GRASSLAND FIRES IN HUNGARY – EXPERIENCES OF NATURE CONSERVATIONISTS ON THE EFFECTS OF FIRE ON BIODIVERSITY

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Abstract. Fire as a natural disturbance has been present in most European grasslands. Controlled burning was also an important component of the traditional landscape management for millennia. It was mainly used to reduce litter and woody vegetation and to maintain open landscapes suitable for farming. Due to socio-economical changes traditional and sustainable use of fire was ceased and replaced by arsons and technical fires in Europe. Despite its wide application in the past and the considerable extension and frequency of current grassland fires, the impact of fire on the grassland biodiversity is still scarcely documented in Europe. The aim of this study is to offer a perspective on the issue of fire impact on grasslands, by overviewing published information and practical experiences from Hungary. Our results suggest that fire can be detrimental for several taxa (e.g. insects or ground-dwelling birds), but can also promote population growth of several endangered species by reducing litter or by creating and maintaining open habitats. We also found that fire may be effective in controlling invasive plant species. The effect of fire on grassland biodiversity may be rather context-dependent. There is a critical need for developing robust evidences on the context-dependence of fire effect on biodiversity. For this, well designed prescribed burning experiments are crucial.
Keywords: *wildfire, prescribed burning; nature conservation management, invasive species, grazing*

Introduction

Fire is a natural disturbance which can occur in all terrestrial ecosystems (Sousa, 1984). Paleoecological evidences show that fire was present in many parts of Europe even before the human colonization of this continent (Feurdean et al., 2012). Burning became a frequently applied management practice during Neolithic ages. Fire was used for a wide range of purposes like maintaining pastures suitable for animal husbandry, preparing arable fields for farming and also for increasing the productivity of farmlands (Vale, 2002; Anonymous, 2010; Papanastasis, et al. 1990). Societies adapting burning as management tool were well aware about the negative effects of uncontrolled fire on the capacity of ecosystems to provide goods and services. Therefore, as every other management intervention, traditional burning was under strict informal regulation at the level of local communities (Anonymous, 2010). The sharp socio-economic changes occurring in Europe in the past two centuries resulted in the erosion of the traditional ecological knowledge regarding burning as land management tool (Bruce and Goldammer, 2004). However, fire still has a key importance in the maintenance of many European landscapes (Anonymous, 2010). The relative importance of natural fires to human made fires decreased significantly with the increasing human domination on the landscapes, and the traditional land management with fire was recently replaced with arsons (illegal burnings for grassland management, fires set for fun and/or by vandalism) and technical fires (Deák et al., 2012; Vázquez and Moreno, 1998; Young et al., 2004). However, arsons are performed with ignoring the traditional knowledge (which would put the fire management into a landscape historical context). Consequently, the application of fire is “out of context” (i.e. its value to maintain specific ecosystem goods and services decreased), and the proportion of large uncontrolled fires increased.

Human activities related to land management influence the frequency and extension of fires in several ways. First the abandonment of the grasslands results in the accumulation of vegetation biomass (Bakker and Berendse, 1999; Valkó et al., 2012a; Kiss et al., 2011; Házi et al. 2011, 2012) which in turn increases the risk of ignition (Brockway et al., 2006; Ónodi et al., 2008). Second, according to climate change scenarios, large parts of Europe will be affected by drier and warmer summers, making these landscapes prone to fires (Garamvölgyi and Hufnagel, 2013; Pautasso et al., 2010). Third the fragmentation of native vegetation (e.g. by urbanisation, infrastructural development and expansion of croplands) will reduce the incidence of large scale burnings (Anonymous, 2010). Thus, it is crucial to understand the ecological processes connected to grassland fires, just as responses of species, functional groups and ecosystems. This knowledge can be applied in designing fire suppression and prevention strategies in the future.

Although fire was and still is a significant factor in many European grasslands, the effects of fire on flora, fauna and habitat structure is poorly studied; only 11 publications were available for international readers (ISI Web of Knowledge, International Forest Fire News) about the effects of prescribed fires in European grasslands (Valkó et al., 2012b). Other source of information includes a few studies on wildfires and the non-published field experiences of land users, managers and scientists.

Aims of the study

Here we overview the field experiences by Hungarian conservation practitioners to understand fire effects on Hungarian grasslands and their biodiversity. The experience of managers can be considered as evidence, besides the published (scholarly or non-scholarly) literature (Sutherland et al., 2004). We present our findings in the context of the European available informations.

Materials and methods

To gain knowledge on the effects of burning on grasslands we compiled a questionnaire including 12 questions (*Appendix 1*). The questions focused on the main attributes of fire events and their effects on plant and animal species together with habitat structures (*Appendix 1*). We distributed the questionnaires among experts of all the ten national park directorates in Hungary. We interviewed them since our goal was to gain experiences from those people who are dealing with the monitoring and management of the majority of nature-close grasslands in Hungary. In this paper we focused only on fire effects on grassland, and did not consider experiences about marsh, heathland, shrubland and forest fires. We simplified the categorization of grassland types from which we gained information as listed in *Table 1*. We always indicated the source of information (from which national park directorate was the data obtained). We used the official abbreviations of the national park directorates (NPDs) in the text; the full name of these parks is presented at *Table 1*. We were aware that the information provided by various experts of the national park directorates, does not always represent the official viewpoint of the institutes. When presenting our results, we combine the informations gathered from the interviews with the available scholarly literature at European level. After these, we will discuss the conservation implications of our findings.

