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Call for contributions

Readers of the International Forest Fire News are warmly invited to send written contributions to the editor at the above address. These may be in the form of concise reports on activities in wildland fire management, research, public relations campaigns, recent national legislation related to wildfire, reports from national organizations involved in fire management, publications or personal opinions (letters to the editor). Photographs (black and white) and graphs, figures and drawings (originals, not photocopies, also black and white) are also welcome.

Contributions are preferably received by e-mail.

The deadlines for submitting contributions to the bi-annual issues are: **15 May and 15 November.**

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Due of the time lag between editing and print/distribution of IFFN, readers interested in meeting announcements are kindly requested to visit the Internet version of this issue for update and short-term announcement of meetings (continuously updated) on http://www.fire.uni-freiburg.de

Preface

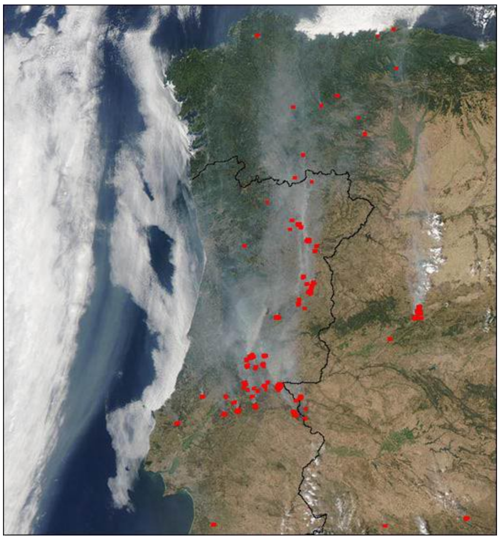
Fires are one of the major causes of ecological, social and economic damage to forests in Europe, especially southern Europe, and North America, destroying or severely damaging every year hundreds of thousands of hectares, causing major damage to property, sometimes loss of life, and often preventing the establishment of ecologically balanced and resilient ecosystems. The causes of fires are complex, with sociological, economic, climatic and forest management aspects. The importance of fire issues, and the necessity to take an international approach has been widely recognised, and there are a number of major initiatives under way, some of which are described in this issue of International Forest Fire News.

Communication between experts, and with policy makers and opinion formers is of the greatest importance to spread knowledge of the situation, its causes and possible solutions, and to promote synergies at the interagency level. UNECE and FAO, with the eight co-sponsors whose logos appear on the inside front cover, are happy to offer International Forest Fire News as a communication vehicle to the international forest fire community. Its usefulness is evident from the strong and continuously growing demand there is for IFFN.

Brigita Schmögnerová
Executive Secretary
UN Economic Commission for Europe

EDITORIAL

During the summer of 2003 in Europe much attention has been given to the extreme wildfires risk in Europe arising from the extremely hot and dry conditions between the Nordic countries and the Euro-Mediterranean region. Portugal was most severely affected by wildfires. The satellite image (below, left) shows fragments of fires burning in the South of the country in August 2003. At the end of the fire season more than 420,000 ha of Portugal's forest lands had been scarred by wildfires.

	
MODIS Satellite image showing fires burning in Portugal on 4 August 2003.	The same satellite sensor depicted smoke columns of wildfires in the United Kingdom burning on 18 April 2003.

The right satellite image shows smoke columns from forest and moorland fires burning in the United Kingdom. The country suffered extreme wildfires during the dry spring of 2003. As a consequence of these fires the formulation of a national strategy was requested by participants of a wildland fire conference convened in Aberdeen, Scotland, in 2004.

That conference also addressed other fires – the use of fire in ecosystem management, especially in the management of Scotland's moorlands (heathland ecosystems). In fact, more and more smoke columns are becoming visible all over Western and Baltic Europe that are arising from an increasing number of research and development projects which are looking at the use of prescribed fire in nature conservation and landscape management.

The focus of this special issue of IFFN is on the use of prescribed fire in the land management of western and Baltic Europe. It may sound ironic to some readers of IFFN that a majority of prescribed burning objectives is focussing on maintaining open vegetation or habitat structures, thus aiming at halting vegetation succession towards forest development. The reason for this include the fact that a large variety of open vegetation types, generated and maintained by hundreds of years of human cultural activities, are hosting valuable biodiversity and representing unique landscape features that are threatened by forest succession.

This special issue is a contribution of the European Fire in Nature Conservation Network (EFNCN) – an activity of the Global Fire Monitoring Center (GFMC) and the Global Wildland Fire Network.

- EFNCN Website: http://www.fire.uni-freiburg.de/programmes/natcon/natcon.htm

Freiburg – Geneva, October 2004

Johann G. Goldammer

PRESCRIBED BURNING IN NORTHWEST EUROPE AND THE BALTIC REGION
A Special Issue of IFFN

The Use of Prescribed Fire in the Land Management of Western and Baltic Europe An Overview

Abstract

In the history of land use in Western and Baltic Europe fire has been an important element in forestry, agriculture, hunting and pastoralism. The use of fire has shaped landscape patterns that have high ecological and cultural diversity, e.g. heathlands, open grasslands, meadows, and swidden (shifting) agriculture sites. In the Nordic countries and Scotland historic natural fires caused by lightning and human-made fires have also significantly influenced the composition and structure of forest ecosystems.

The rapid socio-economic changes in the post-World War II Europe led also to a change of land-use systems and landscape patterns, resulting in elimination of traditional burning practises. Due to new air quality standards and a generally prevailing opinion that fire would damage ecosystem stability and biodiversity, government administrations imposed fire bans in most European countries. During the second half of the 20th century traditional fire use in land management survived in a few places only, such as in heathland management in the United Kingdom or in Finland's forestry.

In the 1970s it became increasingly evident that the abandonment of traditional land-use methods resulted in the elimination of the disturbance events that shaped many valuable landscape types and ecosystems. Changing paradigms in ecology and nature conservation are leading to the reconsideration of fire-exclusion policies in certain land management sectors, including: nature conservation, hunting, forestry and landscape management. A number of prescribed burning research projects throughout Western and Baltic Europe and a revival of traditional burning practices indicate a restoration of the functional role of fire in the management of ecosystems and landscapes.

The paper provides a short overview of a number of case studies from Scotland, Germany, the Netherlands and the Nordic countries and the ongoing process of intra-regional co-operation in the frame of the European Fire in Nature Conservation Network. The individual articles in the following provide more detailed and updated information from projects.

Introduction

The landscape and habitats of Western and Baltic Europe have historically been extensively modified to increase agricultural, forestry, and hunting outputs from the land (Pyne 1997, Goldammer 1998, 2000). Fire has often been a key land management tool that has both prepared the land and maintained it in production. The landscapes of today are therefore largely cultural creations underpinned by the economic and technical capabilities of the people who managed the land. The structural diversity of these fire influenced landscapes and habitats has also allowed significant biodiversity interests to develop over time. The land management influences most closely associated with burning are mowing and grazing. Agricultural systems that involved burning were often only sustainable as long as population growth did not push practitioners towards fire return intervals that were too short to allow the vegetation to recover. When soils became impoverished political strife was often the result.

Political, economic, social and technical influences have changed burning practises over time (Pyne 1997, Bruce 2002). Initially fire was used to develop new land for production. Ancient Norse terms such as *landnam* and *swidden* described the primary development of land for agricultural purposes or for the maintenance of pastoral landscapes. Generally fire practises are part of the oral tradition of land management. Many traditional fire practises continued into the first half of the 20th century.

After World War II the threat of hunger drove agricultural policy throughout Europe towards maximising outputs. This policy drive was supported by research and training in modern agricultural systems. Forestry systems also received similar development support. This support stimulated a rapid uptake of new technology (machinery) and an increasing reliance on external inputs to production systems in the form of fuel for machinery, fertilisers, herbicides and pesticides.

Agricultural, forestry and hunting research has historically tended to avoid fire research as a subject area as it is often associated with damaging wildfires. Fire science, fire ecology and prescribed burning are therefore relatively new terms for land managers in Europe although the underlying concepts have been applied in a traditional way in some cases for thousands of years.

Figure 1. Superficial peatland burning for cultivation in Frisia (Northwest Germany) around 1900. Source: Freilichtmuseum am Kiekeberg, Harburg County, Germany.

Figure 2. Prescribed burning for regeneration of *Calluna* heather, Randbøl Hede (Denmark), around 1900. Source: GFMC Archive (postcard).

Currently both economic and quality of life issues have an increasing influence on fire practises. Due to increased productive capacity and a gradual opening up of markets and reductions in production subsidies, agriculture in Europe is in recession. Marginal land, often with remnant semi-natural vegetation, is being used less intensively or even abandoned. Similarly in forestry there is an over-supply of growing timber in Europe amounting to some 180 million m^3 per annum (UN-ECE/FAO1996). Urban populations have also driven a political desire to conserve habitats and species, to have higher air quality standards and to support the increasing use of rural areas for recreation by largely urban populations. Conversely traditional rural activities and societies have never been under more pressure and are contracting rapidly as a result. Along with the decline and changes in rural economies and societies traditional fire practises are under pressure. The new ideas embedded in prescribed burning concepts often implemented to support nature conservation and landscape management objectives are allowing fire practises to develop once more.

Traditional burning practises that are used to support hunting (grouse moor management), most evident in the United Kingdom, are also gradually changing. Empirically based fire modelling research is also being conducted in a number of countries, including the United Kingdom and Germany. Traditionally burning was often a shared activity between neighbours or it drew on other resources within land management units. There are fewer people with appropriate fire knowledge in rural areas to share the task now. The people left are generally older and less prepared to take the risks of wildfires occurring due to escapes. Insurance is becoming more expensive to obtain and so the use of fire is being constrained in many areas due to the significant resource requirements and financial costs. There is a need to increase the productivity of practitioners by implementing training initiatives and developing a professional prescribed burning skill base. Technical developments and research are also expanding the window of opportunity for burning and helping fire suppression efforts (Murgatroid 2002).

Figure 3. Slash-and-burn agriculture in Finland in the second half of the 19th Century. Painting by Eero Järnefelt (1873): “Raatajat rahanalaiset”. Exhibition of painting: Ateneum, Helsinki, Finland.

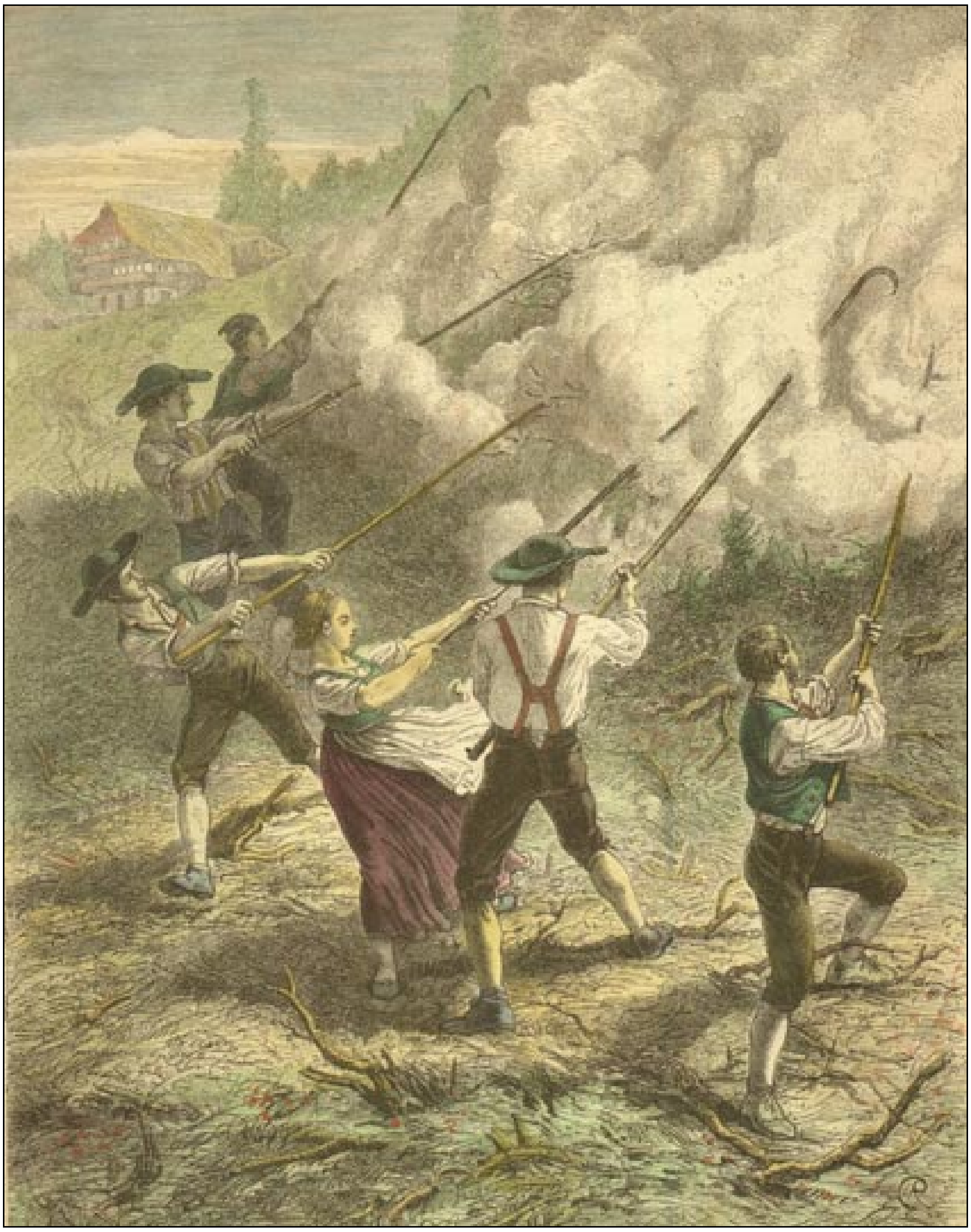


Figure 4. Slash-and-burn agriculture ("Reutebrennen") in the Black Forest, Germany, in the second half of the 19th Century. Source: GFMC archive (unknown contemporary newspaper).

It is also being increasingly recognised that both the cultural and natural heritage of many areas needs the intervention of prescribed fire to mimic disturbance events and maintain open and diverse habitats and landscapes. There are now prescribed burning projects in many of the countries of Western and Baltic Europe supporting a wide variety of land management objectives using a variety of techniques. Information on the work being carried out in the United Kingdom, Netherlands, Germany, Sweden and Finland are given later in this paper. The European Fire in Nature Conservation Network (EFNCN) website is an important focus for discussion (EFNCN 2004).

Climate, Biotypes and Fire Weather

The main climatic influences on Western Europe are latitude, distance from the Atlantic Ocean, topography and the warm oceanic current known as the Gulf Stream. In terms of fire weather the main variations are a rainfall gradient with high rainfall in the west and low rainfall in the east and a temperature gradient from low in the north to high in the south. Wind direction is predominately west to east, i.e. from the Atlantic into the drier continental landmass.

Within this general continental scale view there are regional and local variations. For example areas close to the Atlantic but east of mountain ranges or on the eastern side of islands or peninsula's have significantly lower rainfall than the more western facing mountain ranges (Bruce 2002). Also high-pressure anti-cyclonic systems do develop and create dry air conditions for significant periods. There is generally sufficient rain and warmth for vegetation to grow vigorously throughout the area.

The biotypes range from the Arctic associations in the north and at altitude through the boreal zone covering much of Scandinavia to the temperate zone in Germany. Vegetation types are also influenced by soils and other influences such as grazing regimes. Seasonal changes to fuel types also occur with significant quantities of dead fine fuels created over-winter in the form of grasses, heather and other shrub fuels. The litter layer tends to contribute to available fuels only in droughts or in the drier areas of the eastern boreal and temperate zones.

All parts of Western Europe and the Baltic area can suffer droughts. The period of drought that has an impact on fire hazards and risks depends on fuel types and sizes. So short droughts in the spring before the vegetation has started growing can create extreme fire hazards and risks in a short period of time in grass and heather areas. The effect of reduced grazing pressures creating fine fuels, seasonal curing, drought and multiple ignition sources can be seen in the significant number of large fires that occurred this spring in the United Kingdom.

A common feature of nature reserves and national parks throughout Europe is the cultural influence that man has made on these landscapes (Pyne 1997). Often these reserves are small or have been established in remote areas where soils are poor and the remaining rural populations and land use activities are weak economically, politically and socially. The land is therefore relatively cheap to acquire. Military training areas often use similar areas for similar reasons. Many of the biological and landscape features that are now desired as outputs from these areas are in some ways dependent on the preceding land management activities. The gradual loss of the traditional rural communities using traditional burning activities puts many of the conservation interests at risk as well. Prescribed fire may have an important role in maintaining at low cost some of the most important features of these landscapes.

Prescribed Fire

The Food and Agriculture Organization of the United Nations (FAO 2003) defines prescribed burning as:

> *"Controlled application of fire to vegetation in either their natural or modified state, under specified environmental conditions which allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to attain planned resource management objectives".*

Often habitats gradually atrophy with a build up of over-mature or semi-decomposed material. To maintain an area in its most productive state or to maintain a full range of species in an area may require intervention by burning. Burning is a disturbance event that allows ecological processes to change. It can be used to either maintain a larger area in a similar condition for example to aid a pastoral system or it can be used on a smaller scale to create a more diverse habitat structure.

The main land management objectives that burning can be used to support include:

- To create firebreaks
- To reduce fuel loads
- To break-in new agricultural land
- To improve grazing, especially the early bite
- To remove surface vegetation, the top litter layer and / or the encroachment of bush and trees to aid the natural regeneration of plant species endangered by succession
- To remove branches and other slash, post tree-felling and prior to re-planting
- To improve habitat mosaics for insects, birds, deer and other wildlife

- To provide a natural fertilization of the ground
- To maintain open cultural landscapes
- To preserve examples of culturally important agricultural systems

The list could easily be made longer but each of the following prescribed burning case studies are trying to achieve some or all of the above land management objectives.

United Kingdom

The United Kingdom lies mainly in the oceanic climate zone but there are elements of the sub-arctic communities at higher altitudes in Scotland along with areas in the boreal and temperate zones further south and east. Rainfall also varies significantly between the wet west and the drier east.

Traditional burning techniques are used extensively for habitat management for Red Grouse *(Lagopus lagopus scoticus)* (Miller and Watson 1973, Hudson 1992), an upland game bird that lives in heather *(Calluna vulgaris).* This use of the land developed significantly in the 19th century on the back of the incredible wealth created during the Industrial Revolution in Britain. A lot of this wealth was re-circulated back into the countryside by wealthy individuals buying estates and then managing these estates as hunting reserves. This continues to the present day. Fire is also used extensively to regenerate grazing land for cattle, sheep and deer. In forests, fire is used to clear branches or heather from sites as a ground preparation tool prior to forest establishment by planting or natural regeneration. Firebreaks are also sometimes created alongside forests by burning. Fire is used occasionally on farmland in Scotland to burn straw, a practise that has been stopped in England and Wales. Prescribed burning is used more frequently on private land than on publicly owned land (Bruce 2002). The continuous use of fire by shepherds and gamekeepers provides a continuous cultural link back to swidden practises used when the land was originally brought in to production thousands of years ago.

Fire hazards are increasing in some areas where there is insufficient heather burning. Also where new native pinewoods are being created to fulfil bio-diversity objectives, heather is growing along with the regenerating trees. Heather and grass fuel loads are increasing due to a reduction in grazing pressures caused by the rationalisation of upland farms and pressure from environmental interests and the government to reduce wild deer populations (Deer Commission 2001). The cull of animals during the outbreak of foot and mouth disease in 2002 also contributed to fuel driven fires this spring. Heather also returns to some pine and larch forests after thinning. There has also been a reduction in staff available for heather burning operations due to economic pressures (Hudson 1992). Countering the reduction in available labour resources has been a continuing investment by landowners in fire suppression equipment used for burning operations in the form of all terrain vehicles with small tanks and very high pressure low volume fire fogging systems attached (Bruce 2002).

There have been recent developments with new occupational standards (Lantra 2002) agreed both for heather burning and forest and moorland fire fighting. New best practise guidance (SEERAD 2001) has been developed to support heather burning as well. Training courses are being developed to develop the new skills that are required. Research into appropriate Fire Danger Rating systems and fire behaviour models for the United Kingdom is on-going. Recent research has shown that heather fires in Scotland can produce fire intensities up to 15,000 kW/m. Such high fire intensities have health and safety implications (Bruce and Servant 2003).

Prescribed burning to improve the habitat of the woodland grouse, the Capercaillie (*Tetrao urugallis*), has started. Areas of pinewoods where heather growth is suppressing blueberry *(Vaccinium myrtillus)* under the pine tree canopy are being burnt. Initial results indicate successful regeneration of blueberry is occurring. No pine trees were killed by initial crown scorch. A fire prescription for this work is gradually being developed using a mixture of American, Australian and European (Rheinhard and Ryan 1988, Wade 1986, AFAC 1996, Uggla 1973, Sirén 1973) material as a basis that will be interpreted along with the results of the monitoring work.

See also contribution” Prescribed Fire in a Scottish Pinewood: a Summary of Recent Research at Glen Tanar Estate, Aberdeenshire” in this issue.

Netherlands

The Netherlands lies on the border between the oceanic and temperate zones. The main interest in prescribed fire in the Netherlands is on nature reserves and military training areas. Most of the areas with semi-natural vegetation is owned by the state (Van der Ven 1973). Over 40% of semi-natural vegetation in the country is heathland. The main objectives are to conserve particular heathland plant species *(Arnica montana)*, black grouse and certain insects (Van der Zee, this volume). Burning is allowed only in the winter and is carried out in dry conditions with low wind speeds. Permission must be obtained from local communities and fire brigades prior to burning. Ignition patterns depend first on whether a deeper slower up-wind fire is desired or a faster down-wind surface fire is the aim. Fire control is maintained by burning within cut control lines and fire suppression support is given by fire brigade units provided by the military.

Germany

Germany lies mainly in the temperate zone. Dry lightning does occur occasionally (Goldammer 2000). The main natural vegetation type is deciduous woodland. However there are extensive areas of poor sandy soils where pine would have been the predominate species. It is on the poorer soils that heathland developed largely from man's historic fire interventions. These areas are becoming recolonised by secondary succession.

A few years ago burning was completely banned in Germany. Other techniques such as "Plaggen" or sod-cutting were used to conserve heathlands (Prüter et al., this volume) but these are very expensive techniques. Now a variety of prescribed burning projects are underway. These vary from heathland restoration projects where the grasses and heather are burned to maintain biodiversity, culturally important swidden agricultural sites, open areas in vineyards and open landscapes in tourism areas. A key feature of the all the projects is extensive consultation with stakeholders.

Heathland restoration work using prescribed burning is occurring at: Schleswig-Holstein (Hoffmann and Goldammer, this volume), Lower Saxony (Niemeyer, this volume), Lüneburg (Prüter et al., this volume), and at Lausitz in Brandenburg (Plettenberg et al., this volume). The latter project also has the objective of improving Black Grouse habitat. Grassland and pasture restoration using prescribed fire is occurring at Baden-Württemberg (Page 2000, Schreiber, this volume). A UNESCO World Heritage site in the Middle-Rhine Valley is also treated by prescribed burning (Bonn 2002).

In many areas on steep slopes or on poor soils where agriculture is no longer profitable, such as in Baden-Württemberg the farmland has been abandoned allowing secondary succession to scrub and forest. A number of endangered species have become threatened by this change in habitat and there is a need for secondary disturbance mechanism, such as prescribed fire.

Some long term studies such as at Diepholz in Lower Saxony have shown that prescribed burning in the winter has allowed better nutrient cycling, higher quality feed, a reduction in vegetation height that has helped birds, insects and reptiles.

