Flora 209 (2014) 446–455

Contents lists available at ScienceDirect

Flora

journal homepage: www.elsevier.com/locate/flora

Vegetation patterns of floodplain meadows along the climatic gradient at the Middle Elbe River

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ARTICLE INFO

Article history:
Received 2 February 2014
Received in revised form 17 April 2014
Accepted 23 April 2014
Edited by Brigitta Erschbamer
Available online 20 May 2014

Keywords:
Azonal vegetation
Alluvial meadows
Climatic impact
Riparian meadows
River corridor plants

ABSTRACT

Central European floodplain meadows are characterised by flooding mainly in winter/spring and dry conditions over the summer. They harbour many rare and endangered plant species. We studied the vegetation of floodplain meadows along the regional climatic gradient of the Middle Elbe River. This gradient exhibits rather continental conditions in the south-east and oceanic conditions in the north-west. We aimed at detecting the influence of climate on the vegetation of floodplain meadows along this gradient.

Along the Middle Elbe River (Germany), we recorded the vegetation of wet and mesic meadows in 2010. The results revealed differences in species composition especially in wet meadows: vegetation plots of wet meadows clustered in the DCA ordination according to their geographic location from west to east. Sample scores of DCA-axes of both meadow types correlated with the long-term means of climatic factors such as precipitation or temperature. While species numbers did not differ between study sites, evenness of mesic meadows was higher in the western part of the gradient.

Indicative species of the sites were mainly common meadow species. Species typical for floodplain meadows were relatively evenly distributed along the gradient. Therefore, we confirm that the distribution of typical floodplain species is largely determined by hydrologic and land use conditions rather than by climatic factors. Therefore, we assume that typical floodplain meadow species at the Elbe River are relatively robust against direct climatic changes, as long as these changes do not exceed the range of the climatic gradient today. Concerning the total assemblages of floodplain meadows, those of wet meadows might be more vulnerable to climate change than those of mesic meadows. However, indirectly occurring changes caused by climate change, i.e. water-level changes due to an altered discharge regime of the Elbe River caused by altered precipitation patterns in the catchment, will affect all floodplain species.

Introduction

Floodplain meadows belong to the most threatened plant communities in Europe (Korneck et al., 1996; Joyce and Wade, 1998). The hydrologic conditions of most Central European rivers were heavily modified over the recent centuries. For example along the Elbe River, people began to build dikes approximately 800 years ago, which divided the floodplain into a functional floodplain (directly inundated by river water at high water levels) and a fossil (no longer directly inundated) floodplain (Leyer, 2004). Additionally, land use intensification and abandonment caused a dramatic decline of species rich floodplain meadows since the middle of the 20th century (Leyer, 2002; Krause et al., 2011). Due to this decline and the large number of rare and endangered plant species, floodplain meadows are protected by the EU Habitats Directive (92/43/ECC; habitat type 6440: alluvial meadows of Cnidion dubii). Still, floodplain meadows can be found today along many Central European rivers such as the Elbe (e. g. Leyer, 2002), Oder (e.g. Korsch, 1999), Danube (e.g. Ružičková et al., 2004), and Rhine (e.g. Donath et al., 2003; Hölzel and Otte, 2001).

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http://dx.doi.org/10.1016/j.flora.2014.04.006
0367-2530/

Climate is considered to be an important driver determining plant distribution ranges on a global scale (e.g. Woodward, 1987). Riparian vegetation, however, generally shows a so called 'azonal' distribution, suggesting that this type of vegetation is not primarily influenced by climatic variables (Ellenberg, 1996). Instead, other factors such as hydrologic conditions and land use are predominantly important for the vegetation of floodplains (e.g. Leyer, 2004; Krause et al., 2011).

Previous studies on floodplain vegetation mainly focused on the effects of hydrologic conditions as the most important factor affecting functional floodplains, especially the aspect of flooding (e.g. Leyer, 2004; Follner and Henle, 2006; Marchetti and Aceñolaza, 2012). Flooding usually causes erosion and sedimentation (Krüger et al., 2006), temporarily anaerobic soil conditions (Langer and Rinklebe, 2009), and affects the nutrient regime of the soils (Beltman et al., 2007). Flooding supports species which are adapted to it (Blom and Voesenek, 1996). In floodplain areas at higher elevations, which mainly consist of sandy sediments, drought stress gains importance during summer.

Land use is another important factor affecting floodplain vegetation (Franke, 2003; Krause et al., 2011). Without human impacts, functional floodplains in the European lowlands would be dominated by softwood (with *Salix* and *Populus* species) and hardwood (with *Ulmus* and *Quercus* species) floodplain forests (Dziock et al., 2005). The most abundant land use in the functional floodplains of Central European lowlands is grazing and mowing. Especially in mown grasslands (floodplain meadows), species-rich vegetation with a characteristic zonation of plant species from lower to higher elevated areas developed (Leyer, 2002). This kind of vegetation depends on low-intensity but regular land use (i.e. mowing twice annually without applying fertilizers).

