FDR Implementation and Calibration in the Alpine region of Italy

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Introduction

The Alpine environment is a realm of snow rather than fire. Avalanches, landslides and floods are considered leading threats, so that reconstructions of fire history and fire ecology are almost absent (Tynner *et al.* 2005), and development of an Alpine fire culture is unfavored. Though forest fires are seen as a minor issue, Regional Administrations are providing costly fire fighting services and must also provide a safe work environment to fire fighters. Since 1972 , in Italy fire suppression and prevention have been managed at regional level (1972, DPR n. 8), National Government goes into action just when emergency becomes particularly serious. Along the past year, several Forestry Services have attended technical meetings to share expertises and to find common solutions. The creation of an "Alpine Forest Fire Rating System" has been taken into account, also involving neighbouring Countries. This option makes sense, if one thinks that average area of an Alpine region is around (120x120)km^2. In addition, a sub-regional Alpine network has been added to GFMC global networks during the Joint Meeting of the Wildland Fire Advisory Group / Global Wildland Fire Network held in Freiburg on July, 2008 (http://www.fire.uni-freiburg.de/GlobalNetworks/globalNet.html).

Key factors as winter fires and complex terrain make the Alpine environment unique. Most of the wildfires occur between December and April, when the growing season is over and the fine fuels are dry (Reinhard *et al.* 2005). The incised valleys create pronounced differences in snow cover between southern and northern sides, influencing both fire danger rating and fire behavior predictions. The geography of the Alpine region, crossroads between the Mediterranean, the Atlantic and the Eurasian zone, affects landscape structure and forest composition. The continental gradient influences especially local climate and fires severity, that increases from the sea to the internal valleys. Ground fires and persisting smouldering rates are quite frequent and may need several days to be extinguished. These kind of fires can affect the root systems and also be damaging respect to tourism activities. On the other hand, wildfires are caused by humans most of the times, up to percentages higher than 90%, even if the burnt area depends on meteorological conditions and available fuels. The anthropogenic factor, together with the winter fire season, marks a important discrepancy between Alps and Canada, where the Fire Weather Index System was born. While in Canada FWI calculations are stopped during winter, in the Alps snow persistence on the ground is extremely uneven, both in time and space. The threshold value to stop the calculations, indicated by Alexander (2002) and equal to 52 days, is not frequent but can be reached in the most internal valleys (Cesti 2004), putting fire managers in front of problematical choices. In fact, snow can melt very quickly when fall winds are present, especially on the southern hillsides.

Due to fragmentation of fire management into different Regional Offices (seven Regions sharing 100,000 km^2), it is challenging to get a sufficient amount of data and to provide an exhaustive picture. Differences in fire severity along the Alpine arc has been just partially investigated (Bovio and Camia 1997) so that, at this stage of reporting, the best option is to compare three Regions placed in the Western, Central and Eastern Alps, respectively Aosta Valley, Lombardy and Veneto (figure 1). They are implementing a FDR system at different stages of advance and producing data to be analysed.

The objective of this work is to report on FDR stage of implementation in the Alpine Regions of Italy and to present a pilot study on calibration of FWI in the Eastern Alps.

