Use of Prescribed Fire in Land Management, Nature Conservation and Forestry in Temperate-Boreal Eurasia

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Recebido em 29/03/2015 – Aceito em 05/04/2015

RESUMO – Em vastas áreas da Eurásia temperada-boreal, o uso do fogo, com as tradicionais práticas de corte e queima e outras perturbações associadas ao cultivo da terra, contribuiu para moldar as paisagens com alta diversidade e valor ecológico e cultural, como as *heathlands*, campos abertos e prados. Em relação à biota euro-siberiana oriental, a incidência de fogo por causas naturais contribuiu para moldar florestas abertas e resilientes, como a floresta de taiga *(light taiga*). As rápidas mudanças socioeconômicas nas últimas quatro décadas e as tendências recentes de crescente êxodo rural por toda a Eurásia, no entanto, resultaram em um abandono das práticas tradicionais de manejo da terra. Com a eliminação destas perturbações geradas pelo cultivo, incluindo as práticas tradicionais de queima, extensas áreas da Europa estão se tornando áreas de pousio, um processo associado com sucessão ecológica que leva à cobertura arbustiva ou florestal e uma perda generalizada de habitats abertos. Junto à perda de valiosa biodiversidade, as terras abandonadas constituem um aumento no risco de incêndios florestais – tendência que é revelada pelo crescente número de incêndios catastróficos, extremamente severos. De modo similar, a exclusão do fogo em ecossistemas naturais tais como as florestas de coníferas ao norte da região boreal e na região sub-boreal na Eurásia resultou na mudança da composição da vegetação a aumento do risco de incêndios, notavelmente na região centro-oriental da Eurásia. Mudanças em paradigmas nas áreas de ecologia e conservação da natureza atualmente têm levado à reconsideração das políticas de exclusão do fogo em certos setores responsáveis pelo manejo da paisagem e da terra, conservação da natureza e manejo florestal. Este artigo é uma versão atualizada de "White Paper on Use of Prescribed Fire in Land Management, Nature Conservation and Forestry in Temperate-Boreal Eurasia" (Goldammer 2009).

Palavras-chave: áreas agrícolas; conservação da biodiversidade; manejo do fogo; práticas culturais.

ABSTRACT – In large parts of temperate-boreal Eurasia the use of fire, including historic slash-and-burn (shifting) agriculture and other disturbances by land cultivation have contributed to shape landscape patterns of high ecological and cultural diversity and value, e.g. heathlands, open grasslands and meadows. In the eastern Euro-Siberian biota, e.g. in the light taiga, natural fire contributed to the shaping of open and stress-resilient forest ecosystems. The rapid socio-economic changes in the past four decades and the recently increasing trend of rural exodus all over Eurasia, however, have resulted in abandonment of traditional land-use methods. With the elimination of these disturbances by cultivation, including traditional burning practices, large areas of Europe are converting to fallow lands, a process that is associated with ecological succession towards brush cover and forest, and an overall loss of open habitats. Besides the loss of valuable biodiversity the abandoned lands constitute an increase of wildfire hazard – a trend that is revealed by

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a growing number of extremely severe fire disasters. Similarly, the exclusion of fire in natural ecosystems such as northern boreal and sub-boreal coniferous forests in Eurasia has resulted in changing vegetation composition and an increase of wildfire hazard, notably in Central-Eastern Eurasia. Changing paradigms in ecology and nature conservation currently have led to reconsideration of fire-exclusion policies in certain sectors of land / landscape management, nature conservation and forestry. This paper is an updated version of the "White Paper on Use of Prescribed Fire in Land Management, Nature Conservation and Forestry in Temperate-Boreal Eurasia" of 2009 (Goldammer 2009).

Keywords: biodiversity conservation; cultural pratices; fire management; laud management.

RESUMEN – Antecedentes y justificación

En grandes zonas de clima templado en Eurasia boreal el uso del fuego, como las praticas antiguas de roza y quema en agricultura y otras perturbaciones de cultivo de la tierra han contribuido a dar forma a los patrones del paisaje de gran diversidad y valor ecológico y cultural, por ejemplo, brezales, prados abiertos y prados. En la biota eurosiberiana oriental, por ejemplo, en la taiga luz, el fuego natural contribuyó a la conformación de los ecosistemas forestales abierto y resistentes el estrés. Los cambios socioeconómicos rápidos en las últimas cuatro décadas y recientemente la tendencia cada vez mayor de éxodo rural en toda Eurasia, sin embargo, se han traducido en el abandono de los métodos tradicionales de uso del suelo. Con la eliminación de estas perturbaciones por el cultivo, incluidas las prácticas tradicionales de quema, grandes zonas de Europa se están convirtiendo en barbechos, un proceso que está asociado con la sucesión ecológica hacia la cubierta del cepillo y el bosque, y una pérdida general de hábitats abiertos. Además de la pérdida de valiosa biodiversidad, las tierras abandonadas constituyen un aumento del peligro de incendios forestales - una tendencia que se manifiesta por un número cada vez mayor de los desastres de incendios extremadamente graves. Del mismo modo, la exclusión del fuego en los ecosistemas naturales, tales como norte los bosques de coníferas boreales y sub-boreales de Eurasia, ha dado como resultado el cambio de composición de la vegetación y un aumento del peligro de incendios forestales, especialmente en Eurasia Central y del Este. El cambio de paradigmas en la conservación de la ecología y la naturaleza actualmente han hecho reconsiderar las políticas de exclusión de fuego en ciertos sectores de la gestión de la tierra / paisaje, conservación de la naturaleza y la silvicultura. Este documento es una versión actualizada del "Libro Blanco sobre el uso de quemas en el Manejo de la Tierra, Protección de la Naturaleza y Bosques Templados en Eurasia boreal" de 2009 (Goldammer 2009).