The unique open landscapes of the wine growing areas in the middle of the Rhine valley, developed over centuries, are under threat from economic changes that are reducing the area of vines under cultivation. Along with this reduction of viticulture is a reduction in associated grazing. As land is laid fallow secondary succession to shrub woodland is gradually dominating this unique World Heritage Site. The species that are dependent on the open xerothermic habitats are being lost. Prescribed burning techniques are being used on the steep slopes to maintain the more open habitats. High intensity upslope fires are being used with some success.

In general the results of the projects are indicating that bio-diversity is stable or increasing after the prescribed burning interventions. They are also achieving most of their direct objectives of heathland regeneration or the maintenance of open landscapes at reasonable cost. Operationally the burns have been successful coping with a variety of fire behaviour including some high fire intensities. Other fire modelling research is being carried out.

Sweden

Sweden lies mainly in the boreal zone, with Scots Pine the main species. Fire has been a key agent shaping the structure of this largely forested country. The term for the type of traditional slash and burn agricultural system developed here was “svedjebruk” (Pyne 1997). However since the early 1800’s Swedish land use interests have been dominated by industrial forestry. The road network used to support timber extraction and efficient fire suppression systems have restricted the area of forest burnt to between 300 - 5,000 hectares per annum. In the past it is estimated that the fire return interval was 58 years when 1.7% of the forest burned annually. The level of burning today is a fraction of this (Niklasson and Granström, this volume).

The absence of fire has pushed several hundred of fire-adapted and fire-requiring species, predominantly invertebrates, from being common to being rare or even extinct in the country. A few of these species are strictly dependent on fire *per se* while the major part of this group depend on structures and processes that fire events provided in the past such as: openness and sun-exposure, dead wood, damaged trees with lowered vitality, fire scars and burnt ground. Another strongly negative effect of the combination of intensive forestry and fire suppression is the lack of seral stages dominated by deciduous trees such as *Betula, Populus* and *Salix.* The reproduction from seeds of *Populus* and *Salix* is strongly promoted by fires and is now a rather rare event. The flagship species white-backed woodpecker *Dendrocopus leucotos* is now on the verge of extinction in Sweden as it has been confined to older deciduous dominated forest, typically created by fire. Only a hundred years ago this bird was common all over the country.

Burning was used extensively between 1950 – 1970 when around 10,000 hectares was burnt annually. The objective of this burning was to prepare the forest floor for natural regeneration in areas that had been clear felled. The gradual mechanisation of the forest industry reduced labour availability and at the same time labour costs grew rapidly so the practise stopped.

More recently Swedish industrial forestry has been coming under increasing pressure both economically and from the environmental movement. The awareness about fire has increased dramatically among foresters and public but this interest has not yet been turned into action when it comes to using prescribed fire as a tool. The structures, substrates and effects of fire has influenced the design of alternative management regimes. For example. The Swedish Forestry Stewardship Council (FSC) certification scheme indicates that 5% of felled areas must now be burnt. This level of burning has not been achieved. This is largely due to a lack of practitioners, anxiety over the risk of escapes, and a lack of resources.

Fire research in Sweden is mainly concentrated in Umeå University in the north of Sweden with studies on succession, fire behaviour, fire history. plant-plant interactions ecosystem functioning and paleoecology. Uppsala University has a strong tradition in entomology. In southern Sweden, some paleoecological research has been done and fire history studies have just started along with some pilot studies in fire behaviour and flammability. A lot of the research in other fields of ecology can be ascribed to fire or has fire a common denominator.

Finland

Finland lies in the boreal zone. The landscape is dominated by pine and spruce forests. It was not always so. According to pollen analysis, slash-and-burn swidden agriculture started in eastern Finland about 2000 years ago. It was estimated that about 4,000,000 hectares of forest land was affected by the slash-and-burn agriculture by the end of 19^{th} century. By the beginning of the 20th century, some 50 to 75 percent of Finland's forest area had been exploited in this manner. In the eastern part of Finland, shifting cultivation was practised longer and more intensively than anywhere else in the country. Industrial forestry however became increasingly important and in the 1929 burning was restricted (Sirén 1973, Goldammer 1998).

With the end of the era of shifting cultivation in the early part of this century, methods derived from this practice began to find use in the regeneration of under-productive forests. Burning of logging waste and the raw humus layer was recommended as a means of promoting the natural restocking of regeneration sites. Broadcast-seeding-on-snow in spring, with prescribed burning preceding it, found widespread use in the 1920s. Prescribed burning in those times amounted to approx. 8,000 ha per year. With time, however, this method's popularity declined; in the 1930s, the annual area burnt in this manner was only a few hundred hectares a year.

Prescribed burning enjoyed a comeback after World War II and the peak of over 30,000 ha was reached in the mid-1950s. This was because the displacement of people from areas of Karelia annexed by the Soviet Union, created a need for new farmland to be created. It was also useful in assisting with the regeneration of northern Finland's spruce stands to pine, characterised by their thick layer of raw humus. However, this prescribed burning's second coming came to an end in the latter half of the 1960s when it was replaced by mechanized site preparation. The area annually treated fell to 500-1000 ha a year and stayed at that level up to the recent past.

The reasons behind the decline in prescribed burning have primarily been technical. The success of prescribed burning depends on weather conditions and this leads to difficulties in organising the operation. The risk of fire getting out of control, the increasing popularity of mechanised site preparation, the risk of nutrients being leached from the soil, and the increased risk for fungal or insect epidemics in the dense young pine stands are the most common forest regeneration problems associated with prescribed burning.

The cultural importance of burning in Finland is very significant (Pyne 1997). The eastern part of Finland was one of the last areas where the slash-and-burn agriculture was carried out in Europe. The Koli National Park in eastern Finland was established in 1991 where there are still many deciduous mixed forests and slash-and-burn meadows (in Finnish: aho) on burned sites in the park. In addition, there are stone constructions related to slash-and-burn culture still visible in the old slash-and-burn sites (Lovén and Ääismaa, this volume).

Since the year 1994, every year a small area ranging from 0.3 to 2.5 ha of forest has been cut down and traditionally burned and cultivated to maintain the cultural tradition. Other objectives include creating a better habitat for endangered species that require fire sites and meadow sites. There is also an extensive information programme for the project. So far more than 5 hectares has been managed by the slash-and-burn activities. In the future, the slash-and-burn activities will be extended in the national park using up to 150 hectares. Constraints on the prescribed fire activities include the conservation of old growth forest, mixed forests with high bio-diversity, distance from heritage dwellings and the resources required for burning operations. Another goal is to make it possible to practise different slash-and-burn methods with local people to maintain the cultural heritage and to avoid political controversies extensive consultations have been made with stakeholders.

Discussion

It is said that the seeds of failure are sown in success and the swings in the use of fire in land management in Western and Baltic Europe have been significant. There have been periods when fire has been used skilfully and sustainably. There have been other periods, when often due to excessive population growth, fire has been used too intensively and ecological damage has resulted.

The rise of “rational“ thinking in the Enlightenment from the 18th century led to an emphasis on manurial systems rather than fire based systems of agricultural fertilisation in most of Europe. Fire was regarded at best as a necessary evil. The rise of input dominated production systems further drew land management away from the use of fire except in pastoral or hunting areas. Some use of prescribed fire continued as part of forestry practise. Politically fire was not popular. The potentially positive ecological value of fire was rarely considered.

There has also always been an economic and a technical influence on the use of fire. It has a cost and it has extensive risks. In some places it has a positive influence and in other situations a negative influence. With the upsurge in interest in heritage issues, both ecological and cultural, over the last 30 years there has been a gradual re-evaluation of the role of fire. Sometimes this has produced a constraining influence such as in the production of Best Practise Guidance in the United Kingdom. In other parts of Western and Baltic Europe where the use of fire had all but died out some of the positive uses of fire are being re-established. A key difference in approach from the past are the extensive consultations that are carried out with stakeholders, especially environmental organisations, at different levels in society.

Practical safety issues relating to the build up of fuel loads, especially fine fuel loads, have yet to be addressed by policy makers. There will always be ignition sources and this leads to significant fire seasons occurring when there are droughts such as happened in the spring of 2003 in the United Kingdom.

Conclusions

The history of the use of fire in land management provokes mixed reactions, usually a negative one, from people who are not closely associated with the need for fire. The development of the full panoply of support systems for prescribed burning such as: fire ecology, fire science, fire models, fire danger rating systems and modern fire suppression systems has been slower than in more fire prone and fire adapted parts of the world such as Australia, the USA and Canada but progress is now being made.

Prescribed fire is developing a new language and framework that will support a better dialogue between stakeholders and a more targeted use of fire in the management of land in many parts of Western and Baltic Europe. The key benefits of the developing European Fire in Nature Conservation Network is the improvement in communication between people managing similar bio-types in similar climates bridging the old barriers of language and culture. The improved dialogue and the new prescribed fire projects will also help to inform policy makers about the factors that influence fire behaviour and consequent fire effects. Thereby hopefully leading to the creation of a more sustainable policy framework for prescribed fire in Western and Baltic Europe.

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DENMARK

Restoration of Dune Habitats along the Danish West Coast

Project objectives

The project aims at restoring threatened and vulnerable coastal dunes and dune heathlands along the Danish West Coast, in order to regain a favourable conservation status. The sites included in this project fall under the Natura 2000 network of protected areas, and cover an area of more than 24,000 ha. The sites are mainly selected for the priority habitat types 2130 (fixed grey dunes) and 2140 (decalcified fixed dunes with *Empetrum nigrum*). The project started in November 2001 and continues to November 2005. It is supported by the European Commission LIFE NATURE- programme.

The main threats to the dune habitats are invasion of non-native species, lack of natural dynamic processes, and eutrophication. The species invading the dune heaths are mainly *Pinus mugo* and *Pinus contorta*. The trees are spreading from the dune plantations established along the Danish West Coast more than 100 years ago. The encroachment of these and other woody species alters the microclimate and hence the conditions for the native biodiversity in the dune heaths. Dense overgrowth and tree encroachment will be removed and dune heath habitats restored on a total of approximately 5700 ha. Furthermore, some of the *Pinus mugo* plantations on the fringes of the dune habitats will be converted back to their original heathland condition.

One of the means of re-establishing natural dynamic processes is restoration of the natural hydrology, by closing drainage dykes and allowing temporary pools and shallow lakes to expand. This is also of great value to the amphibian fauna, and an important component of the project is restoration of 30 breeding localities for amphibians, primarily *Bufo calamita*.

The lack of natural dynamic processes is also sought compensated for by controlled mosaic burning and grazing of the dune heaths. The burnings take place in early spring (February and March), in order to minimise the disturbance to wildlife, and are restricted to small areas (0.2-2 ha) at a time. Typically, areas with old *Calluna vulgaris* and dominated by *Empetrum nigrum* are selected.

The aim is to imitate the natural conditions to which the species of this nature type are adapted, by creating better conditions for the pioneer species and assisting the natural regeneration of characteristic species such as *Calluna vulgaris*. Burning small, interspersed areas at long intervals ensure a mosaic of succession stages and prevent large areas of very uniform dune heath. This is also of great value to the fauna. Cutting and removal of overgrowth is, along with introduction of grazing, a means to counter the ammonium deposition from the atmosphere, which leads to eutrophication of the dune heaths.

The project also has an important element of public information and dissemination. Map tables and information plates are placed on parking lots and other sites in the project area, in order to provide the public with updated information and a better understanding of the nature restoration activities in the area.

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Visual Impressions of Prescribed Burning in Dune Heath, Denmark

Figure 1. Prescribed burning of dune heath. Great care is taken to take advantage of the topography and wet areas. Photo: Danish Forest and Nature Agency

Figure 2. The overgrown areas are cleared mechanically or manually, and will eventually be included in the burning rotation in order to prevent new overgrowth. Photo: Danish Forest and Nature Agency.

FINLAND

Planning of the Sustainable Slash-and-Burn Cultivation Programme in Koli National Park

1. Preface

The ancient slash-and-burn cultivation has played a very important role in the history of human life and the human impact on forest ecosystems in Finland. According to pollen analysis, slash-and-burn agriculture started in eastern Finland about 2000 years ago. About 4,000,000 hectares of forest land had been estimated to be affected by the slash-and-burn agriculture by the end of 20th century (Heikinheimo 1915).

Although the slash-and-burn agriculture diminished at the end of 19th century and stopped totally during the 1940s, many signs of the slash-and-burn activities can still be found in Finland's forests. Eastern Finland was one of the last relict areas where the slash-and-burn agriculture was kept alive in Europe. In Koli National Park, there are still many deciduous mixed forests and slash-and-burn meadows (in Finnish: *aho*) which are standing on previously burned sites. In addition, there are stone constructions related to slash-and-burn culture still visible in the old slash-and-burn sites.

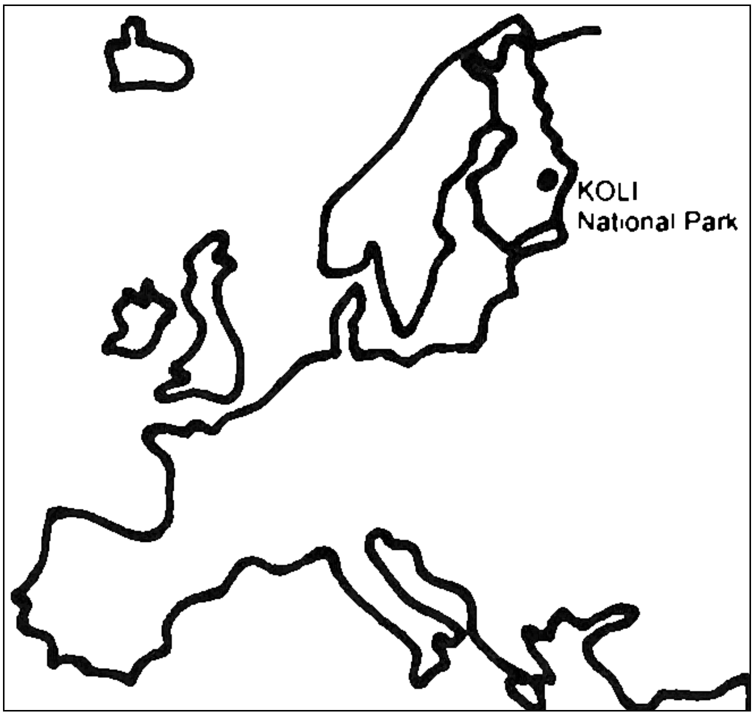

Figure 1. Study area: Koli National Park in eastern Finland.

Koli National Park was established in 1991. At that time, the restoration of slash-and-burn culture and landscapes created by the slash-and-burn agriculture was identified as one of the main tasks of the national park. This mission was designated by the Finnish parliament in the form of law. Since the year 1994, every year a small area ranging from 0.3 to 2.5 ha of forest has been cut down and burned and cultivated according to the traditional methods. So far more than 5 hectares have been managed by the slash-and-burn practices. In the future, the slash-and-burn activities will be extended in the national park to up to 150 hectares.

2. Objectives of the study

The objective of the study is to analyse the dimensions of sustainability in the slash-and-burn agriculture and to produce information for making long term strategic decisions on the slash-and-burn cultivation. The aim of the study is also to identify possible criteria for the social sustainability approach in connection to the slash-and-burn agriculture and the interest of different groups of stakeholders of the national park. The operative outcome of the study will be a plan including sustainable slash-and-burn programmes for two heritage farms in the park for the next 50 years.

3. Methods

3.1 Introduction

Information on the detailed goals for the slash-and-burn programme and the economical, ecological and social impacts of the management is insufficient at the beginning of the project. However, more information would be gained during the project by data analyses and goal surveys. Consequently, a heuristic dynamic planning approach is used in this study. The basic principles of the planning method are: holistic thinking, openness for changes, selection of the forests suitable for slash-and-burn agriculture according the biological, social and economical criteria in co-operation with the interest groups, the simulation of development of forests for the whole management cycle during the planning process and stepwise selection of the forests which will be managed by the slash-and-burn activities operatively every year.

3.2 Steps of the planning method

3.2.1 Goal surveys

A master plan for the next ten years has been prepared by a steering committee in Koli National Park. The steering committee is represented by all important interest groups of the national park. At the beginning of developing the project master plan opinions and objectives concerning slash-and-burn management were identified by a questionnaire.

3.2.2 Identification of the borders of slash-and-burn zones

The steering committee defined two special land use management zones; the natural zone and the cultural zone. The slash-and-burn activities will be done mainly inside the boarders of the cultural zone. The potential sites for slash and burn were defined on the basis of information concerning the land-use history, soil properties, the location of special key biotopes and old-growth forests and the location of old heritage farms, which will act as information and education centres for the local back-forest peasant heritage.

3.2.3 Selection of forests suitable for slash-and-burn cultivation

During the 19th century (actual slash-and-burn time) the slash-and-burn sites were selected according to their distance to the dwellings and their capacity to produce crops. In addition, it was important to consider the properties of the forest, which affected to the workload needed for the slash-and-burn activities.

Today the motives are totally different. The crops are not most important products of the slash-and-burn cultivation anymore. Today it is more important to produce heritage in landscape, environment for endangered fire- and meadows-oriented species, and information on cultural heritage for pupils, students and tourists, for instance. This is why the steering committee evaluated different qualities of forests in order to find the best selection for the forests for slash-and-burn cultivation. The qualities were related to slash-and-burn history (gained from past inventories), topography, soil, age of the forests, and location in relation to heritage dwellings and lakes. At this step the costs of the slash-and-burn activities or the volume of the forest timber were not yet involved in the planning.

Since the slash-and-burn cultivation requires a lot of resources, it was clear that only small part of the national park can be managed by using this activity. Thus, only the areas inside the cultural zone and some man-made forests on the natural zone were selected to the further planning.

The answers of the steering committee were guiding the planning process; the unfavourable sites, like high priority old growth forests and mixed forests with high biodiversity, were excluded completely from the further planning process. Further, a special rank-value for every site was calculated according to the goals and their importance expressed by the steering committee. The ranking scale was between 0 to 12. All stands which had better value than 5 were selected to the next step of the planning process, which gave up about 200 hectares more or less favourable sites for management.

Figure 2. Fire in a slash-and-burn in Koli National Park in 1994. Photo: Metla – Ismo Hyttinen

3.2.4 Planning of the sustainable slash-and-burn programme

The slash-and-burn agriculture requires a lot of work and other resources. The market value of timber and labour can be taken into account when calculating the total financial consequences of the slash-and-burn programme and the optimal schedule for management activities.

The goal of Koli National Park management is to develop a slash-and-burn programme which will not have any negative consequences for national park's biodiversity (ecological sustainability). Another goal was to make it possible to practise different slash-and-burn methods continuously in co-operation with the local people (social sustainability). Under these restrictions, the slash-and-burn programme should be financially as cost-effective as possible.

In order to analyse the economical results of different slash-and-burn programmes, a special calculation system was created. The name of the systems is KALA and it is based on the Excel programme. The KALA calculates the year when the forest can be technically and economically burned. The forest must contain a certain amount of biomass (about 60-80 m^3/ha) to produce ash in fire until it is ripe to be burned. The system produces also a suggestion on the method which could be used on slash-and-burn of a certain forest. In addition, the system calculates how much timber could be taken out from the slash-and-burn site for some other economical use. Finally KALA calculates the margin profit and the net present value of the slash-and-burn programme.

Figure 3. Rye grows in the ash and humus mixture of boreal spruce (*Picea abies*) forest after slash and burn in Koli National Park in 1999. Photo: Metla – Lasse Loven.

3.3 Preliminary results

The aim of the study was to create a slash-and-burn programme for Koli National Park for the next 50 years with 5 sub-periods in 10 years intervals. The selection of the stands was made in the middle of each sub-period. The development of the forests was simulated to the middle of each sub-period by a forest stand simulator called METKA. After simulations, the simulated data was transformed into KALA-system. The final selection of sites, which had ecologically and socially equal and favourable potential for slash-and-burn, was made on basis of the margin profit (positive or negative) criteria.

The KALA-system calculates different parameters concerning the management programmes. They include area of the slash-and-burn programme, volume of the stands, costs and incomes of the programme, net present value of the programme etc. By comparison of two separate programmes it is possible to draw conclusion about the facts which affect the profitability of the programme, for instance. In addition, the slash-and-burn programmes will be visually analysed by using the MapInfo 6.0 programme. Finally, the areas which will be under continuous slash-and-burn rotation and the areas which will only once be burned will be identified.

4. Discussion

The planning of sustainable slash-and-burn programme is very challenging planning problem. The national parks have many tasks, some of which are exclusive. The method used in this study can not create a fully optimal comprehensive management programmes, but it offers many advantages. First, the programme created by this method takes into account the goals and objectives of the most important interest groups of the national park. Second, it pays attention both the ecological, economical and social dimensions of sustainability. The ecological aspects are playing most important role, since the most of the forests were excluded from the programme due to ecological reasons. Participatory planning was part of social sustainability. The economical aspects were taken into account when choosing the final program after the ecological and social criteria were fulfilled.

The sustainable slash-and-burn plan shall be tested in the practical operations in Koli National Park during next 50 years. The environmental effects of the management, like the impact on flora, insects, fungi and soil shall be monitored and reported. The ancient swidden fires have returned as a living heritage to the boreal forests-hill landscape of in Koli National Park, Finland.

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Forest Fire Research in Finland

Effective wildfire suppression and diminished use of prescribed burning in forestry has clearly eliminated the role of fire in Finnish forest ecosystems as compared to pristine stands. The reintroduction of fire back to nature has therefore been suggested in various instructions, forest certification and forest conservation programmes. At the same time it is recognized that possible climate change might cause increased fire risk also in Finland in the future. Various interests to fire have led to remarkably increased fire research activities in recent years. Several national research organisations, Universities, Polytechnic schools and Ministry of Interior are working together with landowners, forest companies and other end-users despite of sometimes contradictory aims. At the same time, possibilities to fire prevention and minimizing fire risks and reintroduction of fire because of biodiversity aspects are being studied. The overall aim is to help in creating national fire use strategy and aim to controlled use of fire. This is a task that should be recognized also at European level. This overlook describes briefly part of the ongoing fire research in Finland that is connected to European level fire research.

Introduction

Considering the role of fire in Finnish ecosystems, different era's in the past can be distinguished, and over the last hundred years there has been a drastic decline of area burned in Finnish forests. In pristine forests number of fires was probably lower than today, but their size was on an average higher. Humans have affected the forests in southern Finland for at least 4000 years, and today practically all forests in Finland have been affected by human utilization. Increased population and forest utilization increased also fire frequency. Human impact and especially several centuries lasting slash-and-burn cultivation further increased fire frequency as compared to pristine forests. Between 1865-1870, up to 55,000 to 70,000 hectares (ha) burned annually with the average forest fire size being 131 ha (Saari 1923). By the beginning of the 20th century slash-and-burn cultivation was finally denied. The annually burned area remained, however, up to 40,000 ha/yr until the end of the 1960s, when clear change especially in state owned forests can be seen (Figure 1).

This change was caused e.g. by the use of prescribed burning which started to be used in the beginning of 20th century to enhance forest regeneration. Prescribed burning now replaced the era of slash-and-burn cultivation in keeping the fire in nature. The golden era of prescribed burning, when annually 30,000 ha could be burned, lasted until 1960s, when mechanical site preparation replaced it (Figure 2).