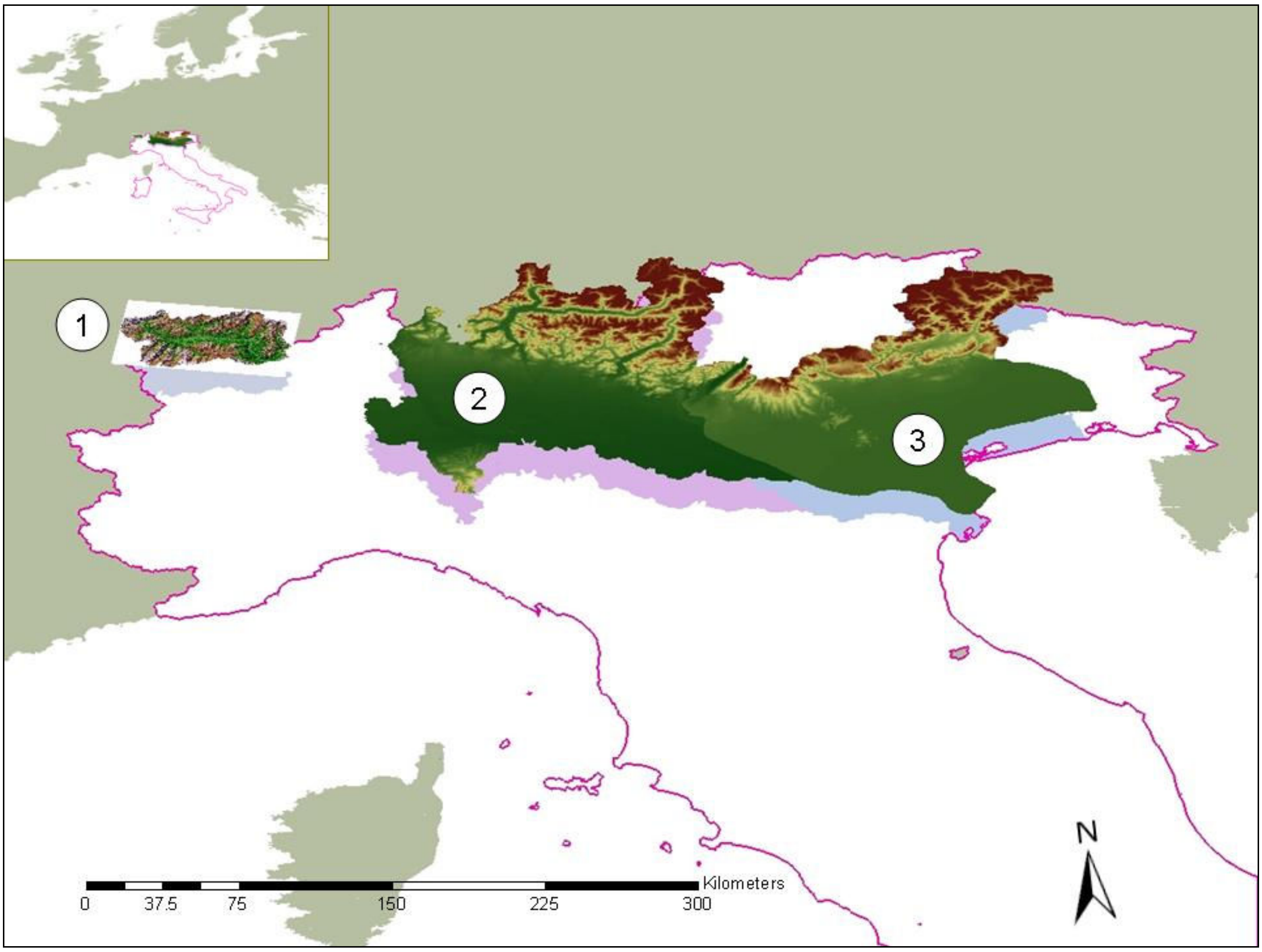


Figure 1. Localization of Aosta Valley (1), Lombardy (2) and Veneto (3) in Northern Italy.

FDR implementation along the Italian Alps

At the present time, only four of the seven Regions touching the Alps are engaged with projects on FDR implementation (Aosta Valley, Piedmont, Lombardy, Veneto). The stage of advance is quite different, going from launched (Aosta Valley and Piedmont) to just started systems (Veneto and Lombardy).

In the Aosta Valley, placed in the internal Western Alps, implementation of FWI started in 1994. Definitive calibration of the index was carried out in 2004, mainly by using operative personnel expertise and observations (Regione Autonoma Valle d'Aosta, 2005). The threshold values vary depending on months and are divided in 7 danger levels (table 1). The index is spatialised by 15 weather stations, placed on hillsides that are well known by fire managers and monitored by local teams. In addition, a risky areas map has been created, to point out where fires are supposed to spread wilder, namely pinewoods growing in the foothill belt, especially if facing south (figure 2). After 14 years, the Aosta Valley Fire Service is drawing first conclusions on FWI performance. The main concern regards few but severe large fires (figure 3) occurred in pine stands (*Pinus sylvestris*). During 3 and a half years they collected live fine fuels moisture contents (every 15-30 days) to find out prediction models for critical live needles moisture by using the FWI system codes. In fact, Cesti (2004) observed that crown fires occur when pine needles moisture is quite high (115-130% depending on needle type: old or young needle), but under 95 – 110% (critical live needles moisture) crown fires develop more severe or even eruptive. Results showed that FWI System can be used to predict severe crown fires in winter time, even if they must be reinforced (Valese *et al*, in progress paper). FWI performance is not that good during summer (Cesti p.c.), when high and very high danger levels are over represented, giving back a unacceptable number of false signals. An additional work on threshold values in summer time should be carried out. In 2003 summer the percentage of lightening-caused fires went up to 22% (Cesti p.c.), showing that under extreme weather conditions they can represent hot spots.