Palabras clave: areas agrícolas; conservación de la biodiversidad; manejo del fuego; prácticas culturales.

Introduction

In the landscapes of temperate-boreal Eurasia the prevailing fire regimes are shaped by human-ignited fires. Direct fire application in land-use systems and human-caused wildfires – ignited accidentally, by negligence or otherwise deliberately set – have influenced cultural and natural landscape since the beginning of land cultivation. Natural fires (fires started by lightning) are occurring all over the Eurasian region. However, only in Northern Europe and the adjoining Western and Central Asian regions natural fires constitute a significant factor, which is influencing the natural composition and dynamics of ecosystems at landscape levels.

Currently the use of fire in ecosystem management in Europe is predominantly targeting those vegetation types, which either have been shaped by human-ignited fires over historic time scales or where the application of fire reduces the vulnerability to and damages of uncontrolled fires. Fire is also used as a tool to substitute abandoned cultivation practices and for the control of wildfires. Such fire application is based on scientific evidence of the benefits of fire, is usually restricted to small areas and is referred to as "prescribed burning".

However, there is increasing awareness of the need to integrate natural fires in the concept of managing natural forest and non-forest landscapes. Large tracts of forest ecosystems of the Euro-Siberian region have been shaped by and adapted to lightning fires historically. An integration of natural and also human-caused fires in the remote landscapes of Siberia, where no infrastructures exist and access is difficult, is a demanding approach.

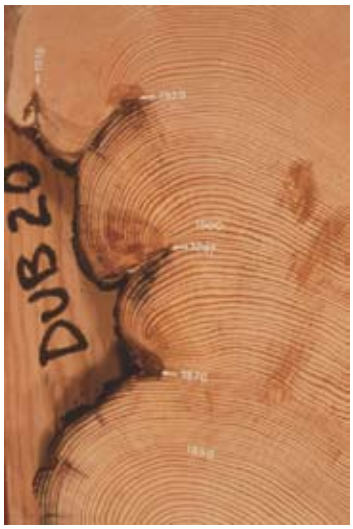
In the following broad classification of fire regimes and burning practices a number of examples of fire use in ecosystem management are provided which reflect a highly diverse range of applications.

Natural fire regimes

The integration of naturally ignited fires (by lightning) in vegetation management aims at maintaining the natural dynamics of fire-dependent or at least fire-adapted or fire-tolerant ecosystems. In North America, a continent hosting a broad range of fire-adapted ecosystems, the use or "integration" of natural fire under controlled conditions in the overall management of the ecosystems dates back to the 1960s and was referred to as "Let Burn", "Prescribed Natural Fire", and more recently "Wildland Fire Use" (van Wagtendonk 2007). In the greater European / Eurasian space the use or the management of naturally ignited wildland fire to accomplish resource management objectives is not yet developed. In Western Europe (including the Euro-Mediterranean region and the Nordic countries) the functional role of natural fire had limited impact on the evolution of ecosystem properties and thus to their future maintenance – despite the presence of remarkable adaptations to fire, e.g. in some Mediterranean ecosystems (Naveh 1975). Thus, there is a limited acceptance of allowing a naturally ignited fire to burn – even if the wildfire would burn within the "prescriptions" set by the ecosystem management plan.

However, in the Western and Central Asian region there are large tracts of forest ecosystems that have been shaped by natural fire, e.g. the pine (*Pinus* spp.) and larch (*Larix* spp.) forests that constitute the "light taiga" in Siberia and adjacent regions. In this rather extended biome there is a strong need to introduce the concept of allowing natural fires to burn, mainly in order to maintain open, fire-resilient stand structures and to reduce the risk of stand-replacement fires. Starting with the first East-West international conference "Fire in Ecosystems of Boreal Eurasia" (Goldammer & Furyaev 1996) and the Fire Research Campaign Asia-North (FIRESCAN) (FIRESCAN Science Team 1996, 2013) a dialogue with the forestry authorities of Russia (and the predecessor administration in the former Soviet Union, the State Forest Committee) has been initiated to replace the fire exclusion policy in the protected zone of the Russian Federation, Mongolia and Kazakhstan by an integrated fire management approach, which would include the use of natural fire and prescribed burning (Goldammer 2013a). Between 2008 and 2013 three major scientific-technical events have taken place in Mongolia and Russia. The First International Central Asian Wildland Fire Conference "Wildland Fires in Natural Ecosystems of the Central Asian Region: Ecology and Management Implications" was held in Mongolia in 2008 and had significant impact on the review of past approaches in forest and fire management and on the ongoing process to formulate fire management policies in the region (Byambasuren & Goldammer 2013). In 2012 and 2013 two "International Fire Management Weeks" were organized in Krasnoyarsk Region, Russia, and resulted in the formulation of recommendations for adapting the fire management policy of the country with reference to the use of prescribed fire, allowing natural wildfires to burn within prescription and to take advantage of natural regeneration processes.[1] The aspect of changing fire regimes as a consequence of climate change and land-use change has been addressed in a dedicated conference in 2013 and resulted in a strong warning to the governments of the region that the changes ahead may result in a threat by dangerous fires in future.

