Forest fire research and management options in Austria: lessons learned from the AFFRI and the ALP-FFIRS networks

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Abstract

An increasing probability of forest fires in Austrian alpine ranges, as hypothesized by Gossow et al. (2008) at the first conference „Managing Alpine Future", could meanwhile better be evidenced for several aspects – thanks to the FWF-supported „Austrian Forest Fire Research Initiative" (AFFRI) and to the EU INTERREG Alpine Space supported project „Alpine Forest Fire Warning System" (ALP-FFIRS). In this contribution, some lessons learned from both interdisciplinary forest fire management research projects will be presented. An important prerequisite for the intensified forest fire studies in Austria was an improved documentation of such events. Fire record data were some years ago still rather incomplete and biased (for instance, with respect to fire damage compensation claims). Since 2002, the Austrian fire fighting brigades started to document their fire attacks on their web sites, which improved data access more general. However, the causes of ignition are often unknown. Like elsewhere, also in Austria anthropogenic forest/wildland fire causes are dominating. But also naturally ignited forest fires, predominantly by lightning strikes, play a remarkable role – up to 40% in the summer months in the last decade on average. These findings are most relevant in the three (so far) evidenced forest fire „hot spots" in Carinthia, Lower Austria, and Tyrol. Fire ignition depends often on specific fire weather windows and on fuel conditions, respectively: there are years with more spring fire probability, and years with more summer fires; 2003 offered both. In adapting existing modelling approaches for Central European conditions, the mountainous topography requires particular attention to a spatially explicit prediction of fuel load and particle size besides other important fuel characteristics such as bulk density, heat content, and moisture of extinction. However, the data sources for this characterisation are often limited which reduces the chances for any predictions. Additionally, the interpretation and communication of fire danger warning levels based on fire weather indices (FWI) are critical for fire management activities and raising awareness of the public. A number of indices have been developed so far, and many of them are currently applied in operational conditions. The research activities aim to identify appropriate approaches for calculating FWI and characterising fuels in different eco-regions of the mountain forests. They will serve as a basis for the further development of a fire hazard model for mountain conditions taking into account the complex interactions between weather, vegetation, topography and socio-economic factors. Based on these and future findings, we will support involved fire fighting brigades with more accurate information about fire intensities and fire behaviour. Consequently, foresters in hot spot areas should become more interested in prophylactic measures focusing on silvicultural and technical measures in order to reduce the fire susceptibility of mountain forests. In that context barkbeetle attacks, storm blow downs, and snow breakages – all likewise fuel additive – are potential forest protection targets.

Keywords: forest fire, hazard management, Austria

1 Introduction

Austria is dominated by mountains and mostly alpine environments. This implies that the environment in terms of climate, vegetation and fauna is highly diverse. The topographic characteristics connected to the alpine environment influences climate as well as vegetation composition. This extremely distinct environment results in a wide variety of sites with different levels of susceptibility and predisposition to fire. Additionally the negative impacts of storms, bark beetles, and other natural hazards are critical factors for the vulnerability of mountain forests. It is hypothesized that the risk of forest fires will increase in coming years and decades in the Alpine Space too (Lindner et al. 2010; Lorz et al. 2010; Gossow et al. 2008, 2009). As a consequence of the impacts of climate change, weather extremes could increase in coming decades, including more storm events, more lightning strikes during thunderstorms, less snow and rain precipitation as fire-supportive agents. In the Mountains, the pronounced topography and climatology is further strengthening weather effects on fire behavior and propagation. The topography can influence the spread of fire through natural fire breaks such as lakes, rivers and ridges; also, slope and orientation influence the fire spread (Flannigan et al. 2000). Especially in the mountain forests the role of topography for the fire behavior is still unclear.

While significant progress has been made in assessing forest fire risks, most risk assessments have paid low attention to social and economic factors influencing fire risk. Wildfire patterns are linked to human activities and land use (Conedera et al. 1997), including vegetation management (Prestemon et al. 2002) or its abandonment (e.g. for Mediterranean and new EU member countries, cf. Goldammer 2002). Also Mercer & Prestemon (2005) suggest that, in addition to the ecological and climate variables that are typically used in wildfire risk analysis, the socioeconomic conditions of communities included in fire prone landscapes also influence wildfire risk.

Especially the conditions, in Central Europe and in the more central and eastern Alps are not comparable to areas with more wildland fire experiences like in Mediterranean countries. Research results as well as modeling practices from these regions will have to be adapted for a fire hazard rating or fire behavior modeling in mountain areas (Alps, Meteors, and Pyrenees). What makes forest management partly also more difficult in the Mountain Forests, is the patchwork of small-sized farm-belonging forests and larger private or federal forest estates, with, correspondingly, quite different harvesting, tending, and management interests and investment efforts/facilities. Varying ecological conditions and forest ownership patchwork result in strong heterogeneity and ask for smaller assessment areas for fire hazard rating and management planning than practiced, for instance, in taiga regions of North America or Siberia.