Danger levels	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Extreme	>26	>30	>43	>58	>64	>67	>68	>73	>67	>52	>40	>37
Very high	18-26	20-30	27-43	36-58	41-64	39-67	41-68	43-73	40-67	32-52	26-40	24-37
High	11-17	13-19	16-26	21-35	23-40	22-38	23-40	24-42	23-39	19-31	16-25	15-23
Medium	7-10	8-12	9-15	11-20	13-22	12-21	13-22	13-23	12-22	11-18	9-15	9-14
Low	4-6	4-7	5-8	6-10	6-12	6-11	6-12	7-12	6-11	6-10	5-8	5-8
Very low	2-3	2-3	3-4	3-5	3-5	3-5	2-5	3-6	3-5	3-5	2-4	2-4
Minimum	0-1	0-1	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-1	0 -1

Table 1. FWI threshold values and danger levels by month. Source: Regione Autonoma Valle d’Aosta (2005)

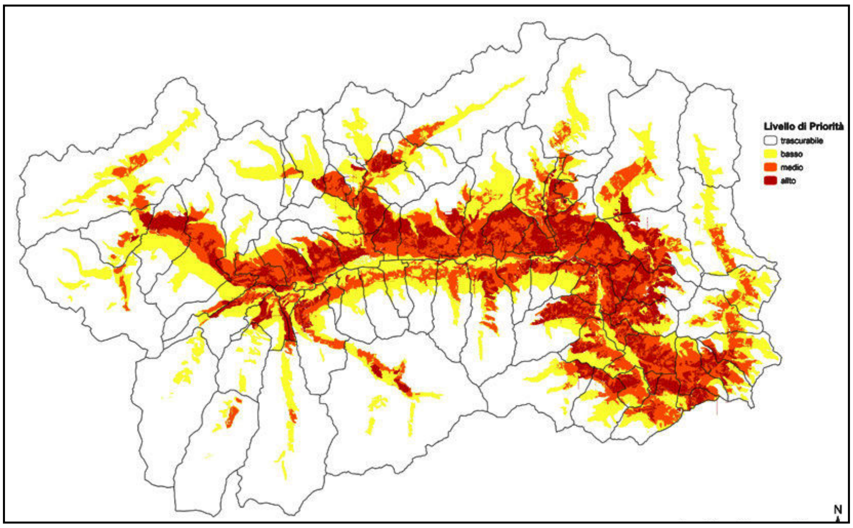


Figure 2. Aosta Valley risky areas map. Source: Regione Autonoma Valle d’Aosta (2005)

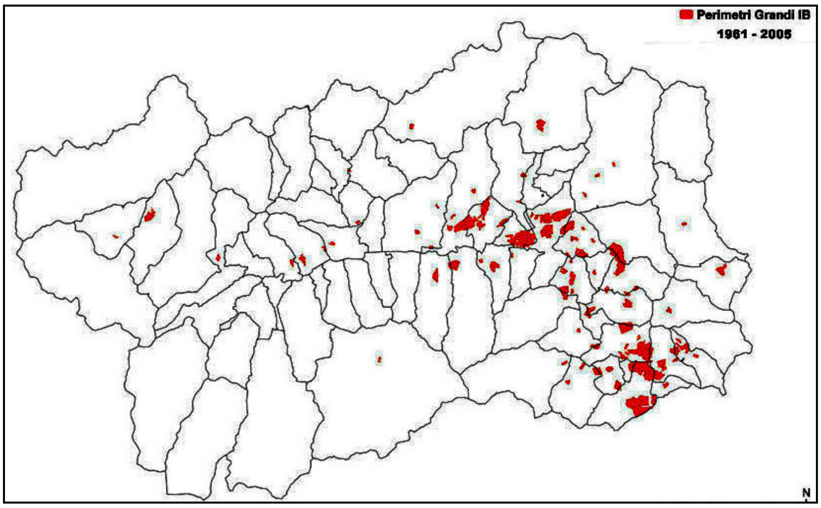


Figure 3. Perimeter of large fires occurred between 1961 and 2005 in Aosta Valley. Source: Regione Autonoma Valle d’Aosta (2005)

