Potential Fire Intensities in the Alpine Region based on characteristic fuels in Austria and Italy

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Abstract

Fire management in the mountain forests aims to reduce the impact of forest fires on the Alpine environment through prevention and mitigation measures. In this context the knowledge about fire behavior and fire intensity of the main fire prone vegetation types is a prerequisite for the planning of operational procedures. We describe the approach for the estimation of potential fire intensities in the Alpine region and present the methodologies and materials used to calculate fire intensities for different weather scenarios based in a case study.

Fuel models play a mayor 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 we have developed fuel models for the most fire prone mountain forests in Austria which are mainly dominated by Pine (Pinus sylvestris, Pinus Nigra) and a set of fuel models for broadleaves forests in Italy (Veneto region) based on data collected in the Vicenza province. Models have been selected by considering their potential to describe fire behavior based on an index derived from statistics of fire occurrence. For other vegetation types we used the standard US fuel models. The FLAMMAP software was used to calculate the potential fire intensities for the various scenarios. We defined a set of fuel moisture scenarios for the selected fuel models from very low to high fuel moisture values and three wind scenarios comprising “realistic conditions for the alpine space”. The results indicate that forest fires in pine stands can reach under dry conditions combined with strong winds fire intensities up to 1850 [kw/m]. For chestnut stands intensity values up to 2660 kw/m² have been calculated. Due to the combination of live fuels and dead fuels fire behavior in pine stands were quite sensitive to changes in live fuel moisture. The higher intensities in Chestnut stands seem to occur due to fuel loads and fuel bed characteristics. However, these levels of fire intensities can be considered to express moderate suppression difficulty. The results of this analysis can be used to define fire danger levels for suppression activities in the Alpine region .

Keywords: [Fuel models, fire intesity, FLAMMAP, fire suppression]

1. Introduction

In the alpine arc with its vast forests, with large portions of them being coniferous, and the large variability in terrain and climate is not easy to estimate fire behaviour and its potential consequences. Forest fires with their strong interaction of climate, vegetation and topography make it difficult for fire mangers to set up appropriate measures for preparation. Fire intensity is one parameter of fire behaviour which is used regularly to estimate suppression difficulties. There exists currently not much knowledge about the range of potential fire intensity within the possible combination of climate, fuel and topography within the Alps. The ALPFFIRS project is aiming at the harmonization of a common fire danger system all over the different countries along the alpine arc. Within that project, suppression difficulties and their relation to fire intensities are examined. To calculate fire intensities custom fuel models of vegetation types, with special importance to local fire managers, have been developed. This fuel models are used within a selected case study area which is assumed to compromise the range of topographic variability in the alpine areas of interest. To conclude the simulations the well known Flammap tool was used to run 24 simulations for each fuel type. The results will show what range of potential fire intensities is to be expected with respect to vegetation, topography and weather.

2. Material & Methods

2.1 The approach

The Flammap (Finney, 2006) tool is set up to simulate potential fire behaviour at the landscape level. It is possible to put together a landscape from different parameters which influence fire behaviour and to define weather factors reflecting characteristic fire weather situations. To calculate potential fire behaviour for different landscapes for a comparative study, is challenging, due to the necessary data sets. Especially fuel maps are not available in many areas. Setting up fuel maps is a tenacious work which requires experience and appropriate data which makes it possible to define a relation between vegetation and fuel type. In order to compare possible fire intensities for characteristic fuel types in the mountainous area we have chosen a simplified approach. We set up a "virtual" landscape which is representative for the alpine landscape. This landscape was designed based on a case study area located at the Southern Rim Alps of Carinthia. Here we assume that altitude, aspect and slope vary in a way which is equal to comparable regions with similar landscape features.
Assuming that the main driver for different fire intensities are fuel type, dryness of fuel and wind speed we set up 24 scenarios. These scenarios consist of 8 different fuel moisture scenarios. Those fuel moisture scenarios are based on the ones used in the BEHAVE plus fire behaviour package and have been used for example to develop the US standard fuel models (Scott and Burgan, 2005). The fuel moisture scenarios are combined with three different wind speed scenarios which include low wind speed (8 m/s), moderate (18 m/s) and extreme wind conditions (40 m/s). The wind scenarios have been based on the low, average and high wind speeds measured within our case study region. The combination of fuel moisture and wind scenarios covers weather conditions from low fire danger weather to extreme fire weather situations.

