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# The Biodiversity Exploratories: a large-scale framework project for functional biodiversity research

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## Abstract

The Biodiversity Exploratories (www.biodiversity-exploratories.de) are a broad-scale research project with 300 people involved addressing interactions between land-use intensity, biodiversity and ecosystem functioning in agricultural grasslands (and managed forests). The project started in 2006 and aims at gathering data for functional biodiversity research, for both basic and applied questions. In each of three study regions in Germany, 50 grasslands have been selected along a broad gradient in land-use intensity, ranging from unfertilised sheep pastures and single-cut meadows up to intensely fertilised three-cut grasslands or mown pastures. The Biodiversity Exploratories investigate, for example, relationships between land use and ecosystem functions to explore options as to how grassland management can promote high-level ecosystem services. We also show results of a sward disturbance and seed addition experiment, which successfully enriched plant diversity in almost all grasslands under study. The encountered seed and dispersal limitation is, on the one hand, a major obstacle for species conservation, as plant diversity does not automatically recover after a phase of highly intensive grassland management. On the other hand, a depleted species-pool is also of agricultural relevance, as in extensively used grasslands, the annual yield and other important ecosystem functions were shown to potentially benefit from more diverse plant communities.

**Keywords:** functional biodiversity research, permanent grasslands, nature conservation, ecosystem services, grassland management, grassland restoration

## Introduction

Why is it important to study the effects of biodiversity on ecosystem functioning? Functional biodiversity research explores drivers of biodiversity changes and subsequent functional consequences for ecosystems and the goods and services they provide. Experimental evidence demonstrates that more diverse model ecosystems have higher levels of functioning than less diverse systems, e.g. increased biomass production at higher levels of plant diversity in experimental grasslands (Isbell *et al*., 2011). However, we still do not know much about real-world effects of biodiversity on ecosystem functioning. Due to far-reaching changes in land use and environment, we additionally need to understand the effects of these major global drivers on the interactions between biodiversity, biogeochemical processes and ecosystem functioning (Fischer *et al*., 2010). Finally, the translation of findings into practice has to be facilitated, for example, by restoring plant diversity in species-poor agricultural grasslands.

## Materials and methods

The Biodiversity Exploratories (www.biodiversity-exploratories.de) were established in 2006 within three regions in Germany. The project comprises 300 study plots, with 50 plots in grasslands and 50 plots in forests in each region. Grassland plots are arranged along a gradient of land-use intensity, which can be seen as representative of large parts of Central Europe (Fischer *et al*., 2010). Management ranges from extensively grazed, unfertilised pastures and single-cut meadows to highly fertilised three-cut meadows or mown pastures. All plots are on-farm and regularly managed. Along with the differences in management, the productivity of the sites varies strongly from 0.3 to 4.5 t DW per ha (peak standing crop in mid-May), as does plant species richness (12 to 71 vascular plant species on 4 × 4 m; Klaus *et al*., 2013). The high number of spatial replications and the 300 people from different research institutions involved make the Biodiversity Exploratories one of the largest research projects on ecosystem functioning worldwide. The three study regions differ in landscape, climatic, geological and topographical conditions, species pools and socio-economic settings. They reflect a gradient of rising altitude, increasing precipitation and slightly decreasing annual mean temperatures from north-eastern to south-western Germany. The regions are (1) the Schorfheide-Chorin in the north-east, a fairly flat post-glacial landscape; (2) the National Park Hainich and surroundings in Central Germany, a loess covered calcareous low mountain range; and (3) the Schwäbische Alb in the south-west, a slightly more elevated calcareous low mountain range with loamy soils.

In 2014, we established a full-factorial seed addition and sward disturbance experiment in four 7 × 7 m subplots in 73 grasslands across the three regions. For the disturbance treatment, the top 10 cm of the grassland sward were destroyed in October using rotovation tilling or a rotary harrow. The subsequent seed addition (reseeding) consisted of adding a highly diverse, region-specific seed mixture of plant species from the regional species pool. The mixtures were the same within but differed among the regions and contained 47 to 66 species including grasses, legumes and non-legume herbs. Seed addition was done twice, in November and the following March. Further details on the experimental set-up can be found in Klaus *et al*. (2017).

## Results and discussion

Land use intensity is a major driver of ecosystem functioning in these grasslands and biodiversity loss is an important mechanism by which land use affects multifunctionality, the simultaneous provision of multiple ecosystem functions and services (Allan *et al*., 2015). Although the strength of the land-use effects on the 14 studied ecosystem services varied considerably among the three regions, supporting and especially cultural services suffered most from land-use driven biodiversity losses (Allan *et al*., 2015). The restoration of biodiversity in agricultural grasslands might therefore be able to offset some negative effects of intensification by promoting the delivery of a wider range of services. When experimentally altering plant diversity, seed addition had increased plant species richness already seven months after the treatments, but only in combination with sward disturbance. This short-term increase was significant for all regions with an average rise of 38% (+10 species per 4 $m^2$ plot) compared to the untreated control plot. Only in one region (Schorfheide-Chorin), was germination from the seed bank able to significantly increase plant diversity after disturbance, even without seed addition. However, germination from the seed bank had a much smaller effect on diversity than seed sowing and most of the species that recruited spontaneously were arable weeds (Klaus *et al*., 2017). During the second season after the experiment was established, the effect of the disturbance and seed addition treatment strengthened to increase in plant diversity by 55% (+15 species per 4 $m^2$ plot). During the next years, we will assess how this increase in plant diversity will affect ecosystem functioning, for example, nutrient retention and litter decomposition.

## Conclusion

Large-scale research projects such as the Biodiversity Exploratories provide the potential to substantially advance our mechanistic understanding of drivers of ecosystem functioning and can provide knowledge about the importance of biodiversity for ecosystem processes and services. To increase plant diversity in grasslands, a combination of sward disturbance and high-diversity seed addition is most promising to overcome seed and dispersal limitation of grassland species and can therefore, be recommended for ecological restoration when other restoration measures such as hay transfer are not feasible. The established experiment will also enable us to analyse long-term effects of vegetation change on ecosystem processes and on the diversity of other taxa in real-world grasslands. In addition to protecting species-rich sites, nature conservation should also consider measures to actively enrich plant diversity of existing permanent grasslands e.g. by explicitly rewarding such measures in agri-environmental schemes and as greening measures.


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