After the Second World War, the structure of Finnish forests was shaped by intensive forest management, aiming to efficient timber production. Forest management, using compartments of 1-100 ha as basic operational units, aimed at fully utilizing the sites' wood production potential by converting naturally heterogeneous stands to homogeneous even-aged single-species stands using clear-cut harvesting and silvicultural treatments such as thinning and planting. At landscape level the management goal was a fully regulated even-aged forest, where each stand age class covers an equal area. This led to a mosaic of even-aged forest stands with extensive road network for forest utilization. E.g. in southern Finland's managed forests there is currently only on average 2 m^3/ha of coarse woody debris (CWD), while in natural forests there is 60-90 m^3/ha. This means that the average volume of CWD has decreased by 90-98%. A steep decline in annual area burned happened in 1960s and 1970s when both wildfire and prescribed burning areas dropped significantly. Even-aged stands with low levels of fuel, fragmented forests together and more developed fire suppression tools, changes in legislation and people's attitudes etc. led to a situation where the role of fire and other natural disturbance processes were nearly totally eliminated from Finnish forests. Currently around 500 hectares is burned annually in wildfires and 2 000 hectares in prescribed fires with the average size of one fire being less than one hectare (Finnish Forest Research Institute 2004).

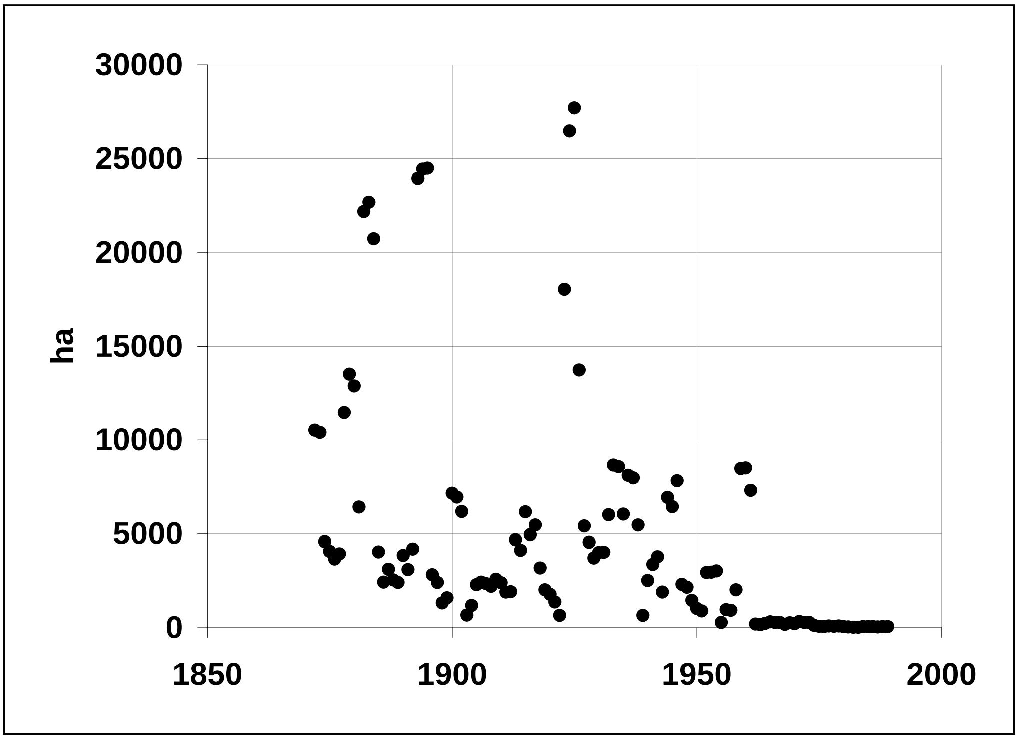

Figure 1. Annually burned area in state owned forests. Source: Forest and Park Service, Suvanto 2004

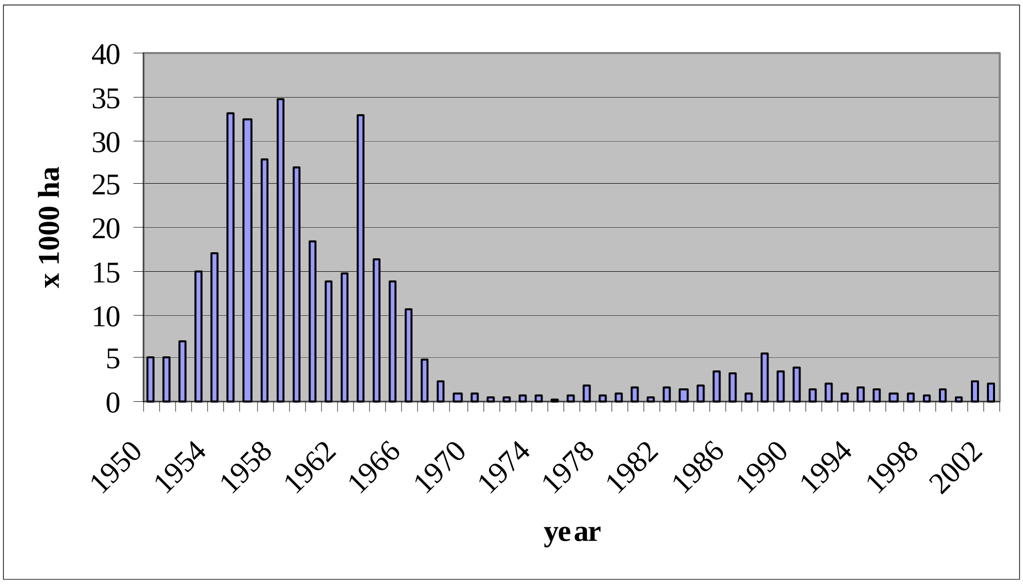

Figure 2. The annual area of prescribed burnings in Finland between 1950-2002 (Finnish Forest Research Institute. 2004, Lindberg and Vanha-Majamaa 2004).

Various ways to reintroduce fire back to nature?

The use of fire in restoration aims to imitate a forest fire disturbance with a natural regeneration and succession after that. Restoration burnings are usually understood as burnings most often in conservation areas. In the last five years restoration burnings have begun to establish a status of “normal” method, and although there are no national statistics available, the areas have increased recently to about 100 hectares annually, while the total area of all restoration burnings performed is estimated to be still only a couple of hundreds of hectares. In the future there is a national goal to burn about 1 300 hectares in next ten years (Working group...2003), the amount still being rather low.

Occasionally a question has also been raised if in certain conditions existing forest fires could be let to burn under control. This could be done especially in conservation areas so natural disturbances could shape the landscape and forest structure as in natural fire regimes. Practical safety issues and interpretation of legislation have prevented the possible use of this kind policy and the attitudes of rescue authorities are still very suspicious so it is very unlikely that a *let burn policy* will be introduced in Finland in the near future.

It has also been suggested that especially larger forest fire areas should be purchased to conservation areas so that larger-scale post disturbance areas with natural succession could be created. In state-owned forests this has been possible to do in a few occasions, but otherwise this kind of acts have been rare. Also new more voluntary-based methods of maintaining biodiversity are introduced, such as land owner being able voluntarily suggest fire areas to be purchased for conservation either permanently or for a fixed time, but these acts have also been very rare. Finally, increase in prescribed burning area has been suggested and even promoted in many programmes, but no increase can yet be seen (Finnish Forest Research Institute 2004).

Consequently, entire ecosystems have been modified and the changes have not always been favourable to all forest species. Some species are directly threatened by the elimination of fire, but even species that are relatively common have been affected by altered site conditions and stand structures. In the future, however, possible climate changes may cause increased fire risk. There has been a clear need to develop fire research in order to be able to answer several different aspects concerning fire and aim to controlled fire use.

Current research activities

During the last two years 65 forest stands and sample plots have been burned for research purposes in Southern and Northern Finland. Half of the burning experiments are connected to a restoration experiment, in which effects of logging and prescribed burning as tools to maintain and restore biodiversity are being studied. Another part of the experiment is connected to a study where fire behavior in different vegetation types and forest structures is being studied. In this part the goal is finally to develop fuel type and fire risk classification of Finnish forests. The national team includes Finnish Forest Research Institute (FFRI), Ministry of Interior, Helsinki and Jyväskylä University, Finnish Meteorological Institute, VTT, Geological Survey of Finland, Environmental Agency, Häme and Seinäjoki Polytechnic schools, and as land-owners besides FFRI, Forest and Park Service, UPM-Kymmene and City of Hämeenlinna.

When studying fire behavior in different vegetation types, we have burned 30x30 meter plots in different vegetation types and forest structure from clear-felled areas to mature forest with three replicates each (Figure 3). Studied forests include stands dominated by Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and birch (*Betula pubescens, B. pendula*).

During the fire event, fire spread, flame length and weather conditions have been measured (Figure 4). After fire, various fire effects, such as tree mortality, changes in the soil and vegetation etc. have been studied. With these experimental burnings research tasks are generally various and research aims finally to create fuel type classification of Finnish forests, description of fire behavior in different vegetation types, develop Finnish fire risk index & forest fire risk assessment. In connection to this, e.g. FMC measurements and flammability tests with different materials have been carried out. The collected information will be finally also used in developing prescribed burning and restoration methods and techniques.

Figure 3. Ignition of the experimental fire in a *Pinus sylvestris* stand.

Figure 4. Recording of fire behaviour parameters during the fire experiment

In order to study the usability of fire as a restoration tool, we located a logging and prescribed burning experiment in Norway spruce-dominated mature managed forest stands, described as mesic-site type in stand characteristics (Figures 5 and 6). However, each stand included a paludified patch. These depressions are common in mesic forests though they are not normally distinguished in stand characteristics. In small-sized wet depressions (paludified patches) e.g. species composition, the basal area of aspen (*Populus tremula*, rich in epixylic species and therefore important species for biodiversity) and the amount of CWD are often highest. Since these wet depressions are likely not to burn as easily as dry areas, we hypothesized that small-scale site type variation in combination with fire play an important role in restoring structures, dynamics and species in these mesic sites.

Stands (1-3 ha) have been treated with shelterwood cuttings (50 m^3 ha^{-1} of standing retention trees) and three levels of down retention trees (5, 30, and 50 m^3 ha^{-1}) to create woody debris, as well as with prescribed burning or no burning. In addition, control stands, where all trees were left standing were included. Each of the combination of treatments was replicated 3 times, for a total of 24 stands. Within each stand, sample quadrates (20 $\times$ 40 m) were randomly selected, avoiding edge effects, on wet and dry biotopes, for a total of 48 sample quadrates.

With the restoration experiment the main task is to study ecological impacts of fire and compare the results to effects of logging. We are concentrating on studies on stand structure and tree mortality, regeneration of the tree stand and the effects of different microhabitats on regeneration, succession of ground and field layer vegetation, changes in humus and soil, effects of logging and fire on epixylic lichens and bryophytes growing on coarse woody debris, colonization of epixylic species after disturbance, effects of fire on invertebrates, CWD dynamics and polypores, functional groups of microbes and effects of fire on them etc.

Some of the study areas, such as those for restoration studies, are guaranteed for research for the next 20-30 years with the land-owners. Follow-up studies will therefore be able to be done for a long period.

Figure 5. Logging and prescribed burning experiment in Norway a spruce-dominated mature managed forest stand

Figure 6. Restoration burn in a spruce-dominated mature managed forest stand

Table 1. Treatments in the restoration experiment (DR = Down retention, SR = Standing retention)

	Burn	Replicates	Unburn	Replicates
Treatment 1. & 2.	$5m^3$/ha DR $60m^3$/haSR	3	$5m^3$/ha DR $60m^3$/haSR	3
Treatment 3. & 4.	$30m^3$/ha DR $60m^3$/haSR	3	$30m^3$/ha DR $60m^3$/haSR	3
Treatment 5. & 6.	$60m^3$/ha DR $60m^3$/haSR	3	$60m^3$/ha DR $60m^3$/haSR	3
Control	No cuttings	3	No cuttings	3

Total 24 forest stands

National fire research is currently also part of larger European fire research, as we are participating to two European funded fire projects. SPREAD (Forest Fire Spread Prevention and Mitigation) is concentrating on studying various aspects of fire. EUFIRELAB (Euro-Mediterranean Wildland Fire Laboratory), is a wall-less Laboratory for Wildland Fire Sciences and Technologies in the Euro-Mediterranean Region and serving as a coordinating project among European fire researchers and end-users.

General goal is to find tools, especially in the Mediterranean, for minimizing fire risk, but especially in the Boreal, to study reintroducing fire back to forest ecosystems, final aim being controlled fire use strategy.

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GERMANY

Re-establishment of Traditional Heathland Management Tools in the Federal Forest Service District Lausitz, Brandenburg State, Germany

Historical land management tools to preserve more than 100 ha of *Calluna vulgaris* (L.) Hull heathlands are currently reintroduced in Brandenburg State, Germany. The Federal Forest Service (FFS), in collaboration with the Fire Ecology Research Group / Global Fire Monitoring Center (GFMC), restored the traditional technique of prescribed burning as a landscape and habitat management tool.

The heathlands are located in a former Air Force bombing range of the German Democratic Republic. Training activities over more than two decades caused frequent fires which had a positive effect on the establishment of the *Calluna* heathland. The termination of military activities in 1989 required the development of new management tools to maintain this unique ecosystem. The FFS up to date had successfully applied mowing for short-term regeneration of heather. However, in the long run mowing as sole management tool proved insufficient to encourage *Calluna vulgaris* to propagate. For this reason the FFS decided in 2002 to employ prescribed burning as an additional management technique.

In February and late August 2002 the FFS District Lausitz, technically implemented by the GFMC and in collaboration with the local fire brigade of Döbern, conducted several burns, each not bigger than half a hectare. Focus of the FFS was the development of a cost effective management tool for the maintenance and improvement of Heathland ecosystems and habitat for Black Grouse (*Tetrao tetrix* L.). The aim of the GFMC was to promote the use of prescribed burning in land management in the Baltic Region. The project is also contributing to the development of a decision support system for catastrophic wildland fire events, a project conducted by the GFMC in the frame of the German Research Network for Natural Disasters.

With these projects the FFS District Lausitz has taken a lead role in advancing fire knowledge of German forest ecosystems, both in terms of wildfire control in the pinewood/heathland interface and in the controlled use of fire as a landscape management tool.

The project has shown that it is possible, both in operational and in ecological terms, to use prescribed fires with varying intensities to modify the *Calluna* structure, to suppress succession and improve Black Grouse habitat. The fires successfully simulated natural and human-made disturbance events. All fires burned within the prescription.

Plot Survey – October 2004

Evaluation of the areas burned in 2003 and 2004 showed very promising results in terms of *Calluna* regeneration and in eliminating tree and bush succession, particularly birch (*Betula pendula*). However, the areas burned in summer 2003 showed a wide variety of response to fire concerning the response of birch. On one plot (No. II) 70% of the total number of birch trees affected by fire re-sprouted, while nearly all tress were killed on a plot nearby (No. III) – a phenomenon that can be explained by different conditions of micro-relief and water availability. *Calluna* regeneration was good on both plots.

In contrast, in the late winter-burn areas the tree succession was well suppressed on all plots. *Calluna* regeneration on all plots was exceptionally good.

The last survey of the experimental plots I-IV was conducted in October 2004. New sub-plots were established in addition to the sub-plots that were already used for a Diploma thesis (Casper 2003). The sub-plots were 20 m^2 in size. Numbers per burned area (plot) vary according to different area sizes. In the sub-plots all trees (dead and alive) were counted as well as all *Calluna* plants. The numbers displayed in the tables are % that is alive and resprouting.

The sub-plots were situated in and around the center of the burned area to avoid edge effects, where the fire was not yet fully developed. Small trees that were consumed fully by the fire were not counted in this survey.

It was not possible to determine what type of fire burned on each sub-plot. For the summer fires we assume head fires, whereas the winter fires burned mainly as flank fires.

Table 1. Survey October 2004 – *Calluna* regeneration and birch survival

Plot I (Winter Burn 2001/2002)		
	Sub-Plots	
	A	**B**
Calluna regeneration (resprout, %)	99%	86%
Birch survival (resprout, %)	32%	12%
Calluna seedlings (number)	< 15	> 25

Table 2. Survey October 2004 – *Calluna* regeneration and birch survival

Plot II (Summer Burn 2002)				
	Sub-Plots			
	A	**B**	**C**	**D**
Calluna regeneration (resprout, %)	21%	16%	52%	42%
Birch survival (resprout, %)	88%	92%	93%	90%
Calluna seedlings (number)	0	<15	0	0

Table 3. Survey October 2004 – *Calluna* regeneration and birch survival

Plot III (Summer Burn 2002)		
	Sub-Plots	
	A	**B**
Calluna regeneration (resprout, %)	42%	35%
Birch survival (resprout, %)	12%	19%
Calluna seedlings (number)	<15	<15

Table 4. Survey October 2004 – *Calluna* regeneration and birch survival

Plot IV (Winter Burn 2002/2003)		
	Sub-Plots	
	A	**B**
Calluna regeneration (resprout, %)	98%	100%
Birch survival (resprout, %)	7%	6%
Calluna seedlings (number)	>50	>50

Conclusions

In conclusion of the October 2004 review first trends of fire response can be derived:

- The low number of *Calluna* seedlings on the summer burn areas may be a consequence of the extremely high fire temperatures that may have damaged the seeds. Temperatures over 500°C reduce *Calluna* germination. Temperature measurements on Plot II showed maximum temperatures of over 800°C, although these measurements were taken only on single points and not continuously all over the burn-area. Due to high fuel loads and extreme fire weather conditions temperatures most likely have exceeded 500°C all over Plots II and III.

- The fact that the birch trees on Plot II resprouted heavily compared to Plot III could be explained with slightly different soil structures on the two plots. The fire characteristics on both plots were very similar and do not allow any conclusions that could explain the difference in tree survival. Further experiments are needed.

- The comparison between the winter and summer burns show some significant differences. The survival of trees after a summer burn is very high, which was not expected. Resprouting of *Calluna* was relatively low and seedlings are hardly found on the summer burn areas.

- The winter burns all show extraordinary good results for the *Calluna* regeneration. The survival rate of trees is low. Also the number of *Calluna* seedlings is exceeding the expectations. It seems that late winter burns produce extraordinary better results, both in *Calluna* regeneration and killing of the tree and bush succession.

At this stage of time and research the programme will focus on winter burns as a regular management tool. It is planned to conduct more summer burns to understand the differences in the summer plots II and III.

Encouraged by these results the Fire Ecology Research Group and the FFS secured funding by the Brandenburg Nature Foundation (NaturSchutzFonds Brandenburg) to continue the prescribed burning programme in 2005 and 2006.

Due to the good economic and ecologic results the prescribed burning project in the FFS District Lausitz was presented on several public fora and workshops in Germany and neighbouring countries.

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Visual impressions of heather burning in Zschorno, Lausitz

Figure 1. Birch (*Betula pendula*) and heather (*Calluna vulgaris*) succession in Zschorno. In May 2002 the tree layer was completely inventoried before burning. Photo: GFMC.

Figure 2. Preparation of experimental sub-plots in which birch is cut before the application of prescribed fire. Post-fire studies will compare the recovery of standing and cut birch trees after the application of fire. Photo: GFMC.

Figure 3. Start of prescribed fire in Zschorno on 20 August 2002. The headfire is set at the edge of a burned fire break. Photo: GFMC.

Figure 4. Prescribed fire in progress in the birch-stocked plots (20 August 2002). Photo: GFMC.

Figure 5. Post-fire view of the August 2002 burn. The hot fire has removed the accumulated organic layer and provides suitable conditions for *Calluna* regeneration. Photo: GFMC.

Figure 6. The fire team: Staff members and forest workers of FFS District Lausitz, Cottbus University and GFMC. Photo: GFMC.

Conservation Methods for *Calluna* Heathlands by Prescribed Fire in Schleswig-Holstein State, Germany

Project objectives

The project aims to investigate the effects and test operational procedures of prescribed burning in the maintenance of diverse heather species associations and succession stages in Atlantic heathlands of Northern Germany. The project was initiated in 2002 and will continue 2005-2006.

The use of prescribed fire in diverse heather species associations and succession stages in the nature conservation areas of Northern Frisia (Nordfriesland), Schleswig-Holstein State, Germany, aims to substitute cost-intensive mechanical treatments and to restore historic burning practices

Since 1984 a variety of tools for heathland management have been used large- scale in the management of old, matured and grass-dominated stands of *Calluna vulgaris*, e.g., by mowing, mulching, grazing and swiping). The aim of these methods is to preserve different succession stages. In some of the nature conservation areas these practices produced a mosaic of different development stages of the heather vegetation. For technical, financial and nature conservation reasons it is now aimed to combine the above-mentioned management tools with prescribed fire.

The use of heavy machinery is limited due to the vulnerable features of the terrain: The impact of heavy equipment would destroy microclimatic and micro-topographic structures which are vital for a number of species.

The first prescribed burns took place in late summer of 2002 in different types and degradation stages of heathlands. It was important to gain local experience as the fire characteristics are completely different – due to different climatic conditions – from heathland fires in other regions of Germany.

After successful tests a series of follow-up prescribed fire experiments were conducted between 2003 and 2004. Technical and scientific implementation of the project is under the responsibility of the Fire Ecology Research Group / Global Fire Monitoring Center (GFMC), Max Planck Institute for Chemistry, Freiburg, Germany.

First results reveal that in general, the post-fire regeneration and re-establishment of *Calluna* is satisfying. On most plots tree succession is suppressed. However, birch (*Betula pendula*) responds quite commonly by re-sprouting. Even where the raw humus layer is not consumed completely the regeneration of *Calluna* seedlings is abundant. This effect is also visible on plots that had been covered by dense Crowberry (*Empetrum nigrum*) stands before the fire.

In November 2004 the Nature Conservation Agency conducted a survey of all plots that were burned since the beginning of the project. The following is a summary of the results to date and a recommendation for the future use of prescribed fire in the nature conservation areas of Northern Germany:

- Prescribed fire for *Calluna* regeneration proved to be always effective. No differences between winter and summer burns were recorded, besides that after a winter fire the flowering starts already in the same vegetation period. A fair amount of *Calluna* seedlings is found on all plots.

- Crowberry stands burn with high intensities, the duff and raw humus layers burn only if allowed to smoulder for a longer period. On most *Empetrum* plots, *Calluna* seedlings were found between the resprouting Crowberries. *Calluna* regenaration is significant slower compared to *Calluna* stands, but it seems possible to bring *Calluna* back on *Empetrum* stands.

- Die-back of bush and tree succession is not uniform. Conifers are generally killed by fire, whereas older birch trees react with basal resprouting.

- There are observations that indicate late winter burns to be effective in killing birch trees. Comparable observations are made in Brandenburg State.

Figure 1. *Calluna* heathland on Sylt Island, Braderup Nature Conservation Site, subjected to succession. Photo: GFMC.

Figure 2. Cost intensive mechanical removal of the raw humus layer for *Calluna vulgaris* regeneration, Sylt Island. These mechanical measures, including disposal of harvested biomass, cost ca. 25,000 Euro / ha. Photo: GFMC.

Figure 3. Prescribed burning operation in *Empetrum* / *Calluna* stands in the Lütjenhom Nature Conservation site, Schleswig-Holstein, 5 September 2002. Photo: GFMC.

Figure 4. Raw humus layer superficially reduced by prescribed burning in 2002. The photograph taken shows regeneration of *Empetrum* in 2003. Lütjenhom Nature Conservation site, Schleswig-Holstein, 5 September 2002. Photo: G. Hoffmann.

- If the area that has to be burned is already grass dominated (*Deschampsia* and/or *Molinia*) certain limitations in the use of fire for *Calluna* regeneration were observed.

- The fertilizing effect of the ash can be seen clearly in heavy resprouting, which must be grazed by sheep. A very positive effect is the reduction of soil covering litter and as a consequence a higher number of lizards and insects were recorded on these areas.

- There are assumptions from the United Kingdom and Denmark that burning with high frequencies (even annually burning) is damaging and reducing the grass sward in the long term. If the raw humus layer is not too thick *Ericacaea* will have a slight advantage. In general, grass dominated areas with a thick grass sward are limiting the use of prescribed fire for *Calluna* regeneration.