2.1 Fuel models

Fuel models play a mayor 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 we have developed fuel models for selected fire prone mountain forests in Carinthia, Austria which are mainly dominated by Pine and a set of fuel models for broadleaves forests in Italy (Veneto region) based on data collected in the Vicenza province. 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 used for this study have been developed within national funded research projects and cover vegetation types which are of particular interest for fire managers of the involved regions due to their fire regime. The Austrian Partners contribute a Pine fuel model which was developed to represent *Pinus sylvestris* forest stands which are of particular interest for fire management in Austria (Arpaci et al., 2010). The Italian Partners provided two deciduous fuel models for chestnut (*Castanea sativa*) and hornbeam (*Ostrya carpinfolia*) stands. For all other vegetation types the standard US fuel models from (Scott and Burgan, 2005) were used. For the coniferous forests we used the fuel models Timber litter (TL - linked to three classes TL1, TL3, TL5) according to the fuel load we expected to have in the different forest stands (Table 1).

Table 1: Fuel models used for simulations

Fuel Model	1 h, fuel load[to/ha]	10h, fuel load [to/ha]	100 h fuel load [to/ha]	Live herbaceous fuel load [to/ha]	Live woody fuel load [to/ha]
TL1 low load, cp. conifer litter	2.24	4.93	8.07	0	0
TL3 mod. load, conifer litter	1.12	4.93	6.27	0	0
TL5 high load, conifer load	2.57	5.6	9.86	0	0
Austrian Pine	2.57	3.87	0.85	0.49	2.84
Italian Hornbeam	3.8	1.65	0.17	0	0
Italian Chestnut	6.26	1.	0	0	0

To simulate realistic fire behavior scenarios it is necessary to define a reasonable set of fuel moisture conditions. In this context we selected a set of fuel moisture scenarios which cover very low fuel moisture till high fuel moisture values. These scenarios have been taken from the Behave software (Andrews et al. 2008) which is used to test and calibrate fuel models in the USA. The results allow displaying the possible range of fire intensities for alpine fuel situations.

Table 2: Fuel Moisture scenarios

Scenario	1hr [%]	10 h [%]	100 h [%]	Live herbaceous [%]	Live woody [%]
D1L1	3	4	5	30	60
D1L3	3	4	5	90	120
D2L1	6	7	8	30	60
D2L3	6	7	8	90	120
D3L1	9	10	11	30	60
D3L3	9	10	11	90	120
D4L1	12	13	14	120	150
D4L3	12	13	14	120	150

2.2 Spatial data

To calculate fire behavior in a spatial context it is necessary to create several data sets which provide input for fire behavior simulations for each cell within the defined area of the virtual landscape. The Fuel Map of the virtual landscape was derived with the help of five input layers: a forest map, a Corinne Land cover map, the aspect and slope derived from a DTM and a NDVI map.
The landscape cover map CORINE is based on a classification of Landsat images. The Forest map of Austria was classified according to Forest type and Timber Volume. 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). Additionally the amount of timber was estimated. This amount 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. This information was used to distinguish fuel types and fuel amount.