[1] The recommendations of the "First International Fire Management Week" (2012) are included in Goldammer (2013) and are available online with the results of the "Second International Fire Management Week" (2013):
http://www.fire.uni-freiburg.de/GlobalNetworks/BalticRegion/KrasnoyarskFireManagementWeek.html



Figures 1 and 2 – Dendrochronological analyses provide historic evidence of recurrence of natural surface fires in the "light taiga" of Siberia and thus the influence of fire in shaping the composition and dynamics of pine (*Pinus* spp.) and larch (*Larix* spp.) forest ecosystems. Photos: GFMC.

Cultural fire regimes

There are some similarities of slash-and-burn agriculture globally (Goudsblom 1992; Steensberg, 1993). Similar reasons and the involvement of similar tools and methods have been applied traditionally between the tropics and the northern boreal environments. Pollen and charcoal records in Western Europe reveal the advent of slash-and-burn agriculture in the late Neolithic between 4300 and 2300 BC (Rösch et al. 2004). Since then the historic use of fire has been manifested in the development and shaping of a variety of land-use systems in the region (Goldammer *et al*. 1997a, b; Pyne 1997). Mechanical treatment, intensive utilization of biomass for domestic purposes, the impact of domestic livestock grazing and the application of fire modified formerly forested lands to open lands and shaped distinct landscape mosaics. These open land ecosystems provided habitat requirements for a flora and fauna that otherwise is not occurring in forest ecosystems. Modern agricultural practices and the reduction of fire use due to legal restrictions or prohibitions in most European countries on the one side, and the rural exodus associated with the abandonment of traditional land management practices, including fire use, on the other side are dramatically altering these ecosystems. The rural depopulation and the rapid increase of fallow is resulting in a loss of open land ecosystems and habitats and is even resulting in an alteration of whole landscape patterns. At the same time the increasing availability of phytomass – a consequence of the decrease of its use – has resulted in an increase of fuel loads at landscape level and thus in increasing wildfire hazard.

There are a number of reasons and approaches in Europe to maintain or to restore the traditional use of fire in some ecosystems or land-use systems. These are explained below.

Restoration of traditional practices of swidden agriculture

There are a few cases in Europe where a reconstruction or restoration of abandoned slash-and-burn agriculture practices is demonstrated. These attempts have primarily a "museum" character and are serving educational purposes with a touch of landscape pattern restoration. Until the middle of the 20th Century slash-and-burn agriculture in Europe was widely practiced and involved a spatio-temporal land-use pattern similar to the traditional, small-scale "shifting cultivation" in the tropics. This system has shaped landscape features over many centuries, some

of which are still visible today, for instance the still visible small-sized burning plots with their distinct successional patterns (Goldammer *et al*. 1997). There are two regions where this kind of fire treatment is practiced for demonstration purpose:

- Koli National Park in Finland is the only national park in the world that has a fire symbol in its logo. In Koli the traditional slash-and-burn practice is demonstrated regularly and reveals the importance of this traditional land use on the composition of Finland's boreal coniferous forest that has been shaped by this cultivation over centuries (Lovén & Äänismaa 2004).
- Historic slash-and-burn practice in the Black Forest of Germany: There are two sites near Freiburg (Yach & Vorderlehengericht) where the procedure of rotational cutting and use of coppice trees, the burning of residuals, followed by seeding and harvest of wheat, with subsequent fallow and forest regrowth period, are demonstrated (Lutz 2008).

There is also a scientific interest to reconstruct earlier slash-and-burn practices, e.g. those that evolved in the late Neolithic. The most recent experiment to reconstruct Neolithic fire cultivation was conducted in 1999 in Forchtenberg, Germany (Rösch *et al.* 2002).

Figures 3 – Swidden agriculture in the Black Forest, Germany, in the late 19th Century. Source: Historic copperplate print, archive of GFMC.

Figures 4 and 5 – Demonstration traditional slash-and-burn practice. Left: Koli National Park, Finland. Right: Vorderlehengericht, Black Forest, Germany. Photos: Koli National Park and GFMC.

