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Contrasting effects of land use legacies on grassland restoration in burnt pine plantations

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ABSTRACT

Legacies of previous land use may affect ecosystem recovery after the specific land use has ceased. Determining which legacies do limit ecosystem recovery is critical to perform effective ecological restoration. Pine (*Pinus* spp.) plantations have replaced various natural habitats including woodlands, shrublands and grasslands worldwide. Following pine tree removal, the restoration of these habitats may be complicated by pine plantation legacies. In this study, we tested three factors that may constrain grassland recovery in a former pine plantation following burning in an inland sand dune region in Hungary. We evaluated the effects of pine litter removal, native grass seeding and the presence of invasive *Asclepias syriaca* on vegetation composition during seven years of recovery using generalised linear mixed effect models and non-metric multidimensional scaling. We found that litter removal did not facilitate grassland regeneration. Grass seeding led to a fast recovery of grass cover, but negatively affected the abundance of unseeded target species. The presence of *Asclepias* had only transient effects on seeded grasses but positively affected unseeded target species richness. We conclude that sand grasslands have high restoration potential in burnt pine plantations despite the presence of several land use legacies. We found no evidence that pine litter or the presence of *Asclepias* would negatively influence grassland recovery, which implies that their removal is not necessary for a successful restoration. We suggest that moderate seeding densities of native grasses need to be applied to avoid the suppression of other target species.

1. Introduction

Land use legacies are changes in ecosystem conditions that persist even after the specific land use has ceased (Foster et al., 2003). Previous land use may affect the recovery of targeted ecosystems during restoration via altered propagule availability of species, and abiotic and biotic constraints on community re-assembly (Corbin and D'Antonio, 2012). Legacies are generally viewed in the context of regeneration limitation (Corbin and D'Antonio, 2004; Foster et al., 2003) but their potential positive effects on recovery may also be notable (Jiang et al., 2010; Morris et al., 2014). Identifying important legacies that should be mitigated or utilised during restoration is critical to perform effective ecological restoration.

Exotic pine species (*Pinus* spp.) are widely planted for timber production in many parts of the world (Richardson and Rejmánek, 2004). Due to the broad ecological tolerance of several pine species (Leege and Murphy, 2000), pine plantations occupy not only previous native forest habitats but also former shrublands and grasslands. Native grasslands deliver important ecosystem services that plantations cannot provide, such as long term carbon storage and livestock production (Naidoo et al., 2008). They may also have exceptionally diverse flora and fauna (Pykälä, 2003), therefore the restoration of these habitats is of high conservation priority (Habel et al., 2013). The success of grassland restoration in former pine stands depends on the mitigation of pine plantation legacies that act as regeneration barriers (Bisteau and Mahy, 2005). Filter-based community assembly models suggest that environmental, dispersal and biotic ecological filters may be altered during land use change and they may need to be mitigated to reach favourable community composition (Hulvey and Aigner, 2014).

With the presence of pines, the originally treeless communities experience major changes in environmental conditions such as altered radiation (Cseresnyés et al., 2006), nutrient cycling (Farley and Kelly, 2004) and hydrological regime (Holmes et al., 2000). Dickie et al. (2014) observed major changes in soil attributes caused by *Pinus contorta* invasion into native grasslands in New Zealand. They reported increased available nitrogen and phosphorus content and bacterial dominance. In contrast, several studies detected no major difference in

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soil attributes between former pine plantations and natural vegetation a few years after pine removal and concluded that soil characteristics did not interfere with regeneration (Szitár et al., 2014; Zaloumis and Bond, 2011). Pine litter may be a longer-acting factor due to its slow decomposition rates caused by high C/N ratio and high lignin content of pine needles (Taylor et al., 1989). The thick pine litter layer operates as a physical barrier to seed bank formation (Pywell et al., 2002) and germination (Navarro-Cano et al., 2010). Pine litter may also change disturbance regime by increasing fire frequency and intensity (Cseresnyés et al., 2006). Therefore, many authors suggest that pine litter should be removed as part of an effective restoration (Navarro-Cano et al., 2010; Sturgess and Atkinson, 1993).

Pine plantations alter vegetation composition in former grasslands (Szitár et al., 2014). Disturbance associated with the establishment of plantations promotes early-seral annuals (Maestre and Cortina, 2004), while altered light conditions favour forest herb establishment (Bremer and Farley, 2010; Halpern et al., 2012). Pine plantations have lower grassland species richness and abundance than former grasslands both in the aboveground vegetation and in the seed bank (Piqueray et al., 2011). The extent of seed bank depletion depends on several factors including time elapsed since afforestation, seed persistence in the soil and seed rain (Cuevas and Zalba, 2010). Native species can recolonize degraded habitats but it is a slow process operating at a decadal time scale even when available propagule sources are present in the surroundings (Catling and King, 2007). Thus, native seed addition following pine removal is often recommended overcoming dispersal limitation (Holmes et al., 2000; Piqueray et al., 2011). With the reintroduction of dominant grass species one can restore the main structure and functions of grassland communities. Native grasses may also facilitate the establishment of other target species (Gasque and Garćia-Fayos, 2004).