In Veneto, before 2007, fire danger was not monitored at all. To start the FDRS a simple way to spatialize the index should be found as well as an automatic and user-friendly application. The project was funded by "Forest Focus" programme (Reg. CE 2152/2001) and realized by Veneto Fire Service in fellowship with University of Padova. A climatic analysis was performed by using 62 weather stations and 30 years long data series (monthly minimum and maximum temperatures; monthly cumulated rains), dividing the region in 11 homogeneous areas (Valese *et al.* 2008). Then 11 weather stations were chosen, representative of the climatic areas, to provide daily inputs (figure 4). Output was a intranet-accessible Daily Map of Fire Danger with FWI codes table attached (figure 5). In these early stages, the Map is used more by the Central Fire Office, responsible for declaration of alert state, than by peripheral Services, who move actually the operative fire fighting machine. For the system development it will be necessary to keep alive the connection between regional and local level, being the correct way to check FWI performance. By now, Aosta Valley threshold table has been used and a Chi-square test has been run for two climatic areas (figure 6), area n.9 and area n.7, to check the reliability of danger levels in use, considering occurrence of fire and non fire days . In both cases danger level 7 (extreme danger) was not represented at all, highlighting the need of a specific calibration for the region.

In Lombardy the FDR system is starting and calculations are provided by a large number of weather stations, that have not already been screened. Participation to the technical meetings with other northern Regions has been helpful to address future choices of Meteorological Service (ARPA Lombardia), who is the one committed to implement experimentally FWI.

In table 2 are presented descriptive data about Aosta Valley, Lombardy and Veneto, that emphasize topographic and climatic traits having influence on fire severity at regional scale. The incidence of föen, the typical Alpine fall wind, on fire severity is a major trait in the Western and Central Alps, while in the Eastern Alps the incidence is reduced by both valleys orientation and average elevation. föen comes from North - NorthWest and warms depending on mountains elevation, that is higher in Aosta Valley and Lombardia. In Veneto, where mountains difference in level is lower than 3000 m, air mass is subjected to lower compression, resulting in lower speed and dehydration power (table 3). Together with continental gradient, wind factor plays on fire severity that is higher on the west side of the Italian Alps.

