The need for a prescribed burning expertise in Italy: north-western moorlands conservation management by fire

D. Ascoli[1], R. Marzano[1], R. Beghin[1], G. Bovio[1]

Abstract

European countries are interested in new fire management policies considering the "wise use of fire" as one of the innovative approaches. In Italy, prescribed burning for wildfire prevention and conservation management is a contentious issue. The national law, L.353/2000, does not mention it but Regions are allowed to regulate prescribed burning in their fire management plans. The knowledge about prescribed burning applicability on the Italian territory is limited. We provide the background and methodology for a long-term research project on the ecological effects of prescribed burning and grazing for conservation management of moorlands located in the Managed Nature Reserve (MNR) of Vauda, north-western Italy. Rotational fire and grazing by local farmers were dominant features in moorlands management. Currently these rural practices have been abandoned and the dominant fire regime is characterized by uncontrolled fire in winter (December-March) with most sites being burnt once every 4 years. This raises a serious conservation concern: moorlands are changing to woodlands, with the risk that the biodiversity inherent to this environment will be lost. The ecological effects on vegetation of different fire regimes and grazing techniques are studied. Fire behavior is considered a critical issue. Experimental units are 1250 m^2. Each unit is treated according to one of six treatments, each replicated at least four times: "Fire each 4 or 8 years with or without subsequent grazing" are treatments that approximate the predominant traditional fire regime and grazing practices of the region; "Fire each year" and "Unburnt" ones are the control treatments. All treatments have been applied for 3 years from 2005 to 2007; other 6 years are planned. Is fire suitable for conservation management of NW Italy moorlands? What does involve prescribed burning use in alpine regions? The Vauda research project has been designed to identify suitable management answers and to create a fire experiment expertise to evaluate ecological sustainability of prescribed burning for fire prevention in Italy.

Introduction and objectives

Prescribed burning for fire hazard reduction (Mc Arthur 1969; Fischer 1978) and for ecosystems maintenance (Chandler 1983; De Bano 1998) was introduced in Europe in the early eighties (Botelho and others 2002). After 25 years, its operational use remains very limited (Xanthopoulos and others 2006). From 2006 to 2010 the European Union is funding a Research Project titled "FIRE PARADOX", that involves 31 institutions from 13 countries, including Italy. The aim of the project is "…to develop new policies for fire management and forest fire risk reduction, adapted to European constraints" (www.fireparadox.org); the development of a prescribed burning expertise in Europe is one of the main goals of the project.

[1] Department AGROSELVITER, University of Torino, via L. da Vinci 44, 10095 Grugliasco (TO); tel. +39 011 6705553, fax +39 011 6708734; e-mail: d.ascoli@unito.it.

Nevertheless in Italy the use of prescribed burning is a contentious issue. The general policy law on wildfire (L.Q. 353/2000) does not mention prescribed burning, as well as its specific guidelines, while the draft bill (P.L. 6195/1999) was providing that the "management objectives of prescribed burning are always due to scientific or economic interests and are always limited to: fire hazard reduction, fuelbreak maintenance and fire dependent ecosystem management…technical procedures and authorization system must be provided by regional fire management plan". As a consequence of the rule gap few Italian Regions regulate prescribed burning use in their fire management plan; moreover they use different prescriptions and terminology. In Piemonte Region, North-West (NW) Italy, since 1994 (Regional Law L.R. 16/1994) prescribed burning is legally recognized but the fire management plan (Regione Piemonte 2007) barely regulate it; furthermore it does not provide for the objectives to achieve and the natural environments in which it is useful to introduce fire as a management tool. This is essentially due to a lack of knowledge.

The Italian scientific literature concerning prescribed burning is scanty and deals with the subject mainly describing how and why overseas countries use it and the advantages or disadvantages of this technique (Calabri 1984; Stefani 1985; Bovio 1996; Cesti 1999; Senatore 2000a).

Few papers broach prescribed burning from a critical point of view: is it possible to use prescribed burning in Italy?, in which ecosystems?, with which objectives?, which are the ecological effects?, which are the constraints?

Some authors (Susmel 1974; Calabri 1981) listed the constraints related to the introduction in Italy of prescribed burning at a large scale: stands characteristics; forests mainly located in mountain territories; breaking up of properties; vast wildland-urban interface; juridical and administrative impediments; public opinion; lack of scientific studies.