Plantation forests usually have increased richness of exotic species (Becerra and Simonetti, 2013). Fire may further promote invasion by temporarily increasing the availability of nutrients in the soil (Nuñez and Raffaele, 2007) or by breaking seed dormancy of invasive species (Mojzes and Kalapos, 2015). *Pinus* removal may also help the invasion of other non-native species (Dickie et al., 2014). Exotic species can be either 'drivers' of ecosystem processes by significantly suppressing native species in the invaded community or 'passengers' by simply taking advantage of environmental changes (MacDougall and Turkington, 2005). The distinction between the two roles is important, as restoration efforts need to focus primarily on 'driver' exotic species to mitigate their adverse ecological effects.

In 2007, pine plantations within a protected area in central Hungary were killed by a wildfire. Based on a five-year vegetation monitoring campaign, we found that the non-native common milkweed (*Asclepias syriaca* L., hereafter referred to as *Asclepias*) dominated recovering grasslands. Török et al. (2003) list this species among the most frequent alien species in Hungary, but the observed effects of *Asclepias* on native species are contradictory (Gallé et al., 2015; Kelemen et al., 2016; Szitár et al., 2014). Improved understanding of the impact of *Asclepias* during vegetation recovery is necessary for planning adequate grassland restoration.

In this study, our objective was to test experimentally three major factors that may constrain the restoration of open sand grasslands in former pine plantations in central Hungary following burning and clear felling in 2007. Our specific questions were the following: (1) Does the removal of pine litter facilitate grassland recovery? (2) Does the seeding of native grasses enhance the regeneration of open sand grasslands? (3) Does the presence of *Asclepias* affect the regeneration of grassland vegetation?

2. Material and methods

2.1. Study site and species

The study site is located in the Kéleshalom Nature Reserve in the Pannonian biogeographic region of Hungary in Central Europe (46°23′ N, 19°19′ E). The site is 60 ha in area (Fig. 1), composed of inland sand dunes with an elevation range between 140 and 148 m a.s.l. It is covered by poorly developed coarse-textured soil with sand content over 90% and humus content below 1% (Szitár et al., 2014). The climate is continental with a minimum monthly mean air temperature of −2 °C in January and a maximum monthly mean of 22 °C in July (Szitár et al., 2014). Mean annual precipitation is 550–600 mm.

The natural vegetation of the region is Pannonian forest steppe with a mosaic of open sand grasslands, mesic sand grasslands, and poplar-juniper woodlands (Szitár et al., 2014). Open grasslands are typically situated on dune tops and sides, while mesic grasslands and woodlands characterize interdune depressions. Open sand grassland (*Festucetum vaginatae danubiale*) is a Pannonian endemic semi-arid community bound to nutrient-poor, coarse-textured calcareous sand (Kovács-Láng et al., 2000). Two perennial bunchgrasses, *Festuca vaginata* W. et K. and *Stipa borysthenica* Klokov, co-dominate the vegetation interspersed with subordinate perennial herb species. Due to unfavourable soil and geomorphological conditions, a major part of the precipitation cannot

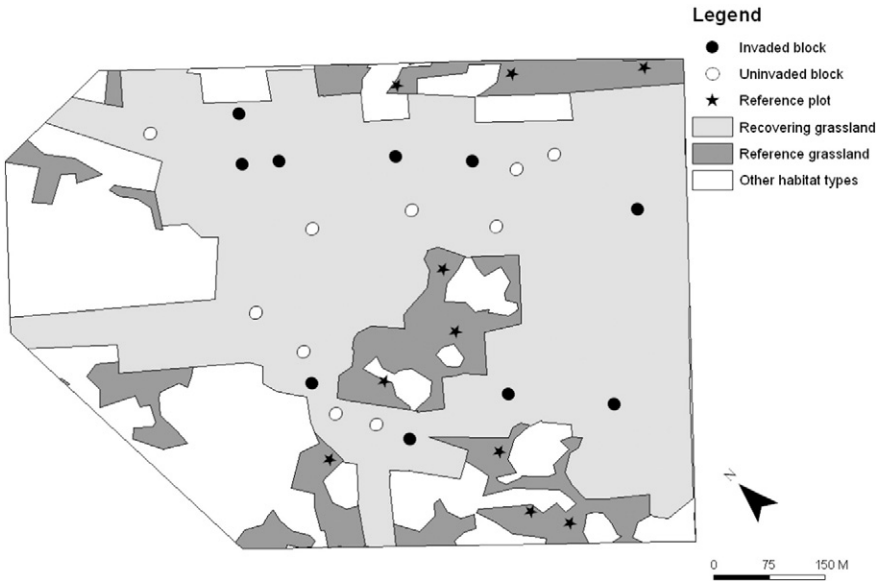

Fig. 1. Map of the study site showing the position of treatment blocks and reference sampling plots. Other habitat types stand for woody patches.