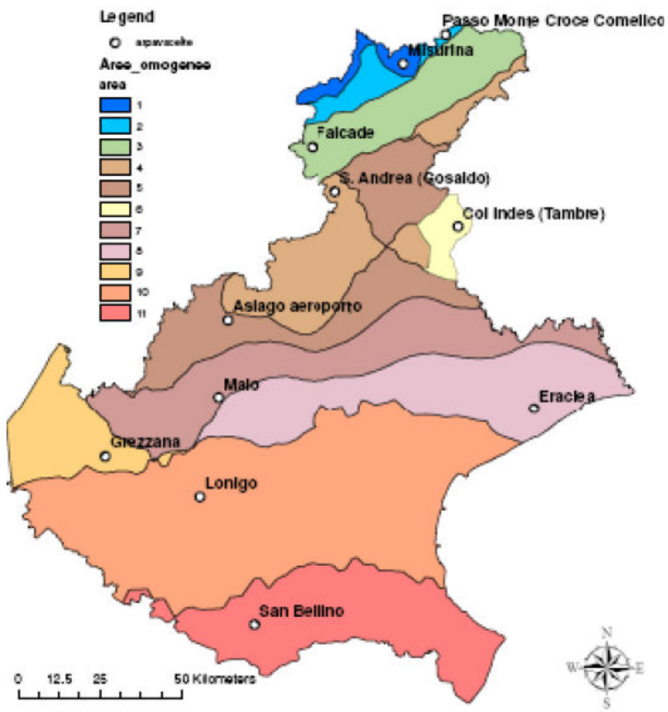
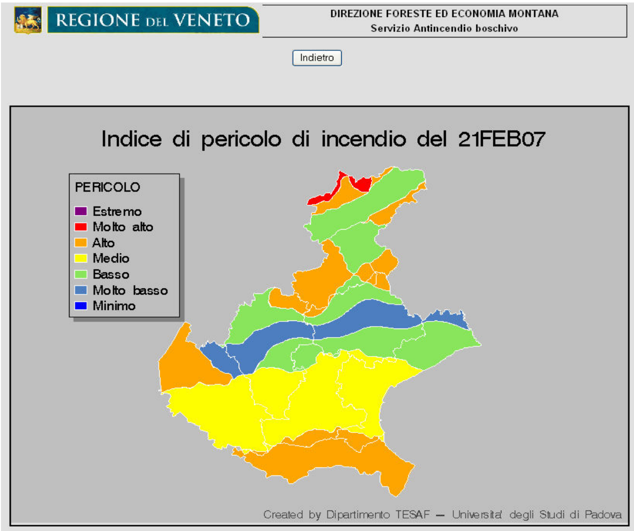
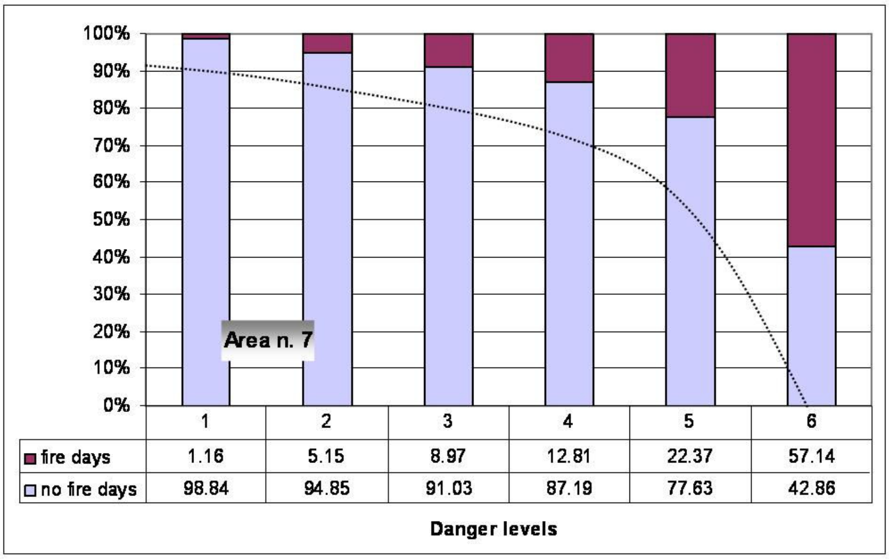


Figure 4. Map of homogeneous climatic areas and representative weather stations used to compute FWI. Source: Regione Veneto (2007)