Leone and others (1999) made public the results of a questionnaire survey, conducted in the course of the FIRE TORCH Project (Botelho and others 2002), to identify and analyze current knowledge and perception of the prescribed burning technique among the personnel of the Italian State Forestry Corps and forest researchers. The authors report that the most important reasons for conducting prescribed burning are considered to be the reduction of hazardous fuels, the management of competing vegetation and the conservation of fire-dependent species; the possible escape of fire and possible damages to the environment are the main concerns; legal requirements, lack of qualified personnel and poor knowledge of the ecological role of fire in forest ecosystems are the main reasons that hamper the application of prescribed burning in Italy.

All the authors stressed the necessity to improve knowledge of prescribed fire effects with reproducible methodologies and comparable results (Stefani 1985), promoting long term and multidisciplinary experimental studies to evaluate fire use sustainability (Calabri 1988).

Up to now few fire experiments have been conducted in Italy; moreover these studies deal with specific ecological aspects of fire use, such as forest fuels modification (Buresti and Sulli 1983; Senatore 2000b) or fire impact on soil functionalities (Giovannini and Lucchesi 1997; Bovio and others 2001; D'Ascoli and others 2005; De Marco and others 2005).

Landscape-scale fire experiments involving whole-ecosystem manipulation have been very useful to study fire behaviour and ecosystem responses to fire throughout the world (Hobbs and Gimingham 1987; Trabaud 1991; Marsden-Smedley and Catchpole 1995; Gould and others 2001; Biggs and others 2003; Williams and others 2003; Fernandes and others 2004; Viegas and others 2006).

In this paper we advocate the necessity to promote similar studies in Italy, that investigate the ecological effects of prescribed fire in different ecosystems under a multidisciplinary and long-term perspective.

At the Managed Nature Reserve (MNR) of Vauda, Piemonte, such an experiment has been established to determine the effects of various fire regimes and grazing procedures on heathland communities of NW Italy. The aim of the research study is dual: on one side there is the objective to provide the land users with suitable tools for conservation management of endangered heathland ecosystems; on the other we are developing a methodology to study and evaluate prescribed fire effects and use sustainability that could be extended to other Italian realities.

This paper is meant to describe the rationale for this experiment, crystallize the key research issues, and provide an overview of the methodology, as a prelude to subsequent reports on details of the research findings.

Fire and grazing in moorlands

European *Calluna vulgaris* (L.) Hull (heather) heathlands (moorlands) are found mostly in the United Kingdom, Ireland, along the coasts of NW Europe, in part of Scandinavia and Central Europe (Gimingham 1961; Thompson 1995). Outside their main distribution area, heathlands are present in some isolated areas in South Europe, where forest removal combined with local climatic conditions and acidic soils favored the establishment of heathlands belonging to the *Calluno-Ulicetea* phytosociological class (Sindaco and others 2003; Bartolomé and others 2005).

European heathlands developed 4000 years ago as a result of forest clearance and they have been maintained by disturbance regimes resulting from the combination of heather grazing, burning and harvesting (Gimingham 1972). Since the last 50 years, these traditional management practices have been gradually abandoned, resulting in a reforestation process within areas previously occupied by heathland ecosystems (Webb 1998); because of the consequent reductions in their overall distribution, heathland ecosystems have recently been classified as greatly endangered (EC Habitats Directive 92/43/EEC).

In Italy moorlands are rare ecosystems, mainly located in isolated areas on the NW plains (Sindaco and others 2003). Among the urban growth these areas represent an important shelter for several endangered plant species that survive in the wet sites typically located within the heathland matrix (Mugion and Martinetto 1995; Regione Piemonte 2004).

Fire and grazing have been an important evolutionary factor in the development of moorlands in NW Italy. In the past fire was one of the common management techniques applied by shepherds to reduce the proliferation of trees and to maintain pastures for livestock management. Nowadays, as a consequence of social and economical changes in the area, both practices are marginal. Modifications in land use and management, such as the prohibition and the loss of the traditional fire use

knowledge, lead to uncontrolled winter fires (December-February-March), with most sites being burnt once every 4 years under extreme fire weather. The changed fire and grazing regime has resulted in a process of transformation into new communities with a lower inherent biodiversity. These changes are similar to those described in the Atlantic area, but encroachment occurs faster; species like *Populus tremula* L. (European aspen), *Betula pendula* Roth (birch) and *Frangula alnus* Mill. (glossy buckthorn) form large, dense stands of juvenile trees that secondarily develop into woodlands with the establishment of *Quercus robur* L. (English oak) and other species of the climate-limited potential vegetation (*sensu* Bond 2005). Consequently, moorlands are naturally developing into woodlands (*fig. 1*), with the risk of losing the typically high biodiversity of these ecosystems and their historic and landscape values (Mugion and Martinetto 1995; Regione Piemonte 2005).

Figure 1—Open moorland and trees encroachment at the MNR of Vauda.