Maintenance of grazing lands

The use of fire in maintaining openness and species composition on grazing lands is the most common practice that has survived its early application throughout Eurasia. Pastures that are threatened by succession are traditionally burned in a region stretching from the Western Mediterranean via the Balkans to East Europe. Although banned by law in most countries, the burnings are still practiced in many places. Together with burning of agricultural residuals (c.f. section 2.4) pasture burnings are a major cause of wildfires that are also affecting forests and even the wildland-residential interface. The illegality of burning is often resulting in "hit-and-run" practices, i.e. pastoralists setting fires and disappear from the site in order not to be sued. This is often resulting in uncontrolled fires with a high likelihood of development and uncontrollable spread of devastating wildfires to adjoining terrain. While many countries did not yet attempt to introduce a solution to this problem, Spain has made significant progress by developing a government-supported permit and support system for the use of prescribed fire for grazing improvement and fire social prevention (Velez 2007). Similarly, prescribed burning for rangeland improvement is practiced by several French prescribed burning teams, including the Department Pyrénées-Orientales (Faerber 2008). For a European survey on prescribed burning practices, including grazing land management, see Lázaro (2008).

Nature conservation and biodiversity management

The major focus and activities in the use of prescribed fire in Western Europe is for the conservation and restoration of the biodiversity heritage of former cultivated lands or lands otherwise affected by human-ignited fires (habitat and biodiversity management). The range of application is rather wide, as reflected by the activities conducted in the frame of the Eurasian Network for Fire in Nature Conservation (ENFNC).[2] The following examples represent the main target systems for the application of prescribed fire:

- **Heathlands**: The composition and extent of Atlantic and continental heathlands (mainly dominated by *Calluna vulgaris*) has been shaped by grazing, cutting of heath, sod and turf layers and by burning throughout centuries. Burning is conducted in the United Kingdom (Davies *et al.* 2008; Scotland Government 2008), to a lesser extent in Southern European countries such as Portugal and Italy (Ascoli *et al*. 2009), and predominantly in Central and Northern Europe, e.g. in Denmark (Jensen 2004), the Netherlands (Vogels 2008, Bobbink *et al.* 2009), Norway (Kvamme & Kaland 2008) and Germany (e.g., Brunn 2009, Mause 2008, Goldammer *et al.* 2009, 2012). Endangered target species for habitat conservation burning include e.g. the Black Grouse (*Tetrao tetrix*) or game species such as Red Grouse (*Lagopus scoticus*).
- **Wetlands**: Maintenance of peat bogs, open fen mires, e.g. in Poland and Belarus, is practiced to maintain the habitat requirements of endangered plant and animal species, e.g. birds such as the Aquatic Warbler (*Acrocephalus paludicola*) or the Spotted Eagle (*Aquila clanga*) (Tanneberger *et al*. 2009). Moorlands in Germany that are threatened by succession are treated with prescribed fire in addition to other means such as waterlogging, tree cutting, mowing and mulching (Niemeyer 2004).

[2] http://www.fire.uni-freiburg.de/programmes/natcon/natcon.htm. See also the special issue No. 30 of UNECE/FAO International Forest Fire News at http://www.fire.uni-freiburg.de/iffn/iffn_30/content30.htm

- **Grasslands**: Similarly to the wetlands, xerothermic grasslands or *Molinia* meadows are hosting birdlife or plant species threatened by extinction, e.g. orchids, steppe grasslands plants or calcareous grasslands plants. Prescribed burning the Münsingen range in Southern Germany, a former military exercise and shooting range in which fires caused by the military had created and maintained openness for a century, is used for preserving the open habitats for endangered birds such as the Northern Wheatear (*Oenanthe oenanthe*) and the Woodlark (*Lullula arborea*).
- **Forests**: The use of prescribed fire in the restoration and maintenance of habitats of species dwelling in forests is pioneered by management in Finland and Sweden. Traditionally fire has been used in the boreal forests of the Nordic countries in order to improve growth and productivity of tree stands by removing the temperature-isolating raw humus layers or to facilitate natural forest regeneration (Viro 1974, Mälkönen & Levula 1996). Since the 1990s there are first experiments and currently extended application underway to use fire for creating forest stands under the pre-industrial conditions, i.e. more open stand structures, and to create habitats of endangered insect species (e.g. *Stephanopachys linearis* and *S. substriatus; Aradus* spp.) and wood-decaying fungi as well as habitats for vascular plants (Rydkvist 2008).

Figures 6 and 7 – Historic and contemporary use of fire in the Nordic countries. Left: Danish postcard showing a fire set in Randbøl Hede – today Randbøl Hede Nature Reserve – in the early 20th Century (Source: GFMC archive). Right: Modern farmers learning the ancient farming technique of heathland burning in Norway in 2005. Source: Kvamme & Kaland (2008), photo courtesy by A. Aalen.


Figures 8 and 9 – Structurally rich heath-juniper ecosystems with individual pine and birch trees in Lunenburg Heath Nature Park shaped by fire, grazing and mechanical treatment. Photos: R. Köpsell and J. Prüter.



Figures 10 to 12 – Control of birch and pine succession (left) in Zschornoer Heide Nature Reserve (Brandenburg State, Germany) is controlled by prescribed fire (middle and right: prescribed burning in 2002). Photos: GFMC.