- Most difficult is the partial or complete reduction of the compact raw humus layer (Figure 4). Under sufficiently dry conditions the raw humus should be allowed to burn as long as possible. Experience gained in the last two years show that slow-burning or smouldering ground fires must be observed and secured over night and sometimes the following days – this makes the burning operations more cost and labour intensive. Ploughing a mineralized strip around the area to be burned will stop the ground fire from spreading.

In conclusion, maintenance burning of not grass dominated heathlands is an effective and low-cost management tool to suppress the bush and tree succession and regenerate *Calluna*. For grass-dominated areas further experiments are planned.

The promising results in *Calluna* and *Empetrum* heathlands are encouraging the future use of fire in nature conservation and heathland management.

To date all test areas were small and burning was done very carefully to demonstrate the possibility to use fire under prescription and to ensure acceptance of the project. It is envisaged to expand the burn sizes significantly to ensure that fire is used efficiently for the maintenance and management of the endangered heathlands in Northern Germany.

In 2004 a partnership with the University of Kiel was established. The University of Kiel is using the experimental sites for long-term research on fire effects on soil and water.

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Studies on the Impact of Prescribed Burning and Sheep Grazing on Northwest German Heathland Ecosystems

Project objectives / project structure

Supported by German Federal Ministry for Education and Science (BMBF) a project has been brought into life in January 2001 in order to investigate the future importance of prescribed use of fire, sheep grazing and removal of raw humus or mowing for the development of heathland ecosystems. The project's three-year's term is lasting from January 2001 to December 2003.

The project is coordinated by Alfred Toepfer Academy for Nature Conservation (NNA) in Schneverdingen.

Additionally, NNA integrates GIS-based information into the project, for example maps with grazed areas in Lüneburger Heide nature reserve, maps with long-term vegetational investigation plots, or maps with the last twenty years' mechanically managed plots.

In order to simplify the input of floristic and faunistic data, an area-specific database with connection to GIS is going to be worked out.

Special focus is set on the transfer of nutrients. These transfer processes as well as the development of vegetation dynamics after prescribed burning, sheep grazing and mechanical management measures are investigated by University of Lüneburg, Institute for Ecology and Environmental Chemistry. Leachate and soil samples are analysed for Nitrogen, Phosphorus, Potassium, Calcium and Magnesium with nylon suction cups and lysimeters. Additionally, atmospheric deposition and biomass samples are analysed for their nutrient contents as well.

Since the consequences of ecological effects for nature conservation have to be considered in a socio-economic context, University of Lüneburg, Chair for Business Administration, especially Environmental Management, researches the socio-economic effects of the various management measures.

Therefore, especially two methods are used: the cost-effectiveness analysis and the cost-benefit analysis, including the research on the management measures' acceptance by various stakeholders.

Combining the results of both the ecological and the economic studies, the engineering office Dr. Kaiser – Working Group Land and Water, tries to transfer the results of the small-scale investigations to a landscape approach by finding out potential areas for prescribed burning in NW Germany using GIS. Therefore, all NW German open oligotrophic ecosystems (for example *Calluna*-dominated heathlands, oligotrophic grasslands or peat bogs) have to be identified and estimated according to their respective potential to be burnt under prescribed conditions.

A first GIS-based analysis of the Lower Saxonian-wide mapping of habitats being especially valuable for nature conservation shows, that there are 40.000 to 60.000 ha of open oligotrophic ecosystems.

Furthermore, the working group is going to find a way to integrate the project's outcomes into landscape planning methods.

In order to be able to assess the management measures according to their ecological effects, the impacts of each of the measures on the various environmental media (mankind, animals, plants, soil, water, air, climate etc.) is analysed using the project's outcomes and experiences taken out of relevant literature.

The project sets the investigation focus on areas in the Lüneburger Heide and Diepholzer Moorniederung.

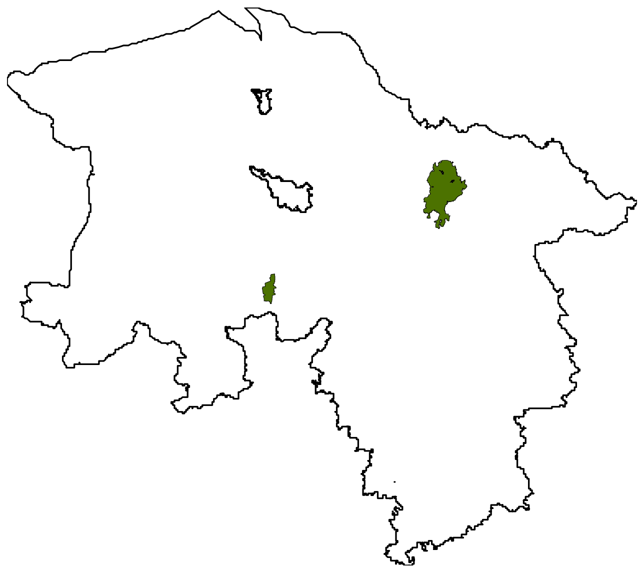

Figure 1: The project's study plots are located in Lüneburger Heide Nature Reserve (*Calluna* heathlands on mineral soils; northeast) and Neustädter Moor Nature Reserve (*Calluna* heathlands on organic substrate; southwest).

Figure 2. Different management measures in Lüneburger Heide Nature Reserve and Neustädter Moor Nature Reserve. From left to right: (1) typical *Calluna*-dominated heathland in Lüneburger Heide Nature Reserve, (2) prescribed burning in Neustädter Moor Nature Reserve; (3) grazing by Gray Horned Heath Sheep; (4 top) mowing; (4 bottom) sod-cutting ("Plaggen").

Thus it is possible to study the impacts of prescribed burning and sheep grazing on heathland ecosystems both on mineral soils (Lüneburger Heide) and on organic substrate (degenerated peatbog areas in Neustädter Moor East of Diepholz; see respective paper).

The management measures are practically implemented by Verein Naturschutzpark (VNP) association in Lüneburger Heide Nature Reserve and by BUND - Diepholzer Moorniederung association in Neustädter Moor Nature Reserve.

Both working groups are adding data about the up to now experiences with management in practice.

In close co-operation with Veterinary University of Hannover, Institute for Animal Ecology and Cell Biology, NNA does research on the influence of various management measures on invertebrates.

The project is funded by German Federal Ministry for Education and Science (Bundesministerium für Bildung und Forschung, BMBF).

Permits

All management measures are coordinated with the regional administrative bodies, which are the appropriate authorities for nature reserves.

Practical implementation

Prescribed burning is realized in winter only (November to February).

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Prescribed Burning of Moorlands in the Diepholzer Moorniederung Lower Saxony State, Germany

Location , type of vegetation

The long-term and full-time nature conservation project of the BUND (Bund für Umwelt und Naturschutz in Deutschland) regional organization in Lower Saxony is located in the high moor Lowlands of Diepholz, mainly in the district of Diepholz.

Main objectives and first results

Conservation of open high moor areas (with a grazing tradition) where a satisfactory stabilizing effect cannot be reached by means of waterlogging.

The objectives of prescribed burning goals aim to maintain successional stages of *Molinia caerulea*, *Erica tetralix* and *Calluna vulgaris*. Prescribed burns are conducted on pre-drained high moor peat. Each year different areas are burnt in January-February.

The tradition of sheep husbandry by old shepherds at the edges of the moor was taken up by nature conservationists; where the last herds of sheep were kept the ecologically most valuable moor and heath areas were to be found because they had still remained open.

Pastures for nature conservation were established by single adherents of conservation of natural resources as well as by various foundations with the help of nature conservation administrators. The sheep races involved are German moorland sheep. The goal of sheep grazing is to preserve open moor and heath areas, and to restore open moorlands that were subjected to woodland succession.

Prescribed burning is a traditional way to preserve these open landscapes, especially if it is heath-covered grazing land. The advantages of prescribed burning include:

- immediate release of nutrients;
- reduction of vegetation height as a prerequisite for habitats and existence of certain endangered species of breeding birds, insects, and reptiles;
- better access to the nutrients within the system due to the fact that sheep can feed on lower parts of vegetation;
- higher quality of the feed for both herbivores and sheep.

Figure 1. Winter prescribed burning in the Diepholz high moor.

Additional means for keeping the moor and heath areas wide open are e.g. waterlogging, cutting down surplus birches, gradening of peat-diggings, mowing and mulching. Thus, the conservation and the restoration of large open as well as semi-open moor and heath areas of a size of several thousand hectares have been achieved as a first result in this project. Progress checks are being kept both in the faunistic and vegetation range in commission and under the authorization of the Nature Conservation Administration.

Figure 2. Post-fire vegetation recovery in the Diepholz high moor. Unburned moor surface in the upper right part of photograph. Photos: F. Niemeyer

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Website: www.bund-niedersachsen.de/diepholzer-moorniederung

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Use of Prescribed Fire in Maintaining Open Cultural Landscapes in Baden-Württemberg State, Germany

Project Summary

The prescribed burning project has a long tradition: Starting in 1975 the long-term research project aims to investigate the long-term consequences of the use of prescribed fire in maintaining the openness of abandoned (fallow) agricultural and pasture sites.

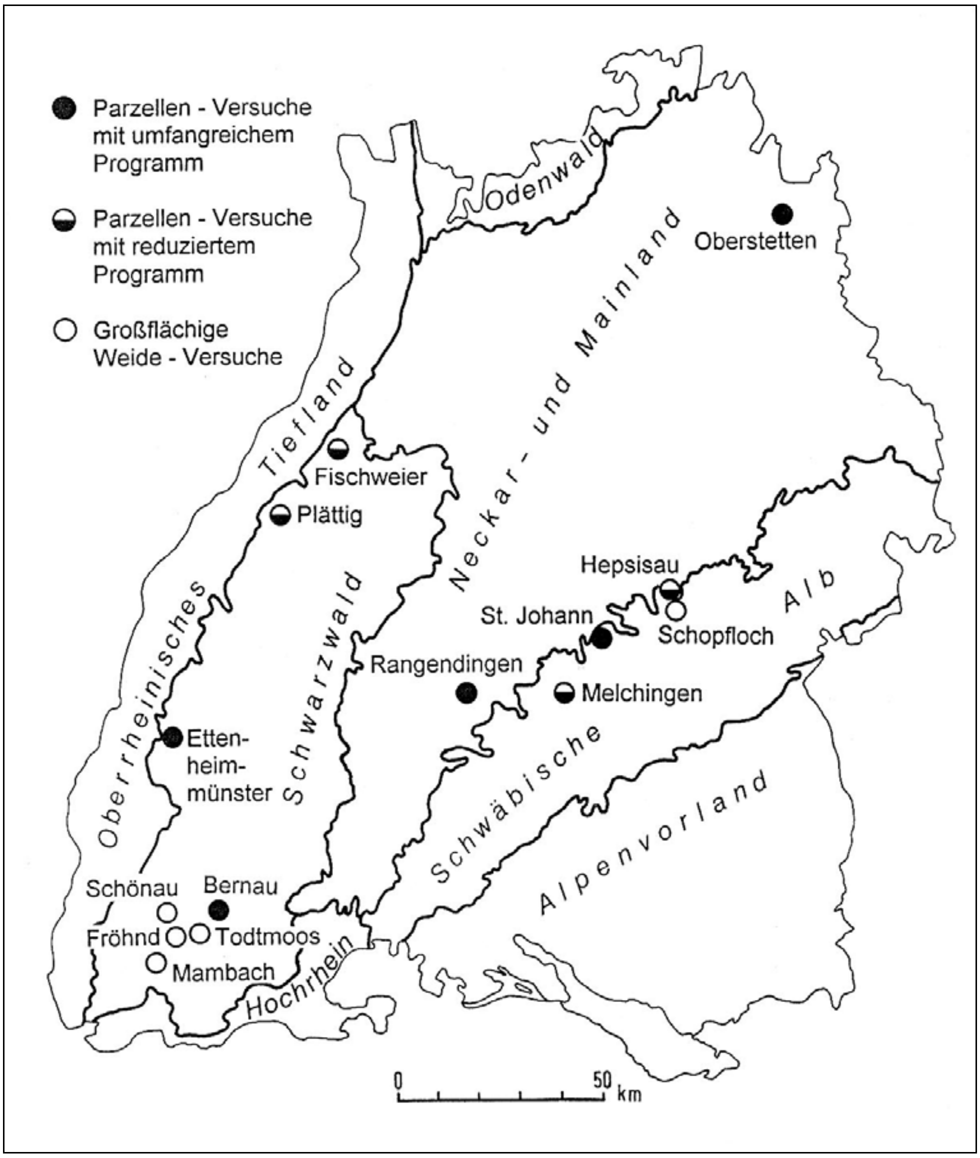

Figure 1. Location map of experimental sites in Baden-Württemberg.

The experimental plots are distributed over 14 sites in Baden-Württemberg, located between Tauberland and the Southern Black Forest. Site characteristics vary and include dry to moist sites, on warm to cold exposures, various soil depths and acidity, including shallow poor soils and fertile deep soils. The site and vegetation characteristics are described in detail in a rich list of scientific publication and theses. For details on publications and sites: See Annexes I and II.

Visual Impressions of Prescribed Burning in SW Germany Starting in the 1970s

Figure 2. Demonstration prescribed winter fire near Hechingen (February 1978). Photo: GFMC.

Figure 3. Demonstration of the use of a "hot" ring fire to produce high mortality in successional woody vegetation (Hechingen, February 1978). Photo: GFMC.

Figure 4. Prescribed burning exercise with representatives of nature conservation authorities and scientists, Hechingen, February 1978. Photo: GFMC

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Annex I: List of Publications

This list includes the main publications and scientific theses dealing with fallow site research, including the use of prescribed fire, in the fallow research programme of Münster University

Braukmann, H.-J., G. Broll, and K.-F. Schreiber. 1995. Veränderungen von Regenwurmzönosen im Laufe der sekundären Sukzession von Grünlandbrachen in Südwestdeutschland. Mitt. Dtsch. Bodenkundl. Ges. 76, 573-576.

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Hülß-Metzker, D. 1995. Generative Diasporenbanken in verschiedenen Pflegemaßnahmen ausgesetzten Grünlandbrachen Baden-Württembergs. Stuttgart (U.E. Grauer), 193 S.

Moog, D., P. Poschlod, St. Kahmen, and K.-F. Schreiber. 2001. Comparison of species composition between different grassland managements – 25 years fallow experiment of Baden-Württemberg. Applied Vegetation Science, in press

Neitzke, A., 1991. Vegetationsdynamik in Grünlandbracheökosystemen. Arbeitsber. Lehrstuhl Landschaftsökol. Münster 13 (2 Bde.), 140 S. + Abb.- u. Tab.Bd.

Schiefer, J. 1981. Bracheversuche in Baden-Württemberg. Beih. Veröff. Naturschutz Landschaftspflege Bad.-Württ. 22, Karlsruhe, 325 S.

Schiefer, J. 1982. Kontrolliertes Brennen als Landschaftspflegemaßnahme? Natur u. Landschaft 57, 264-268.

Schiefer, J. 1983. Auswirkungen des kontrollierten Brennens auf Vegetation und Standort auf verschiedenen Bracheversuchsflächen. Freiburger Waldschutz-Abh. 4, Hg. Forstzool. Inst. Univ. Freiburg, 259-276.

Schreiber, K.-F. 1978. Kontrolliertes Brennen als Pflegemaßnahme in der Brachlandbewirtschaftung. VW-Symp. Feuerökologie, Freiburg i. Br. 1977. Freiburger Waldschutz-Abh. 1, Hg. Forstzool. Inst. Univ. Freiburg, 107-124.

Schreiber, K.-F. 1997. 20 Jahre Erfahrung mit dem kontrollierten Brennen auf den Brachflächen in Baden-Württemberg. „Feuereinsatz im Naturschutz“, NNA-Ber. 10, 5, A. Toepfer Akad. Naturschutz, Schneverdingen, 59-71.

Schreiber, K.-F. 2001. 25 Jahre Landschaftspflegemaßnahmen in den Bracheversuchsflächen in Baden-Württemberg. Akademie-Ber. 2, Naturschutz-Zentrum Hessen, Wetzlar, 5-42

Annex II: A list of diploma theses and detailed site descriptions (in German) is published on the website of the European Fire in Nature Conservation Network (EFNCN) at:

http://www.fire.uni-freiburg.de/programmes/natcon/natcon.htm

Prescribed Burning in Landscape Management and Nature Conservation: The First Long-Term Pilot Project in Germany in the Kaiserstuhl Viticulture Area, Baden-Württemberg, Germany

1. Introduction: Fire as a Substitutive Disturbance Process

The majority of protected areas in Central Europe is not of pristine nature. They are embedded in landscapes that have been shaped by land-use systems over centuries. These systems historically involved processes such as burning, grazing, mowing and cutting which transformed natural landscapes to unique ecosystems. These ecosystems provide habitats for many plant and animal species which are under protection today, including many endangered (red list) species. The recent socio-economic developments, however, resulted in structural changes of the rural space. Many agricultural sites are treated less intensively or are abandoned because farming is no longer profitable. As a result human-made open ecosystems are lost. Without disturbance secondary succession leads to a tree- and shrub-dominated vegetation form which is the potential natural vegetation type in most parts of Central Europe. As a result, many plant and animal species adapted to or were found in these ecosystems will face the threat of extinction.

If the maintenance of these abandoned ecosystems is desired, it is necessary to introduce substitute-disturbance processes into these areas to maintain the dynamics of processes which have shaped these landscapes historically.

To ameliorate the problem, several options can be taken into consideration. These options include traditional mowing, grazing, cutting practices, and the use of fire as a vegetation management tool. Mowing, grazing and cutting are already practised in nature conservation in Germany. But the lack of financial and personnel resources, including the loss of skill and expertise, limits the use of these practices. Thus, alternative approaches are needed. Prescribed burning could offer a potentially efficient and relatively cheap tool to achieve the land management objectives of the areas in question.

2. Fire Management on the Vineyard Slopes in the Kaiserstuhl Area

In the following an example is given how prescribed burning can be used as a substitute measure in landscape management. The aim of the research project is the investigation of the application of prescribed burning for maintaining the traditional open meadow-type vegetation structures on slope sites which are threatened by secondary succession.

The study is currently conducted in the Kaiserstuhl area, an old volcano fragment dating back to the Tertiary, located in the Rhine valley in southwest Germany. Most of the lower parts are covered by an up to 16 m-deep loess layer. The history of wine cultivation in the area dates back to the 8th century. Since then farmers grew wine on terraces built on the hilly terrain. The traditional vegetation cover on the slopes between the terraces was of a meadow-like grassland (Figure 1).

Although the natural vegetation cover in the area is of a bush- and tree-dominated forest type, vineyard slopes have a distinct vegetation cover dominated by grass. These ecosystems were maintained by mowing and occasional burning until World War II. After the war the area experienced a dramatic increase in wine growing and sharp decrease of animal husbandry with its associated mowing and cutting practices. As the farmers no longer needed hay to feed their cattle, they began to burn the slopes in winter so as to suppress the growth of bush and tree species in order to maintain open vegetation structure.

In 1975, following the Federal German nature conservation law, the State of Baden Württemberg imposed a ban of the free burning (broadcast burning) of vegetation. Since then the slopes were cultivated only in some exceptions. The consequence was the ever increasing expansion of bush and trees into these areas due to secondary succession. The result was a decrease or loss of habitats for many plants and animal species that are adapted to or found in these ecosystems, and require more light and higher ground temperatures, conditions that prevail in open ecosystems.

Fig.1. The typical structure of the old historical vineyards is an alternation of narrow terraces where the vines are cultivated and small steep slopes covered by a meadow-like vegetation.

Figure 2. With the consolidation and restructuring of farmland in the 1960s and 1970s, large terraces were constructed with slope heights stretching up to 40 m with over 100% inclination. Since their establishment they have been treated only in exceptional cases.

The slopes in the old historical vineyards were only up to 8 m high. But with the consolidation and restructuring of farmland property in the 1960s and 1970s, bigger slopes of up to 40 m high and with over 100% inclination were constructed (Figure 2). Except for the initial grass layer establishment on the slopes, no human intervention has taken place in the area. Today, both the new and the historical slopes serve as a medium for secondary succession to run its course. Given the extent of the area (four square kilometres only in the central part of the Kaiserstuhl area), a major investment of time and money is required to maintain the traditional grass-dominated open structures by cutting and/or mowing. As an alternative, this project proposes the use of prescribed burning to achieve the landscape objectives set for the area.

4.1 Objectives of a Prescribed Burning Project

The objectives of the research project were to determine whether prescribed burning of small plots in late winter could be used to maintain and promote the traditional open vegetation structure, the habitats and occurrences of typical and characteristic animal and plant species on the slopes of the vineyards of the Kaiserstuhl area. Three project studies were conducted in the late 1990s:

4.2 Vegetation study

Effects of different fire types on the composition, structure and distribution of the vegetation types of the open, meadow-like ecosystems were monitored. The reaction of some typical species which immigrate and extend since the beginning of the succession period 20 years ago were observed. In addition temperature and soil moisture measurements on burned and unburned plots were undertaken. The first results of the investigations are as follows:

Measurements of the soil temperature (at 10cm depth) and the soil moisture content (0 to 20 cm depth) on burned and unburned plots were taken (Figure 3). Depending on the location, an increase of the monthly average temperature up to 7°C on the burned plot in comparison with the unburned plots was discovered in the first vegetation period after burning. At the same time there was a partially significant decrease of the soil-moisture content on the burned plots. So the burned stands became warmer and dryer. In a longer perspective this could be of interest because it is especially the xerothermic fauna and flora which suffers under the abandonment and the secondary succession. The former use of the slopes produced relatively warm and dry conditions which gave the opportunity for continental and sub-Mediterranean species to find habitats here.

To observe the effects of different fire-types on the grassy and herbaceous dominated vegetation, permanent investigation plots were installed. Six or eight observation plots of the size of $1m^2$ were distributed on every treatment unit. With the help of a "frequency analysis" changes of the species composition and distribution were observed over three years. To investigate the reaction of the vegetation, evenness/number of species diagrams were used. Figure 4 gives an example how the vegetation of an relatively moist stand reacts of different fire treatments.

To carry out the frequency analysis a $1m^2$ frame subdivided in 16 sub-units (25x25 cm) was laid over the vegetation. In each sub-unit the species and their cover (%) were recorded. This method provides a very high resolution inventory and even very small changes in species distribution can be detected (Fischer 1986). In the diagram the average evenness and the average number of species of every treatment-unit were plotted and the changes from year to year were marked with arrows. The number of species is a parameter to describe the richness of an ecosystem. The evenness (%) describes the distribution of the species. 100% means that there is no hierarchy and all species are equally distributed. The smaller the evenness number the more dominated is the ecosystem by one or a few species (Häupler 1982).

The overall results revealed that on the investigated slopes in general there was no major shift observed, neither in the number and composition of species nor in the distribution (evenness). However, an observation period of three years is rather short to obtain reliable results on long-term response of vegetation. But from other studies on comparable sites in the state Baden-Württemberg where such investigations were carried out over 20 years, it is known that the structure of fallow meadows can be maintained with the help of prescribed burning (Schreiber 1997).

Another question was how brushes and trees respond to fire. It was noted that sprouts with a diameter of less that 2 cm (at 30 cm height) are generally killed by fire, but most of the species resprout in the following spring. Under a prescribed burning regime with short fire intervals of two to three years it seems to be possible to keep young succession stages at its early stage, but it is not possible to remove them completely. It cannot yet be concluded whether the spread of shrubs and trees can be stopped with the help of fire. It seems that under a broad range of conditions the still open, grass-herb dominated vegetation structures may be maintained by fire, while it is doubtful that brushes which spread through rhizomes can be stopped in a long term.