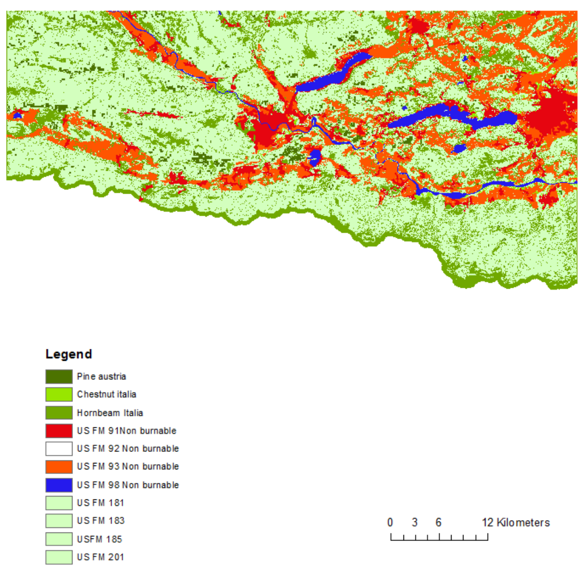

Figure 1: Fuel map of the virtual landscape

The NDVI layer is a product of our research activities to identify tree species with the help of remote sensed data. The main idea is that each tree species has a unique photosynthetic activity for the whole year. This photosynthetic activity can be estimated with the Normalized Differenced Vegetation Index (NDVI). We used time series of NDVI maps from remote sensed data (MODIS sensor) 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. Identification was based on the distance of a cell with its NDVI curve to the specific tree NDVI one year profile. We set a value of 400 as maximum distance to the pine NDVI curves. This value promised a good result identifying pine stands within the case study area (Arpaci et al. 2010) .
All topographic related maps as elevation, slope and aspect were created using the DTM Alpine arc.
All necessary data layers have a resolution of 30 m. We used the Arc Model builder within ArcGIS to create a multi-criteria fuel mapping tool. We combined the datasets to assign appropriate fuel models to vegetation- and land cover types.

3. Results

In general the results (Table 3) obtained from the simulation runs for fire intensity are similar to those reported from North American forests (Goto et al. 2005). Due to the amount of live fuel, pine stands are sensible to changes of fuel moisture within dead and or live fuel. The fire can reach under extreme dry conditions combined with strong winds fire intensities up to 1850 kw/m². For chestnut stands intensity values up to 2660 kw/m² have been calculated and for hornbeam about 500 kw/m². The higher intensities in Chestnut stands seem to occur due to fuel loads and fuel bed characteristics. Interpreting these values according to commonly used suppression difficulty tables only a “moderate” class can be derived (e.g. Veneto suppression Levels in table 4) or even lower. When calculating fire intensities for suppression strategies we considered the worst case scenario ergo the maximal potential fire intensity as most important. But that does not mean that these intensities are normal fire behavior developing under less than extreme conditions.

Table 3: maximal potential fire intensities kw/m² for selected fuel types

	Pine			Chestnut			Hornbeam		
Windspeed/ Moisture	8	18	40	8	18	40	8	18	40
D1L1	1125	1318	1853	802	1174	2661	500	500	500
D1L3	611	716	1007	802	1174	2661	500	500	500
D2L1	860	1008	1417	488	715	2661	223	223	500
D2L3	462	541	541	488	715	1619	223	223	223
D3L1	719	843	1186	363	531	1204	142	142	142
D3L3	357	357	639	361	531	1204	142	142	142
D4L1	633	741	1042	308	450	1020	113	113	113
D4L3	350	410	576	308	450	1020	113	113	113

4. Conclusions

While using tools like FLAMMAP and GIS and customized fuel models it seems possible to define fire behavior scenarios within a typical alpine landscape. Considering only the potential for emerging fire intensities and not trying to answer questions about quantities and locations of fire intensities within a real landscape this approach seems promising. Bearing that in mind it should be possible to discuss with fire managers possible strategies about fire fighting or necessary resources.

Table 4: Suppression levels from Veneto region, Italia

Difficulty	Flame length [m]	Fire intensity [kw/m²]
Very low	1.2	350
Low	1.2 - 2.5	350 -1700
Moderate	2.5 - 3.5	1700 - 3500
High	3.5 - 4.0	3500 - 5000
Extreme	> 4.0	>5000

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