Figures 13 to 15 – Post-fire views of prescribed burns in Zschornoer Heide Nature Reserve immediately after sthe burn (left) and two years after the fire. Photos: GFMC / E. Brunn.

Substitutional fire use

The use of fire as a tool to substitute or replace another form of vegetation treatment is referred to as substitutional fire use. In Central Europe there are abundant open vegetation types that were shaped by agriculture, grazing or other land use (e.g., extraction of biomass for harvesting domestic fuels, stable litter, thatching material, etc.). Some of these open land habitats have a high biodiversity or landscape conservation value. In the late 20th Century many sites threatened by succession have been maintained by mechanical (mowing, mulching, etc.) or prescribed grazing measures that were financed by public subsidies. However, increasing costs and financial constraints of public budgets on the one side, and a rapid increase of fallow on the other side during the last three decades, have prompted scientists and conservationists to replace costly mechanical and grazing measures by prescribed fire.

Fallow management on small-scale and extreme habitats

The problem of increasing fallow is not only restricted to former grazing lands. The abandonment of traditional land use is also affecting sites that have been utilized for hay production by mowing. In regions where the open grasslands have a high value for landscape aesthetics and tourism, major public subsidies have been used in the past to keep these lands open by mechanical means. However, besides the limitations due to increasing costs there are also limitations to use machinery on small-sized private property plots, on open lands on steep slopes or on sites intermixed with trees, e.g., high-conservation value xerothermic grasslands with interspersed trees. Long-term investigations in using fire to maintain openness on small-scale fallow plots in Southwest Germany were initiated and monitored since the mid-1970s (Schreiber 2004).

Another example of using fire as a substitutional tool is practiced in the viticulture region of Southwest Germany. Traditionally the xerothermic slopes between vineyard terraces in Southwest

Germany (Kaiserstuhl) were mowed by the landowners and the hay used to feed cattle. The mowing of the grass strata on the slopes was very labor intensive and could not be mechanized. Thus, with the socio-economic changes in the viticulture sector beginning in the 1950s the winegrowers abandoned the treatment of slope vegetation, which very rapidly responded by bush encroachment and succession towards tree stands – a development detrimental to the microclimate for wine growing and also not well perceived for landscape-aesthetic reasons by the local populations. Excessive use of fire to maintain openness during the 1960s did not observe the rules necessary to protect vulnerable flora and fauna, especially when burning was conducted large scale and at progressed development stages in springtime. A complete fire ban imposed by law in the 1970s resulted in progressing succession as a consequence of neglected maintenance of the xerothermic sites. Since the late 1990s a scientific research project elaborated a framework of a prescribed fire regime (Page & Goldammer 2004) which is now replacing mechanical treatment and is practiced by ecologically sound small-sized burnings during the winter period in two counties of Southwest Germany (Rietze 2008, Goldammer *et al.* 2009).

Figures 16 – Prescribed fire is used to maintain openness of fallow slopes in the Kaiserstuhl viticulture region. Fire is now replacing traditional mowing (Southwest Germany). Photo: GFMC.

The targeted application of small-sized fires for creating mosaic- or edge-rich habitat structures is common in the management endangered bird species, e.g. Black Grouse (*Tetrao tetrix*) (cf. 2.2.3), capercaillie (*Tetrao urogallus*) and Hazel Grouse (*Tetrastes bonasia*). While capercaillie habitat management by fire has been proven successful in Scottish pine-heath forests (Bruce & Servant 2004), similar approaches elsewhere in Europe were less successful. For instance, capercaillie populations increased in some sites of the Black Forest (Germany) that were disturbed by hurricane "Lothar" in 1999. Wind throws and wind falls, partially salvage-logged but with snags remaining, resulted in the formation of edge-rich habitat structures preferred by capercaillie. The populations

began to disappear with the onset of regeneration of spruce (*Picea abies*) and the development of succession towards dense forest. Small-scale, mosaic-rich prescribed burning application was intended to

- control abundant regeneration of spruce (*Picea abies*) to maintain general openness
- create vegetation-free areas (mineral soil exposed) for food search / scratching
- maintain refuge areas (small groups of young stands and thickets)
- foster berry/shrub cover, particularly black berry (*Vaccinium myrtillus*), as a key source of nutrition
- foster softwoods
- foster structural diversity through a detention of the development of closed high forests in parts of the stands
- maintain tree stumps and snags as sitting places
- maintain appropriate trees as sleeping and singing places

However, in the long run these burnings could not be implemented on a regular basis because of the prevailing moist conditions on altitudes of around 1000 m a.s.l. of the Black Forest.