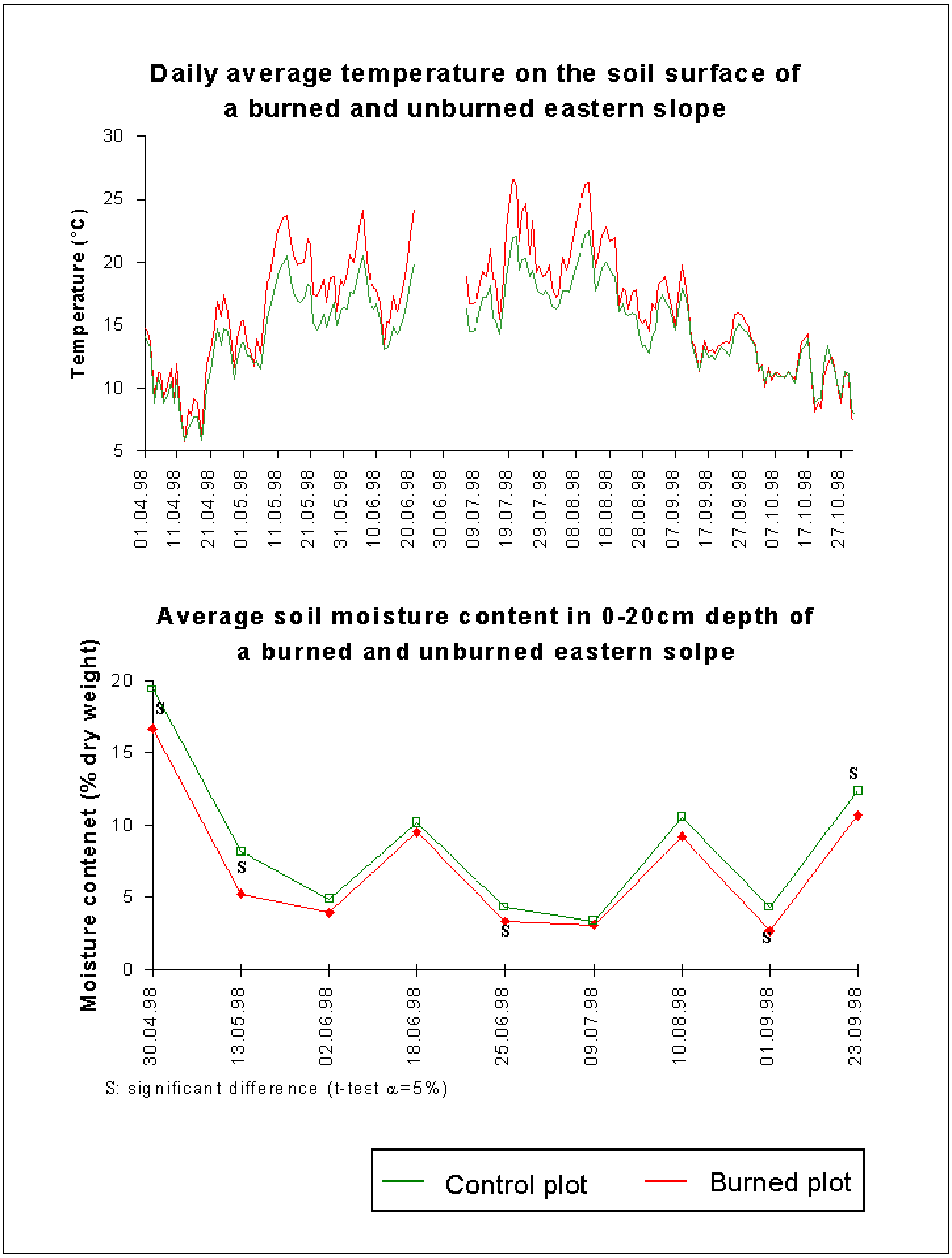

Figure 3. Soil temperature and soil moisture content in the vegetation period after the winter burning session 1997-98 on a burned and on a control plot on an eastern slope.

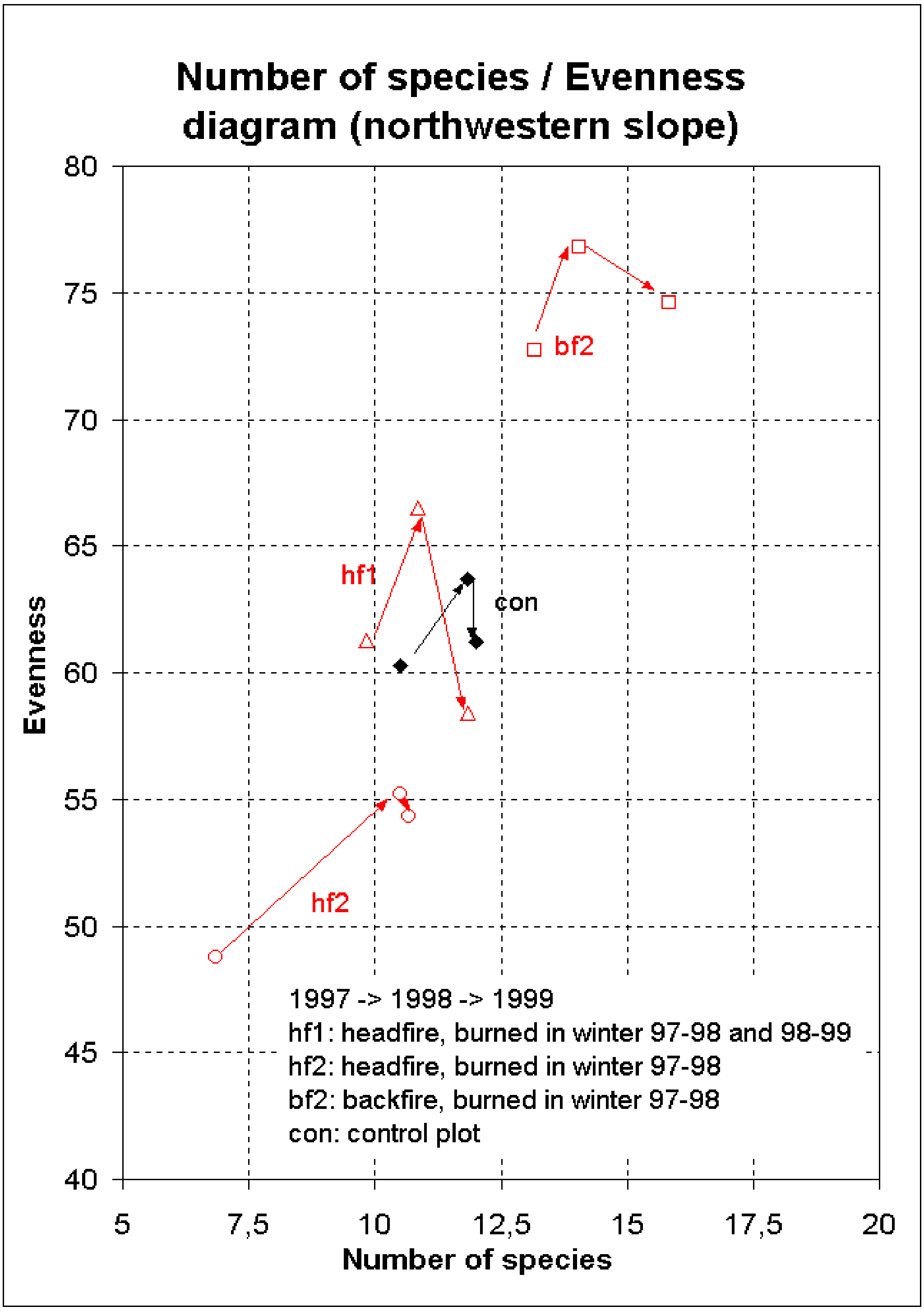

Figure 4. Number of species / Evenness diagram of a north-western slope. Neither on the burned or the unburned plots a significant shift in the distribution or average number of species can be observed in the last three years. Also the species combination is more or less the same. Note: To carry out the frequency analysis a 1m^2 frame subdivided in 16 sub-units (25x25 cm) was laid over the vegetation. In each sub-unit the species and their cover (%) were recorded. This method provides a very high resolution inventory and even very small changes in species distribution can be detected (Fischer 1986). In the diagram the average evenness and the average number of species of every treatment-unit were plotted and the changes from year to year were marked with arrows. The number of species is a parameter to describe the richness of an ecosystem. The evenness (%) describes the distribution of the species. 100% means that there is no hierarchy and all species are equally distributed. The smaller the evenness number the more dominated is the ecosystem by one or a few species (Häupler 1982).

4.3 Faunistic Study

Earlier investigations conducted in the 1980s on the slopes of the Kaiserstuhl area indicate that arthropods hibernating in the grass-layer are killed by prescribed fire conducted in wintertime. Individuals which hibernate in the soil usually survive. The concern about the loss of individuals affected by fire is of minor concern because the burned plots are relatively small and surrounded by unburned plots. Thus, the immigration rate after fire is very high and takes place very rapidly. Therefore there is just a temporary shift of populations, and no sustainable change in the species composition was observed so far (Lunau and Rupp 1988). In this project, the direct and indirect effects of fires on snails have been investigated. The snail populations served as indicators for the rate of spread of the post-fire re-colonisation.

Figure 5. A (upper): Burning of an experimental plot in January 1998 by an upslope headfire. The red-white sticks are used to determine the rate of fire spread. **B (lower):** The same slope immediately after burning. The typical mosaic of burned and unburned patches generated by prescribed burning is clearly recognisable. Unburned patches are important for the re-colonisation by animals.

The results of the faunistic study indicate that no shift was found in species composition of snails on burned and unburned plots. In most cases the number of the individuals were significantly reduced on the burned plots. The migration rate of big snail species is very small (average: 5 to 10m/year). The maximum distance covered was about 30m/year.

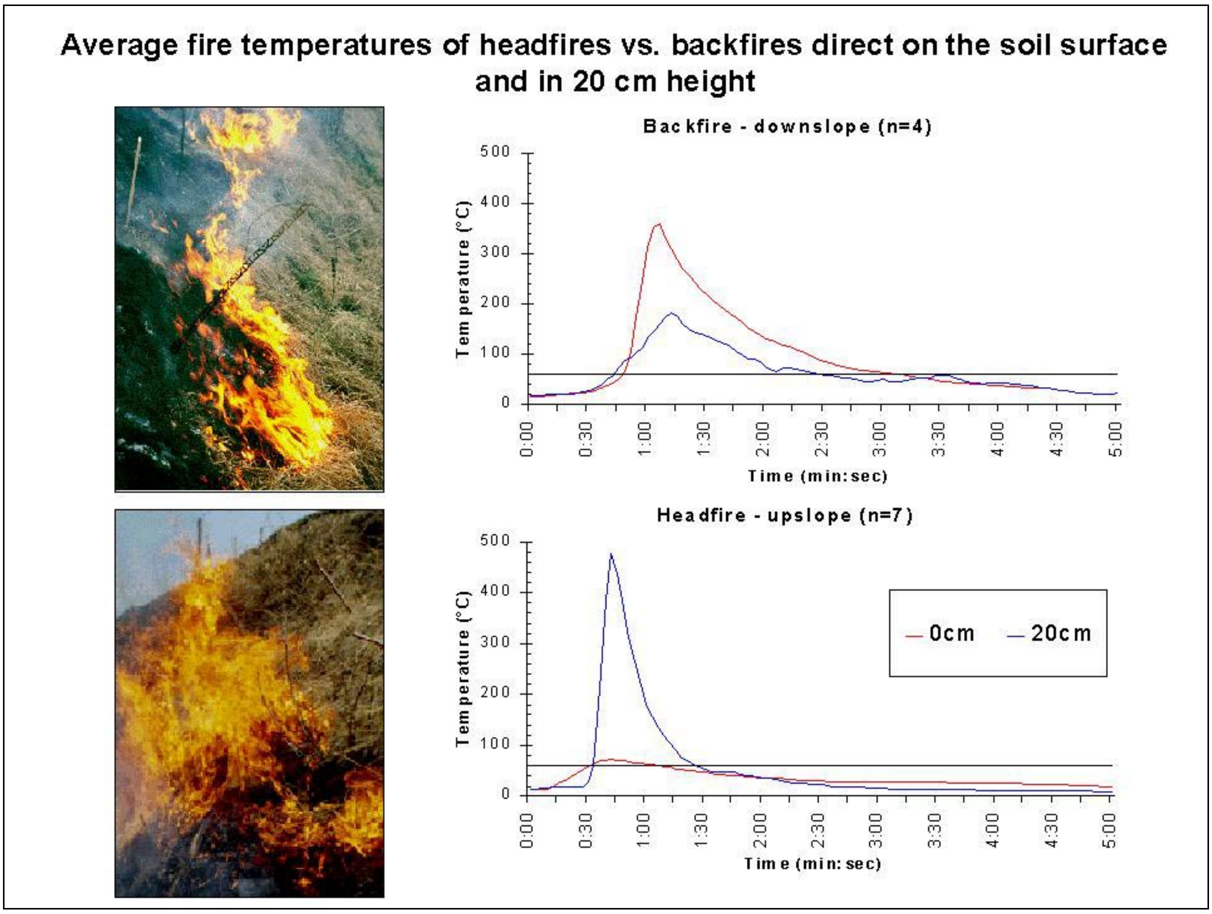

Figure 6. Average temperatures of headfire and backfire on the ground and in 20 cm height. The backfire creates very high temperatures directly on the ground. The animal and plant species which hibernate on or in the ground are much more affected by this type of fire as compared to a headfire which has its maximum temperature some decimetres above ground.

4.3 Socio-Economic Component

At the start of the project discussions with different groups of society which are involved in agriculture, viticulture and landscape management in the region (farmers, municipality, governmental and non-governmental nature conservation organisations) revealed conflicting views on the potential application of prescribed burning. While farmers and local municipalities unanimously requested for a restoration of general permission to use prescribed fire as a tool to suppress succession, the governmental nature conservation bodies and NGOs were concerned about the negative impact of burning on ecosystems concerned and on the environment in general. In order to create a common discussion platform, to overcome controversial views and to develop a mutually acceptable and harmonised management strategy a "Round Table on Slope Management in the Kaiserstuhl Area" was created.

During four round-table sessions in winter 1999-2000 an agreement was achieved which was accepted by all parties. The first result was a general strategic paper called "Model for the future development of the vineyard slopes in the Kaiserstuhl area". In this paper it is stated that the open vegetation structures which still exist in the region should be maintained and that different management tools which include prescribed burning must be applied to obtain the desired results. This agreement and statement for the first time in Central Europe accepted prescribed burning as a tool for landscape management. In the Appendix of the strategic paper a detailed prescription is given how fire has to be (re-)introduced in landscape management in the future. The general framework states:

- Prescribed burning will be restricted to the winter season (between November and February) under specifically defined weather conditions.
- The burned parts have to be small (not more than half of a slope which belongs to one section of land (often but not necessarily identical with ownership; the absolute maximum is a 50m-wide portion of an individual slope) and it is not allowed that two burned parts border on each other. With this prescription a mosaic of burned and unburned plots is guaranteed which is a vital prerequisite for re-colonising of damaged fauna, particularly arthropods.
- The owner of the slope is responsible for the management. Everybody is eligible to obtain a permission for the use of prescribed burning under the condition that he/she has participated in an information and training programme.
- In winter 2000-2001 prescribed burning was introduced in one municipality. Based on the positive experiences the whole Kaiserstuhl area has been included in the programme starting in winter 2002-2003.

After the research phase a six-years test period (2000 until end of 2005) served to test if the management goals can be accomplished with the introduction of prescribed burning. Meanwhile more than 3000 farmers / viticulturists have participated in prescribed burning training courses.

It is currently planned to expand the use of prescribed burning in viticulture areas to the North of the Kaiserstuhl area (Northern Breisgau).

5. Conclusions

The Kaiserstuhl prescribed burning project still has a catalytic and pilot function in the landscape of prescribed burning projects in Germany. In the near future the State of Baden-Württemberg will revise its current Nature Conservation Law. It is quite possible that the current restrictions on the use of fire in natural systems may be modified towards a regulation that would allow exemptions for burning based on a burning permit system.

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Research and development project "Sustainable development of xerothermic slopes of the Middle Rhine Valley, Germany"

Introduction

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 loss of any interest in land use as the traditional "management tool" on the other hand. Therefore, possibilities of a sustainable development of this "model region" with its characteristic xerothermic slopes are studied in the research and development project taking into account nature conservation as well as socio-economic issues.

Habitat characteristics

Characteristics features of the managed habitats are:

- inclination ≥ 50%, merely the upper slopes towards the plateau are more or less shallow
- thin, skeletal schist soils, some areas are covered by pleistocene loess
- average annual temperature of 9.5°C
- annual precipitation of 520 mm (southern part) up to 600 mm (northern part).

Together with its neighbouring valleys, the Middle Rhine Valley represents one of the largest coherent xerothermic areas of Germany. Various xerothermic habitats and vegetation types are classified as endangered in Germany or even on the European level. The necessity for the development of management concepts to protect this landscape is emphasised by the inscription of the Upper Middle Rhine Valley in the World's Heritage List as a protected cultural landscape since 2002.

Over centuries, the landscape has been formed by the cultivation of vine, the shallow slopes were used as common pastures for domestic livestock, as arable land or coppice. However, since the last boom of viniculture at the end of the 19th century the area under cultivation is continuously declining from more than 2000 ha to about 500 ha today. Depending on the surrounding vegetation and former use, open habitats are lost after several years or decades in favour of shrubs and woodland communities. For species of open xerothermic habitats extinctions caused by habitat loss and increasing fragmentation can be already observed or have to be expected in future.

In order to prevent further losses of the characteristic open habitats, the project intends to test the suitability of different conservation strategies, differentiated after the stage of succession and inclination of the slopes. These strategies include traditional and alternative forms of land-use (viticulture, fruit-growing, grazing) as well as different management concepts without any economic interest. The latter particularly take into account the claim of a re-establishment of dynamic processes as characteristic elements of the natural as well as historical cultural landscape. For this purpose, especially the following management strategies will be established, which are in Germany or at least with regard to steep slopes not tested until today:

- More or less uncontrolled ("semi-wild"), extensive grazing by horses and goats on the steep slopes in all stages of succession on an area of about 60 hectares.
- Clearing the shrub-dominated shallow slopes with tank-tracks. In order to do this, two links of a tank-track with a weight of about 1.5 tonnes are mounted in a steel-frame and drawn by a tractor through the shrub vegetation. Shrubs with a trunk-diameter up to 15 cm break and die off because the bark is peeled.
- Prescribed burning in winter (January/February) and late summer (August till October) on the steep slopes. The controlled burning is performed on an area of 0.1 up to 1.0 ha and is tested for the three dominating stages of succession:
    - grass stages (Arrhenathero-Inuletum)
    - *Rubus*-dominated stages
    - by *Prunus mahaleb* and *Cornus sanguinea* dominated succession stages

The use of prescribed burning is therefore tested not only as a tool for nature conservation (conservation of grass-dominated stages) but also in the sense of a restoration burning in order to restore open xerothermic habitats out of scrub-dominated habitats.

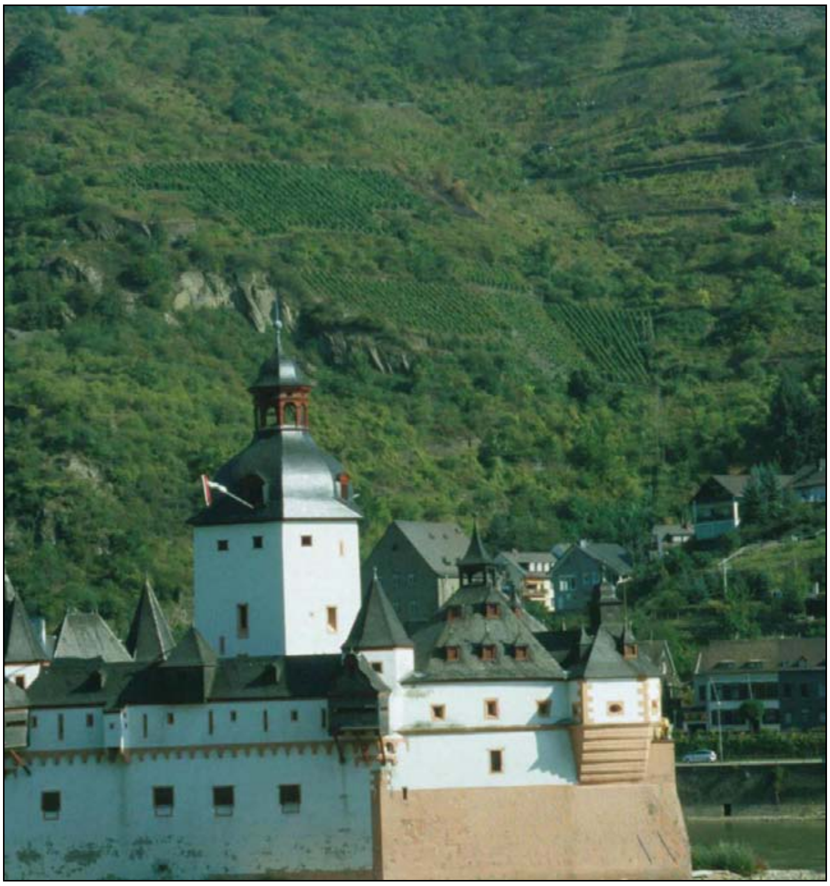

Figure 1. The landscape of the Middle Rhine valley, recognized as a UNESCO World Heritage site, has been shaped by viticulture over centuries. Abandoned viticulture lands on extremely steep slopes are undergoing succession – an old cultural landscape is endangered. The photo shows Kaub fortress and the slopes on the East side of Rhine river. Photo: GFMC.

Figure 2. Close up of y typical abandoned vineyard at Kaub. Photo: GFMC.

Figure 3. Upslope-running prescribed fire on an abandoned, *Rubus*-dominated site, close to a cultivated vineyard close to Gutenfels Castle / Kaub (7 September 2002). Photo: GNOR.

Figure 4. This photograph of a prescribed fire near Boppard demonstrates the extremely steep slopes along the Rhine valley. Photo: GNOR.

The realization of the different conservation strategies started in summer 2002. All management strategies are compared and valued under conservation aspects as well as socio-economic issues.

Project implementation

The project (duration November 2001 to October 2004) is implemented by:

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Technical support

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Max Planck Institute for Chemistry, c/o Freiburg University

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Bonn, S. 2002. Management concepts for abandoned xerothermic slopes in the middle Rhine Valley - a case study for the sustainable development of cultural landscapes. In: Pasture Landscapes and Nature Conservation (B. Redecker, P. Finck, W. Härdtle, U. Riecken, and E. Schröder, eds.), 253-261. Springer-Verlag, Berlin-Heidelberg.

Gesellschaft für Naturschutz & Ornithologie Rheinland-Pfalz e.V. (GNOR) 2005. E+E-Vorhaben Mittelrhein - Nachhaltige Entwicklung xerothermer Hanglagen. Final report (in prep.)

Habitat Management in Military Training Areas, Germany

OFFENLAND: Habitat Management in Military Training Areas in the Pleistocene Lowland of Northeast Germany: Fundamentals of Nature Conservation and Practical Implementation

Acting partner: Brandenburg Technical University (BTU) Cottbus

Cooperation partners: University of Freiburg, University of Potsdam, The State Museum of Natural History Görlitz, The Institute for Agricultural Engineering (ATB) Bornim e.V.

Valuable open landscape biotopes, which are characterised by great biodiversity, cover large surfaces of military training bases. The conservation of these areas requires appropriate measures that ensure they remain open.

As integral part of the BMBF sponsored project OFFENLAND (Fkz 01 LN 0008), clearing of vegetation by shooting exercises and mechanized manoeuvres on an active military installation in eastern Germany were investigated.

Restrictions as limited access to the study area and extraordinary efforts in getting special permits to work on those areas should be considered. Beyond doubt the ignorance of the intensity, temperature and time of fire is another continuous problem while working with “fires of opportunity”.