Table 1. *Official names, abbreviations and total area of the Hungarian National Parks and grassland types affected by burning based on the questionnaire survey.*

National Park Directorate										
Abbreviations	**ANPD**	**BFNPD**	**BNPD**	**DDNPD**	**DINPD**	**FHNPD**	**HNPD**	**KMNPD**	**KNPD**	**ŐNPD**
Official names	Aggtelek NPD	Balaton-felvidék NPD	Bükk NPD	Duna-Dráva NPD	Duna-Ipoly NPD	Fertő-Hanság NPD	Hortobágy NPD	Körös-Maros NPD	Kiskunság NPD	Őrség NPD
Total area (ha)	19.892	56.793	39.063	50.105	60.314	23.488	74.222	51.066	48.198	43.950
Characteristic grasslands										
Steppic grasslands										
Alkali steppes			*		*	*	*	*	*	
Loess steppes	*	*	*		*		*	*	*	
Steppes on sandy soils					*	*	*		*	
Steppes on rocky outcrops	*		*							
Mesophilous and wet meadows										
Lowland mesophilous meadows			*				*		*	
Mountain mesophilous meadows			*							*
Wet meadows (fen meadows and marshes)	*		*		*	*	*	*	*	*
Degraded grasslands										
Degraded dry grasslands							*		*	
Old-fields and abandoned vineyards	*				*		*		*	
Grasslands with woody species										
Wooded pastures			*							
Grasslands threatned by woody encroachment	*		*							
Grassland-shrubland mosaic habitats	*	*							*	
Not specified				*						

Results of the questionnaire survey

We received completed questionnaires from all ten national park directorates indicating the importance of the topic and the awareness of grassland burning. Here we summarise and evaluate the experiences on grassland fires based on the information derived from the questionnaires (see *Table 2*).

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Grasslands affected by burning

Fire types – Human-induced and wildfires

According to the questionnaire survey, grassland fires are typical in all Hungarian national parks in several grassland types. The ANPD, BNPD, HNPD and KNPD are those national parks which have to face with most extent fires (*Table 2*). Majority of the reported fires are human-induced ones, mainly arsons. The general aim of the arsons is presumably illegal grassland and rangeland management. Illegal burning is generally applied for (i) improving the quality of the grasslands (pastures and hay-meadows), (ii) reducing the amount of accumulated litter, (iii) rolling back weeds and shrubs and (iv) enhancing grassland productivity. (v) Arsons are usually applied for maintaining road verges because of its cost effectiveness (*Table 2*). These activities affect several 10,000 hectares per year in total. Fires set for 'fun' should be mentioned as well, as in many regions they affect extent areas. Some of the grassland fires are originated from the spreading of fires initiated to eliminate by-products of forestry (forestry waste: branches, leaves, sawdust) and reed management (leaves, flowers, broken stems). This phenomenon can also have reverse effects: grassland fires often spread over reed beds, forests and even settlements. Technical fires are often initiated by heavy machinery used in grassland management. One of the most frequent igniters are the sparks induced by the friction of overheated metal moving parts of mowing machines. Wildfires are less typical than human-induced fires in every national park except for FHNPD, where all the reported fire events were considered as wildfires. Fires set for nature conservation purposes are so rare that we did not include them in the table. The reason for the infrequent application of fire in nature conservation is that Hungarian environmental authorities – like in many other countries in Europe – generally do not issue permits to apply prescribed burning. The decision is generally justified with the protection of air quality.

Fire season

Fire events occur in all seasons of the year (*Table 2*). The occurrence of fire was most typical in spring (Végvári et al., 2011). Regular spring fires were reported from five national parks (ANPD, BNPD, DINPD, HNPD and KNPD).

Land use

Fires were most typical in unmanaged grasslands, but they were reported also in mown and grazed stands. Cessation of management increased the probability of fire events, mainly due to litter accumulation. A high number of fire events were reported from hay-meadows (ANPD, BNPD, DINPD, FHNPD, HNPD, KMNPD, KNPD, ŐNPD). The most common reason reported was that technological fires ignited by mowing machinery are generally applied in hay-meadows. The other reason for more frequent fire events in meadows is that the biomass removal has an uneven temporal pattern: till the day of mowing there is a high, even biomass accumulation. This pattern is in contrast with the grazed sites, where due to the continuous management there is a lower, uneven biomass accumulation.

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Table 2. *Occurrence of grassland burning in Hungarian national park directorates based on the answers for the questionnaires.*

	ANPD	BFNPD	BNPD	DDNPD	DINPD	FHNPD	HNPD	KMNPD	KNPD	ŐNPD
Burnt area (/year)	1,000-10,000 ha	a few 10 ha	1,000-10,000 ha	N.A.	300-400 ha (Tápió-vidék)	0-30 ha	200-3,500 ha	a few 10 ha	100-1,000 ha	<100 ha
Size of burnt patches	0,1-100 ha	a few ha	0.5-70-(200) ha	0.1-5 ha	1-50 ha	5 ha	0.1-300 ha	a few ha	1.5-40 ha	a few ha, burning in stripes
Ratio of arsons	majority	inconstant	majority	majority	inconstant, majority	not present	50%	inconstant	majority	majority
Reasons for arsons	formerly grassland management, nowadays “fun” or “habit”	inconstant	suppressing weedy species, increasing productivity	grassland management	grassland management, spreading of fires from reed industry	not present	grassland-, road verge management, spreading of fires from reed industry, "fun"	spreading of wasteland fires	grassland management, spreading of fires from reed industry	removal of hay
Timing of burning	II-IV., in case of wet spring IX-X.	inconstant	III-IV., in some cases VII-VIII.	VI-XI.	generally III., can be in X-IV.	I-VI.	generally VI-VIII., can be in III-IV.	IV-X.	generally II-IV., can be in VII-IX.	IX-X.

Grassland types

Fire is present in almost every grassland types of Hungary (see *Table 1*). The most affected grassland types are wet meadows (in 8 national parks) and steppic grasslands (loess steppes in 7, alkali steppes in 6 and steppes on sandy soils in 4 national parks). Regular fires are also typical in old-fields, abandoned vineyards and grassland-shrubland mosaic habitats.

Effects of fire on the structure and biodiversity of grasslands

Structural effects

One of the most characteristic effects of fire is that it reduces the amount of accumulated litter (BNPD, DINPD, DDNPD, HNPD, KMNPD, KNPD, Altbäcker, 2005; Ónodi et al., 2008; Ónodi 2011; Ryser et al., 1995) and in some cases it creates open soil surfaces (KMNPD, Antonsen and Olsson, 2005; Hansson and Fogelfors, 2000). Fire temperature and severity increases with the amount of accumulated litter; that is why fire causes less damage in short-grass grasslands like alkali steppes compared to grasslands characterised by tall grasses like alkali meadows. In abandoned loess steppes and alkali meadows accumulated biomass results in extremely high-temperature fires especially after a long dry period. In this case even roots and grass tussocks can be damaged and disintegrated (HNPD; Miller, 2000). In some cases the original state recovers in 3-5 years (in case of good water supply and proper management by grazing; HNPI), but in other cases the encroachment of competitor grasses (mainly *Calamagrostis epigeios*) is typical (HNPD; Végvári et al., 2011).

