et al., 2008), is either affected by the bedrock (Scheffer et al., 2002) or else has been modified as a result of fertilizer applications (Seeber and Seeber, 2005).

Data collection

We first collected 1507 vegetation relevés from the literature (see Appendix), which had been recorded following the method of Braun-Blanquet (1964). This collection comprised meadows, pastures and abandoned areas from 60 different sites. Thereby the plot size ranges from 12 m^2 to 25 m^2. All relevés included detailed information on land use, geographical coordinates and the site factors for altitude and slope angle. For regions where no literature data were found, we consulted local experts (farmers, park rangers and agrarian decision-makers of the particular districts) about the location of remaining mountain hay meadows and pastures. From this information we then recorded 265 vegetation relevés from 84 sites. Furthermore, at 30 sites we recorded 110 vegetation relevés of intensively used meadows from valley regions (between 650 and 1200 m a.s.l.), in order to compare them with lightly used ones. Fieldwork was carried out between 2005 and 2007. Vegetation relevés were recorded according to the method of Braun-Blanquet (1964): the minimum area ranged from 6 m^2 (in intensively fertilized meadows from the valley) up to 20 m^2 (in mountain meadows without fertilization), depending on the heterogeneity of the grassland area; most of the relevés covered an area of 12 m^2 (i.e. 4 m × 3 m). At least two relevés were recorded for each study site, the variables altitude, slope, and pH ($CaCl_2$) of the topsoil (0–10 cm) were measured and the managing farmers were interviewed to obtain exact information on land use. For statistical calculations we transformed the indications of Braun-Blanquet (1964) to dominance values in percent (according to Tasser and Tappeiner, 2004): r = 0.1%, + = 0.3%, 1 = 2.8%, 2m = 4.5%, 2a = 10%, 2b = 20.5%, 3 = 38%, 4 = 63%, and 5 = 88%.

Land use was divided into three main groups (Table 1): (1) meadows, which were subdivided into (a) unfertilized mountain meadows (UM) – mown every year or infrequently every second to third year, (b) fertilized mountain meadows (MM) – mown once a year, but grazed by animals before and/or after mowing and (c) fodder meadows (FM) – mown two to five times a year, mostly of valley regions; (2) pastures, which were subdivided into (a) lightly used pastures (LP) with unattended grazing animals during the vegetation period and (b) intensively used pastures (IP) in fenced sites or near stables with high stocking of grazing animals; (3) young abandoned areas (AA), which were formerly mown and having lain fallow for not more than 30 years; older abandoned areas were excluded, and the year of the last mowing was based either on literature or interviews.

In alpine grasslands a smooth transition from fertilized meadows (mostly with cattle dung manuring) to meadows without fertilization, abandoned areas and pastures of different grazing intensities is observed. Therefore, land-use intensity (*LUi*) was classified according to Tappeiner et al. (1998): For meadows we summed every human impact I_h (mowing, fertilization) and divided it by the frequency of these interferences in years a. The same pro-