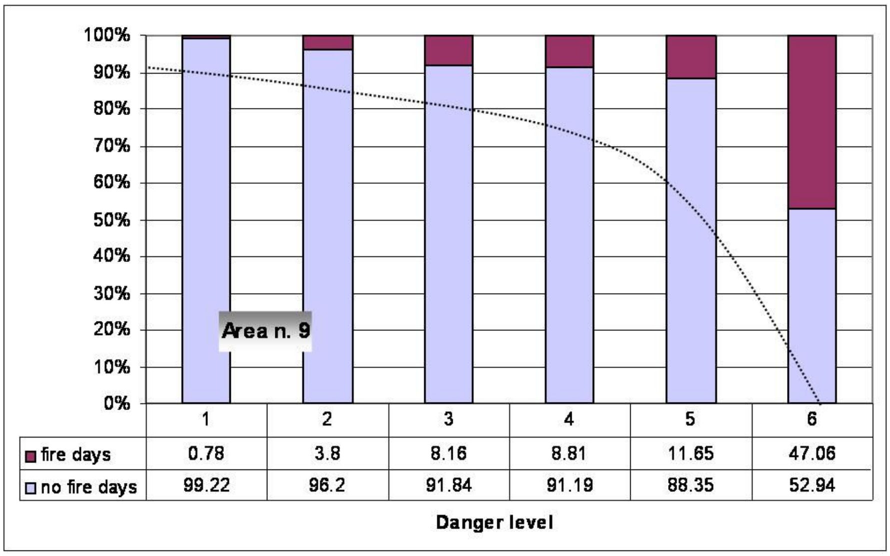


area	ffmc	dmc	dc	isi	bui	fwi	dsr	PERICOLO
1	91.90	54.94	152.49	8.84	57.81	21.94	6.44	Molto alto
2	90.50	58.13	160.36	6.89	60.99	18.85	4.92	Alto
3	80.09	48.76	177.30	1.63	57.79	5.48	0.55	Basso
4	88.32	66.85	200.55	5.58	72.92	17.75	4.42	Alto
5	60.51	18.03	158.41	2.01	28.07	4.04	0.32	Basso
6	91.21	37.73	200.69	6.89	51.33	17.19	4.18	Alto
7	76.65	23.17	179.20	1.04	35.01	2.10	0.10	Molto basso
8	78.31	30.92	190.34	1.31	43.98	3.51	0.25	Basso
9	87.81	60.76	186.19	4.93	66.92	15.43	3.45	Alto
10	86.28	39.90	181.26	3.97	51.47	11.20	1.96	Medio
11	90.30	62.60	169.01	6.05	65.01	17.73	4.41	Alto

Figure 5. Intranet-accessible output: Daily Map of Fire Danger and FWI codes table. Source: Regione Veneto (2007)



	1	2	3	4	5	6
fire days	1.16	5.15	8.97	12.81	22.37	57.14
no fire days	98.84	94.85	91.03	87.19	77.63	42.86



	1	2	3	4	5	6
fire days	0.78	3.8	8.16	8.81	11.65	47.06
no fire days	99.22	96.2	91.84	91.19	88.35	52.94

Figure 6. Contingency tables comparing fire days and non fire days occurrence by danger level, for Area n. 7 (1994 - 2000) and n. 9 (1992 - 2006). Data provided by Regione Veneto

	Aosta Valley	Lombardy	Veneto
Alpine zone	Western - internal	Central - internal	Eastern – close to the sea
Topography	Very incised valleys high slopes, difference in level up to 3000 m	Incised valleys, high slopes	Less incised valleys, lower slopes
Annual maximum temperature average (°C)	15 *	17 **	15.4 ***
Annual cumulated rain (mm)	800 *	990 **	1550 ***
Fall wind incidence on fire severity (Föen)	High incidence	High incidence	Low incidence

Table 2. Topographic and climatic traits having influence on fire severity in Aosta Valley, Lombardy and Veneto. Source: ARPAV Arabba, ARPA Lombardia, Nucleo AIB Regione Autonoma Valle d'Aosta
*(Aosta weather station); **(Sondrio weather station); ***(Belluno weather station)

Region	Site	Starting day and higher intensity time	Burnt area (ha)	Weather station	Average wind speed (km/h)
Western Alps (Aosta Valley)	Nus, Verrayes	March 12th, 2005 (16:00 – 24:00 hrs)	257	Aosta	41
Central Alps (Lombardy)	Prata Camportaccio	January 19th, 2007 (16:00 – 24:00 hrs)	171	Samolaco	29
Eastern Alps (Veneto)	Monte Sperone (Sospirolo)	March 23rd, 2002 (16:55 – 24:00 hrs)	23	Sospirolo	10

Table 3. Average wind speed during the higher intensity time of three fires placed in a Western Alps (Aosta Valley), Central Alps (Lombardy) and Eastern Alps (Veneto). Source: ARPAV Arabba, ARPA Lombardia, Nucleo AIB Regione Autonoma Valle d'Aosta, Servizi Forestali Belluno

Calibration

The Chi-square test applied to Veneto pilot areas, puts in evidence that number of fire days increases as danger level becomes higher, but the fact that extreme level is not represented means that Aosta Valley threshold values do not fit completely to Veneto. Climatic areas n. 7 and n. 9 have been chosen to test a methodology for calibration to be then extended to the entire Region. Precisely, the fires occurred inside Verona Province (figure 7) have been taken into account, since in this area fires localization and date were available and FWI could be computed for more than 10 years, using Malo and Grezzana weather stations data. The area is influenced by Garda Lake, playing a mitigating role on climate extremes, as shown in figure 8.