Invasive and weedy species

The effects of fire on invasive species vary depending on burning conditions and grassland type (Keeley, 2006). Overall, invasive species with a hard seed-coat (e.g. Fabaceae species) and/or a good re-sprouting ability seems to be favoured by fire. One invasive plant species (*Robinia pseudo-acacia*) was found to benefit from fire: fire

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enhanced its germination and the spreading of the sprouts (BNPD, DINPD and KNPD; see also Maringer et al., 2007). In case of some other invasive species, contradictory experiences were reported even for the same species. Regular fires can facilitate the spreading of *Solidago* species in lowland meadows (DINPD and KNPD; see also Simmons et al., 2007), probably because these species have an effective re-sprouting ability from rhizomes. In contrast, according to the experiences in the DDNPD regular fire events combined with grazing can be a proper tool for controlling the population of the invasive *Solidago* species in lowland meadows (see also Johnson and Knapp, 1995). It suggests that the suppression of *Solidago* species by livestock grazing is more feasible after burning, than with grazing alone. On one hand, fire makes infested grassland stands more adequate for the (re)introduction of grazing by removing the accumulated litter and shrubs. On the other hand, *Solidago* species allocate most resources to re-sprouting after fire, therefore the production of secondary metabolites is lower. Similarly, Cummings at al. (2007) found that the poisonous invasive species *Lespedeza cuneata* can be rolled back effectively by the combination of prescribed burning and grazing in North-American prairies. The cover of weeds increased after fire events in several grassland types (DDNPD, DINPD and HNPD). In alkali grasslands the cover of certain short lived weeds like *Chenopodium album* and *Amaranthus albus* increased in the year after fire, but their proportion decreased to the original level for the second year (HNPD; Blumenthal et al., 2005; Végvári et al., 2011).

Woody species

Hungary harbours several grassland habitat types (like forest steppes on sandy soils and wooded pastures) which are characterised by the co-occurrence of woody species. In such habitats fire has serious detrimental effects on *Juniperus communis*. The reason for this is that *Juniperus* ignites easily, and its high content of volatile oils makes it highly susceptible to burning. In most cases fire extirpates shrubs locally (ANPD, BNPD, KNPD; Ónodi et al., 2008, Thomas et al., 2007). Fire is also an important natural determinant of the dynamic of ecosystems dominated by *J. communis*. For example, fire events with a *ca* 10-20 year frequency are important in forming and sustaining the mosaic structure of the habitats dominated by *Juniperus* (Altbäcker, 1998). In mixed stands of *J. communis* and *Populus alba*, burning increase the area of open grasslands. However, *Populus alba* and sometimes *Robinia pseudo-acacia* can invade the opened areas after fire, finally resulting in the decrease of grassland cover and the encroachment of woody vegetation (KNPD; Ónodi et al., 2008), including shrubs like *Prunus spinosa* and *Crataegus monogyna* (BNPD, DINPD, KNPD). Similarly to *J. communis*, fire also suppresses resinous pine species, such as *Pinus nigra* (BNPD) and *Pinus sylvestris* (ANPD; Carlisle and Brown 1968) which are common invaders of unmanaged grasslands. Fire can also damage single trees in wood-pastures (BNPD, DINPD; Kenéz, 2007; Szabó, 2007). In the traditional wood-pastures from Southern Transylvania (Romania), the uncontrolled pasture fires damages especially the large, ancient trees (oaks), every year (Hartel et al., 2013). As the large ancient trees are keystone structures for biodiversity (Manning et al., 2006), their disappearance may have serious consequences on the local and regional biodiversity of entire landscapes.

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Perennial grasses

Frequent fires generally cause an increased abundance of competitor grasses with tillers, like *Brachypodium pinnatum* (ANPD; Kahmen et al., 2002; Köhler et al., 2005; Ryser et al., 1995) or *Calamagrostis epigeios* (HNPD, KNPD; Hille and Goldammer, 2007; Marozas et al., 2007). In some cases burnt grasslands are invaded by the terrestrial form of reed (*Phragmites australis*, KMNPD). In foothill steppic grasslands formed in abandoned vineyards single fires resulted in the decreased abundance of *Stipa tirsa* (BNPD). Consequently due to lowered competition and reduced amount of litter, fire resulted in the population growth of two rare species (*Echium russicum* and *Thlaspi jankae*), both listed in the Annex II of the Habitats Directive. In parallel, the cover of *S. tirsa* increased considerably (BNPD) after frequent fires in the same habitat type. Similar to this pattern in the Tardonai-hills the abundance of the *Stipa pulcherrima* increased after regular burning and parallel several subordinate species were rolled back (Garadnai, 2007). In loess steppes the abundance of grasses decreased while that of forbs increased after fire (KMNPD).

Rare and protected forbs

The effects of the fire on protected and rare forb species depends strongly on burning season. Spring and summer fire can have different effects even on the same species depending on the phenological state and specific traits of the species. A recent study has demonstrated that the major traits determining the response of plants to fire are their (i) life form, (ii) presence/absence of perennating buds, (iii) density, spatial orientation and some other characteristics of the seeds (Pyke et al., 2010). Perennial species are least sensitive to fire, as they can more easily recover in the years following fire. Annual species are most sensitive before seed set and seed dispersal. Species with long-term persistent seeds or underground storage organs are better adapted to fire than species with transient seed banks or aboveground perennial buds (Pyke et al., 2010). The precipitation patterns considerably influence the effects of fire on vegetation. Whereas the vegetation can recover easily after fire in a year with a normal or high precipitation, fire often leads to degradation in dry years (BNPD).

