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# Litter removal does not compensate detrimental fire effects on biodiversity in regularly burned semi-natural grasslands

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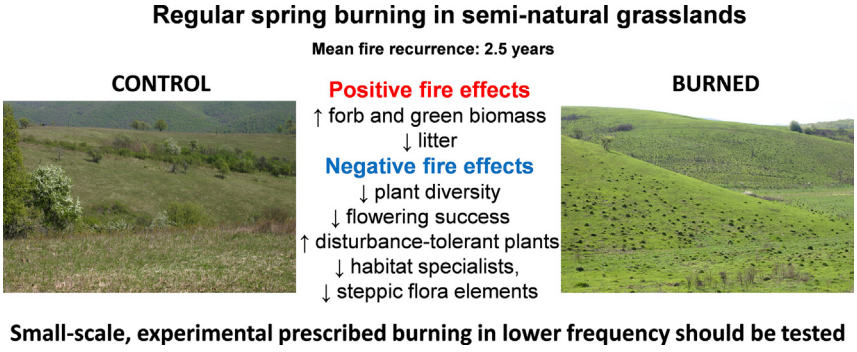
## HIGHLIGHTS

- We studied the effects of regular spring burning in species-rich foothill grasslands.
- Forb biomass and living biomass increased, litter decreased in burned grasslands.
- Plant diversity and flowering success were higher in unburned control grasslands.
- Species composition remained similar, but specialist plants declined after fire.
- Prescribed burning should be tested in small patches and lower frequency.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Regulation of plant biomass accumulation is a key issue in effective grassland conservation in Europe. Burning is an alternative tool to regulate biomass dynamics in semi-natural grasslands even in the absence of grazing or mowing. We tested the effects of regular spring burning on the biomass fractions and fine-scale plant species composition of species-rich foothill grasslands in North-Hungary. There were five regularly burned and five control grasslands in the study; we collected twenty 20 × 20-cm sized biomass samples from each. We analyzed the main fractions (litter, graminoid and forb biomass), and the species-level biomass scores, and flowering success in the control and burned grasslands. We revealed that fire increased the amount of forb biomass and decreased the amount of litter, which suggested that regular burning might be feasible for regulating biomass dynamics. The non-metric multi-dimensional scaling (NMDS) showed a high similarity of the control and burned grasslands in species composition. However, plant diversity, and the number of flowering shoots decreased significantly in the burned grasslands. In regularly burned sites we found a significant decline of specialist species, as well as of steppic flora elements. Our results showed that besides its positive effect on biomass dynamics, high-frequency burning threatens the overall diversity and specialist plant species in semi-natural grasslands. We recommend that proper fire regimes should be first studied experimentally, to provide a scientific basis for the application of prescribed burning management in such habitats.



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## 1. Introduction

In Europe semi-natural grasslands have been created and maintained by natural and anthropogenic disturbances, such as clear-cutting of forests, grazing, mowing and fire, which regularly remove the accumulated biomass and prevent the encroachment of shrubs and trees (Poschlod and Wallis de Vries, 2002). Thus, disturbance plays a crucial role in maintaining the open landscape structure in these ecosystems. Regular biomass removal decreases interspecific competition for light, controls litter accumulation and suppresses competitor species; thus, allows the co-existence of several light-demanding forbs (Dengler et al., 2014; Habel et al., 2013). Preservation of these grasslands relies on essential disturbance regimes, which control biomass dynamics and woody encroachment and thereby support the maintenance of the characteristic species composition. Such disturbance regimes usually include grazing and mowing which are the most common land use practices in grasslands (Tälle et al., 2016).

Formerly, socio-economic structure of many regions favored low-intensity and extensive agriculture, i.e. extensive grazing or hand-mowing of marginal, species-rich semi-natural grasslands (Babai and Molnár, 2014). Nowadays industrialization and urbanization, as well as agricultural intensification all resulted in the depopulation of rural areas and the abandonment of marginal semi-natural grasslands (Halada et al., 2017; Valkó et al., 2011). This situation makes the conservation of semi-natural grasslands challenging, because the implementation of formerly typical grazing or mowing regimes is problematic in regions, where there are no animal husbandry anymore; thus, there is no need for pastures and hay (Isselstein et al., 2005). The introduction of some kind of biomass removal regime in such marginal areas is urgent in order to prevent the formation of secondary scrublands or forests, and to halt the disappearance of the conservation values of semi-natural grasslands (Valkó et al., 2012). It is crucial that biomass removal should be of such an intensity, severity and frequency, which can prevent litter accumulation and woody encroachment, but is not detrimental for characteristic species of semi-natural grasslands (Valkó et al., 2014). These species have been mostly adapted to extensive biomass removal regimes (moderate grazing or hand-mowing, Isselstein et al., 2005); thus, it is still a question whether they can tolerate other types of biomass removal such as burning.