Pitfall trapping, monitoring of the vegetation and soil analyses did not indicate any serious decline of abundance or vitality of species. Activity-densities of epigeic arthropods were not significantly affected by fire. Effects on the composition, structure and distribution of different vegetation types were observed. A typical mosaic of recently burned, earlier burned and unburned patches brings about a high variety of different vegetation patches. Furthermore varying soil qualities and fire intensities affect the secondary succession in many ways. Immediately after burning, representatives of all important groups of the soil microfauna were found alive in the upper soil layers. Shallow, short-term and small-sized patchy vegetation fires did not reveal any severe short- or longer-term impacts on abundances or biomasses of testate amoebae.

The results from this study highlight the fact that the “unintended side effect” of routine military exercises - especially shootings – may be an appropriate and feasible tool to create and preserve open landscapes with valuable open habitats for localized and rare animals.

Anyhow the establishment of prescribed fire in landscape management needs intensive and consolidated educational advertising. Local people and public authorities have to be convinced of the cost-effectiveness and environmental compatibility of controlled fire after a long tradition of fire fighting and fire suppression.

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Visual Impressions of the Offenland Project

Figure 1. Burned pine forest (Photo: Stumpf)

Figure 2. Small sized patchy vegetation fires result in a mosaic structure (Photos: M. Wanner)

The Use of Prescribed Fire on Embankments along Railway Tracks for Reducing Wildfire Ignition in Germany

Introduction

During the extremely dry year 2003 more than 800 wildfires occurred along the railway network throughout the Federal Republic of Germany, resulting in considerable operational disturbances and delays of trains. In order to ensure safety of railway traffic and fire fighters the tracks have to be closed immediately after reporting of a fire. The response to the fire alert by the fire services is quite rapid. However, the duration of track closure is determined jointly by the fire services and German Railways (Deutsche Bahn AG). Opening of the railway traffic is permitted after fires are extinguished. Thus, the duration of halting the traffic does not depend on the coordinated organization of the response. Most critical is the composition of vegetation and fuel loads in the immediate vicinity of tracks on which trains have to reduce speed by breaking. Sparks that are generated by the breaks provide the ignition source of flash fuels within a belt of a couple of meters width on both sides of the railroad track. Thus, German Railways is investigating options for fuel management, especially in extreme droughts such as in the summer of 2003. Prescribed burning for fuel reduction is one of the fuel management options.

Figure 1. Railroad track embankments also constitute a risk of fires spreading into residential areas such as this situation in Unterfranken, Bavaria.

Figure 2. This family home was damaged by wildfire spreading from the slope in summer 2003.

The Fuel Complex

The embankments of those railroad tracks that are typically affected by wildfires is dominated by grass cover. During dry summers, at the peak of the fire season, the desiccated grass layer constitutes a flash fuel bed which is easily ignited by sparks – even if these have a short lifetime of glowing.

Figure 4. Typical grass fuel bed on embankments along a railroad track in Unterfranken, Bavaria, Germany. The main species grass species in this region include *Glyceria declinata*, *Brachypodium pinnatum* and *Arrhenatherum elatius* (Poaceae), which become highly flammable during dry spells.

The Use of Prescribed Fire in Wildfire Hazard Reduction

The application of controlled fire to reduce the risk of uncontrolled wildfires along railroad tracks had a long tradition in Germany until the early 1970s. However, the methods of burning were not based on scientific research. There was also a lack of safety standards. With the new Federal and State Nature

Conservation Laws as well as the waste disposal regulations of the 1970s, the use of fire as a tool for disposing agricultural waste or maintenance of open grasslands was prohibited. As a consequence mechanical treatments replaced burning, making embankment maintenance labour-intensive and costly.

The existing laws and by-laws, however, provide exemptions from the general fire ban which are granted under certain exemptions. In order to obtain such an exemption accompanying research must prove that there are no negative effects of prescribed fire application on the environment and that precautions and safety rules are observed to exclude the risk of uncontrolled fire spread and undesired side effects of burning.

The target fuels for fire treatment are primarily flash fuels, notably the grass layer, that must be burned under prescribed conditions immediately before the onset of extreme wildfire danger, i.e. during the summer months. Slopes with high fuel loads, e.g. residues of mechanical shrub and tree clearings, may be burned during the winter months.

Other aspects of prescribed burning on railroad embankments include the necessity of halting succession from grass-stage vegetation towards bush and tree encroachment. This is not only a consideration affecting traffic safety. Open slopes along railroads are providing valuable home for valuable floristic and faunistic biodiversity, including endangered species. For instance, the habitat requirements for lizards (e.g., *Lacerta viridis,* Lacertidae) include open grass stages and a warm soil surface during daytime. Some plant species are endangered due to bush and tree succession, e.g., heather (*Calluna vulgaris, Erica tetralix*) – a development which can be controlled by the application of prescribed fire.

Figure 5. Timing and coordination of prescribed burning operations with railway traffic control is required to ensure safe traffic. This photograph shows a prescribed burning trial along a single-rail track in Bavaria.

First Experiences in 2004

After the devastating fire season of 2003 German Railways requested the support of the Fire Ecology Research Group / Global Fire Monitoring Center (GFMC), Freiburg, Germany, to conduct initial trials in order to prove environmental-friendly and safe burning procedures. First experiments were conducted in Bavaria inn August and September 2004.

Figure 6. Passing of a passenger train during a prescribed burning operation. The photograph reveals the importance of prescribed wind conditions. Smoke management considerations in average situations require burning at the downwind (lee) side of embankments in order to drive the smoke away from the rails.

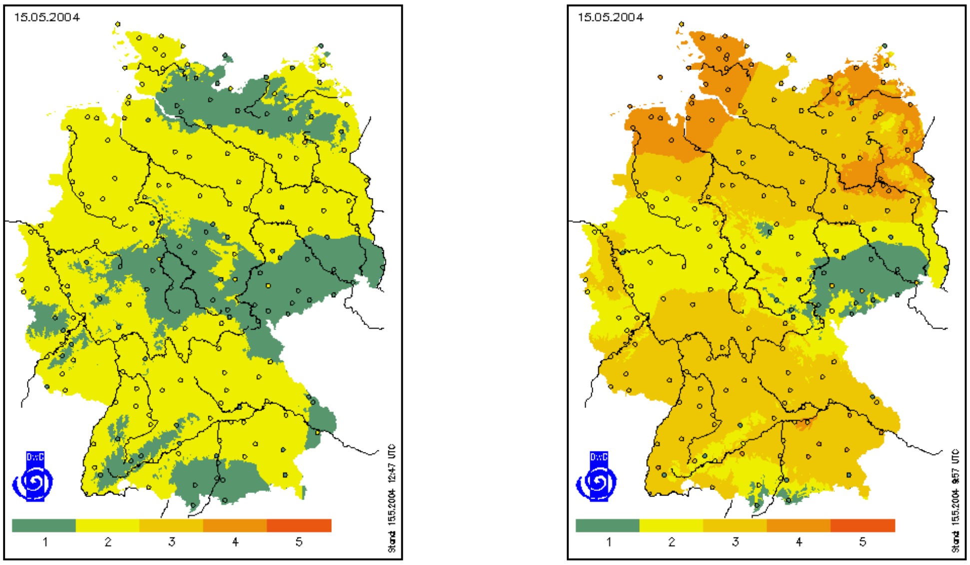

Figure 7 a,b. Comparison between the DWD Forest Fire Index vs. Experimental Grassland Fire Index (Example of 15 May 2004).
Source: http://www.agrowetter.de/Agrarwetter/fbidx.htm

Prospects for 2005-2006

Based on the experiences gained in 2004 German Railways and the GFMC intend to continue a series of test burns and the consolidated development of prescribed burning guidelines for the specific use on railway embankment conditions. One of the core activity will be the training of personnel. It is aimed at handing over the torch to German Railways by end of 2005.

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Slash-and-Burn Experiments to Reconstruct Late Neolithic Shifting Cultivation

Introduction

The origin of agriculture in the Near East was in a region where the wild ancestors of the cultivated plants grew in a more or less open landscape. The spread of agriculture to the northwest into Europe covered forested landscapes and therefore required clearing to practise agriculture. According to older opinions, Neolithic agriculture was rather simple and hadn't developed sophisticated methods of manuring and tillage. Therefore people had to shift their fields regularly to avoid bad harvests (Childe 1929, 1952, 1960, Sangmeister 1950). But on the authority of later research the fertile soils of the loess belt in Central Europe, colonized during the Early Neolithic of Central Europe (about 5600 to 4300 B.C. cal.), allowed adequate yields for many years without manuring. Adequate yields in this case mean between five and eight dt/ha, as calculated for the Early Modern age three-field-system. Based on those yields are also quantitative models of Neolithic agriculture and nutrition (Jacomet and Schibler, 1985). For these reasons permanent fields and settlements were postulated (Modderman 1971, Lüning 1980 a, b). Neolithic agriculture was different from recent shifting cultivation in the tropics and also different from early modern age slash-and-burn agriculture on poor soils in mountains.

In the late Neolithic, between 4300 and 2300 B.C., people colonized fresh landscapes outside the loess belt, in the low-mountain region and in the former glaciated regions of the pre-alpine lowlands and those of northern Central Europe and southern Scandinavia. Pollen and macrofossil data from lake-shore settlements, peat and lake sediments of the northern pre-alpine lowlands indicate shifting cultivation and slash-and-burn agriculture (Rösch 1987, 2000) for this period. Obviously the Late Neolithic agriculture was different from the Early Neolithic agriculture in the loess belt. But it is not sure if this was a slash-and-burn system and under which circumstances and with which results this system worked. Therefore experiments are necessary.

Material and methods

To deliver new and different arguments to the discussion, we started 1994 with agricultural experiments to reconstruct Late Neolithic land use (Bauer 1998, Rösch 1998). Since 1998 these experiments have been carried out in Forchtenberg, northeast of Stuttgart, where the Forest department of Baden-Württemberg put an area of 3.5 ha with mixed deciduous forest at our disposal (Schulz 1999, Rösch et al. 2002a, b). The soil type of the area is Luvisol and Stagno-Luvisol according to WRB (FAO 1998); the climate is moderately suboceanic with an annual average temperature of about 9°C and an annual precipitation of about 850mm. The area has been forested for at least 200 years and is surrounded on all sides by forest. In the eastern part, where the best soils are located, Celtic fields indicate former agriculture.

The area was divided into 34 single plots with an extent of 30 x 30 m. Every year one or two plots are cleared for experiments. At the moment experiments are being carried out or succession processes after experiments are under observation on nine plots. The experiment is a multidisciplinary approach with the participation of different scientists. Data are collected concerning:

- burning temperature, charcoal and carbon circle
- archaeo-ergonomic data
- yields of different cereals
- soil biology and chemistry
- soil structure and morphology
- vegetation, seed bank and pollen precipitation

The normal cultivation procedure is as follows:

- Clearing of the forest in winter by cutting the trees. This is done partly with power saws, partly with copies of Neolithic stone axes to calculate the effort for clearing using original tools and technology.
- Removing the stems and wood with a diameter thicker than 10 cm
- Burning a part of the cleared area, between 50 and 150 m^2, using the remaining thin, dry wood as fuel. This is done in autumn to grow a winter crop or in spring to grow a summer crop. To burn the top soil and vegetation completely, a burning roller of wood is moved slowly

over the area, using long hooks for pulling and feeding the fire permanently with wood (Figure 1). Burning an area of 100 m^2 demands the day's labour of a number of people.

- Sowing cereals a few days after burning, preferably after the first rain, in single holes made by a wooden stick. The holes are at distances of 16 cm and each contain ca. 8 grains. The resulting seed density is ca. 300 grains per m^2. As crops we use all cereals known from the Late Neolithic, *Triticum aestivum* (modern and old race) and *Triticum monococcum* as winter crops, *Triticum durum*, *Triticum dicoccon* and *Hordeum vulgare* (modern and old race) as summer crops.
- Removing tall weeds once in the autumn-sown crop and twice in the spring-sown crop.
- Protection of the yields from game by fences, from birds by nets, and from mice by special walls made of metal sheets.
- Harvesting the ripe cereals, partly by using copies of Neolithic harvesting tools.

Figure 1. Burning by moving the fire with hooks slowly over the ground

Apart from this standard procedure we also test a first growing season after clearing without burning and long-term agriculture at the same place without burning and fertilizing, but with tillage by hoeing. As far as animals are concerned, experiments to integrate livestock, especially goats and pigs, in the land-use system, have also started. The aim is to look for possibilities of weed regulation and tillage without fire or manpower.

Results and discussion

Important results of the experiment are:

- fire temperature in the soil shows a large variation, but normally at a depth of 1 cm the temperature is above 80°C and at 2 cm above 60°C. So nearly all weeds are suppressed (Figure 2).
- with burning the average yields of autumn-sown cereals are higher than 20 dt/ha on the poorer and more than 40dt/ha on the better soils (Figure 3). With spring-sown cereals the yields are about 1/3 lower, due to shorter growth time and higher weed pressure.
- without burning the yields are less than a ¼ on the poorer soils or less than ½ on the better soils compared with burning
- Growing cereals at the same place for several years without burning and fertilizer and growing cereals after clearing, but without burning and fertilizer, results in yields between nearly 0 (poor soils) and lower than 5 dt/ha (better soils).

- The main reasons for the high yields after burning are the mobilisation of nutrients, the rise of the pH, which makes nutrients better available, especially for wheat, and the suppression of weeds.
- These so called weeds are mainly not typical crop weeds but trees and shrubs, herbs of the forest floor or from clearings and forest fringes recovering from their root-stocks, or freshly germinating. Their development is very vigorous and makes growing on the same place in the following years very difficult and time-consuming.

Figure 2. A field burned and sown in autumn is here to see in spring. The wheat has well developed and the field is free of weeds. In the background *Anemone nemorosa* is flowering outside the burned area.

Figure 3. A burned field shortly before harvest. The wheat is in dense stand and more or less free from weeds, whereas in the surrounding tall thistles and other weeds cover the ground.

Conclusions

Assuming the availability of sufficient forest and wood, the slash-and-burn technology with shifting cultivation achieves higher yields compared with permanent agriculture and also compared with the usual agriculture with tillage and fertilizing on permanent fields as known from the iron age and medieval period. Clearing the forest is time-consuming, but the most important disadvantage is a lower total yield in a completely used landscape, because of much fallow land used to produce new wood for fuel during long-term fallow phases. Therefore a growing human population must substitute this type of agriculture by more sophisticated but even more lavish technologies. Whether long-term slash-and-burn agriculture with several cycles on the same place results in a deterioration of the system remains an open question for this long-time research project.

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NETHERLANDS

Burning of Heathland in Military Areas in the Netherlands

Project Objectives

Heathlands in the Netherlands are mainly managed by mowing, grazing or sod-cutting. Due to their use as military training areas, some heathlands are treated different: On the large artillery shooting ranges Oldebroek and Harskamp, the open areas are managed by fire. Due to unexploded ammunition, sod-cutting or mowing is not possible, so that prescribed fires are used. Burning is almost abolished in The Netherlands, but is has always been one of the traditional treatments to sustain and regenerate heather. It is remarkable that especially in the military areas, that are burned regularly, rare and endangered species are found, which are not existing in any other place of the country. One example is the Heath Bush cricket at the heathlands of the Oldebroek shooting range: This grasshopper was recorded as to be extinct in 1987, but in 1999 it was discovered on the previously burned areas at Oldebroek. This species can be found nowadays only at two places in Europe: at the place mentioned above and at the Lüneburger Heide in Germany.

Additionally, many rare plant species benefit from the burnings: At the Harskamp shooting range, the largest populations in The Netherlands of *Arnica montana* can be found, amongst other species like *Pedicularis sylvatica, Scorzonera humilis* and *Polygala vulgaris*.

Of course, fire is not beneficial for all species, but the examples mentioned above make strong arguments to reconsider fire as a promising method to manage heathlands. Further research on this topic would be very helpful.

It should be noted, though, that areas which are dominated by high grass coverage, can not be re-converted into heathlands by fire. Sod-cutting is more appropriate in these situations.

Figure 1. *Arnica montana* at the artillery shooting range Harskamp.

Figure 2. Prescribed burners in action.

Permits

The local communities in conjunction with the fire brigades can permit the prescribed burns. Conditions have to be suitable before the fire, especially an incomplete consumption creates unwanted air-pollution.

Practical approach

Burnings are conducted in winter only, under the supervision of the military fire brigades. Patches and lines with no fuels are used as fire lines to control the fire. The danger that the fire gets out of control is very small.

The fire is set under a given set of weather parameters only, so just a few days are suitable each year. The weather must be dry with slow winds (wind speed of 2,5 to 4). Too fast winds make it hard to control the fire, too slow winds do not spread the fire well enough. The fire intensity is controlled by different firing techniques, either fast wind-fires or slow backing fires with high consumption or organic materials. Slow fires also consume many seeds stored in the organic humus layer and animals which are dormant in upper soil layers. In the case of heathlands with grasses, we therefore burn with the wind.

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POLAND

Peatland Fires on Biebrza Marshes, Poland

The description below accounts to the research programme, which consist of several research projects. The projects are independent activities, although they are all related with a topic of fire and they will cover a broad spectrum of research issues – reasons for fire, it's effects on soil, fauna, flora and management tools. It is intended that all this projects will have separate budgets and each of them can stands on it's own. Some of these projects are already going on, for other money was applied for and others are in preparations or in plans. The description which can be find below address the research programme and can be seen as a main outline of it. Different projects can be placed in this framework for research.

Project Title: Biebrza Peatland Fires – Reasons, Effects and Consequences for Nature and Management on Post-Fire Sites

General Aim

The aim of this integrated research project is to study the effects of the deep fires on the peat land. The focus of this research is on fen and moss-fen peatlands, which are rich ecosystems, often located in the river valleys and used by man in more or less intensive way. The focus of the study will be on:

- vegetation processes (species survival, succession),
- effect of fire on fauna
- the habitat changes (peat and soil conditions, detrimental chemical compounds)
- management on the post fire sites.

There are many types of fires with respect to its length, character, timing and impact on the living organisms and some of them are said to cause a serious loss of biodiversity and significantly change the habitats. The deep, underground peat fires are among the most destructive. Our purpose is to investigate the consequences of deep fires for the vegetation, animals and abiotic environment. We will also plan to explore the possibilities of applications the innovative techniques (Remote Sensing, modelling) to monitor, predict and prevent the fire.

Important question the project addresses is how to manage the post-fire sites in order to restore the valuable nature. We also would like to look how the fire acted as a management tool in the past and how it can be possible to apply fire as a management tool today.

We are going to explore risks of mismanagement, knowledge gaps and uncertainties about fire and finally the common opinion and legislation towards fires. Bringing together the theoretical concepts, new nature conservation paradigms and empirical knowledge we would like to formulate new policy towards management in nature sites.

Objectives

In order to be able to control the fire and properly manage the post fire areas monitoring, mapping and collecting information about the conditions before and during the fire as well as about the burning process is needed. Fight against the deep peatland fires is very difficult and sometimes practically impossible. To avoid fires or predict the risk of its occurrence, gaining knowledge about reasons and circumstances of fire in the peatlands seems to be essential. The following objectives should fulfil described needs:

- Map the burnt areas, based on Remote Sensing techniques and in-the-field measurements
- Describe spatial and physical features of fire
- Define the reasons, conditions and dynamics of fire
- Develop the early warning system (fire-alert model)

Elimination of vegetation and changes of soil cause a severe change in peatland ecosystem. On the post-fire sites the new processes of soil forming, vegetation succession and re-colonisation by fauna take place. The combustion of higher peat layers influences the conditions after the fire. Physical and hydrological properties of the peat remaining in deposit are being changed also, especially the volume density and porosity.

Long-lasting penetrating peatland fire is threatening for people not only on account of smog, but also on formation of highly toxic organic compounds, like polyaromatic hydrocarbons (PAHs). The following objectives of the project have been set in order to explore the ecological consequences of fire occurrence:

- Investigate the long- and short-term effects of fire on vegetation, species composition and succession processes
- Study the fire impact on habitat conditions
- Study fire impact on fauna
- The influence of compounds emitted during fire on human health

The peat land fire is usually perceived as a disaster for nature and source of negative effects on natural ecosystem. On the other hand fire can be seen as a natural force which brings back the ecological balance on the partly degraded and desiccated peat lands. It is a drastic disturbance that removes the layer of dry, degraded peat and allows new peat formation processes to start. Thus fires on peatlands may draw back the succession stages and help with re-establishing of the low vegetation. Fire can be also a management tool useful to stop or slow down the succession on the abandoned wet meadows. Farmers on the extensively maintained wet meadows, sedge meadows and heather often used it with in the past.

The objectives of the project related to management are as follows:

- Develop the management options to maintain and restore the valuable vegetation and fauna on the post-fire sites
- Investigate the impact of different management measures on post-fire sites
- Develop effective monitoring system on the post- fire sites

Outcomes and Plans

International co-operation: Fire is a problem of the international importance. In many cases they cause a loss of already partly desiccated, scattered and fragmented peatlands and contribute to the CO_2 emissions to the atmosphere.

In many countries (Scotland, Netherlands, Sweden, Finland) fire was use in the past to maintain the extensively used areas and remove the dead biomass. Today fire is a potential management tool, which may help to restore some types of ecosystems, however we don't have enough knowledge on this topic. In order to explore and understand the complex issue of fire we should work internationally and develop a strong network of partners. We also would like to explore the nature policy. In order to provide sufficient means for further project realisation, we aim at exploring new financial sources (like EU funds). We believe that by means of promoting nature management partnership, exchange of ecosystem expertise, strengthen the relationship between sustainable agriculture and nature management our project will be a true implementation of biodiversity protection policies. Within this project we aim at international collaboration, which contributes to sustainable development in Poland but also benefits nature in other European countries. In this project we would like to start a fruitful co-operation between various research institutes, nature management organisations and non-governmental organisations from Poland and Germany, the Netherlands and hopefully in a future also Baltic States, Slovakia, Czech Republic, Hungary and others. In this way we would like to bridge a gap between science, policy, private and public parties. The international co-operation on this topic will also significantly contribute to capacity building of scientific staff of institutes from Poland and abroad.

Long-term goals. These goals include:

- Develop the rules for monitoring of fires and effects of fires on biodiversity (on the local, regional and international scale)
- Investigate the succession processes on the post-fire areas (including fauna and flora)
- Investigate the impact of fire on other ecosystem processes – like soil processes and hydrological regimes
- Assess use of fire as a tool in nature management and nature conservation. Develop the guidelines how to use it and evaluate the risks and limitations of using the fire

- Develop the network of the research institutions and other organisations (e.g. NGOs), which work on the topic of the peatland fires

Short-term goals. The goals include:
- Assess the impact of fires on different elements of biotic and abiotic environment
- Explore the application of remote sensing techniques in burnt area mapping and monitoring different processes occurring on this places. Explore the application of remote sensing together with GIS methods and modelling in evaluating the risk and preventing the fire
- Monitor the vegetation, soil and fauna changes and succession on the post-fire sites
- Start the post-fire management experiments in order to develop the best options for nature restoration

During the first phase (2003-2004) we established a network of experts, coming from field of science, management and policy-making. We are aiming at building partners network, develop the full research programme and explore the funding possibilities. We are also planning to organise workshop meeting and participate on seminars on this topic, in order to strengthen the collaboration with international and national partners. The projects in second phase (2004-2008) will allow starting long-term research on vegetation structure and processes, management options on the post-fire sites and establishing the on the post-fire areas. In long-term this project would contribute for hydrological and ecological models, biodiversity assessments and estimations of role of wetlands in global climate change. Changes caused by fire should be considered in the hydrological and ecological models, describing the functioning of wetlands.