Different management regimes, including grazing at different stocking rates, prescribed fire and mechanical cutting have been applied to halt the loss of this habitat throughout Europe (Whittaker and Gimingham 1962; Hobbs and Gimingham 1984; Sedláková and Chytrý 1999; Calvo and others 2002; Pakeman and others 2003; Niemeyer and others 2005; Vandvik and others 2005; Britton and Fisher 2007).

Our hypothesis is that prescribed fire and grazing could be suitable tools for the conservation management of Italian heathlands.

The Vauda experiment started in 2005 to monitor heathland responses to different management options along a period of 9 years.

The Vauda experiment

Study Site

The MNR of Vauda (7° 69' 53'' E, 45° 23' 18'' N), 2635 ha in area, is 20 km N-NE of Torino, at an altitude of 240 to 480 m. Part of the area is a disused military firing ground rescued from urban growth from at least two centuries (Mugion and Martinetto 1995); the Reserve has been established in 1993 (L.R. 23/1993) to preserve the naturalistic and landscape characteristics of the area.

The climate of this area is continental, with about 81% of the mean annual rainfall (1000-1100 mm) falling between April and November. The snow covers the ground for 14,2 days a year mainly distributed between December and February. The driest month is March with 35 mm of rain and 0.3 days with snow. Mean annual temperature is 11.8 °C, with monthly means ranging from 1.6 °C in January to 21.9 in August (Data Source – Nimbus 1993-2004; http://www.nimbus.it).

The study area is located on almost level land (<2% slope), on acidic soils rich in silt and clay classified as Typic Fragiudalf (Soil Taxonomy), with a loamy subsurface horizon of high bulk density (fragipan) that makes this soil poorly drained and frequently water-logged until water is eliminated by evaporation and evapotranspiration (IPLA 2004).

The Reserve occurs on a stream terrace plateau, formed in the Pleistocene by the Stura di Lanzo River, and dissected by the major creeks which form the western (Torrente Fisca) and the eastern (Torrente Malone) boundaries (*fig. 2*) (Mugion and Martinetto 1995).

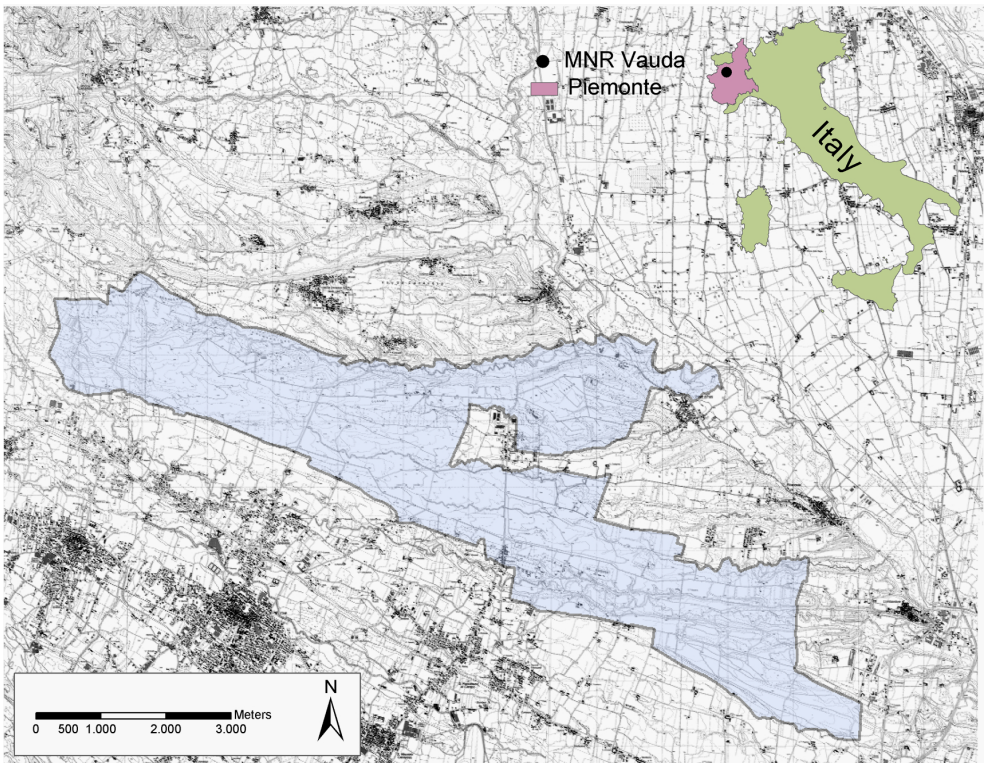

Figure 2—Location and boundaries of MNR of Vauda, Piemonte, Italy.