At a preliminary step, 4 dataset have been taken in consideration: 1) all days; 2) fire days; 3) multiple – fires days; 4) large fires days (fires larger than 4 ha). For every dataset the 25th, 50th and 90th percentiles values have been computed and the methodology proposed by Andreaws *et al.* (2003) has been applied to check the index efficiency and to explore the dataset. Then, 90th and 97th percentiles values have been used as the lower limits for the highest staffing class levels (Helfman *et al*. 1987). The "fire days" dataset is the one chosen to fix the limit values for every month (table 4), but the amount of data limited the analysis, since FWI values were not well represented. Then, the other datasets have been employed to adjust the values.

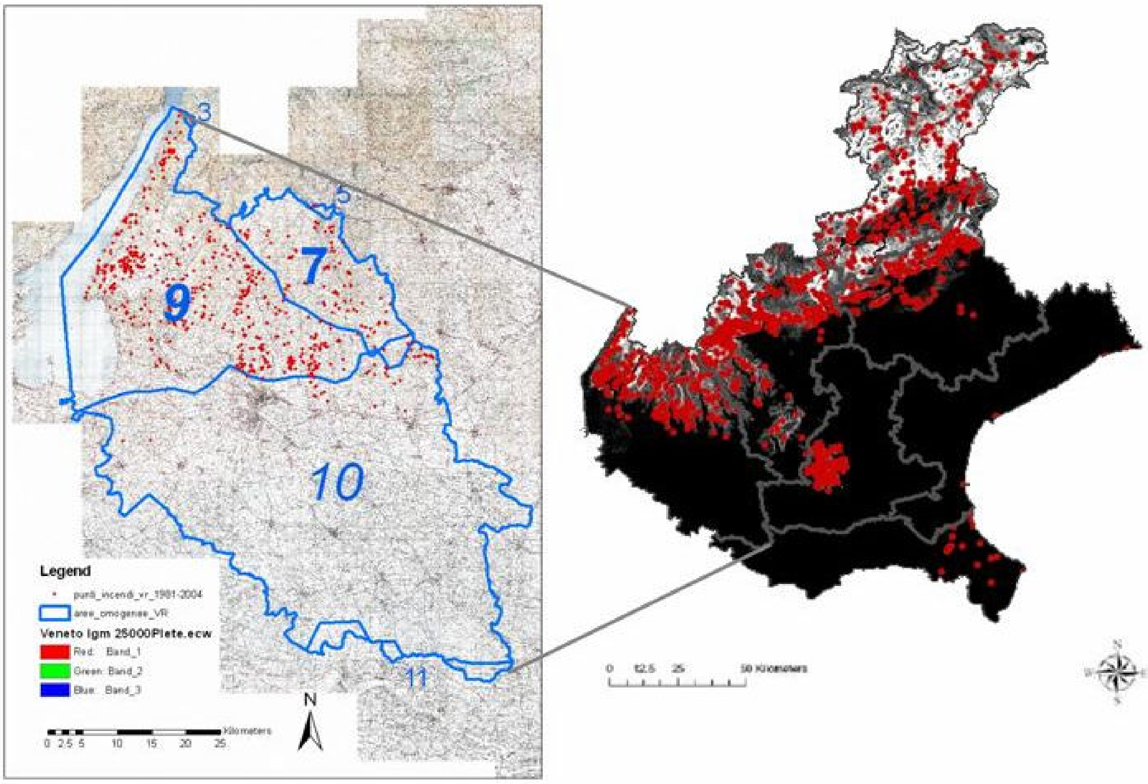


Figure 7. Localization of Verona Province (on the left) in Veneto Region and localization of fires (in red) in test areas n. 7 and n. 9. Data provided by Regione Veneto