Scientific and practical outcomes: After each research project a separate report will be prepared and presented to the co-operating institution. A number of scientific publications will be prepared. It will provide the high quality scientific research, which will support the future research projects on this topic and the nature management in peatlands. The outcome of the project will be also predictions of fire risk on peatlands. During the part of the project dedicated to management, different management options will be compared. The guidelines for sustainable protection and management of nature and landscape will be developed as well as widely supported policy options on response to fires on peatlands. This knowledge will help in setting appropriate nature management and fire and post-fire monitoring in the region and elsewhere.

Research Area

The study is carried out in Biebrza River valley, in Northeast of Poland. Biebrza Marshes are known as a reference area for many fen peatlands and river valley wetlands, due to outstanding and well preserved nature, and due to character and magnitude of natural processes taking place there. The research areas will be selected in Biebrza National Park (BNP) and its surrounding (e.g. buffer zone). Since the national park was established the fires took place there almost every year. Deep-seated fire, i.e. penetrating to lower layers of peat deposits occurred in Biebrza National Park, where it destroyed several hundreds hectares of fens. Some of the burnt areas will be investigated. The study plots can be located in the Middle Basin of the valley, close to the Kapice village, where an area of several hundred hectares was burnt in 2002. Other possible study plots are: “Triangle” north of Goniadz town also in the Middle Basin and Bagno Lawki in the Lower Basin of Biebrza valley. The specific locations will be defined later during the project implementation.

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SWEDEN

Fire in Sweden – History, Research, Prescribed Burning and Forest Certification

Since most of Sweden lies within the boreal and boreo-nemoral zones, fire has, up until recently, also played a major role in shaping the forests. Out of the total forested area of 23 million hectares (ha), only a few hundred thousand ha forest belongs to the temperate deciduous zone where presumably the rich hardwood forest composed by *Fagus, Quercus, Fraxinus, Ulmus, Tilia, and Acer* sp. has been less influenced by fire in the past. Although most of our forests are shaped by fires it is not until the recent decade forest managers and public has become aware of this. Research about fire or rather research *related* to fire has increased dramatically in the last years, largely catalysed by a growing concern for environmental issues.

At present only a fraction of the forest land burns annually (in the order of 0.017 - 0.0017%), from a few hundred hectares in wet years to a few thousand ha in a dry summer (max c. 5 000 ha). Most of the ignitions are today human caused but lightning ignitions can cause a substantial amount of the fires in dry years when periods of high pressure are followed by thunderstorms with little or no rain following. The number of lightning ignitions follow a N-S and W-E gradient where the highest amount occur in the southeastern summerdry part of the country (in the order of 0.2 ignitions per 10 000 ha and year) and the lowest lightning ignition frequency in the high altitude northern forests (a factor 0.1 or less than in the southeast) (Granström 1993).

The burned area per year which allows conclusions on the *fire frequency* or the *fire-return interval* today is very different from the past situation due to effective indirect and direct fire prevention and suppression efforts. The network of forest roads is extremely dense, even in the north and allows for early attack by fire fire-fighting crews. According to fire history studies (Kohh 1975; Zackrisson 1977; Engelmark 1984; Niklasson and Granström 2000) fires were occurring at 50-150 yr-interval in the north and down to 20 yrs in the south (Page et al. 1997, Niklasson and Granström 2000, Niklasson and Drakenberg 2001). A very rough national average of the annually burned area of about 1.7 % of the total forest area is equivalent to a 58 yr-return interval. Fire suppression became effective around 1860-1880 over most of the country and since then burned area diminished to a seemingly steady level since the 1950s. In the southern part suppression seems to have started less uniform and generally earlier. The reasons behind the rapid decline in fire frequencies is somewhat debated although there are evidence for strong human impact on the fire regime from some regions (Niklasson and Granström 2000, Granström 2001). The rapid growth of organized forestry and expanding timber industry over most of the country in the late 1800s should have had a major effect on this process.

The long time of fire suppression in combination with an increasingly intense industrial forestry has had negative consequences for many species. While the loss of old trees must be ascribed more to forestry than fire suppression, the absence of fire has pushed several hundred of fire-adapted and fire-requiring species, predominantly invertebrates, from being common to rare or even extinct in the country (Ahnlund and Lindhe 1992, Ehnström, Långström et al. 1995, Wikars 1997). A few of these species are strictly dependent on fire *per se* while the major part of this group depend on structures and processes that mainly fires provided in the past such as: openness/sun-exposure, dead wood, damaged trees with lowered vitality, fire scars, burnt ground. Another strongly negative effect from the combination of forestry and fire suppression is the lack of seral stages dominated by deciduous trees such as *Betula, Populus, Salix.* The reproduction from seeds of *Populus* and *Salix* is strongly promoted by fires and is now a rather rare event. The flagship species white-backed woodpecker *Dendrocopus leucotos* is now on the verge to extinction in Sweden being confined to older deciduous-dominated forest, typically of fire origin. Only a hundred years ago this bird was common all over the country.

Although the awareness has increased dramatically among foresters and public about fire, this has so far very little been turned into action when it comes to using fire as a tool. Although the structures, substrates and effects of fire has influenced the design of alternative management regimes (Angelstam 1998) the incorporation of fire is hampered by a lack of practitioners, anxiety for loosing control of burns and a lack of resources. In fact, according to the Swedish certification criteria under the Forest Stewardship Council as much as 5% of the annual clear-cut area should be burned. This is hardly accomplished at present, and these burnings typically lack from a species-oriented view resulting in superficial burning of the organic layer but high tree layer mortality (Granström 2001, pers obs.). The burning for regeneration purposes had a renaissance in the period 1950-1970 (annually on the order of 10 000 ha) but ended rather abruptly due mainly to rapidly growing labour costs and rationalization of management systems.

Figure 1. Prescribed burning according to the certification standards in June 2001 on former state forest land in southern Sweden. High intensity, often mortal to left-behind trees, due to voluminous slash and ignition pattern, is a common picture in these type of fires. For large forest owners, prescribed fire is required on 5% of the annual clear-cut area to meet the FSC certification standards. See: http://www.fsc-sweden.org/gron/Swedish%20FSC-standard1.html#6.4

Figure 2. The effects of the severe and dramatic fire of 1999 in Tyresta National Park attracts many field visitors. However, according to tree ring evidence such high-mortality burns were rare in the past. Up until the late 1600s the area burned every 30 years by low-intensity fires where after almost no fires occurred until now.

Fire research in Sweden is mainly concentrated to Umeå in the north with studies on succession, fire behaviour, and fire history (Granström, Schimmel, Niklasson, Zackrisson, Linder and others), plant-plant interactions, ecosystem functioning (Zackrisson, Nilsson, Jäderlund), paleoecology (Segerström, Hörnberg). Uppsala has a strong tradition in entomology (Wikars, Ehnström, Weslien). In southern Sweden, some paleoecological research has been done in the past (Bradshaw, Hannon, Lindbladh) but very little other research. Fire history studies has just started (Niklasson) and pilot studies in fire behaviour/flammability (Niklasson and others). A lot of the research in other fields of ecology can be ascribed to fire or has fire a common denominator. It is out of the scope here.

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UNITED KINGDOM

Prescribed Fire in a Scottish Pinewood: A Summary of Recent Research at Glen Tanar Estate, Aberdeenshire, Scotland

Summary

The role of natural disturbance in maintaining important ecological processes in natural Scots Pine woodland is becoming increasingly recognised. With increasing pressure to secure the future of pinewood species such as the Capercaillie (*Tetrao urugallis*), it has become necessary to develop innovative management techniques to manipulate habitat conditions in the absence of browsing pressure. The use of prescribed fire is one of the most promising such management techniques, and is widely used for resource management in similar ecosystems in North America and Australia. Preliminary research conducted at Glen Tanar Estate has demonstrated the potential benefits of prescribed burning, and has produced a number of useful insights to help shape the development of this technique in Scotland.

Introduction

The complex role of fire in the ecology of natural Scots' pine forest is well documented for many parts of its extensive distribution (Goldammer and Furyaev 1996), where fire is accepted as an important natural factor in the maintenance of a mosaic of forest types at the landscape scale. In Scotland, however, fire has generally been ignored as an ecological variable even though it has potentially positive attributes. This is presumably because the negative impacts of fire on native woodland have historically been very serious (Steven and Carlisle 1959) and there is an understandable fear of wildfire and its risks to person and property. Also the likelihood of fire occurring and its consequent ecological importance as a disturbance event is easily overlooked the oceanic climate of the United Kingdom.

Whilst caution is justified, the assumption that fire is not a significant natural force the UK climate is unfounded. It is likely that fire has been a significant *natural disturbance mechanism* within the native pinewoods of Scotland (Peterken 1996). Historical evidence (Aberdeen Journal 1826) indicates a significant risk of landscape scale fire started by dry lightning (*i.e.natural)* impacting upon remnant Scots' Pine woodland, particularly in the eastern highlands. This is an area that experiences a semi-continental climate where short-term droughts are common. At one site in the eastern highlands, Glen Tanar Estate, the natural fire return interval has been estimated to be in the region of 80-100 years, based upon the historical evidence of the past four centuries (Marren 1986, Miller and Ross 1990). By ignoring, rather than studying, the role of fire in forest ecology in Scotland, there is a danger of exposing areas to damaging wildfires and failing to recognise an important ecological process.

The distinctive wildlife of the pinewoods, such as the Capercaillie (*Tetrao urugallis*), is affected by the gradual changes to habitat structure that occur over time. In some long established native pinewoods such as Glen Tanar and Abernethy, where grazing has been restricted over a long period, Blueberry *(Vaccinium myrtillus)* areas are becoming dominated by long rank heather to the detriment of woodland grouse species (R. Moss, pers. comm.). Burning areas has been shown to help blueberry regenerate and compete with heather (Welch et al. 1994).

One of the key factors in improving the Capercaillie population is to undertake measures to improve chick survival. One way of achieving this is by providing Capercaillie broods with a varied habitat structure that allows movement and provides shelter and contains a relatively high proportion of Blueberry (Summers et al., in press), which is important for the diet of Capercaillie in a number of ways. Firstly, it supports caterpillars and other insects that are an important food source for chicks shortly after hatching (Cramp and Simmons 1980, Kastadalen and Wegge 1985, Picozzi et al. 1999). Secondly, the leaves are eaten (Storch 1993, 1994) especially in the summer, and the berries are eaten in the autumn (Borchtchevski 1994).

Figure 1. Rank heather in a prepared prescribed burn plot in the Glen Tanar Pinewood

In the UK the traditional muirburn techniques that are used to manage heather habitats for Red Grouse are the most common use of fire (Bruce 2002). Muirburn is also used extensively to manage and 'improve' grazing land for cattle, sheep and deer in upland areas (Hamilton 2000). However there are considerable differences between the traditional techniques used for burning in the UK and prescribed burning operations found in other countries.

The management team at Glen Tanar Estate recognised that there were significant gaps in their knowledge of fire and have therefore been actively involved in fire research and the development of improved fire suppression systems over the past five years (SGFFPG 1999, Bruce 2002, Murgatroid 2002, Lantra 2002). In the spring of 2002 the agency Scottish Natural Heritage commissioned Glen Tanar Estate to carry out applied research into prescribed burning in the form of a series of burning trials. Similar trials were also undertaken by the Royal Society for the Protection of Birds (RSPB) at Abernethy Forest Reserve in 2002.

Objectives For Prescribed Burning Trials at Glen Tanar

- To investigate the relationships between fire behaviour and fire effects in a pinewood context
- To increase the proportion of Blueberry in the shrub-layer of the pinewood, by burning a number of strips of heather without damaging other parts of pinewood ecosystem.
- To inform the development of *fire prescriptions* appropriate for the Scottish pinewood context.

Figure 2. Photo Prescribed Fire on the Strone in the Glen Tanar pinewood

Planning the trial burns

The lack of information on prescribed burning techniques appropriate to pinewoods in Scotland led the team towards adapting prescribed burning concepts and experience from other countries with similar ecosystems. One of the key concepts emerging from this review was that conifers similar to Scots Pine suffered from fire-induced mortality as a result of three main processes (Reinhardt and Ryan 1988):

a) crown scorch
b) damage to the cambium layer at the bole of the tree
c) damage to the roots.

A fire prescription was prepared with these factors in mind and with the knowledge of some key fire behaviour variables. First, that there is an established relationship between flame length, fireline intensity and height of lethal crown scorch for conifers. As a rule-of-thumb fire is lethal to foliage at a ratio of 1:6 to flame length (AFAC 1996) and mortality is likely when the scorch is greater than 30 – 50% of the live crown. (Alexander M, personal comment). Second, it has been established that damage to the cambium layer diminishes in proportion to the thickness of bark protecting the tree, and furthermore that bark thickness generally increases with tree age and DBH (Wade 1986). Third, it is accepted that water creates an effective thermal barrier, therefore roots in saturated soil are reasonably well protected from the heat pulse generated by a passing fire front (Chandler et al. 1983).

As has been mentioned previously a key objective was to kill the heather and Blueberry bushes but not damage the Blueberry rhizomes. Work in Swedish pinewoods by Schimmel and Grandstrom (1996) indicated that by controlling ***fire severity*** (which is defined as fire effects upon soil and litter layers) that this would be possible. Again the method that can be used to achieve this is to use the protective qualities of a damp moss and litter layer.

The design of fire prescriptions therefore incorporated the need for tall enough trees to avoid excessive crown scorch; large enough trees to have sufficient protective bark, and soils that were sufficiently damp to avoid excessive root damage. Sites were chosen with these features and Prescribed Burn Unit Plans and Operational Plans were developed for each site.

Methods

The burn plots were encircled by a double-width swiped trail, a further control line was burned in stages against the wind up to the swiped line, to a safe depth of at least two and a half times the estimated maximum flame length. The control lines were patrolled by teams using beaters and fire-fogging units to prevent any escapes. Fires were then ignited across the whole width of the plots, usually 20-25 metres wide, using a modified knapsack sprayer and were burned as headfires (i.e. burned with the wind) in short strips of 15 to 35 metres in length.

Site, Environmental and Fuel Conditions

Table 1 below summarises information collected during experimental fires conducted at two carefully selected sites on 27 and 28 March 2002. The sites were chosen to be representative of areas where prescribed burning might be most usefully employed to improve field layer Capercaillie habitat. Two plots were burned at each site, a smaller plot for the initial test run and then a larger plot after conditions had been fully assessed.

Results

As the table below shows the speed and intensity of the fires in Site 1 clearly demonstrated the combined effects of a continuous and very high available fuel load, along with fairly low fine fuel moisture content (70–85 % dw) and a relatively strong and persistent wind. Flame lengths in the backing fire and flank fires were generally lower than those in the head fire, being in the range 0.5 to 1.5 m. The maximum rate-of-spread was estimated to be around 1200 m/hr (see Table 1), which is four times greater than any rate of spread of moorland fires in Scotland, previously recorded (Hobbs and Gimingham 1984).

At Site 2 considerable difficulty was encountered in trying to burn the first plot, due to the unreliability of the light winds at the time., However, by mid-afternoon burning conditions had improved dramatically: windspeed had increased to 11–16 km/h and there was a drop in relative humidity from 62 % to 48 %, and bright sunshine with air temperatures up to 17°C. Burning proceeded with caution, the need for which was emphasised when flames spotted forward onto the top of two adjacent 8M standing dead trees (snags) just outside the plot's control line. The burning snag had to be felled and removed to the blackened area to prevent the fire escaping. Flame lengths in the headfire were generally within the range of 1-3 metres, although flares up to 4-5 metres were noted in areas of open canopy where the heather fuel load was greatest. In the backing and flanking fires, and in areas of broken heather and *Vaccinium*, flame lengths were much shorter (0.5 to 1.5m), with patches of pure Blueberry burning in places with 30-40 cm flames.

Table 1. Summary: Site conditions, weather, fuel quantity, and fuel moisture

	Site 1: Counseltree Burn (forest edge site)	**Site 2: The Strone (within-forest site)**
Site description:		
Altitude	380 m	340 m
Aspect	S.W. facing	S. – S.W. facing
Slope	5 – 10%	10%
Soil	Shallow, well-drained podsol on granite substrate	Moist peaty soil over granite, impeded drainage in places
Area	Plot 1: 25 x 60m (0.15 ha) Plot 2: 27 x 100m (0.27ha)	Plot 1: 23 x 44m (0.10 ha) Plot 2: 30 x 50m (0.15 ha)
Field Layer Vegetation	NVC H12b: *Calluna* - *Vaccinium* dry heath with scattered mature pine trees and limited pine regeneration	NVC W18b: Dry pine woodland with *Calluna* and *Vaccinium* dominated understorey, with occasional *Sphagnum* spp. and *Empetrum nigrum*.
Overstorey	None	Mature well-spaced Scots pine with an average dbh of 50.5 cm, average heights of 14-18m, average canopy base 6-10m and a density of around 160 trees per hectare.
Fuel Load	High: estimated 20.5 t/ha of 'available' fuel (<5mm diameter)	Moderate: estimated 11.8 t/ha of available fuel
Weather conditions:		
Average windspeeds	15 – 30 km/h	3 – 13 km/h
Max windspeeds	40 – 48 km/h occasionally	14 – 15 km/h
Relative humidity	65 – 70% throughout the day	62% (at 11 am) 48% (at 1 pm)
Fuel moisture content:		
Fine fuel %MC (dw)	70 –85%	83 – 94%
Moss/Litter % MC (dw)	287 % (at 10 am) 197 % (at 4 pm)	205% (at 10 am) 100% (at 4 pm)

Table 2. Summary of fire behaviour characteristics

	Site 1: Counseltree Burn (forest edge plots)	**Site 2: The Strone (understory – forest plots)**
Typical headfire flame lengths	3-4m, with flares up to 6-7m	0.5 – 3m, with flares up to 5m
Typical flank/backfire flame lengths	0.5 – 1.5m	0.5 – 1m
Forward rate of spread	500 – 1260 m/hr	150 – 385 m/hr
Fireline intensity*	6800 – 15400 kWm^{-3}	1150 – 3050 kWm^{-3}

* N.B. Fireline intensities were much higher than any previously recorded in Scotland and are at the upper limit for surface fires recorded in other countries (Chandler, 1983). In the Australian Fire Danger Rating system (AFAC, 1996) these fires would carry "very high" and "extreme" fire danger ratings.

Fire effects

Despite the relatively high fire intensity the fires at both sites largely succeeded in improving the condition of the field layer for woodland grouse. The majority of the rank heather was killed by the fire and is being succeeded by vigorous regeneration of *Vaccinium* spp., particularly in the woodland site where Blueberry has rapidly become the dominant component of the field layer. The majority of the dense moss layer was also killed off by the burning, and in some places was visibly consumed by the fire. This is also likely to create slightly more favourable micro-sites for tree seedling establishment. However the main humus layer that hinders regeneration (Edwards 1980), remains.

Two weeks after the understorey burns at the Strone, a detailed examination was made of the fire effects within the plots. Individual trees within burned plots were mapped and examined closely for crown scorch, bole charring, and any other fire-related effects. A total of 12 and 28 trees were located and assessed within the plots, and a summary of the results can be seen in Figure 3 and Tables 3.

Over three-quarters of the trees examined suffered crown damage, in the form of needle-scorch, to varying extents. The crown scorch is seen to have affected foliage up to 16 m above the ground in places, with an average upper limit of 7-8 m above ground level. The average proportion of the entire crown that has been scorched is around 20-25%, but around 18% of the trees studied (7/40) have suffered crown scorch of 50% or more.

The amount of crown scorch seemed to relate closely to the flame length of the fires as they passed under the trees. This in turn was related to whether this was part of the headfire, flank fire or backfire and also depended upon the variability of fuel loading across the site.

The ultimate impact of this level of crown scorch on mature Scots Pine trees is not yet clear. The damage may accelerate mortality due to poorer nutrition through loss of foliage and increased susceptibility to insect and pathogen attack. However, studies upon red and white pine in North America have indicated that individual trees have a 50% chance of surviving a 75% loss of foliage (Methven, cited in Van Wagner, 1973). All trees, even those with more than 75% crown scorch, in the understorey burn plots on the Strone were still alive when inspected in August 2004.

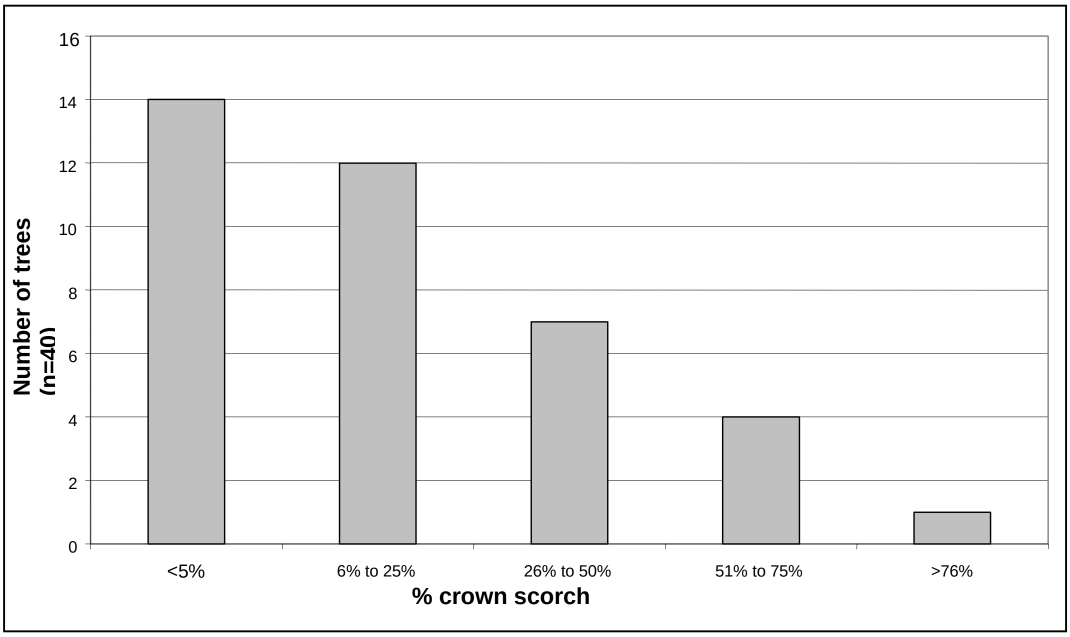

Figure 3. Number of trees within each crown scorch band

Almost all of the trees within the plots were affected by bole charring(see Table 3) however no specific data on cambial damage has been collected, and the contribution of this factor to tree mortality is difficult to determine. It is reasoned that cambial damage was minimised by selection of a stand of mature large diameter trees, with proportionally thick bark to provide thermal protection.

Table 3. Summary of bole charring and crown scorch resulting from experimental understorey burning trials within Scots Pine woodland (Site 1) at Glen Tanar Estate.

		Height of Bole Charring (m)		**Crown Scorch**	
		Lee side	**Windward side**	**Upper limit of crown scorch (m)**	**% of total crown affected**
Plot 1 (n=12)	Range	0 – 2.5m	0 – 1m	0 – 14m	0 – 60%
	Mean	1.1m	0.38m	8.17m	19.6%
Plot 2 (n=28)	Range	0 – 5m	0 – 1m	0 – 16m	0 – 81%
	Mean	2.2m	0.38m	7.0m	24.6%

The impact of the fire upon below ground processes is much more difficult to assess. However, it is envisaged that root damage was minimised by ensuring that burning took place at a time when the moss/litter layer was wet, thus providing a high degree of thermal insulation to the soil. The vigorous recovery of Blueberry from underground roots and stems (Figure 4) indicates that this strategy was successful.