Occasional fire events before the flowering and ripening period (April-May) can cause a considerable increase in the population of *Pulsatilla* and *Adonis* spp. In the BNPD fire had a positive effect on the population of *A. vernalis*. Occasional spring fires occurring after snowmelt initiated the germination of the *Adonis volgensis* (KMNPD; Illyés et al., 2007). On the populations of *Pulsatilla pratensis* ssp. *hungarica* former military fires and further occasional arsons had a positive effect by reducing the litter and creating open gaps favouring germination and seedling establishment (HNPD). Occasional fires had a positive effect on the populations of the protected *Thlaspi jankae, Phlomis tuberosa, Prunella grandiflora, Ranunculus illyricus* in mesophilous meadows originated from clear-cuts (BNPD) and on *Chamaecytisus supinus* in lowland hay-meadows (ŐNPD). Increase in abundance of certain species can be related to induced germination and seedling emergence which is facilitated by (i) temporal increases of soil nutrients after fire (Blodgett et al., 2000), (ii) decreased competition of living neighbours (Maret and Wilson, 2005) and (iii) new open soil surfaces which favour the germination of several species (Rebollo et al., 2001). (iv) The smoke and its aqueous solution (smoke-water) promote the germination of several species (Mojzes and Kalapos, 2012). Geophytes regenerate well after fire from their underground storage

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organs (Pyke et al., 2010). Fire can increase their populations by providing more favourable microsites by the removal of accumulated litter. These findings were confirmed by the experts opinions. In KNPD a considerable population growth of *Bulbocodium vernum* and *Crocus reticulatus* was observed after late winter fires. However, later fires in the flowering period (early spring) are detrimental for the populations of *Pulsatilla grandis, A. vernalis* (BNPD) and *P. nigricans* (FHNPD). In frequently burnt steppic grasslands, the flowering shoots of *P. grandis* decreased to 5-10% of that was found in the previous years (BNPD). Due to frequent fires the population of the *T. jankae* was reduced to 10% in 6 years while even in the neighbouring non-burnt patches the population grew (ANPD).

Animal species

Fire has significant effects on the elements of fauna. The most important reasons for animal injury or death caused by fire are (i) oxygen deficiency, (ii) exposure to lethal heat and (iii) toxic compounds of smoke (Engstrom, 2010). The most vulnerable animal taxa are those with limited mobility. Negative effects of fire on invertebrates, was reported from almost all national parks. Especially the rare and endangered species are vulnerable which live on the ground surface or lay their eggs on the surface of short herbs or inside their shoots (ANPD, BNPD, DINPD, FHNPD, HNPD, KNPD and ŐNPD). Autumn fire negatively affects ant populations as a result of overheating the nest (HNPD). The vulnerability of a species is higher in sensitive life stages, like in nesting season or moulting period (e.g. snakes in ecdysis; Russel et al., 1999). In the nesting season fire has detrimental effects on ground-dwelling birds like *Otis tarda*, *Asio flammeus*, *Vanellus vanellus, Limosa limosa* and *Tringa totanus* (HNPD, KMNPD, KNPD; Lyon et al., 2000; Swengel, 2001; Végvári et al., 2011). Populations of *Ablepharus kitaibelii* are threatened by early spring fires, while populations of *Lacerta viridis, Sorex* spp. and *Carabus* spp. are endangered by late spring and summer fires (BNPD).

Fire has some sort of secondary effects on animals, mainly through changes in habitat structure and food availability (Engstrom, 2010). Fire can have a positive effect on the population of the *Euphydryas aurinia,* by favouring the population growth of the host plant of the butterfly (*Chamaecytisus supinus*; ŐNPD). Fire often increases food availability and quality; recently burnt sites are preferentially selected by grazing ungulates (Fuhlendorf and Engle, 2001) because foliage of re-growing herbs and shrubs is more palatable, richer in nutrients and crude protein (Tracy and McNaughton, 1997). Predators and scavengers are also attracted to burnt sites because of the more abundant and more exposed food source compared with non-burnt sites (Lyon et al., 2000). This especially applies to small mammals which are preyed upon by avian predators in large densities as a result of vegetation cover loss. As a behavioural adaptation to fire-exposed prey storks, buzzards, falcons, harriers, eagles and large-bodied gulls (e.g. *Larus cachinnans*) are generally attracted to burning vegetation, possibly using smoke as visual and its smell as olfactory clues (Conner et al., 2011; Lyon et al., 2000). While raptors specialize on small mammals which are trying to escape from fire, storks and gulls can find large quantities of burnt or escaping flocks of orthopterans. Post-burning sites attract sizeable flocks of migrating waders – mostly plovers (*Charadrius* spp.) – especially after rainy periods. Winter wildfires seem to be an effective tool for establishing open lek areas for *Otis tarda* in unmanaged grasslands (HNPD; Végvári et

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al. 2011). Bustards need open grassland patches for lekking, where females are attracted to loose groups of displaying males. In this case, areas burnt in the previous year with short green vegetation seem to have multiple benefits for lekking bustards: (i) the grass is short which increases visibility and manoeuvrability of males' movements (ii) short green grass and white balls of displaying males create larger visual contrasts than for unburned, tall and yellow vegetation thus possibly attracting more females to lek sites (iii) burned sites provide larger amounts of prey for lekking males which can enhance breeding success (HNPD).

Grassland recovery

The original (pre-fire) vegetation usually recovers well after non-regular fires, but in some cases active post-fire management is needed (Pyke et al., 2010; Robichaud, 2000). Mesophilous and wet meadows in a good nature conservation state regenerate well in a few years after burning (HNPD, KNPD). Active post-fire management is generally applied for reducing the possible negative effects of the fire in meadows of the DDNPD and alkali steppes and alkali meadows of the HNPD, which usually includes grazing and/or brushcutting. Moderate grazing applied after the fire event helps in decreasing the abundance of weeds and recovering the habitat diversity. Alkali grasslands of the KNPD and HNPD generally regenerate quickly after fire and post-fire management is not essential for their recovery. In alkali landscapes, fire does not have permanent negative effects on the diversity and species composition of the grasslands (HNPD).

Effects of fires on land use

As a side effect of burning, grasslands become more adequate for grazing and mowing after fire: the amount of litter decreases, standing dead biomass disappears and the quality of the forage increases (ANPD, HNPD, KNPD, Tracy and McNaughton, 1997). This phenomenon motivates many land users to apply unauthorised fire management on their land. An additional reason for this practice is that - as in case of arable lands - farmers use fire to decrease the population of some pathogens and pest species (Lyon et al., 2000).