The major vegetation associations are characterized by different stages of the succession towards oak-hornbeam forest (*Carpinion* Issl. 31 em. Oberd. 53), ranging from open heathland dominated by *Calluna vulgaris* and *Molinia arundinacea* Schrank (tall moor-grass) to aspen-birch thicket stands, on the stream plateau and woodland on the creek slopes.

A recent study (Regione Piemonte 2004) has enlightened the naturalistic importance of the Reserve in housing several national endangered species (*Gentiana pneumonanthe, Salix rosmarinifolia, Ranunculus flammula, Eleocharis carniolica, Juncus bulbosus, Achillea ptarmica, Scutellaria minor, Rhynchospora fusca, Carex hartmanii*) and rare species connected to wet sites located in the heathland matrix (*Campanula bertolae*, *Diphasium tristachyum*, *Eleocharis carniolica, Hemerocallis lilio-asphodelus*, *Juncus tenageja*, *Lythrum portula*, *Utricularia australis*, *Veronica scutellata*). Moreover the Reserve represents one of the few strips of land, among the continuous and extended urban tissue of NW Italy, for migrant birds nesting (*Coturnix coturnix, Alauda arvensis, Hirundo rustica)*.

Experimental design

Each experimental unit at Vauda is 1250 m^2. Each unit is treated according to one of six treatments:

(1) Fire each 4 years; (2) Fire each 8 years; (3) Fire each 4 years with subsequent goat grazing; (4) Fire each 8 years with subsequent goat grazing; (5) Fire each year; (6) Unburnt.

Treatments 1 to 4 approximate the predominant traditional fire regime and grazing practices of the area; treatments 5 and 6 are the control treatments.

Each treatment is replicated in four blocks characterized by different stages of the succession from open heathland (without juvenile tree encroachment) to aspen-birch thicket stand.

All treatments have been applied since 2005.

Management objectives

A prescribed fire drives at inducing defined ecological effects to achieve clear and unambiguous land management objectives (Pyne and others 1996).

The management objectives at the MNR of Vauda are:

- to limit trees encroachment competition with moorland characteristic species, determining a reduction of land subjected to secondary succession, reducing stump resprout capability or inducing stump mortality;
- to regenerate *Calluna vulgaris* moorland distinguishing species creating a mosaic of uneven-aged stands;
- to enhance species and structural diversity;

Vegetation survey

A systematic monitoring of pre-treatment and post-treatment vegetation dynamics is an essential activity to assess the effectiveness of management (Andersen 1999).

Competition dynamics between individuals, such as mortality, spatial structure and species diversity, are assessed along fixed transects before and after the treatment.

To study tree responses, the species of each individual stump is determined; its position within the transects through relative coordinates and the number of stems per stump are recorded; for each stem belonging to a stump, basal diameter, height, crown insertion and crown projection are measured. During the seasons following treatments crown mortality, sprouting capability (number and sprouts dimensions) and complete plant death (i.e. top-killing and failure in resprouting) are assessed.

To study sward structure, cover and botanical composition responses to treatments, we used the *Vertical Point Quadrat* (Warren Wilson 1963) and Braun Blanquet phytosociological methods (Pignatti 1995).

Geo-chemical cycling analysis

In order to preserve species and heathlands communities in the longer term it is critical to study the effects of fire and grazing on the cycling of carbon and soil properties. Periodical fire may result in net denitrification and nutrient losses through leaching and erosion; produce rapid or decreased mineralization rates, alter C : N ratios; change soil hydrologic functioning and degrade soil physical properties (De Bano and others 1998; Neary and others 1999).

Fire can affect the microbial community activity and structure and consequently soil fertility and resistance to disturbances (D'Ascoli and others 2005).

In each experimental unit pre and post treatment soil samples are collected in the organic layer (0-1 cm) and in alteration layers A_1 (1-3 cm) and A_2 (3-10 cm).

Soil organic matter content, total and available element concentrations (K, Mg, Na, Mn, Fe, Cu, Pb), microbial carbon, respiration, metabolic quotient and coefficient of endogenous mineralization are measured in the superficial soil layers.

Fire prescription and control

Prescribe fire management is conducted by burning in a specific fire environment (the prescriptions) and following specific operational procedures (the burn plan) (Pyne and others 1996).

According to the regional law (L.R. 16/1994), prescribed burning must be applied under the direction and responsibility of the State Forestry Corps that establish the occurring of the fire environment.