Figure 4. Blueberry regeneration in understorey three months after fire

Figure 5. Vigorous Blueberry regeneration

Conclusions

- The project has shown that it is possible both in operational and ecological terms to use prescribed burning, even with high fire intensities, to successfully modify the shrub layer structure and composition to improve Capercaillie habitat within pinewood areas. The fires have achieved the primary objective of improving the environment for Blueberry, by removing competition from heather without damaging Blueberry rhizomes.

- The fire intensities were on average within prescription. Some damage has nonetheless been inflicted on the trees, largely caused by headfires. To minimise damage to the overstorey it will be necessary to restrict flame lengths. This could be achieved by:

    - Changing the ignition pattern to include more backfires, flank fires and narrow spot line ignition.
    - Burning when fuel moisture contents are higher.
    - Burning downhill.
    - Alternatively, burning could simply be concentrated at the forest edge and in canopy gaps.

- The very high fire intensities produced by these fires have highlighted the potential dangers of a wildfire occurring in rank heather, where flame lengths and fireline intensities can reach the top end of the spectrum for surface fires There is a need to give careful consideration to the hazards and risks created by such fires and the need to put in place effective control measures. These may include fire planning, training, sourcing of appropriate equipment, and the use of prescribed burning to reduce fuel loads and to create firebreaks.

- The successful use of prescribed fire to simulate natural disturbance events should stimulate a process of re-evaluating the range of potential benefits of prescribed fire in Scottish pinewoods, and should call into question fire policies that completely exclude the use of fire.

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COUNTRY REPORTS

ESTONIA

Forest Fires in Estonia - A Review

The total forest area is 2.011 million ha in Estonia. Forests cover 48% of Estonia's territory. In the five-year period 1999 to 2003, 846 forest fires were registered covering a total area of 4137 ha. The average area of a forest fire was 4.9 ha. Fires that take place in bogs and other areas covered with vegetation are included among forest fires in Estonia.

Table 1. Forest fires in Estonia in 1999-2003

Year	Number of fires	Area burned (ha)	Average area burned (ha)
1999	130	1103.4	8.48
2000	158	683.6	4.33
2001	91	61.7	0.68
2002	356	2081.7	5.85
2003	111	206.6	1.86
Total	846	4137	4,9

The number and area of forest fires varies from year to year. The table shows that there were quite few forest fires in 2001 and the total area of fires was also small. In the next year (2002) 2081.7 ha of forest burned – the biggest area in the last 40 years (in the last extreme fire year 1963 the total area burned was 3755 ha).

Forest fires are caused by the following reasons: human negligence and carelessness – 51%; arson – 13%; natural factors – 1%; reasons unknown – 35%.

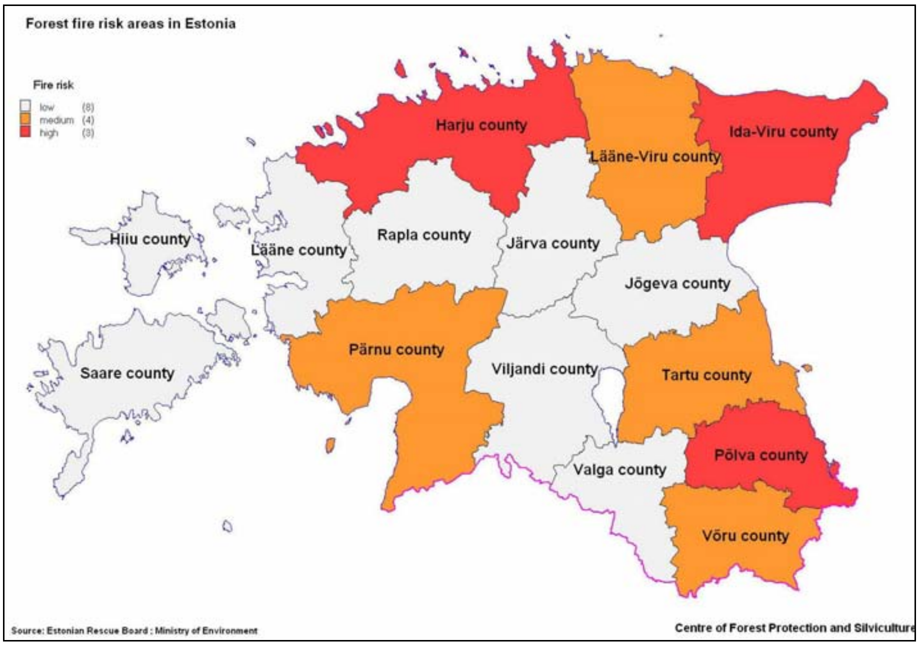

Figure 1. Fire risk map of Estonia

Public policy and the organisation of forest fire protection measures

Fire prevention is the task of the Ministry of the Environment and the Rescue Board under the jurisdiction of the Ministry of Internal Affairs. Pursuant to the Forest Act, the Ministry of the Environment shall monitor the forest fire situation and implement measures to prevent and suppress extensive and especially dangerous fires. Pursuant to “Estonian Forestry Development Programme until 2010” approved by the Parliament in 2002 the main attention in forest protection is paid to the prevention of damages. In state forests, forest fire protection systems are built and maintained by the manager of state forests. In private forests, the state supports forest owners in compliance with the All-Estonian Forest Fire Protection Plan – if there are sufficient funds available. Prospectively, national legislation will be harmonised with international norms on forest fire protection. County Rescue Services prepare forest fire suppression plans each spring.

Detection of forest fires

Forest fires are detected from fire towers and on special patrol flights (started at the third fire risk level). Keen observers also pay phone calls to officials and report of fires detected. Pursuant to the Forest Act, detection of forest fires from fire towers and on patrol flights is the task of State Forest Management Centre, a profit-making state agency.

Notification

Common emergency phone (phone number 112) was introduced. Now all the information on forest fires is received on the same phone. Positioning methods are used to localize fires.

Response Units

Pursuant to the Rescue Act, the suppression of forest fires is the task of the Rescue Board under the jurisdiction of the Ministry of Internal Affairs. The Estonian rescue services have 100 professional fire brigades ready to respond 24 hours a day. An agreement concerning response to emergencies has been concluded with the Defence League and a relevant Act provides for the inclusion of the Defence Forces. The subdivisions of the Rescue Board work to improve the technological basis for forest fire suppression; the aim is to create a mobile and rapidly applied water supply system reckoning with the location and density of Estonian lakes and rivers. Fire pumps of various capacities and hose lines of various diameters have been purchased for this purpose and will further be purchased. One helicopter (type MI-8) and 1 water container (2000 litre) in the possession of the Border Guard Aviation Group can be used for the suppression of forest fires.

Actual research and development projects

A development project aimed at increasing the fire resistance of forests in the Vihterpalu region (Harju County) was launched at the initiative of the Estonian Forestry Board. The final report contains instructions for forest owners (including the state) on dividing certain forest areas of high fire risk with fire protection belts, on digging water ponds and building fire protection roads, on tidying roadsides.

In connection with Estonia’s integration into the European Union attention has been paid to compliance with European directives (Council Regulation [EEC] No. 2158/92 and No. 2152/2003) since 2000, and a number of development projects have been planned in this respect. The projects address the determination of fire risk levels and the compilation of fire protection plans. Research projects aimed at determining the reasons for forest fires and their backgrounds have been designed. The Ministry of the Environment orders the research and the projects.

A project aimed at preparing forest fire protection maps for all the rural municipalities was ordered by the Ministry of the Environment and launched in 2004.

Major shortcomings in the fight against forest fires

In the area of prevention, the awareness of the general public is insufficient. Budgetary funds are insufficient, especially those earmarked for covering expenses related to forest fires. The lack of human and technical resources can be witnessed when several major forest fires have to be suppressed simultaneously.

Figures 2 and 3. Use of traditional tools and methods of fire fighting in Estonia

Figures 4 and 5. Sufficient supply of water for suppression of fires in organic layers (e.g. in peat and bogs) is critical for successful intervention of the Estonian fire brigades.

Assistance required in case of extensive forest fires

It is our hope to receive fire suppression planes and helicopters equipped with water containers from our neighbouring countries when some extensive forest fire breaks out.

National interest in the regional co-operation of the Baltic States with other regions

Estonia considers the continued co-ordinated activities of the countries in the Baltic region in the sphere of forest fires a high priority.

Co-operation with Finland in what concerns the early detection of forest fires from satellites has been quite successful. We hope this project will be further developed.

Estonia has concluded mutual assistance agreements with the Republic of Finland, the Kingdom of Sweden and the Republic of Latvia in the area of rescue services. These agreements enable us to receive promptly technical assistance and counselling in case of necessity, applying procedures previously agreed upon. So far, we have not used this possibility and we hope there will be no need for it in the future, but the existence of these agreements certainly gives an important positive impact to bilateral co-operation in the area of rescue services in general.

Opening access to one’s country for foreign specialists-observers would certainly be a positive development in case of extensive and long-lasting forest fires. The exchange of experience in case of actual disasters would be highly beneficial.

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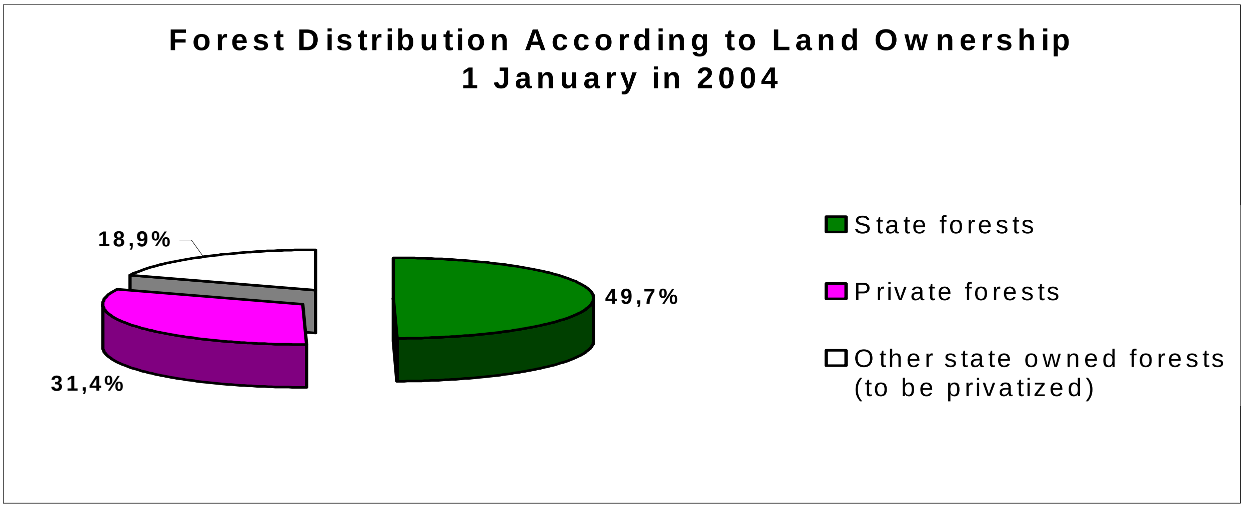
LITHUANIA

Forest Fires in Lithuania

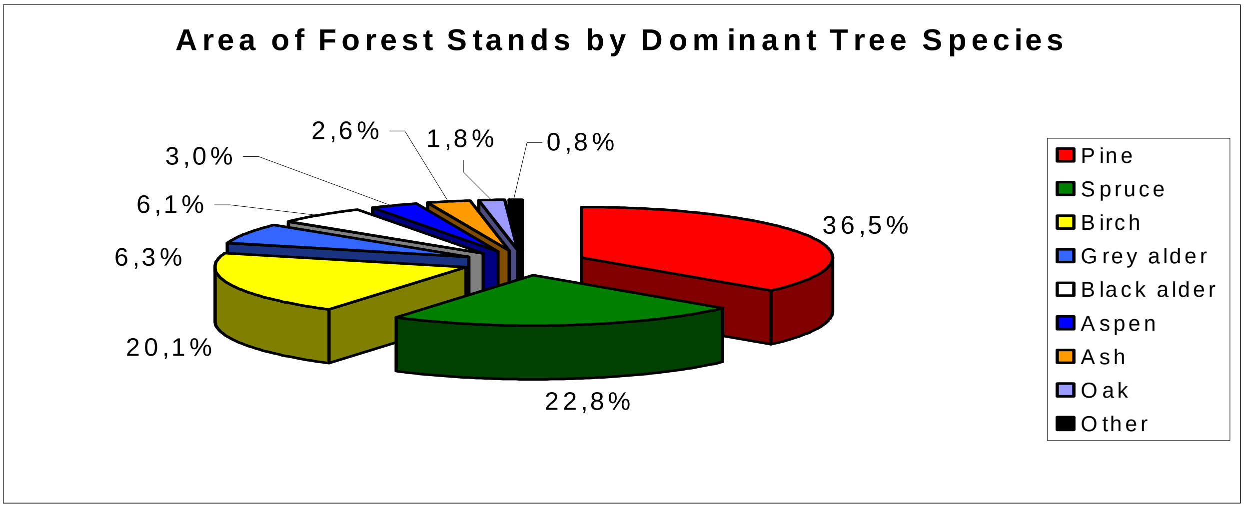
Lithuanian forests statistics

Forests cover up to 2.045 million ha or 31.3 % of the territory of Lithuania. In average 0.59 ha of forestland falls to one inhabitant of the Republic. The average age of forests stands is 53 years.

State forests occupy 49.7 %, private forests 31.4 %, and reserved for privatisation 18.9 % of the total forested area of Lithuania. The number of private forest owners 209,000, the average domain size is 4.5 ha.

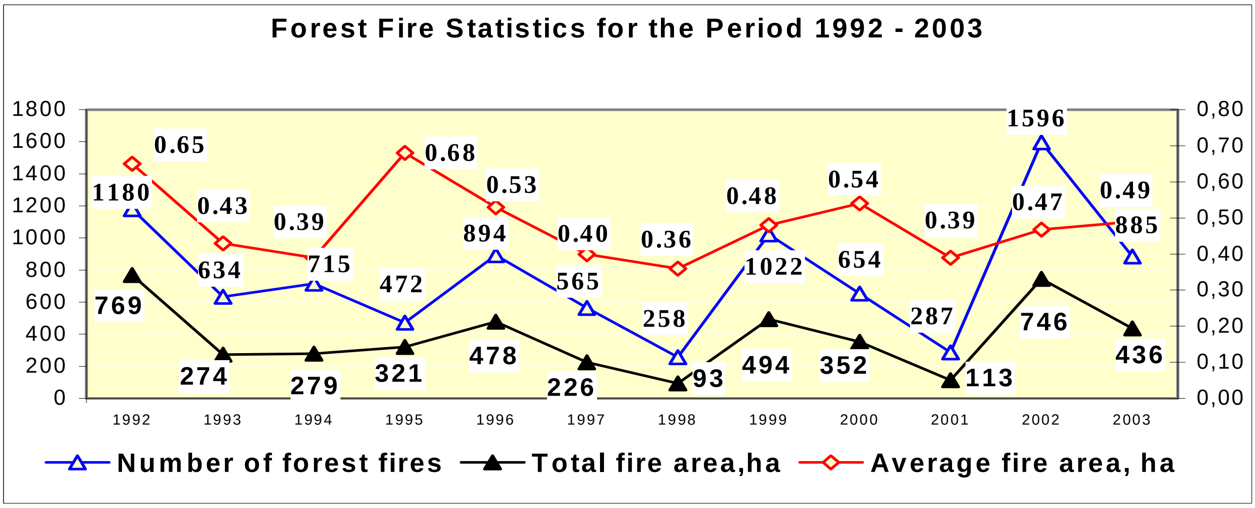


In Lithuania pine stands cover 42 %, spruce - 22.8 %, hard deciduous trees species - 4.5 % of the total forest area. In state forests coniferous tree species occupy 67 %, deciduous - 33 %. In private forests and in the reserved for privatisation forests coniferous tree species stands cover 52 %, deciduous - 48 %.



Forest fires statistics

On average every year in Lithuania more than 750 forest fires are registered, during which more than 350 ha of forests are damaged. It corresponds about 0.5 million Litas (about € 150,000) of loss. The number of forest fires significantly increases during hot and dry meteorological conditions (for example, in 1992, 1999, 2002). The main causes of forest fires include: negligence of forest visitors and burning of dry grass in spring time. On average every year 70 % of forest fires are ignited by forest visitors, 14 % by grass burners and 16 % by intentionally set fires.



The registration of forest fires is performed by Directorate General of State Forests. Detailed statistical figures are processed In a database. These statistical data can be accessed on the web site www.gmu.lt.

Natural fire hazard of Lithuanian forests

In accordance with Forest Fire Prevention Regulations, the Lithuanian forests fall into three fire hazard classes (high, medium, low) with reference to the dominant tree species (coniferous or deciduous), age (older or younger than 40 years), forest site types (soil humidity and nutrient status). About 40% of Lithuania's forests are in the high fire hazard class, 23% medium, and 37 % low. Forests of mixed fire hazard are distributed unevenly and often are included in large forest areas of high fire hazard.

In terms of the fire hazard the forest massifs mostly endangered by wildfires are Druskininkai-Varėna (145,000 ha), Labanoras-Pabradė (91,000 ha) and Kazlų Rūda (59,000 ha).

Integral state system of fire prevention measures

Pursuant to the Law of Forestry of the Republic of Lithuania, the integral state system of fire prevention measures is applied within the forest territories, not depending on type of ownership. This system includes the measures for forest fire surveillance (forecast and detection), prevention and fire protection. The main objectives of the system are: to reduce forest fires hazards, to improve their prevention, to increase forest stands' resistance to fires, to forecast, watch, detect and extinguish fires. The Lithuanian Directorate General of State Forests is a founder of 42 state forest enterprises, and coordinates the implementation the integral state system of fire prevention measures.

Forest managers and owners are responsible for the state fire protection status within their forest territories. Mostly the implementation of integral state system of fire prevention measures is financed by the funds of 42 state forest enterprises and national budget.

In the territory of Lithuanian forests the integral state system of fire prevention measures is applied, not depending on property forms. These measures include:

- Forest fire surveillance (forecast and watch)
- Forest fire prevention
- Forest fire protection

Forest fire forecast and detection

The probability of forest fires occurrence is forecasted by complex of figures of meteorological conditions (complex fire danger rating index), which determine the class of fire rate. Totally there is 5 classes of fire rate: the first - lowest and the fifth - highest. Directorate General of State Forests every day updates the map with classes of fire rates within territories of state forest enterprises in the web page www.gmu.lt. Depending on classes of fire rates, in state forest enterprises there is organized the duty on fire watchtowers and in forestries. The duration of duty is determined depending on classes of fire rates. The society is informed about forest fire danger through Lithuanian radio every day.

In Lithuanian forests there are more than 100 fire watchtowers for forest fire detection and identification of their location. In fire watchtowers those who are on duty, are supplied with detection equipment and radios. Video cameras are very rare in the fire watchtower because of their high price. When the view from the watchtowers is bad, and during the highly critical fire risk period, state forest enterprises conduct ground patrolling.

A new plan of fire watchtower distribution is being prepared this year. Also a special radio system will be set up this year. This will be an effective measure for a good radio connection between administration of state forest enterprises and forestries, also with fire brigades and other fire protection and rescue services as well as with neighbouring state forest enterprises.

Forest fire prevention measures

State forest enterprises pay a lot of attention at forest fire prevention measures and at forest management activities. In the territories of high forest fire hazard special measures are projected and implemented. Forests are divided into blocks and firebreaks, mineral fire break lines are renewed or established, especially along peat-bogs and railway routes). Fuel breaks consisting of belts of broadleaved trees are also set up. Fire places that correspond to the fire safety requirements are constructed in recreation areas. Fire watch towers are repaired and fire equipment is checked before the beginning of the critical fire period; warning signs and stands are put up, and forest roads are cleaned. Lithuanian forests encompass 28,500 km of roads that make up approximately 14.4 km per 1000 ha of forests. Such network of forest roads enables to define the sites of forest fire breakout and effectively organize their extinguishing. Not less than 10,000 km of mineral fire breaks lines are renewed and established every year.

During the critical fire season strict control measures of forests and especially in peat-bog areas are applied. During the critical fire-break out periods these peat bogs, once ignited, may result in large and long lasting forest fires. The state forest enterprises have to deal with complicated tasks in extinguishing peat fires due to the lack of special fire equipment. Large quantities of water are needed to fight peat fires. The Fire and Rescue Department carries the main workload of putting out peat fires. Practically all peat fires are stopped by nature - only after long lasting rains.

Constant information of the public about forest fire prevention issues is implemented through press, radio and TV. The press is reporting about the damages of ecosystems caused by fire, TV is translating and broadcasting video clips about forest fire prevention themes, and radio remembers about careful behaviour with fire. Printing and distributing of short informative publications is organized.

The fire service training centre has established a programme for the education of forest fires safety leaders. These training courses are organized for those officials of the state forest enterprises who are responsible for forest protection, as well as for foresters.

Forest fire protection measures

State forest enterprises are responsible for establishing forest fire brigades. Their size, tasks and equipment is determined by the fire hazard class. There are minimal technical equipment requirements for basic and reserve fire brigades. Such teams must be provided with the fire extinguishing, transport and communication means. All forestries have implemented the primary measures for forest fire suppression. State forest enterprises responsible for forests rated in the first fire hazard class, form 2-4 basic fire brigades and 2-3 reserve fire brigades. Basic fire brigades are provided with fire trucks and water cisterns. Reserve brigades are equipped with trucks for transportation of personnel. State forest enterprises responsible for the second forest fire hazard class establish 1-2 basic fire brigades and 1-2 reserve fire brigades. A basic fire brigade consists of 4-6 members, reserve brigades not less than 10. Fire teams must be on duty during periods of high fire danger.

Every year state forest enterprises prepare specific operative forest fire suppression plans. They are coordinated with the forest fire rescue and civil protection services of the municipalities. In such plans there are established special measures of reciprocity and the co-ordination of actions among the fire extinguishing bodies.

The fire brigades of the state forest enterprises are responsible for extinguishing all forest fires that occur in Lithuania. Only in the cases of limited capabilities to put out large forest fires, the city and county fire and rescue units are called up for assistance.

Financing

Annually 500,000 Litas (about € 150,000) are distributed to state forest enterprises from the national budget to compensate the expenditures for forest fire prevention and control. Expenses eligible for compensation include: construction and restoration of fire towers, additional radios, fire trucks and other equipment for forest fire prevention and suppression. State forest enterprises invest about 3-4 million Litas (about € 0.85-1.15 million) for forest fire protection every year.

In 2003 the Lithuanian Forest Research Institute has very successfully performed the task of classifying the forests of the state forest enterprises by forest hazard classes. The institute also analysed the forest fire occurrence, evaluated the status and effectiveness of the forest fire protection system in the context of the European Union system and gave recommendations to improve the national system. The classification of forests by fire hazard classes will serve for receiving financial support from the structural funds of European Union for forest fires prevention measures and for regeneration fire-damaged forests. It is planned, that such financial support would be distributed for those state forest enterprises, which manage forests of first and second fire hazard classes (corresponding to the middle fire hazard class).

Basic problems in forest fire management

The reasons which complicate effectively organise forest fire extinguishing, to implement prevent work and to control the implementation of fire protection requirements are as follows:

1. <u>Carelessness of people:</u> The acute issue is the burning of dry grass in spring. This habit has a long-lasting tradition. People in the cities and villages fail to understand that the grass burning can be dangerous and lead to a forest fire. In dry and hot summers forest visitors in many cases do not observe main fire protection requirements and cause forest fires.
2. <u>Limited financed to procure new and Innovative technologies:</u> There are not sufficient finances for purchasing new technologies, particularly forest fire suppression equipment, and to renew the fire trucks park.
3. <u>Slow implementation of forest fire prevention measures in private forests:</u> The process of forest restitution is still going on and many private forest owners are taking back their property. Nevertheless, the number of forest fires in private forests is increasing as well.

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