WHAT CAN BE INTEGRATED FROM NORTH-AMERICAN GRASSLAND BURNING TO EUROPEAN GRASSLAND CONSERVATION?

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Abstract. Prescribed burning is an integral part of the North-American grassland conservation practice, while in European grasslands this technique is rarely applied. European grassland managers and scientists are increasingly interested in cost-effective, alternative ways of biodiversity conservation and prescribed burning can be a vital solution to several conservation problems. We point out which prescribed burning measures widely used in North-America could be integrated into the conservation of European grasslands. Our goal was to draw attention to the use of prescribed fire as a neglected but promising conservation measure in European grasslands. We found that European studies on this topic are scarce; mostly yearly dormant-season burning is applied. The reviewed studies concluded that this burning type solely is not appropriate to preserve and maintain species-rich grasslands. We also discussed burning studies from North-America to identify which findings can be adapted to the European grassland conservation strategy. In North-America, contrary to Europe, the application of burning is fine tuned in terms of timing, frequency and is generally combined with other restoration measures (grazing, seed sowing or herbicide application). Thus, multiple conservation goals, like increasing landscape-level heterogeneity and invasion control can be linked. We emphasize that for the application of prescribed burning the general findings of carefully designed case studies should be combined with the practical knowledge of conservation managers concerning the local application circumstances to reach specific management objectives.

Keywords: land use change; disturbance by fire; invasive species; climate change; identifying appropriate conservation and restoration objectives; new techniques for management

Introduction

The extension and species richness of grasslands have been in constant decline in many parts of Europe in the past decades; still existing grasslands are threatened by the cessation of traditional management regimes (Kahmen et al. 2002, Köhler et al. 2005). The cessation of traditional management can lead to (i) the accumulation of litter; (ii) encroachment of herbaceous competitors and/or (iii) woody species, each resulting in the decline of target grassland species in the long run (Kahmen et al. 2002, Isselstein et al. 2005). Conservation priorities are generally outweighed by economical constraints in cases when traditional management is not cost-effective. Traditional grazing and mowing are no more sustainable and can have relatively high costs in many regions because of the significant decrease of livestock numbers and a reduced need for forage (Liira et al. 2009, Valkó et al. 2012). Thus, conservation authorities are seeking for less costly and labor-intensive substitutive approaches both for maintaining species richness and eliminating the negative consequences of abandonment in grasslands. Application of carefully designed prescribed burning offers an appropriate and cost-effective substitution to grazing and mowing.

Materials and methods

We evaluated the results of the European attempts to manage grasslands by burning, and assessed whether or not the targeted objectives were achieved. We discussed burning studies from North-America to identify which findings can be integrated into the European grassland conservation strategy with a special emphasis on grassland biodiversity. Our review was compiled using a literature search of electronic sources (ISI Web of Knowledge; JSTOR, Science Direct and Google Scholar) using the keywords ‘fire’ OR ‘burn’ AND ‘grassland’.

Results and discussion

Prescribed burning is the carefully designed application of fire under specified fuel and weather conditions to meet specific resource management objectives and long-term conservation management goals (Castellnou et al. 2010). Prescribed burning practices are well-developed in North-America in various ecosystems like forests, shrublands and in several grassland types. In Europe burning was successfully applied as a conservation management tool in heathlands; shrublands and forests but only in a few cases was used for managing grasslands (e.g. Page & Goldammer 2004).

There are contrasting opinions in considering burning as a management tool. One hand, burning can be used effectively with relatively low implementation costs to manage open landscapes, to reduce accumulated litter, and to decrease the chance of wildfires. On the other hand, burning can also have serious detrimental impacts on grassland ecosystems by promoting the dominance of problem species (e.g. competitors or invasive species) and by damaging several endangered plant and animal species, especially invertebrates. Inappropriate burning can result in a loss of biodiversity in the long run, thus, there is an increasing need for summarizing knowledge on the application of burning in European grasslands considering general (e.g. timing, frequency and duration) and specific (e.g. types of grasslands, effects on endangered species) circumstances.

Grassland conservation using prescribed burning in Europe

We found only 11 studies in scientific electronic databases concerning with prescribed burning in European grasslands. In uppermost of the studies dormant-season burning was applied on an annual basis with a valuable long-term monitoring (up to 28 years, Wahlman & Milberg 2002). Most of them are comparative studies of potential substitutive measures (e.g. mulching, burning or removal of woody plants) of traditional mowing or grazing and their emphasis is not on the application of burning. In the published studies, burning was not combined with any other management regimes or post-fire rehabilitation.

The reviewed studies concluded that yearly burning solely is not an appropriate management option preserving the structure and maintaining species richness in the studied grasslands. In the long run, species richness usually decreases by burning compared to grazing or mowing treatments. Burning leads to an increased dominance of competitor species, like *Brachypodium pinnatum* (e.g. Kahmen et al. 2002; Köhler et al. 2005), and results in a species-poor vegetation similar to abandoned grasslands. The reason why burning proved to be inappropriate in these studies might be that burning was applied annually for many years, and there was not enough time for vegetation regeneration between burning events. Only a few minor positive effects of burning were indicated in the reviewed papers. Although burning did not lead to the targeted species composition, it promoted some rare or endangered species of dry grasslands (Köhler et al. 2005). The elimination of litter layer and the prevention of woody encroachment were also listed as positive effects (Kahmen et al. 2002; Page & Goldammer 2004; Liira et al. 2009). A promising example of the use of prescribed burning in European grasslands was published by Page & Goldammer (2004) and Rietze (2009).