Landscape management

The Middle Rhine Valley (Germany) represents a typical example of the widespread conflict between a high nature conservation value of the cultural landscape on the one hand and the abandonment of traditional land use on the other hand. The Valley constitutes one of the largest coherent xerothermic areas of Germany with habitats and vegetation types that are classified as endangered at European level. The necessity for the development of management concepts to protect this landscape was emphasized by the inscription of the Upper Middle Rhine Valley in the UNESCO World Heritage List as a protected cultural landscape in 2002 (Bonn 2004). In order to prevent further loss of the characteristic open habitats as a consequence of dramatic reduction of vine cultivation and other land use, a research and development project investigated the more or less uncontrolled ("semi-wild"), extensive grazing by horses and goats on the steep slopes, clearing the shrub-dominated shallow slopes with tank-tracks, and prescribed burning (Bonn *et al.* 2009). Prescribed burning was applied successfully during the experimental phase of the project, especially in the grass stage and earlier succession dominated by *Rubus* spp., but turned out to be limited as a tool for restoring overgrown xerothermic habitats on sites in progressed development stages dominated by *Prunus mahaleb* and *Cornus sanguinea* (Driessen *et al.* 2006).

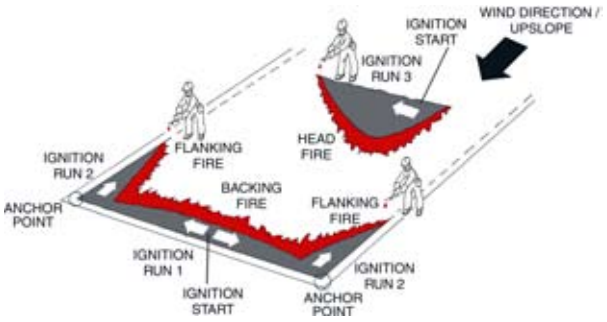
Figures 17 and 18 – The Middle Rhine cultural landscape with small-scale viticulture terraces is rapidly changing under fallow and succession. Combined grazing, mechanical and fire treatments are possible solutions for maintaining the aesthetic impressions of this unique cultural asset. Photos: S. Bonn and GFMC Archive.

There are areas where the objectives of both nature conservation and landscape management are matching and prescribed fire is used for biodiversity management and maintenance of landscape aesthetics, mainly for recreational purpose. Nature conservation sites and nature parks (national parks) hosting *Calluna* heathlands are the most prominent examples of this dual use of fire, especially in Central Europe where these protected areas are important spots for national and regional tourism. The aesthetic impression of the old cultural landscape dominated by the colorful flowering of heath is a high attraction for visitors. A prominent example of such an area is the Lunenburg heath (Germany) with the Lunenburg Heath Nature Park (area: 1130 square kilometres) and at its center the Lunenburg Heath Nature Reserve. As mentioned above, the composition and extent of Atlantic and continental heathlands (mainly dominated by *Calluna vulgaris*) historically has been shaped by grazing, cutting of heath, sod and turf layers and by burning throughout centuries. The use of fire for regeneration of over-aged heath, however, played a role as one of many disturbance agents and has now been restored successfully in Lunenburg heath (Keienburg & Prüter 2006).

Agricultural waste disposal

The use of fire in biomass waste disposal merits to be regarded at separately. While all burning objectives mentioned previously are targeting for a removal or suppression of unwanted, competitive dead or live vegetation elements – either by combustion or by the impact of heat – the removal of unused dead biomass by burning in agriculture (e.g., stubble burning after harvest) and forestry (slash / harvest residual burning after timber harvest, notably on clearcuts) aims at facilitating the growing of the next crops or the regeneration or reforestation of forest stands.

Burning of stubble fields and other agricultural crop residuals in Europe, including burning of pastures, had a long tradition, similar to other regions and continents. However, open burning in the Western part of Europe is now largely banned by law since these the burnings are a major source of wildfires and air pollution. In Eastern Europe and Central Asia, however, agricultural burning – despite legal bans in many countries – is still very widespread and constitutes one of the major areas worldwide that are burned annually (Korontzi *et al.* 2006). One of the problems associated with agricultural burning in Eastern Europe is transport of gaseous and solid emissions that are affecting human health and the atmosphere. The deposition of "black carbon" (soot) from agricultural burnings in Arctic ecosystems contributes to accelerated melting of snow and ice cover due to absorption of sunlight and decreased albedo (CTAF 2009).



Figures 19 and 21 – Training of farmers in safe, controllable agricultural burning is essential to reduce collateral damages, i.e. the escape of a fire to become an uncontrollable wildfire. The EuroFire Competency Standards are a useful training source. Source of photo and illustration: GFMC.

Burning of forest slash – the unused materials left on site after timber harvest – is still practiced in Europe, although to a decreasing extent. In the Nordic countries the main aim is site preparation for regeneration, i.e. to improve accessibility of the site for planting, including the use of machinery. Two techniques are practiced: burning on piles and broadcast burning over a larger area, usually on clearcuts with or without seed trees (particularly in the Nordic countries). At the same time slash burning is also serving to improve site conditions by reducing the raw humus layers and, as a silvicultural tool, to facilitate the germination of natural regeneration. In Russia the use of broadcast slash burning is now practiced to decrease fire hazard on logged sites and promote natural regeneration (Valendik *et al*. 2000; 2001). Also prescribed burning was used to restore forests killed at large scale by insects (Valendik *et al*. 2006). In the Mediterranean countries, burning on piles is used for eliminating tree branches and other residues after tree clearing and thinning on fuel breaks.

The recent move towards more intensive use of renewable energy is calling for the use of forest slash for bioenergy production. At medium- to long-term perspective this may result in a reduction of open forest residual burning.