Several studies tested prescribed burning, as an alternative biomass removal tool in semi-natural grasslands (Kahmen et al., 2002; Köhler et al., 2005; Ryser et al., 1995; Wahlman and Milberg, 2002). The idea of such experiments is to seek for cost-effective and less labor-intensive alternatives to grazing and mowing. Most of these studies found that regular burning in every year leads to an untargeted species composition which is far from the desired state (Valkó et al., 2014). The likely reason is that species characteristic of nonfire-prone habitats are sensitive to high-frequency fire events and in parallel, the encroachment of re-sprouting competitor species poses an additional threat for grassland specialist plant species (Michielsen et al., 2017; Valkó et al., 2014). Even though high-frequency fires can lead to the degradation of nonfire-prone grassland vegetation (Deák et al., 2014; Milberg et al., 2014; Valkó et al., 2014; Wahlman and Milberg, 2002), low-frequency burning might be a proper tool for grassland management in such habitats (Page and Goldammer, 2004; Valkó et al., 2016). Identifying the proper fire return periods is crucial for the successful application of prescribed burning (Fuhlendorf et al., 2009).

The sensitivity of plant species to fire has still remained largely unexplored in grasslands. In European grasslands burning usually was done in small experimental plots (usually between 20–100 $m^2$), and species composition was assessed using visual cover estimation (Hansson and Fogelfors, 2000; Kahmen et al., 2002, Köhler et al., 2005; Moog et al., 2002; Ryser et al., 1995; Valkó et al., 2016) or by recording presence/absence of species in small plots (Liira et al., 2009; Wahlman and Milberg, 2002). Biomass was quite rarely studied (but see Ryser et al., 1995; Valkó et al., 2016; Vogels, 2009), and if so, only living biomass, litter and the biomass of mosses were concerned.

The novelty of our study is that we tested the effects of regular burning by comparing vegetation of grasslands regularly burned by local people with ones that have not been burned. We sampled a high number of plots to control for potential site heterogeneity and variances in species composition. We combined the advantages of studying biomass composition and sophisticated analyses of functional species groups by analyzing biomass samples at the species level. In this way we could directly detect the effect of burning on fine-scale species composition and biomass components.

Our aim was to test the effects of regular spring burning on the biomass and fine-scale plant species composition of species-rich semi-natural dry grasslands. We tested the effects of regular spring burning to evaluate whether it can be a feasible management option for suppressing litter accumulation and maintaining plant diversity in grasslands. We tested the following hypotheses: (i) Spring burning reduces accumulated litter and increases living biomass. (ii) Burning favors disturbance-tolerant and generalist species. (iii) Species confined to nonfire-prone semi-natural grasslands are suppressed by burning. (iv) Species originating from steppe and Mediterranean regions are favored by burning, as they are characteristic to ecosystems regularly exposed to wildfires.

## 2. Materials and methods

### 2.1. Study sites

Our study sites are in the Aggtelek National Park, North-Hungary. We selected ten semi-natural grasslands, belonging to the habitat type 'Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia)', a habitat of community interest in the Habitats Directive (Calaciura and Spinelli, 2008). These grasslands were formed by forest-cutting and have been maintained by extensive grazing or mowing during the past centuries. Festuco-Brometea grasslands often hold an extremely high biodiversity (Habel et al., 2013; Wilson et al., 2012). Typical grass and sedge species of this habitat are *Brachypodium pinnatum*, *Carex montana*, *Festuca valesiaca*, *Helictotrichon pubescens* and *Stipa pulcherrima*. Forbs are usually present with a high diversity; typical species are *Centaurea scabiosa*, *Cirsium pannonicum*, *Dorycnium germanicum*, *Hippocrepis comosa*, *Inula ensifolia*, *I. salicina*, *Peucedanum cervaria* and *Salvia pratensis*. Several rare and protected species, such as *Centaurea triumfettii*, *Chamaecytisus albus*, *Linum tenuifolium* and *Polygala major* occur in Festuco-Brometea grasslands. All grasslands were on South - South-East exposure, between elevations of 200 and 400 m a.s.l. Soils are leptosols formed on calcareous substrates. For location of the study sites and soil parameters, please see Appendix 1.

### 2.2. Treatments

There were five control grasslands, and five grasslands were burned. In control grasslands, there was no fire during the last century. Burned grasslands have regularly been burned since decades. Local people typically burn grasslands in early spring in the study region. The sites were burned with an average burning frequency of 2.5 years. There were slight differences between the yearly patterns of grassland burning, but all burned sites can be considered as regularly burned compared to the estimated fire return period of wildfires in Central-Europe during the Holocene (approximately 150 years, Feurdean et al., 2013). In former times, burning was a typical practice for improving fodder quality, but nowadays the traditional knowledge associated to this practice is disappearing and local people burn the grasslands mainly as a 'habit' (Deák et al., 2014). None of the grasslands are utilized by mowing or