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Impact of site and management on the diversity of central European mesic grassland

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Abstract

The main objective was to quantify the relative impact of current management types on plant species-richness and composition of mesic grasslands with regard to other important determinants such as topography, soil chemical parameters and grassland age. The grasslands were (i) differentiated into management types and vegetation types, (ii) these types were tested for differences in site conditions and species-richness, and (iii) the relative impact of management, site conditions, grassland age and regional scale geomorphology on floristic composition was quantified. TWINSPAN classification of the vegetation separated nutrient-poor from nutrient-rich sites. Results of ANCOVA revealed that vegetation types indicating high nutrient levels showed significantly higher contents of plant available phosphorous and younger grassland age. In partial CCA analyses, the geomorphology accounted for almost one third of explained variance. The current management had a relatively low explanatory value. Soil chemical variables and topography, in contrast, explained together almost twice as much variation in floristic composition.

Keywords: Land use; Marginal landscape; Soil fertility; TWINSPAN; Indicator species analysis; ANCOVA; Partial CCA

1. Introduction

Plant species-richness and floristic composition in grasslands are shaped not only by current site conditions, species pool and management but also by age, site history, and traditional ancient management practices that may have ceased long ago (e.g., Pärtel et al., 1996; Cousins and Eriksson, 2002; Waldhardt and Otte, 2003; Sebastiá, 2004). Phytodiversity over a broad range of environments has been shown to be determined mainly by the overall productivity and the land-use history of the study systems (e.g., Milchunas and Lauenroth, 1993). Studies on the relative importance of management and environmental factors on floristic composition in grasslands have shown either environmental conditions (e.g., Vandvik and Birks, 2002) or current management practices (e.g., Austrheim et al., 1999) to explain relatively more of the floristic variance. The assemblage of plant species in seminatural grasslands is often related to abiotic factors such as soil and topography (e.g., Cousins and Eriksson, 2002; Sebastiá, 2004). Soil fertility has been shown to be an important factor for phytodiversity (Janssens et al., 1998) and increasing amounts of fertilisers in agricultural practice are generally accepted as the main cause of the decline in grassland phytodiversity (e.g., Gough and Marrs, 1990; Smith, 1993; Korneck et al., 1998; Zechmeister et al., 2003). Grazing animals affect vegetation in several different ways, through direct biomass consumption, selective grazing, trampling, urination, defecation, and by acting as dispersal agents (Olff and Ritchie, 1998). Moreover, species-richness and species composition of grassland vegetation depend on the available species pool (Pärtel et al., 1996; Zobel et al., 1998).

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Many grassland studies focus on the phytodiversity of highly endangered communities. In central Europe, these are unimproved seminatural grasslands like the particularly endangered wet meadows and dry calcareous grasslands. But due to agricultural intensification and abandonment, the overall area of the formerly widespread mesophilous grassland of low mountainous regions is currently also in decline (Burel et al., 1998; Mac Donald et al., 2000). This has led to the inclusion of this habitat type in the European Fauna-Flora-Habitat Directive of the European Union (92/43/EEC, European Union, 1992; Ssymank et al., 1998).

Given this background, the aim of this study was to assess and quantify the impact of former and current land use practices, site conditions, and regional scale geomorphology on the grassland phytodiversity of a marginal region, which is characterised by extremely small-scaled fields and highly diverse management schemes. Grassland management practices in the area provide strong differences in disturbance impact ranging from low-intensity pasturing without fertiliser application to mowing three times a year for fodder production (silage). The specific questions addressed in this paper are:

(1) How are grassland vegetation types differentiated in terms of floristic composition, species-richness and site conditions?
(2) How important is current management in relation to other factors such as abiotic site conditions, grassland age and regional scale geomorphology for the floristic composition of grassland stands?

2. Materials and methods

2.1. Study region and sampling

The entire study region (Lahn-Dill Highlands, Germany) has been included in the support scheme for less-favoured areas since 1976 (EC Regulation No. 75/268). Typically, a large part of the landscape is managed by part-time farmers, who adhere to traditional agricultural practices (Hietel et al., 2005). Since the 1950s, the Lahn-Dill Highlands have been subject to major agricultural land-cover changes, resulting mainly in a decline in arable land and an increase in grassland and fallow land (Hietel et al., 2005). In many places, extensive grassland use has replaced the traditional, extremely small-parcelled crop production and crop/grassland rotation. In the study region, a large part of the grasslands is managed according to EU-based agri-environmental schemes, focussing on grassland extensification. The adoption of the agri-environmental schemes ensures a late first mowing not before mid of June, a low input of fertiliser (<30 kg N ha^{-1} year^{-1}) or even the ban of fertilising, and low-intensity pasturing with <1.5 life weight units/ha (LWU). Pasturing on grasslands of the study area is done mainly with cattle, also with horses and few sites are grazed by sheep.

Table 1
Distribution of plots with different management types within geomorphological subunits (GU) of the Lahn-Dill Highlands (Klausing, 1988)

Geomorphological subunit (GU)	GU ID	Management types of plots ($n = 166$)					Elevation a.s.l. (m)
		H	S	M	P[c]	P[h]	
Bottenhorn Uplands	1	6	9	9	6	3	470–530
Hoerre	2	3	6	6	3	0	330–410
Niederweidbach Basin	3	6	0	0	3	2	280–315
Zollbuche	4	9	3	6	3	3	340–490
Krofdorf-Königsberg Forest	5	0	6	3	3	0	320–390
Schelde Forest	6	3	6	0	3	2	350–420
Damhausen Mounds	7	6	0	3	3	0	280–340
Salzboede Valley	8	3	6	0	3	3	245–290
Upper Dill Valley	9	6	6	9	3	3	270–360

Management types: H, hay grassland; S, silage grassland; M, meadow; P[c], cattle grazed pasture; P[h], horse grazed pasture.

Predominant soil types are moderately acidic Cambisols and Luvisols with possible gleysation in the valley floors; Regosols are limited to hilltop positions. The climatic conditions in the region are relatively unfavourable, indicated by a mean annual temperature of 6–8 °C and average annual precipitation ranging from 650 to 1100 mm. In conjunction with the edaphic conditions, the wet climate results in a high variability of the soil-water potential.

The Lahn-Dill Highlands are divided in different geomorphological subunits (GU) (Klausing, 1988) (see Table 1). The subunits are mainly structured by geomorphology, but they differ also with regard to recent land cover and land-use history (Hietel et al., 2005). The heterogeneity across these subunits may have had an effect on the development of different species pools in grassland vegetation, which may be due to a combined effect of contrasting large scale differences in soil properties, climate and land-use history.

To account for the topographical and edaphical heterogeneity of the region, 56 grassland fields (size 0.3–3 ha) were randomly selected within nine GU of the entire Lahn-Dill Highlands. Across all GUs, the fields were then categorised into management types ((i)–(v); see below). Management types were almost evenly spread within the entire Lahn-Dill Highlands (Table 1). To account for the sometimes high internal variability of vegetation within stands, three plots (5 m × 5 m) were randomly placed within each of the 56 fields and these were used as basic sampling unit. Geographical coordinates of plots were recorded using a Garmin GPS. To avoid edge effects, a minimum distance of 10 m to the border of the fields was kept. The composition of vascular plant species was recorded within plots between May and September in 2003 and 2004. Species abundance was estimated on a modified Braun–Blanquet-scale (with cover degree 2 subdivided into $2a = >5–15\%$ and $2b = >15–25\%$). The nomenclature of the vascular plant species followed Wisskirchen and Haeupler (1998).