Figure 1. Burning of a mesic grassland in Hungary (a). On the burned patch, vegetation recovered rapidly, providing forage for herbivores several weeks before the unburned patches (b). For the conservation of endangered species, the appropriate timing of burning is crucial. For flightless species, like the endemic grasshopper *Isophya costata* (c), summer burning can be detrimental. In summer, immobile life stages, like eggs of the endangered *Maculinea alcon* (d) are also vulnerable to fire, while adult butterflies, like the endangered *Lycaena dispar* (e) can escape easily (Photos: Tamás Miglécz, a; András Kelemen, b and d, Balázs Deák,c and e).

Key findings of North-American case studies

In North-America, burning is not only used as a potential substitutive tool of other types of management, but often combined with other measures (grazing, sowing seeds, application of herbicides). Here we summarize the experiences of North-American burning practices which could at least partly be adapted in European grasslands.

Timing of burning. In North-America both dormant- and growing-season burning are applied to achieve management goals considering the phenology of target and unwanted species (Figure 1). Dormant-season burning is the most effective in reduction of the accumulated litter. Growing-season (mid-July) burns are the best to mimic natural fire regimes (Howe 1994). Summer fires can be appropriate if the management goal is (i) to

destroy unwanted species in a vulnerable phenological state; or (ii) to provide a growing advantage for the next year to certain early-growing species.

Frequency of burning. When the aim of burning is to maintain biodiversity or to mimic natural disturbance regimes, burning in every 2-3 years is recommended in tallgrass prairies (Brockway et al. 2006; Fuhlendorf et al. 2009). This return period of fire resembles most to the natural wildfire regimes, and is required for the regeneration of grasslands and for the re-building of fuel loads (Fuhlendorf et al. 2009). When the aim of burning is to control a certain invasive species, high-frequency burning in consecutive years is needed to prevent its regeneration from vegetative buds or seed banks (Di Tomaso et al. 2001).

Combination of fire and grazing; patch-burning. Fire and grazing interact through positive and negative feedbacks causing a shift of spatio-temporal mosaics (Fuhlendorf & Engle 2001). A conservation effort to mimic these natural disturbance regimes and to improve spatio-temporal heterogeneity of grasslands can be fulfilled by the application of patch-burning (Fuhlendorf & Engle 2001). Burning is applied in patches within a large area, each patch is being burned periodically, e.g. once in every 3 years to provide time for grassland regeneration to the pre-fire state. This results in a mosaic of recently burned patches (being preferred by grazing animals, Figure 1) and patches that were burned some years ago (having the highest biomass and lowest grazing pressure). Patch-burning management has several advantages compared to homogenous burning followed by grazing. (i) The increased landscape scale heterogeneity promotes the coexistence of species with different habitat requirements (Parr & Andersen 2006). (ii) Grazing animals can freely select patches with the best forage quality. (iii) Patch-burning can be an effective tool in the suppression of large wildfires by creating heterogeneous fuel structure (Hobbs 1996).

The use of burning for invasion control. Burning can be a successful management tool in invasion control when invasive and targeted native species differ in (i) their phenology or in (ii) their fire-tolerance and -adaptation mechanisms (MacDougall & Turkington 2005). The proper burning date is crucial in invasion control, as inappropriately timed burning can even facilitate invasive plants in arid and semiarid ecosystems (Keeley 2006). Burning can be used to increase the effectiveness of herbicide application in invasion control, because fire removes litter and provides a better contact between the herbicide and the target (Di Tomaso et al. 2006). There are several promising examples of using fire in the control of invasive species like *Lespedeza cuneata* (patch burning, Cummings et al. 2007) or *Centaurea maculosa* (MacDonald et al. 2006).

Post-fire rehabilitation measures. Post-fire rehabilitation techniques are applied to improve regeneration of grassland species by mitigating unwanted effects of burning. To prevent soil erosion seeding a nurse crop can be applied (e.g. non-persistent cereals, Keeley 2006). An effective way of post-fire rehabilitation is mulching or hay transfer which both can reduce erosion and introduce propagules of target species at the same time (Robichaud et al. 2000, Török et al. 2011, Török et al. 2012).

Conclusions

The current grassland management practices in Europe could and should be improved based on the burning studies but given the differences in the fire-history, climate and species composition of grasslands in the two continents, crucial elements of North-American burning practices can only partly be adapted in Europe.

Application circumstances. In most European studies dormant-season burning is applied, but there is a need for experimental studies concerning the possible use of summer burning in degraded grasslands to control certain problem species. Yearly burning gives not enough time for grassland regeneration, and can lead to untargeted species composition. The frequency of burning is largely dependent on grassland types. When the aim of management is to maintain open landscapes and preserve species-rich grasslands, fire return periods of at least three years may be appropriate in European grasslands given the fact that they are evolutionary less adapted to fire than North-American ones.

Management objectives. We should improve the simple burning measures generally applied in European grasslands, in terms of (i) the joint application of grazing and burning, (ii) the use of fire in invasion control, and (iii) the application of post-fire restoration measures. In extent grassland areas (e.g. in alkali and steppe-like grasslands of Central- and Eastern Europe) the application of patch burning management can be a feasible tool to increase landscape-scale heterogeneity. Besides, further experimental studies are necessary to test the applicability of grazing-burning interactions in the control of unpalatable or poisonous invasive plants in European grasslands. Burning has one of the lowest implementation costs among invasion control techniques and it is a more natural way than the application of herbicides which can persist in the soil and also have

negative impacts on characteristic grassland species. Thus, burning should be integrated into European invasion control strategy by carefully designed studies to control certain invasive species. Conducting burning experiments on degraded grasslands highly infested by invasive species have an additional advantage that there is no risk to have detrimental effects of fire on endangered populations. When necessary, post-fire rehabilitation (seed sowing, mulching or hay transfer) can be applied to facilitate the colonization of the burned sites by target species.

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