Consequenly several research initiatives have been launched in recent years to study the specific conditions for fire hazard rating, fire behavior modeling and fire management in Austria. In the nationally funded Austrian Forest Fire Research Initiative (AFFRI) the University of Natural Resources and Life Sciences (BOKU) encompasses two major objectives (i) to identify Forest Fire "hot spots" in Austria in dependence of vegetation, climate and location, and (ii) to develop a fire-vegetation simulator for Austrian conditions. Within the EU funded project ALP FFIRS the Institute of Silviculture at the Department of Forest and Soil Sciences (BOKU) aims to improve forest fire prevention strategies under a changing climate in the Alpine Space, by creating an alpine forest fire warning system in close collaboration with the neighboring partner countries.

This contribution summarizes the major findings of the ongoing research activities in order to provide an overview about the state of art in fire research in Austria.

2 Documentation of forest fires

A wildfire database for Austria has been established within the projects related to the Austrian Forest Fire Research Initiative (AFFRI) and the Alpine Forest Fire Warning System (ALP FFIRS) at the University of Natural Resources and Life Sciences which covers now 1660 forest fire records for the period between 1993 and 2009. A descriptive frequency analysis has been carried out in order to illustrate the characteristics of the recorded forest fires events in Austria (Vacik et al. 2011). Results indicate that the recordings of forest fires and fire frequency varied throughout the years and across provinces. Anthropogenic causes made up for the major part of forest fires in Austria, lightning-caused forest fires have had a share of 18% throughout the whole study period. Spring and summer happened to be the main fire seasons for forest fires in Austria. In terms of the duration of fires in days, it was found that fires lasting longer than one day accounted for only a small percentage of forest fires while most of the forest fires ignited between 11 am and 7 pm in the evening. Two summer seasons most recently (2003 and 2006) have illustrated quite well that, and how widespread and rapidly, forest fires may happen and become an important issue if adequate weather conditions are given. An evaluation of the 2003 forest fires by seasonal differences showed several peaks, one for spring – what is also typical for the more frequent forest fires in Switzerland (Conedera et al. 1997), and what was also the general rule for forest fires in former decades (Gossow et al. 2009). Besides the two quite typical peaks of fire events in spring and in high summer, there was detectable a third one in the second half of June: it coincided with the period of midsummer fires and subsequent ritual fires with regard to Catholic feast-days. These fires are usually ignited high up on the mountains – like the majority of the documented burns in midsummer. As regards the size of fires, most of the forest fires reached less than 1 hectare, followed by fires with a size ranging between one and five hectares. Only a small number of municipalities experienced more than ten fires within the study period. In relation to the forest area the highest number of forest fires records has been observed within the Eastern and Southern Rim Alps as well as the Summerwarm East. This allows to identify three major fire hotspots in Lower Austria (e.g. Neunkirchen), Carinthia (e.g. Villach) and Tyrol (e.g. Schwaz) as well. In this context the majority of fire records exists in the submontane and low montane altitudinal zone. Coniferous forests have been affected by forest fires to a great extent followed by mixed forests. Only a small portion of deciduous forests have been affected by forest fires. The major part of fire ignitions has taken place at south-facing exposures. North facing aspects made up for the second-largest group regarding fire ignitions. The reliability of the available forest fire data in the database proved to be heterogeneous but can be seen as satisfactory. Whereas the data regarding the time, coordinates, size of area burned and cause of fire proofed to be relatively reliable the security of information on the localization of the ignition point and the tree species affected has been rather low. However, data on wildfire frequency and distribution are currently still sparse and incomplete for Austria. With the current wildfire database it is not possible to reveal a clear picture of the forest fire situation in Austria during the last decades, since the data quality, which is influenced by a varying reporting intensity and quality does not allow a thorough analysis of trends (Vacik et al. 2011). Currently, a lot of efforts are made in extending the dataset on wildfires in Austria in order to enable the analysis of the most driving factors for fire ignition.