Effects associated with fire-fighting actions

Disturbance of grasslands during fire-fighting actions can also be detrimental for wildlife. In case of uncontrolled wildfires and arsons there is no opportunity to ensure safety measures in advance. In some cases drastic measures must be taken to protect human life and private property. These measures are (i) establishing firebreaks with ploughing (HNPD, KNPD) or (ii) fire-fighting with earthmoving equipment (KNPD). Fire-engines often produce deep tracks in grasslands, especially in moist soils (e.g. in wet meadows), which results in the degradation of the grassland structure and in creating soil erosion patterns disrupting local hydrology. These linearly disturbed soil surfaces provide proper sites for the germination, establishment and spreading of invasive species. In the ANPD a whole population of *Iris aphylla* ssp. *hungarica* had to be destroyed while establishing a firebreak to protect a forest from the spreading-over of a grassland fire. Besides the negative nature conservation consequences of fire-fighting with earthmoving equipment, the method is not always sufficient in the terms of fire protection, as the semi-buried embers can glow for several days and can cause re-ignition (HNPD).

Discussion

Our results show that the effect of fire is context-dependent and burning can have both positive and negative effects on grassland biodiversity. Uncontrolled fires may have serious detrimental effects on rare species, habitats, personal safety and private property. Generally uncontrolled fires have the following negative effects: (i) the homogenisation of habitats mainly by facilitating competitor grass species, (ii) burning in flowering or ripening period causes serious damages in the populations of protected species, (iii) fire in the nesting season seriously damage the populations of ground-dwelling birds, (iv) fire has a considerable negative effect on invertebrates regardless to the season, (v) it can promote the spreading of invasive species, (vi) damages natural woody vegetation and (vii) fire-fighting actions can lead to the degradation of grasslands.

According to our study, fire can also have positive effects on grassland habitats and grassland species. These results are in accordance with other findings from Europe. (i) Burning decreases the amount of accumulated litter. (ii) Fire can restore or establish habitats and suitable micro-sites for rare plant or animal species. (iii) Combination of fire and grazing was reported to be successful in suppressing the population of invasive plant species.

Implications for nature conservation

Monitoring fires in the landscape

An important component of understanding the effects of arsons and wildfires on wildlife is to create a database which contains records on all fire events and their relevant parameters and sources. These informations will be useful in understanding the origins (e.g. its controlled, or accidental, uncontrolled nature) and spatio-temporal dynamic of fire and ultimately could be useful in prioritizing fire prevention strategies. These observations should be complemented with obvious natural casualties such are the extension of the burnt patch, changes in the abundance of some plant and animal species (e.g. the keystone, or very obvious species). These informations could be gathered e.g. by training rangers in the park.

The need for prescribed burning experiments

According to our results fire does not have definite positive or negative effects from the nature conservation viewpoint. As experimentally robust evidences on the fire effects on biodiversity are lacking in Hungary, we urge the establishment of well designed species- and habitat specific experiments to address the context dependence of fire effects on biodiversity.

Prescribed burning experiments offer the possibility for the quantitative analysis of fire effects and their results can offer solutions for several nature conservation problems: (i) the removal of accumulated biomass from abandoned pastures and meadows, where traditional management is not sustainable any more, (ii) the prevention or suppression of woody encroachment in abandoned pastures and meadows, (iii) the

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control of invasive species (by burning or by the combination of grazing and burning). Prescribed burning might be a proper tool for preventing extent and uncontrolled wildfires (Baeza et al., 2002) and accordingly it can contribute to the protection of personal safety and private property. Furthermore, small-scale, controlled prescribed burning experiments should be designed for the quantitative analysis of fire effects on grassland habitats and species. Based on these results, prescribed burning could be integrated in conservation plans of rare and protected species which found to be promoted by burning.

Application circumstances of prescribed burning in practice

Prescribed burning experiments require a careful application of fire under specified fuel and weather conditions to reach specific goals (Castellnou et al., 2010). Thus, in the planning and implementation phase of prescribed burning experiments, several important details should be considered which we listed here.

Permissions

It is essential to have the permissions of competent governmental bodies and stakeholders: the Environmental Protection Inspectorate, the nature conservation manager (generally the National Park Directorates), land owner/user and the Fire Service. However, the strict regulation of burning by law in most European countries (including Hungary) limits the possibility of implementing even small-scale prescribed burning experiments (Goldammer and Montiel, 2010). The main reasons why prescribed burning is prohibited by law are to mitigate air pollution and/or to protect human life and property. However the emission of air-pollutant compounds from controlled, small-scale prescribed burning experiments would be significantly smaller than that of regular, uncontrolled fires with several 10,000 hectares in each year. Additionally, these small-scale burning experiments could effectively contribute to developing new strategies in nature conservation and even fire suppression.

Defining management targets

As the first step of the planning phase, objectives of the management should be defined (e. g. the removal of litter, facilitating the germination of protected species, suppressing invasive species). Application circumstances like patch size, location of the burnt areas, timing and frequency of burning should be harmonised with these aims.

Survey of the pre-burn state

Prior to burning, species composition of the grasslands should be surveyed, in order to have an overview on that which plant and animal taxa can be potentially affected. Sacrificing one protected species for advancing another one should be avoided. If this dilemma would emerge, burning should not be used. To decrease the risk of damaging the populations of rare species, experimental burnings can be implemented in disturbed areas where no unique nature conservation values are present.

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Extension of burning

In general, burning in a mosaic pattern is the most favourable for most species (Parr and Andersen, 2006). The size of the patches should be approximately 1-3 ha, which enables a fast grassland recovery by resettling of plants and animal taxa from the neighbouring non-burnt patches. It is very important to designate burnt and non-burnt control plots for the better understanding of fire effects.