Wildfire hazard reduction burning

In Europe the concept of using prescribed fire as a management tool to reduce the combustible materials on the surface inside of forest stands, and thus the energy potential and the risk of high-intensity and -severity wildfires, has a relatively short history. It was only after the pioneering work of U.S. scientists in the 1970s and the official recognition of the use of "fire by prescription" by the U.S. Forest Service in 1976 when Europeans formulated the first ideas to consider prescribed burning as a tool for wildfire hazard reduction and presented the first research. The Fire Ecology Symposia held at Freiburg University in 1977 and 1983 (Forstzoologisches Institut 1978, Goldammer 1978, 1983) and a dedicated workshop in Avignon in 1988 (INRA 1988) brought together a community that intended to investigate prescribed fire as a forest and fire management tool. First practical applications and increasingly sophisticated approaches in fundamental prescribed fire research were conducted in Southern and Central Europe starting in the late 1970s (e.g., Goldammer 1979, Delabraze & Valette 1983, Rego *et al*. 1983, Trabaud 1983, Vega *et al*. 1983). The use of fire to reduce wildfire hazard in open lands, including brush lands, namely for the creation and maintenance of fuelbreaks, then entered practice in the Southern European countries Spain, France and Portugal (Valette *et al*. 1993). In the Mediterranean part of France, prescribed burning for hazard reduction has continuously been developed and consolidated along years (Rigolot 2000, Lambert 2008). Prescribed burning for fuel reduction inside forests was practiced first in Portugal in the 1980s (Rego *et al*. 1983, Fernandes & Botelho 2004). Subsequently, in this country, its application became dormant until its recent revival in the frame of the EU Fire Paradox project.

None of the forest ecosystems in Southern and Central Europe, including the natural pine forests, are natural fire ecosystems. Thus, the introduction of prescribed fire for wildfire hazard reduction can be considered as an innovative tool, applicable only in forests with target species resilient or tolerant to low-severity surface fires, such as *Pinus* spp. or *Quercus* spp.. In some cases prescribed fire can be regarded as a substitution tool for replacing historic fuel reduction methods, e.g. the intensive use of biomass for domestic use, or silvopastoral forest use.

In the overall context of landscape ecology the use of prescribed fire on open (non-forest) lands may serve several objectives. On the one hand well-maintained open landscape fragments – either a heritage of the cultural history or strategically planned to reduce "fuel bridges" between fire-vulnerable forests or other ecosystem – allow better access, ease the control of wildfires and enhance safety for firefighting operations. On the other hand the open lands may serve as pasture or for conservation purposes.

Figures 21 to 23 – Prescribed burning inside of standing coniferous forests for wildfire hazard reduction is not yet practiced systematically in the region, although demonstrated occasionally such as here in a pine stand (*Pinus sylvestris*) in Southwest Germany in 2008. Its future application in the Western part of the Euro-Siberian region is probably less likely, whereas its application is strongly recommended in natural coniferous forests of the Central Asian region. Photos: GFMC.

Figures 24 to 26 – Training in the use of the drip torch to set a prescribed fire for creating a "black buffer zone" or to reduce flammable materials on the surface of the forests with high wildfire hazard. Boyarka Forest Research Station and Regional Eastern European Fire Monitoring Center (REEFMC), Kyiv, Ukraine (2014 and 2015). Photos: REEFMC.

Figures 27 – The main objective of prescribed fire application in the Stormyran-Lommyran nature reserve (Sweden) is to restore open stand structures and provide habitats for fire-dependent and fire-adapted species, e.g. the insect species *Stephanopachys linearis* and *S. substriatus*, *Aradus* spp.. Photo: T. Rydkvist.

Figures 28 and 29 – Joint training of professionals and local villagers in the use of prescribed fire for wildfire hazard reduction in native mountain pine forests (*Pinus sylvestris*) in northern Mongolia. The hand-over of prescribed fire by scientists to the practitioners is a high priority issue aimed at reducing destructive wildfires. Photos: GFMC.

Limitations for prescribed burning: contaminated terrains

In some Eurasian countries high-value nature conservation sites are located on former military training areas or shooting ranges. In Germany many of these areas have been used by the military since more than 100 years, others were newly created and especially used during the Cold War. The total extent of sites in Germany contaminated by Unexploded Ordnance (UXO) is ca. 700,000 ha on active and former military training and combat theater sites, i.e. 2% of Germany's land cover. Many of these military exercise areas were located on the territory of the former German Democratic Republic, used by the Soviet Army and the Warsaw Pact allies. The disturbances caused by military activities (e.g., mechanical impacts of direct shooting, fires started by shooting, mechanical impacts by tanks and other vehicles) have resulted in the creation and maintenance of valuable open ecosystems. With the closing of the exercise areas many vegetation types, notably the *Calluna vulgaris* heathlands, are becoming subjected to succession and development towards forests – a trend that is rather undesirable from the point of view of landscape and biodiversity conservation.