The impact of regional climatic gradients on the composition and diversity of floodplain meadows is still unclear. If, however, the climate affects the vegetation of floodplain meadows today, climate change may lead to vegetation changes in the future. Our overall aim was thus to assess, how vulnerable the vegetation of floodplain meadows might be to climate change. Our study area, the Middle Elbe region, is suitable for addressing this topic as the climatic differences along this part of the river are pronounced although the geographic range is relatively short (approx. 250 km). The observed response patterns, though based on a study along the Elbe River, might be applicable to other floodplain regions such as along the rivers Oder, Danube or Rhine, which also cover quite a range of different climatic conditions.

We conducted a field survey and investigated two floodplain meadow types differing in hydrologic conditions: wet (more frequently flooded) and mesic (less frequently flooded) meadows. Other factors as land use and soil conditions were sought to be as equal as possible. We addressed the following research questions: (1) How does the composition and the diversity of vegetation of floodplain meadows change along the Middle Elbe River? (2) If changes occur, are these correlated with climatic variables? (3) Does a higher proportion of plant species with a rather continental distribution grow in the eastern part of the studied gradient along the Elbe River (as an indication for the climatic influence)? (4) How are typical floodplain meadow species (river corridor plants) distributed along the Middle Elbe River?

Material and methods

Study area

The study was conducted on floodplain meadows of the UNESCO Biosphere Reserve Elbe River Landscape (Fig. 1). The Elbe River is one of the largest rivers in Central Europe and flows about 1100 km from the Czech Giant Mountains through the lowlands of Germany to the North Sea. The Elbe is divided into three parts (the Upper, Middle and Lower Elbe) and drains a discharge area of approx. 150,000 km^2 (for detailed information see Hofmann et al., 2005). For this study, only locations along the middle part of the Elbe River were selected to ensure a comparable morphology of the study sites (regarding ground slope and grain size of sediments). The morphology of this river corridor was created during the last ice ages while the river served as a glacial valley. The discharge during the ice ages and following ice melts was much higher than today and thus an extended river corridor was formed. The climate of the study area is characterised by relatively continental conditions in the south-east and oceanic conditions in the north-west (Table 1). The area in the north-west receives approx. 20% more mean annual precipitation than the area in the south-east, while *vice versa* the area in the south-east has approx. 25% more summer days (days > 25 °C). The semi-terrestrial soils of the Elbe floodplains consist mainly of loamy material. Other alluvial sediments such as sand and gravel are present but of minor importance (Schwartz, 2001). Nutrient availability of these soils is high due to nutrient inputs from flooding events. Generally, flooding of the Elbe occurs regularly during winter and spring after snow melt and infrequently during summer after intense rain events. Flooding events are mainly restricted to the functional floodplain (Leyer, 2004), which decreased in extent by around 50–90% over the last hundreds of years along the Middle Elbe River (Brunotte et al., 2009). The functional floodplain along the Elbe River is mainly used as grassland for grazing and mowing. In Lower Saxony, for example, these two land use types are equally important (Franke, 2003). For this study, only meadows were selected that are usually mown twice annually without the application of fertilizers (pers. comm. with local farmers).

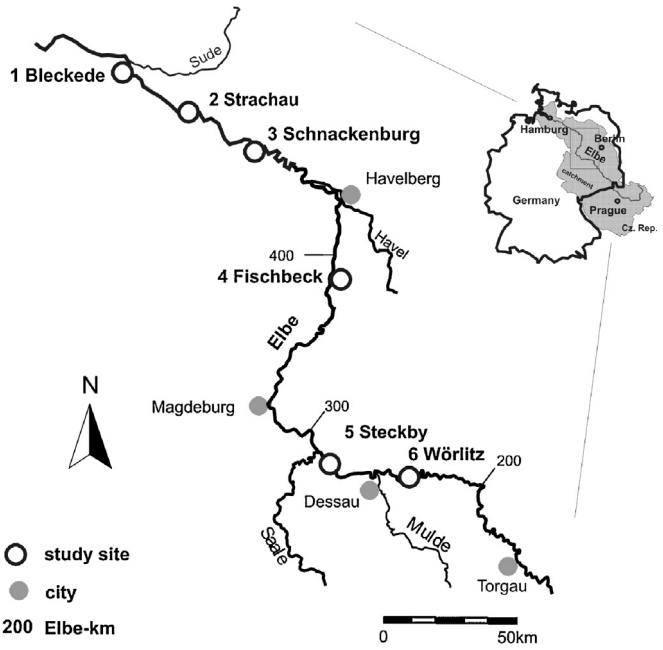

Fig. 1. Study area with study sites along the gradient at the Middle Elbe River; numbered from north-west to south-east: 1 – Bleckede, 2 – Strachau, 3 – Schnackenburg, 4 – Fischbeck, 5 – Steckby, and 6 – Wörlitz.

Study sites and sampling

Six sites were selected in the functional floodplain along the Middle Elbe River (Fig. 1): 1 – Bleckede (53°20′ N, 10°43′ E; northern most site of the gradient), 2 – Strachau, 3 – Schnackenburg, 4 – Fischbeck, 5 – Steckby, and 6 – Wörlitz (51°51′ N,