Frequency of burning

Both European studies and the experiences from Hungary point out that annual burning is not favourable as it results in the degradation of grasslands in the long run (Kahmen et al., 2002; Wahlman and Milberg, 2000). The practice of annual burning allows no time for grassland regeneration, and can lead to untargeted states of succession. When the aim of management is to maintain open landscapes and preserve species-rich grasslands, least frequent burning is recommended. Proper burning frequency significantly varies across grassland types, but at least 3-5 years may be appropriate to avoid degradation.

Burning season

Burning season depends on the grassland type, plant and animal species present and the aim of burning. For example, for the reduction of litter layer late winter or early spring fires (Towne and Owensby, 1984), for invasion control, growing-season fires are the most effective (MacDougall and Turkington, 2005). Some hardly foreseen parameters such as the precipitation in the previous weeks or days also influence the timing of the burning. A general rule is that burning in flowering season of the natural vegetation and in nesting period should be avoided, as it has a high potential for damaging the target communities.

Implementation phase

In the implementation phase well-equipped and experienced teams are needed. Necessary preparations (like creating firebreaks by mowing) should be arranged in every case. Contrary to wildfires if a well planned prescribed burning is applied it is possible to arrange those preparations which are necessary for preventing or minimising the potential negative effects of burning (and even fire-fighting) on natural values, private property and air quality. These precautional measures include precise selection of the area and also taking into account the weather circumstances (direction and strength of the wind). Surrounding areas can be protected by designating the burnt area between natural borders (channels, dirt roads, overgrazed areas or open water surfaces) which can act as natural firebreaks.

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REFERENCES

[1] Altbäcker, V. (1998): Növény-növényevő kapcsolatok vizsgálata homoki társulásokban. – In: Fekete, G. (ed.) A közösségi ökológia frontvonalai, Scientia, Budapest, pp. 123-145.

[2] Altbäcker, V. (2005): Növényzet és növényevők közötti interakciók mechanizmusainak vizsgálata. – DsC theses, Eötvös Loránd Tudományegyetem, Budapest.

[3] Anonymous (2010): White paper on use of prescribed fire in land management, nature conservation and forestry in temperate-boreal Eurasia. - Symposium on Fire Management in Cultural and Natural Landscapes, Nature Conservation and Forestry in Temperate-Boreal Eurasia and members of the Eurasian Fire in Nature Conservation Network (EFNCN), Global Fire Monitoring Center, Fire Ecology Research Group Freiburg, Germany.

[4] Antonsen, H., Olsson, P.A. (2005): Relative importance of burning, mowing and species translocation in the restoration of a former boreal hayfield: responses of plant diversity and the microbial community. – Journal of Applied Ecology 42: 337-347.

[5] Baeza, M. J., Luís, D., Raventós, J., Escarre, A. (2002): Factors influencing fire behaviour in shrublands of different stand ages and the implications for using prescribed burning to reduce wildfire risk. – Journal of Environmental Management 65: 199-208.

[6] Bakker, J.P., Berendse, F. (1999): Constraints in the restoration of ecological diversity in grassland and heathland communities. – Trends in Ecology and Evolution 14: 63-68.

[7] Blodgett, H., Hart, G., Stanislaw, M. (2000): Annual burning decreases seed density in the upper soil layers of the seed bank. – Tillers 2: 31-38.

[8] Blumenthal, D.M., Jordan, N.R., Svenson, E.L. (2005): Effects of prairie restoration on weed invasions. – Agriculture, Ecosystems and Environment 107: 221-230.

[9] Brockway, D. G., Gatewood, R.G., Paris, R. B. (2006): Restoring fire as an ecological process in shortgrass prairie ecosystems: initial effects of prescribed burning during the dormant and growing seasons. – Journal of Environmental Management 65: 135-162.

[10] Bruce, M. A., Goldammer J. G. (2004): The use of prescribed fire in the land management of Western and Baltic Europe: An overview. – International Forest Fire News 30: 2-13.

[11] Castellnou, M., Kraus, D., Miralles, M. (2010): Prescribed burning and suppression fire techniques: from fuel to landscape management. – In: Montiel, C., Kraus, D. (eds.): Best practices of fire use - prescribed burning and suppression fire programmes in selected case-study regions in Europe. – European Forest Institute Research Report 24: 3-16.

[12] Conner, L.M., Castleberry, S.B., Derrick, A.M. (2011): Effects of mesopredators and prescribed fire on hispid cotton rat survival and cause specific mortality. – The Journal of Wildlife Management 75(4): 938-944.

[13] Cummings, D. C., Fuhlendorf, S. D., Engle, D. M. (2007): Is altering grazing selectivity of invasive forage species with patch burning more effective than herbicide treatments? – Rangeland Ecological Management 60: 253-260.

[14] Deák, B., Valkó, O., Schmotzer, A., Kapocsi, I., Tóthmérész, B., Török, P. (2012): Gyepek égetésének természetvédelmi megítélése – probléma vagy gyepkezelési alternatíva? – Tájökológiai Lapok 10(2): 287-303.

[15] Engstrom, R. T. (2010): First-order fire effects on animals: review and recommendations. – Fire Ecology 6: 115-130.