On these former military sites there are some obstacles for using prescribed fire as they are densely contaminated with UXO, which may explode during prescribed burning operations and also during wildfires. A new approach in the use of prescribed fire to maintain openness of UXO-contaminated terrain has been launched in 2009 in Brandenburg State in the nature conservation site "Heidehof-Golmberg" in Teltow-Flaeming County, South of Berlin. This site is classified according to the "Fauna-Flora-Habitat Directive" (FFH) of the European Commission and belong to an overall area of ca. 70,000 ha of FFH lands in Brandenburg State that are endangered by succession and loss of open habitats. The new approach is going to use armored vehicles (former combat tanks converted to fire extinguishing vehicles) to secure personnel during ignition, control of the prescribed fire and mop-up). In future it is envisaged to use aerial incendiary ignition systems to start the prescribed fires from safe distance and over large areas simultaneously, and use Unmanned Aerial Vehicles (UAV) to monitor progress and safety (Goldammer *et al*. 2009,

Goldammer 2013b). This first project of its kind reveals that prescribed burning operations under such circumstances are rather complex and costly.

Similarly there are problems on lands contaminated with UXO and land mines inherited from recent conflicts, e.g. the extended areas covered by land mines on the Balkans, notably in Croatia, Bosnia and Herzegovina and Serbia, totaling ca. 300,000 ha. Not all of these territories may be candidates for prescribed burning. In the context of wildfire prevention and control, however, the threats of explosives must be kept in mind.

Figures 30 – The use of prescribed fire in the maintenance of open habitats on former military exercise areas or shooting ranges requires special safety precautions as unexploded ordnance may detonate during the burning. Photo: GFMC.

Figures 31 to 33 – Unexploded grenades and bombs exposed after fire in Brandenburg State, East Germany (left and middle) and in the South Caucasus (Nagorno Karabakh) (right). Photos: GFMC.

Figures 34 and 35 – UAV-supported ground operations: The manned, armored ignition tank (blue) and the fire suppression tank (red-white) are directed via drone control. GFMC operations in Brandenburg State, Germany, on former military shooting ranges and WW-II combat theatres. Photos: GFMC.

Figures 37 to 39 – Use of the SPOT-55 firefighting tank, a converted T-55 with 11,000 l of fire suppressant (water, foam) operated by DiBuKa, Germany, to safely control prescribed fires or wildfires on UXO- and radioactivity-contaminated terrain. Photos: GFMC.

This refers also particularly to the terrains contaminated by radioactivity, notably in the impact zone of the fallout from the Chernobyl nuclear power plant failure in 1986. Territories most affected and contaminated by long-resident radionuclides of ^{238}Pu, $^{239+240}$Pu, ^{137}Cs and ^{90}Sr are posing a potential threat to human health and security if lifted, redistributed and newly deposited after lifted by an extremely intense wildfire and dispersed by smoke. In the most affected territories of Ukraine, Belarus and Russia the application of low-intensity prescribed fire for wildfire reduction and biodiversity conservation may be feasible but is not yet acceptable under the current psycho-social settings (Goldammer & Zibtsev 2009).

Conclusions and recommendations

This paper provides an evaluation of the state of the art and practice in the use of prescribed fire in land management, nature conservation and forestry in some cultural and natural landscapes of temperate-boreal Eurasia. It is concluded that recent research and the slowly but steadily increasing application of prescribed burning practices are experiencing a revival of fires use in the maintenance and restoration of biodiversity. However, the objectives of prescribed burning and burning methods are based on advanced insights of the ecology and impacts of fire.

The current trend of rural exodus and abandonment of land cultivation in some regions of Europe and the loss of traditional land use is leading to an alarmingly increasing rate of loss of open land habitats with its inherent biodiversity.

The maintenance and in many cases also the restoration of open land habitats by grazing, mechanical treatment and fire use is imperative if threatened biodiversity and landscape features are to be preserved. Prescribed fire may be used in those ecosystems which historically were shaped by cultural fire, or in which prescribed fire may substitute other historic land-use techniques.

A sound understanding of the "pros and cons" of prescribed fire application is necessary as well as the consideration of side effects of fire use. Large areas threatened by land abandonment are embedded in industrialized regions in which society is becoming increasingly unreceptive to smoke emissions. Legal restrictions for open burning must be understood in the context of clean-air rules and overall goal of reducing gaseous and particle emissions that are threatening human health. This perception is reinforced by hysteria of some who consider prescribed fire emissions to increase the anthropogenic "greenhouse effect" and thus global warming.

On the other side it is noted that nature conservation agencies, non-government actors and the general public meanwhile turn out to have a rather sound understanding of the natural role of fire in various ecosystems. Thus the general perception of the "nature of fire" nowadays is better as compared to the situation two to three decades ago.

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Revista Biodiversidade Brasileira – BioBrasil. 2016, n. 2.

http://www.icmbio.gov.br/revistaeletronica/index.php/BioBR/issue/view/44

Biodiversidade Brasileira é uma publicação eletrônica científica do Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) que tem como objetivo fomentar a discussão e a disseminação de experiências em conservação e manejo, com foco em unidades de conservação e espécies ameaçadas.

ISSN: 2236-2886