The prescriptions provided by the fire management plan of Piemonte Region (Regione Piemonte 2007) prescribe to operate:

- in the dormant season;
- on slopes inferior to 20%, with head fire;
- with fireline intensities lower than 120 kcal $m^{-1}s^{-1}$ (500 kW m^{-1});
- air humidity ranging from 30% to 50%;
- fuel moisture content ranging from 7% to 20%;
- air temperature ranging from –6°C and +10°C;
- wind speed ranging from 3 Km/h to 15 Km/h.

In Piemonte, considering the monthly rain fall distribution, that presents a second pick of falls during the early dormant season (October, November and December), it is possible to apply prescribed fire only in the late dormant season; moreover the operative window width depends from snow fall distribution and subsequent temperatures and from the number of Foehn windy days that in NW Italy occur mainly in Winter. Consequently the available operative days are reduced to 15 - 25 days among February and March.

During the experimental fires, precautionary measures against wildfire include a staff of Volunteer Fire Fighters and State Forestry Corps teams and means; moreover a 3 m wide firebreak was realized around the perimeter of each unit.

Fire behaviour analysis

To evaluate prescribed fire effects it is necessary to characterize rate of spread and intensity of fire (Rothermel and Deeming 1980; Pyne and others 1996). Fireline intensity may vary significantly within a fire experiment because of variations in fuel distribution and weather variables, which in turn affect the spatial pattern of fire severity (Cheney 1981; Alexander 1982; Atkins and Hobbs 1995).

To cope with fire behaviour heterogeneity for correlation with fire effects, we quantify fire intensity, using Byram's (1959) fireline intensity equation, and flame temperatures, at a detailed spatial scale.

To calculate fireline intensity equation ($I = Hwr$; kW m^{-1}), we choose a low heat of combustion (H; kJ/kg) of 20.000 kJ/kg. Fuel consumption (w; kg/m^2) is determined by subtracting from before-fire fuel load and residual fuel load sampled the day after fire. Rate of spread (r; m/s) is estimated by timing arrival of the fire front on 2 m-high metal rods positioned within the fuel bed at the intersection points of a regular grid along each plot. This methodology allows to estimate r using Simard's formula (1984): assigning a mean value for each triangle formed by three rods is possible to quantify the spatial variability of fireline intensity precisely along the plot and consequently to associate I to vegetation responses to fire, by studying tree sprouting and rates of survival on the fixed transects.

Fire flame temperatures are measured with an infra-red thermo camera pointed on the vegetation survey fixed transects. With this device it is possible to have a spatial map of residence time curves along the transect, enlightening the hot spots and temperatures manifested at different heights on shrubs and grass tussocks and trees stems and branches.

Relative humidity, air temperature (°C) and wind speed (meters per minute) and direction (azimuth degrees) at 2 m above the ground are recorded every 30 seconds during each burning using mobile weather stations.

Conclusions

Prescribed fire use in Italy is a contentious issue but could be a suitable tool for conservation management of NW Italy heathlands.

To minimize the risks associated with introducing prescribed fire for ecosystem management, it is important to conduct "learning experiments" (Holling 1978 in Andersen 1999) to improve knowledge and thereby future management. A proper understanding of the ecological effects of prescribed fire requires a rigorous experimental approach, incorporating appropriate spatial scales, adequate replication,

multidisciplinary studies, the collection of extensive baseline (pre-treatment) data, and detailed measurements of fire behaviour (Andersen and others 1998).

Such an experiment has been established in the MNR of Vauda, Piemonte, in order to study the ecological effects of different surface fire and grazing techniques on tree encroachment and regeneration patterns of moorlands cyclical processes.

The objective of the Vauda project is to provide land users with prescriptions allowing them to adopt suitable fire and grazing regimes for limiting woody plants, minimizing the negative effects on the ecosystem and maintaining the biodiversity that characterizes the NW Italy moorlands.

In evaluating all these issues, we must be careful not to jump to too far reaching-conclusions: all treatments have been applied from 2005 and at least 6 more years of vegetation monitoring are required to describe moorlands competition dynamics responses to management.

We are aware of the great challenge in translating research results into prescriptions that are applicable by land managers.

Like all landscape experiments, our suffers from logistic and resource constraints. Moreover in Italy, to deal with prescribe burning is complicated; the lack of scientific studies and knowledge about its applicability explains the mistrust of the public administration that turns into rules gap, legal constraints and lack of qualified personnel. Consequently to organize fire experimentations in Italy is even more complex than usual and lacks of that flexibility that is required to apply prescribe fire within the fire weather prescription.

Despite these constraints we wish our experiment will stimulate further discussion to help us frame and implement our experimental design, and will serve to drive future work on prescribed fire studies in Italy.

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