[16] Feurdean, A., Spessa, A., Magyari, E. K., Willis, K. J., Veres, D., Hickler, T. (2012): Trends in biomass burning in the Carpathian region over the last 15,000 years. – Quaternary Science Reviews 45: 111-125.
[17] Fuhlendorf, S. D., Engle, D. M. (2001): Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. – Bioscience 51: 625-632.
[18] Garadnai, J. (2007): Az égetés hatásai az árvalányhajas gyepekre – esettanulmány. In: Illyés, E, Bölöni, J. (szerk.): Lejtősztyepek, löszgyepek és erdőssztyeprétek Magyarországon. – Budapest, private press, pp. 112-113.
[19] Garamvölgyi, Á, Hufnágel, L. (2013): Impacts of climate change on vegetation distribution No. 1 - Climate change induced vegetation shifts in the palearctic region. – Applied Ecology and Environmental Research 11(1): 79-122.
[20] Goldammer, J. G., Montiel, C. (2010): Identifying good practices and programme examples for prescribed burning and suppression fire. – In: Montiel, C., Kraus, D. (Eds.) Best practices of fire use - prescribed burning and suppression fire programmes in selected case-study regions in Europe. – European Forest Institute Research Report 24: 35-44.
[21] Hansson, M., Fogelfors, H. (2000): Management of a semi-natural grassland; results from a 15-year-old experiment in southern Sweden. – Journal of Vegetation Science 11: 31-38.
[22] Hartel, T., Dorresteijn, I., Klein, C., Máthé, O., Moga, C. I., Öllerer, K., Roellig, M., von Wehrden, H., Fischer, J. (2013): Wood-pastures in a traditional rural region of Eastern Europe: Characteristics, management and status - Biological Conservation 166: 267–275.
[23] Házi, J., Bartha, S., Szentes, Sz., Penksza, K. (2011): Seminatural grassland management by mowing of Calamagrostis epigejos in Hungary. – Plant Biosystem 145(3): 699-707.
[24] Házi, J., Penksza, K., Bartha, S., Hufnagel, L., Tóth, A., Gyuricza Cs., Szentes, Sz. (2012): Cut mowing and grazing Effects with grey cattle on plant species composition in case of Pannon wet grasslands. – Applied Ecology and Environmental Research 10(3): 223-231.
[25] Hille, G. M., Goldammer, G. J. (2007): Dispatching and modeling of fires in Central European pine stands: New research and development approaches in Germany. – 4th International Wildland Fire Conference, 13–17 May 2007, Seville. p. 49.
[26] Illyés, E., Jakab, G., Csathó, A. (2007): Jelenlegi és a jövőben kívánatos természetvédelmi akciók, stratégiák a lejtősztyepek, löszgyepek és erdőssztyeprétek megőrzésére. – In: Illyés, E., Bölöni, J. (eds.): Lejtősztyepek, löszgyepek és erdőssztyeprétek Magyarországon. Budapest, private press, pp. 114-119.
[27] Johnson, S. R., Knapp, A. K. (1995): The influence of fire on Spartina pectinata wetland communities in a northeastern Kansas tallgrass prairie. – Canadian Journal of Botany 73: 84-90.
[28] Kahmen, S., Poschlod, P., Schreiber, K.-F. (2002): Conservation management of calcareous grasslands. Changes in plant species composition and response of functional traits during 25 years. – Biological Conservation 104: 319-324.
[29] Keeley, J., Zedler, R. (1987): Reproduction of chaparral shrubs after fire: a comparison of sprouting and seeding strategies. – American Midland Naturalist 99: 142-161.
[30] Kenéz, Á., Szemán, L., Szabó, M., Saláta, D., Malatinszky, Á., Penksza, K., Breuer, L. (2007): Természetvédelmi célú gyephasznosítási terv a pénzesgyőr-hárskúti hagyásfás legelő élőhely védelmére. – Tájökológiai Lapok 5: 35-41.
[31] Kiss, T., Lévai, P., Ferencz, Á., Szentes, Sz., Hufnagel, L., Nagy, A., Balogh, Á., Pintér, O., Saláta, D., Házi, J., Tóth, A., Wichmann, B., Penksza, K. (2011): Change of composition and diversity of species and grassland management between different grazing intensity in Pannonian dry and wet grasslands. – Applied Ecology and Environmental Research 9(3): 197-230.
[32] Köhler, B., Gigon, A., Edwards, P. J., Krüsi, B., Langenauer, R., Lüscher, A., Ryser, P. (2005): Changes in the species composition and conservation value of limestone

grasslands in Northern Switzerland after 22 years of contrasting managements. – Perspectives in Plant Ecology, Evolution & Systematics 7: 51-67.
[33] Lyon, L.J., Telfer, E.S., Schreiner, D.S. (2000): Direct effects of fire and animal responses. – In Smith, J.K. (ed.) Wildland fire in ecosystems: effects of fire on fauna. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. pp. 17-24.
[34] MacDougall, A.S., Turkington, R. (2007): Does the type of disturbance matter when restoring disturbance-dependent grasslands? – Restoration Ecology 15: 263-272.
[35] Manning, A. D., Fischer, J., & Lindenmayer, D. B. (2006): Scattered trees are keystone structures – Implications for conservation. – Biological Conservation 132: 311-321
[36] Maret, M. P., Wilson, M. V. (2005): Fire and litter effects on seedling establishment in Western Oregon upland prairies. – Restoration Ecology 13: 562-568.
[37] Maringer, J., Wohlgemut, T., Neff, C., Pezzatti, G.B., Conedera, M. (2007): Post-fire spread of alien plant species in a mixed broad-leaved forest of the Insubric region. – Flora 207: 19-29.
[38] Marozas, V., Racinskas, J., Bartkevicius, E. (2007): Dynamics of ground vegetation after surface fires in hemiboreal Pinus sylvestris L. forests. – 4th International Wildland Fire Conference, 13–17 May 2007, Seville. p. 22.
[39] Miglécz, T., Tóthmérész, B., Valkó, O., Kelemen, A., Török, P. (2012): Effect of litter on seedling establishment: an indoor experiment with short-lived Brassicaceae species. – Plant Ecology doi: 10.1007/s11258-012-0158-6
[40] Miller, M. (2000): Fire Autecology. - In: Brown, J.K., Smith, J.K. (eds.) Wildland Fire in Ecosystems – Effects of Fire on Flora Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. pp. 9-34.
[41] Mojzes, A, Kalapos, T. (2012): The role of smoke derived from burning vegetation in the regeneration of plants. – Tájökológiai Lapok 10: 247-270.
[42] Ónodi, G. (2011): Legelés és tűz, mint gyepdinamikai tényezők: Kísérletes vizsgálatok nyílt évelő homokpusztagyepekben. – Ph.D. dissertation, MTA Ökológiai és Botanikai Kutatóintézet, Vácrátót.
[43] Ónodi, G., Kertész, M., Botta-Dukát, Z., Altbäcker, V. (2008): Grazing effects on vegetation composition and on the spread of fire on open sand grasslands. – Arid Land Research and Management 22: 273-285.
[44] Papanastasis, V., Kyriakakis, S., Ispikoudis, J. (1990). Forestry and grazing practice in Crete. – In: Grove, A.T., Rackham, O., Moody, J. (eds.) Stability and Change in the Cretan Landscape. Petromaroula 1, Corpus Christi College, England. pp. 42-46.
[45] Parr, C. L., Andersen, A. N. (2006): Patch mosaic burning for biodiversity conservation: a critique of the pyrodiversity paradigm. – Conservation Biology 20: 1610-1619.
[46] Pautasso, M., Dehnen-Schmutz, K., Holdenrieder, O., Pietravalle, S., Salama, N., Jeger, M.J., Lange, E., Hehl-Lange, S. (2010): Plant health and global change - some implications for landscape management. – Biological Reviews 85: 729-755.
[47] Pyke, D. A., Brooks, M. L., D'Antonio, C. (2010): Fire as a restoration tool: A decision framework for predicting the control or enhancement of plants using fire. – Restoration Ecology 18: 274-284.
[48] Rebollo, S., Pérez-Camacho, L., García-de Juan, M.T., Rey Beyanas, J.M., Gómez-Sal, A. (2001): Recruitment in a Mediterranean annual plant community: seed bank, emergence, litter, and intra- and inter-specific interactions. – Oikos 95: 485-495.
[49] Robichaud, P. R., Beyers, J. L., Neary, D. G. (2000): Evaluating the effectiveness of postfire rehabilitation treatments. – General technical report RMRS-GTR-63. U.S. Department of Agriculture, Rocky Mountain Research Station, Fort Collins, Colorado.
[50] Russell, K. R., Van Lear, D. H., Guynn Jr., D. C. (1999): Prescribed fire effects on herpetofauna: review and management implications. – Wildlife Society Bulletin 27: 374-384.