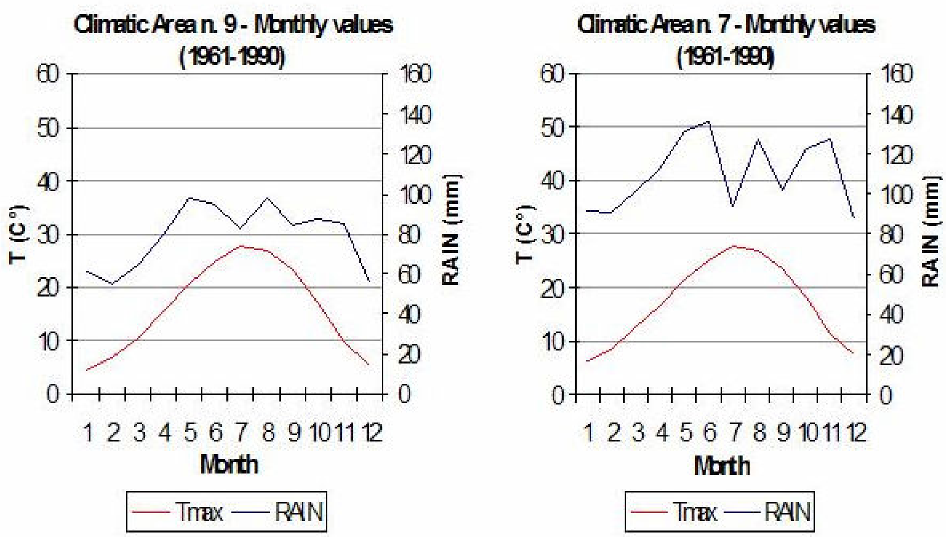


Figure 8. Monthly air temperature and cumulated rain trend in test areas n. 7 and n. 9. Data provided by Regione Veneto

Percentile	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
90°	9	12	12	17	20	28	28	32	32	6	6
97°	12	20	16	20	24	32	32	36	36	8	8

Table 4. FWI limit values of highest danger levels for every month in test areas n. 7 and n. 9, as indicated by percentile analysis (90° and 97° percentiles) and using "fire days" dataset.

Monthly analysis returned just approximate results due to the small datasets available. The month of December was not represented at all and average number of records per month was just around 22 days. It is evident that, respect to Aosta Valley threshold values, highest class levels have to be changed to lower FWI values, but the pilot dataset should be extended to get reliable results. Such difference between Aosta Valley and Veneto depends on climate. Verona is placed closer to the Adriatic Sea, while Aosta Valley lies in the most continental Alps and is also affected by föen.

The same methodology was then applied to a more sound dataset, grouping monthly data by season and getting an average number of records per season equal to 50 fire days. Results in table 5 are more consistent relatively to the "fire days" dataset, indicating values of 15 and 20 for the highest danger classes of winter time. The values of autumn are not reliable, since number of records was just 12 days, that can not be considered statistically significant. It is interesting to notice that summer and autumn fires did not covered large surfaces.

Dataset	Percentile	Winter	Spring	Summer	Autumn
All days	90°	5	19	25	21
	97°	11	27	33	27
Fire days	**90°**	**15**	**24**	**31**	31
	97°	**20**	**30**	**35**	35
Multiple-fires days	90°	12	12	24	24
	97°	20	20	36	36
Large fires days	90°	16	14		
	97°	20	20		

Table 5. FWI limit values of highest danger levels for every season in test areas n. 7 and n. 9, as indicated by percentile analysis (90° and 97° percentiles), using "all days", "fire days", "multiple-fires days" and "large fires days" datasets. Winter = December, January and February; Spring = March, April and May; Summer = June, July and August; Autumn = September, October and November.

The methodology tested in Verona Province has given the first indications relatively to Eastern Alps (Veneto Region) values of FWI during fire days. The same method is recommended to be applied for the rest of climatic areas by merging data by seasons. Being Veneto (like Lombardy) a region where both mountain areas and planes are present (Bovio and Camia 1997), next investigations should evaluate if a different threshold table is needed to embody both topographies. To simplify the system, danger levels could be changed from 7 to 5 classes, similar to most of launched FDR systems (Van Wagner 1987).

Conclusions

FDR implementation in the Alpine region of Italy is still going through a phase of experimentation, even in those Regions (Aosta Valley and Piedmont) where the system run for 14 years. Calibration of danger levels needs a large amount of both weather and wildfires data, collected in a more efficient way once the system is started. Fires reconstruction will also comply with improvement of Alpine culture of fire that is still patchy. The creation of an Alpine Network will be the mean to face with two basic challenges: getting a landscape picture about the Alpine fires and improving the coordination between sub-regions, towards a multi-scale analysis approach. Though Alpine environment is not fire-prone like the Mediterranean one, the striking sensitivity to a potential global warming (Schumacher 2004, Conedera *et al.* 2006) should be taken into account by fire managers and researchers in a proactive frame of preparedness.

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