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Restoration of lowland meadows in Austria: A comparison of five techniques

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Abstract

European environmental policy mandates that biodiversity loss should be halted through restoration. However, knowledge about the efficacy of different restoration treatments for lowland meadows is still incomplete. Our study monitored two restoration projects in South-East Austria that served as compensation measures for the loss of species-rich grassland. We compared the efficacy of five restoration techniques: (1) sod transplantation, (2) natural colonization, (3) hay transfer and additions of seed mixtures for (4) wet and (5) bare soils. Over three years, we measured species richness, number of target species, Shannon diversity and similarity to reference sites. We asked: (A) What is the most effective technique for the restoration of lowland meadows? and (B) Is the applied restoration method more important than abiotic site conditions? We included 66 plots (reference and donor sites: 8 plots, restoration sites: 58 plots) in our study. We sampled data on species composition (4 m × 4 m plots) in three consecutive years since restoration initiation, estimated the slope inclination and analyzed soil parameters (K, P, pH). In general, species composition developed towards the reference vegetation for all techniques but sod transplantation produced by far the best result in terms of species richness and similarity to reference sites. By comparison, hay transfer and natural colonization produced intermediate results but performed better than seeding; the latter led to homogenous, species-poor swards. Soil preparation and abiotic site conditions played a minor role in this early stage of the restoration process, though these factors may gain importance in a longer time frame. We found sod transplantation to be a superior method for lowland meadow restoration in our study area but managers must consider its destructive nature and high costs, which might outweigh its benefits. In this light, hay transfer and natural colonization – or a combination of different techniques – could provide less destructive and more cost-effective alternatives.

Keywords: Compensation measures; Hay transfer; Seeding; Sod transplantation; Topsoil removal

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Introduction

Lowland meadows are important habitats for many plant and animal species in Europe (Habel et al. 2013). They provide significant ecosystem services, including water retention and filtration and have been a source of hay for livestock feeding for many centuries (Hopkins & Holz 2006; Stoate et al. 2009). In many European countries, hydrological perturbation and land use change have led to a decline of lowland meadow area and frequency, and have altered their species composition (Poschlod, Bakker, & Kahmen 2005; de Snoo, Nau, Verhulst, van Ruijven, & Schaffers 2012). This problem is particularly true for South-East Austria, where lowland meadows are critically endangered habitats (Essl, Egger, Karrer, Theiss, & Aigner 2004). Consequently, the restoration of lowland meadows has become a major goal in the last two decades. It aims to counteract the decline of this vegetation type (EC 1992) and to compensate for land degradation (EC 2014), e.g. when new urban areas or roads are built (Conrad & Tischew 2011).

In the last century, restoration of grasslands focused mostly on re-establishing the structure of meadows, giving little heed to site-specific species composition or local provenance (Kiehl, Kirmer, Donath, Rasran, & Hölzel 2010). Often, this led to species-poor communities with low conservation value and little similarity to traditionally managed grasslands (Conrad & Tischew 2011). Nowadays, authorities in Austria and Germany often require the creation of high nature-value grassland using regional seeds to reach a sufficient compensation effect (Molder 2015; Sengl 2015). Regional high-diversity seed mixtures can facilitate the establishment of species-rich grassland by introducing propagules of locally adapted species (Aavik, Edwards, Holderegger, Graf, & Billeter 2012). However, one important disadvantage of such seed mixtures is that they are far more expensive than commercial seed mixtures (Török, Vida, Deák, Lengyel, & Tóthmérész 2011; Mitchley, Jongepierová, & Fajmon 2012). Furthermore, like in other European countries, regional seed mixtures are still scarce in Austria (Sengl 2015). In response to these shortcomings, several studies from across Europe have shown that methods like hay transfer (Hölzel & Otte 2003; Rasran, Vogt, & Jensen 2007) can yield promising restoration outcomes. In addition, sod transplantation (Bruelheide & Flintrop 2000; Klimeš, Jongepierová, Doležal, & Klimešová 2010) was also shown to trigger a high establishment rate of target species. However, in this context we have to note that this method is destructive, because it implies that some areas with the respective habitat (i.e. donor sites) will be highly disturbed (Török et al. 2011). Furthermore, this method is very expensive and requires non-standard machinery (Scotton et al. 2012). Thus, it is only recommended in cases where the destruction of valuable plant communities (e.g. by infrastructural projects) is inevitable (Kiehl et al. 2010). By contrast, passive restoration can be a cost-effective option (Jongepierová, Mitchley, & Tzanopoulos 2007; Sengl, Wagner, & Magnes 2015) but only if diaspore sources are in the close vicinity and low risk of soil erosion and/or invasive species is expected (Kirmer et al. 2012).

In order to ensure that resources are efficiently used within the restoration project, it is essential to use the most promising techniques (Kiehl et al. 2010; Török et al. 2011). However, we have surprisingly little understanding of the general efficacy of different grassland restoration techniques (Walker et al. 2004). In Austria, the situation is particularly critical because little research has been conducted on the efficacy of lowland meadow restoration. As a consequence, practitioners must rely on publications from neighboring countries where climate, soil conditions and species communities can be quite different.

To close this gap, we evaluated five different techniques to restore lowland meadows in South-East Austria. We focused on (1) sod transplantation, (2) natural colonization, (3) hay transfer and addition of seed mixtures for (4) wet and (5) bare soils and measured restoration success through several indices (species richness, number of target species, Shannon diversity and similarity to reference sites). In particular, we asked the following questions: (A) What is the most effective technique for the restoration of lowland meadows? and (B) Is the applied restoration method more important than abiotic site conditions?

We assumed that sod transplantation, hay transfer and seeding of site-specific seed mixtures could be suitable methods for lowland meadow restoration since desired propagules are transferred to target sites (Hedberg & Kotowski 2010; Kiehl et al. 2010). Furthermore, we expected that natural colonization could also lead to a successful outcome, given that restoration sites are directly bordering on species-rich source sites (Sengl et al. 2015). In addition, we hypothesized that abiotic site conditions, i.e. soil nutrient content, would lead to differences in restoration success across restoration methods (Walker et al. 2004). Finally, since several studies reported that providing favorable site conditions can be feasible through topsoil removal (e.g. Hölzel & Otte 2003), we tested this kind of site preparation.

Materials and methods

Study area

The study area was located in South-East Austria in the province of Styria (Fig. 1). Restoration, reference, and donor sites were located in the alluvial valleys of the rivers (A) Feistritz and Lafnitz and (B) Mur. The region has a mild climate with an annual mean total precipitation of 737–827 mm, and annual mean temperatures of 9.1–9.3 °C, respectively (ZAMG 2016). Soils of the study sites are exclusively rainfed and comprise non-calcaric alluvial soils and stagnosols (Lebensministerium, 2016). The potential natural vegetation in this area is alluvial lowland forest as well as acidophilic oak forest on gravel terraces (Kilian, Müller, & Starlinger 1994). In the last centuries, lowland meadows were widespread

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