[51] Ryser, P., Langenauer, R., Gigon, A. (1995): Species richness and vegetation structure in a limestone grassland after 15 years management with six biomass removal regimes. – Folia Geobotanica & Phytotaxonomica 30: 157-167.
[52] Simmons, M. T., Windhager, S., Power, P., Lott, J., Lyons, R. K., Schwope, C. (2007): Selective and non-selective control of invasive plants: the short-term effects of growing-season prescribed fire, herbicide, and mowing in two Texas prairies. – Restoration Ecology 15: 662-669.
[53] Sousa, W. P. (1984): The role of disturbance in natural communities. – Annual Review of Ecology and Systematics 15: 353-391.
[54] Swengel, A.B. (2001): A literature review of insect responses to fire, compared to other conservation managements of open habitat. – Biodiversity and Conservation 10: 1141-1169.
[55] Szabó, M., Kenéz, Á., Saláta, D., Malatinszky, Á., Penksza, K., Breuer, L. (2007): Természetvédelmi-gyepgazdálkodási célú botanikai vizsgálatok a pénzesgyőri-hárskúti hagyásfás legelőn. – Tájökológiai Lapok 5: 27-34.
[56] Thomas, P.A., El-Barghathi, M., Polwart, A., (2007): Biological Flora of the British Isles: Juniperus communis L. – Journal of Ecology 95: 1404-1440.
[57] Towne, G., Owensby, C. (1984): Long-term effects of annual burning at different dates in ungrazed Kansas tallgrass prairie. – Journal of Range Management 37: 392-397.
[58] Tracy, B. F., McNaughton, S. J. (1997): Elk grazing and vegetation responses following a late season fire in Yellowstone National Park. – Plant Ecology 130: 111-119.
[59] Vale, T. R. (2002): Fire, native peoples, and the natural landscape. – Island Press, Washington DC.
[60] Valkó, O., Török, P., Matus, G., Tóthmérész, B. (2012a): Is regular mowing the most appropriate and cost-effective management maintaining diversity and biomass of target forbs in mountain hay meadows? – Flora 207: 303-309.
[61] Valkó, O., Deák, B., Kapocsi, I., Tóthmérész, B., Török, P. (2012b): Gyepek kontrollált égetése, mint természetvédelmi kezelés – Alkalmazási lehetőségek és korlátok. Természetvédelmi Közlemények 18: 517-526.
[62] Vázquez, A., Moreno, J. M. (1998): Patterns of lightning-, and people-caused fires in peninsular Spain. – International Journal of Wildland Fire 8: 103-115.
[63] Végvári, Zs., Ilonczai, Z., Boldogh, S. (2011): A tüzek hatása. – In: Viszló, L. (ed.): A természetkímélő gyepgazdálkodás: Hagyományőrző szemlélet, modern eszközök. Pro Vértes Természetvédelmi Közalapítvány, Csákvár, pp. 189-209.
[64] Wahlman, H., Milberg, P. (2002): Management of semi-natural grassland vegetation: evaluation of a long-term experiment in Southern Sweden. – Annales Botanici Fennici 39: 159-166.
[65] Young, J., Halada, L., Kull, T., Kuzniar, A., Tartes, U., Uzunov, Y., Watt, A. (2004): Conflicts between human activities and the conservation of biodiversity in agricultural landscapes, grasslands, forests, wetlands and uplands in the Acceding and Candidate Countries (ACC). – A Report of the BIOFORUM project, March 2004.

Appendices

Appendix 1. *Questionnaire sent to expert from Hungarian national park directorates.*

1. Are spontaneous fires (wildfires, technical fires) and/or arsons present in the NPD's range of action?
2. If yes, which grassland types are affected? (e.g. steppic grasslands, mesophilous and wet meadows, degraded grasslands or grasslands with woody species)
3. What kind of land-use or nature conservation management is present in the burnt grasslands? (e.g. grazing, mowing, no management; intensity: low, adequate, high)

4. What percent of the fires affects protected or Natura 2000 sites?
5. How far are the affected grasslands from settlements and roads? (e.g. in a close vicinity to settlements; far from roads and settlements)
6. Approximately how many hectares of grasslands are burnt in a year?
7. What is the average extension of the burnt patches?
8. What is the typical period for grassland fires? (season or month)
9. What is the ratio of the arsons and spontaneous fires?
10. What might be the aim of the arsons?
11. Which are the most detrimental effects of the arsons and wildfires?
12. According to the field experiences what are the main effects of fire on natural grasslands? (e.g. changes in the amount of litter; altering the structure of the grassland; effects of burning on woody species, invasives, populations of protected plants- and animal species; regeneration of the vegetation after fire)