3 Ignition of natural caused forest fires

Spring and summer fires make up for a major part of forest fires in Austria. Besides human caused forest fires, lightning are the major reason for ignition especially in the summer months. Austria as a predominantly alpine country experiences a high number of thunderstorms with locally very high densities of lightning strikes, which can ignite almost one third of the forest fires during July and August in the southern parts. In order to analyze the causes of ignition and characterize the lightning induced forest fires a study was made for the period 2002–2009 (Müller et al. 2011). Documented fire records were compared with the real appearance of lightning events, using the "Austrian Lightning Detection & Information System" (ALDIS). ALDIS is one of the best performing lightning detection systems worldwide, with detection efficiency about 98% of all cloud to ground flashes in Austria. The verification of the forest fires caused by lightning was carried out with the help of a decision tree and decision matrices, where the most relevant parameters of flashes (e.g. number, multiplicity, distance, time of impact, location accuracy) and their possible relation to forest fires were described. In this manner, a probability was estimated for each forest fire being caused by lightning. In total 85% of the forest fires that were supposed as being lightning caused fires could be classified with a high probability as correct. 10% of the fires, whose cause was unknown, could also be graded as lightning caused fires and only 1% of those fires, which had likely anthropogenic causes, generated a high probability of being affected by lightning. It could be shown that with the proposed approach in total 17% of the known forest fires in the study period for 2002–2009 could be classified as lightning caused (Müller et al. 2011). Fires initiated by thunderstorm activity seemed to be more frequent at higher altitudinal zones. Primarily the dominating Norway spruce (*Picea abies* L.) was affected by lightning fires, although a disproportionately higher portion of fires could be detected in pine forests.

4 Fuel models and fuel mapping

Generally, fire frequency and severity depend on the dominant tree species as well as on human activities. Vegetation and its distribution pattern affect fire regime characteristics. Topographical characteristics, such as slope, aspect and altitude, as well as potential soil moisture, forest composition affect fire pattern. Bulk density of fuels (that depend on vegetation structure) can strongly influence fireline intensity (Miller & Urban 1999). Many models for surface fire behavior (as well crown fire behavior) are based on topographical factors, accumulation fuels and fuels moisture conditions (Rothermel 1972; Albini 1976). Therefore the estimation of fuel characteristics for different fuel types and the development of fuel models describing the potential fire behavior are essential for fire management.

Consequently a Fuel Map comprising several fuel types was derived for Austria by the use of different input layers (e. g. forest map, CORINE Land cover map, NDVI map, aspect, slope). The CORINE map and the Forest map of Austria are based on a classification of Landsat images. Forest types are classified according to pure deciduous, pure coniferous or mixed stands while mixed stands are classified by the dominating forest type (mixed stand dominated by coniferous trees or deciduous trees). A Normalized Differenced Vegetation Index (NDVI) map is used to identify tree species with the help of remote sensed data. The main idea is that each tree species has a unique photosynthetic activity (a unique NDVI response curve for the vegetative and non vegetative season) which can be determinated by the NDVI value. Time series of NDVI maps from remote sensed data (MODIS sensor) were used to sample tree species specific curves over a full year from control plots (supervised classification). These tree species specific NDVI curves were used to identify other forest stands with a similar pattern (Arpaci et al. 2010c). Additionally the amount of timber was classified into three classes from low, medium till high. This information was used to distinguish fuel types and fuel amount. Open areas which are not stocked where classified as forests after clear cut. These input layers were combined with topographic related maps as elevation, slope and aspect to assign appropriate fuel types to vegetation- and land cover types.

Fuel models play a major role within the estimation of fire behavior as they represent standardized fuel situations which can be assigned to vegetation types and compromise all input variables necessary to calculate fire spread. Based on field sampling and fuel analysis, fuel models for selected fire prone mountain forests have been developed (Arpaci et al. 2010b). Models have been selected by considering their potential to describe fire behavior based on an index derived from statistics of fire occurrence. The fuel models cover vegetation types which are of particular interest for fire managers of the involved regions due to their fire regime. For Austria currently fuel models representing pine (*Pinus sylvestris* L.) forests are of particular interest for fire management. Fuel models for other fuel types are currently under investigation in the context of the recently started FIRIA project (Sass et al. 2011).

5 Fire hazard

Meteorological factors play a key role in affecting wildfire occurrence and behaviour. Weather variables (e.g. temperature, precipitation, wind speed, air humity) are often combined in specific meteorological fire weather indices (FWI) that provide estimations of fire danger level at a given time for a specified operational unit or eco-region. The interpretation and communication of fire danger warning levels based on FWI values are critical for fire management activities. Even more they are often used to prepare and distribute resources for fire fighting and raise the level of awareness of the general public. A number of indices have been developed so far, and many of them are currently applied in operational conditions. However, to identify an appropriate index for different eco-regions in mountainous, hilly and flat terrain is therefore challenging. In a recent study the process of selecting an appropriate fire weather index and the calibration of fire danger warning levels to Austrian conditions was described (Arpaci et al. 2010a; Eastaugh et al. 2011). Data from 110 weather stations in combination with spatially verified fire occurrence data from 1993–2009 were used to calculate FWI values (e.g. Käse 1969; Sharples et al. 2009) on a daily basis and to estimate the threshold values for various danger levels. The adjustment of FWI alert thresholds was done for the nine forest eco-regions in Austria by comparing the daily values of FWI of fire events with the daily values of FWI of days with no fire events. With the interpretation of quartiles and using statistical measures it was possible to set individual warning levels for each eco-region. By grouping the indices with respect to their structure and input parameters it was found out that for Austria rather "simple" indices like the FMI index (Sharples et al. 2009) seem to perform better at the northern Alps edge while the Nesterov index (Nesterov 1949) and M68 index (Käse 1969) are more appropriate for lower elevations in the eastern parts. These findings could be used to calculate fire hazard components related to fuel moisture.

Fire risk is internationally understood as the likelihood of a fire to occur. For the chance of a fire to occur two agents are identified: natural – predominantly lightning – and artificial – man-made. Human activities account for the majority of forest fires in Europe and around the world. The influence of human factors on forest fire risk cannot be disregarded, especially in a densely populated country as Austria, which is characterised by a highly diverse landscape. Although human factors are relatively important in forest fire risk assessment little attention has been paid to their significance so far. In a recent study, a range of socio-economic factors associated with a high forest fire hazard in Austria was investigated by means of logistic regression analysis (Arndt et al. 2011): Relationship between touristic activities, transit infrastructures, agriculture and forestry with the spatial occurrence of forest fires were studied over a 17-year period between 1993 and 2009. The variables of the logistic model indicate that hiking trail density, density of forest roads, agricultural factors as well as railroad density were found to be significant. The developed model was tested with a set of independent cases of forest fire events across the country in order to draw conclusions on a fire hazard model. In this context, a study revealed that sparkles from braking trains had released forest fires in the 1960s in more than a third of the noted cases in Austria, and may became relevant again due to an inadequate fuel management along the railway embankments (Arndt 2007; Gossow et al. 2009). This is especially dangerous in mountainous areas with more curviness of the railway tracks.

6 Fire management

In Austria 4,567 voluntary fire brigades, 6 professional fire brigades (Vienna, Graz, Linz, Salzburg, Innsbruck, Klagenfurt), and about 290,000 fire fighters are – though not equally well trained – prepared for fighting forest fires. Fire fighting operations and fire services are mandatory tasks for the fire department. The task of accepting calls on forest fire alarms and alarming fire departments is done by the fire brigade organizations at province level. The response time for actions in the flatland is < 10–15 minutes, which leads to the fact that the burned area per action is very small (1,000 m^2). In mountain areas the response time is higher, which could lead – under specific circumstances – to larger forest fires. However, beside the short response time, the large staff resource and the large number of fire departments allows operating in an effective manner. In most cases, forest fires can be extinguished rapidly by tank fire-fighting vehicles in the early phase. However, when forest fires are discovered too late, or take place in rough terrain, extensive personnel and equipment are usually unavoidable. In this context, the Austrian Federal Fire Brigade Association organizes special courses to fight forest fires, especially for actions in the mountains using helicopters and air-planes. In all provinces there are specially trained and equipped units of the fire brigades that have special equipment to fight forest fires from the air. For utilizing the aircraft (mostly helicopters of the Austrian Federal Army, the Ministry of Interior (police), or private companies) the fire department has to rely on the support of others. In some provinces, there are also bases for specialized forest fire fighting equipment such as unloading containers for helicopters, water storage tanks or nets for transportation.

The operational control for a single forest fire operation has the district forest officer, or the owner of the affected area. The fire department is only responsible for the operational procedures. The local fire fighters and even the fire brigades at province level have no formal and official role in performing preventive fire protection measures in forests and wooded areas. Only the local forest authority represented by the forest officer can give advice on preventive forest fire measures. In this context, there are usually no formal procedures or warning concepts for the operational use in fighting forest fires. Only through the personal commitment of individual managers, often in synergy with their profession as forester, operational procedures are worked out. These documents and the resulting measures, such as planning materials, water supply maps, infrastructure are therefore available only to a minor extent. Fuel management in general is therefore practically not yet applied in Austrian forests. Even along the railway embankments, fuel management through controlled burning, is still not often applied based on an operational warning and prophylaxis system.

In this context it is also important to mention that the protective effect of forests can be severely reduced by forest fires leading to natural hazards like avalanches and rockfall or storm events and bark beetle infestations. There is an urgent need to find out what are the consequences of severe wildfires, i.e. how long may different communities take for recovery and thus, for re-establishing their protective function. Questions arise like which fire prone areas pose an increased risk for natural hazards, what is the spatial range and intensity of the processes induced and which adaptive measures (e.g. tree species selection, thinning) should be taken? Those questions will be further elaborated in the context of the ongoing FIRIA project (Sass et al. 2011).

Acknowledgements

The research activities presented here have been conducted partly within the frame of the Austrian Forest Research Initiative (AFFRI), which is funded by the Austrian Science Fonds (FWF) with the reference number L539-N14 and the European Project ALP FFIRS (Alpine Forest Fire Warning System), which is funded by the European Regional Development fund of the Alpine Space Program with the reference number 15-2-3-IT.

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