Fire causes influence on wildfire regime

Bruno Capitoni[1], Maurizio Carlini[1], Paolo Fiorucci[2] , Francesco Gaetani[2], Riccardo Minciardi[2], Anna Scipioni[3], Luca Troiani[1]

Abstract

Wildland fire risk can be considered as the effect of several dynamics relevant to heterogeneous factors such as vegetation physiology, meteorology and, of course, the human presence. Considering the close relationship existent between the number of fires and the human action, it seems necessary to take into account the wildfires caused by man. Among these reasons the dominant one (more then 60%) is that of fires caused by agricultural activities and forestry, which were, therefore, deeply investigated.

Basing on the experimental application of a detective fire-cause method, a methodology for the optimal administrative units partition, achieved on the basis of static wildfire risk assessment, is proposed and discussed in detail. To this end, a procedure to identify the zones (administrative units) characterized by specific wildfire regimes is carried out, also taking into account the cause of ignition. Such zones are made by groups of elementary areas, which shown similar behaviour in connection to wildland fires phenomenon.

A case study relevant to Savona, a region placed on the north-western coastline of Italy and frequently affected by severe wildland fire occurrences, is dealt with in this paper, in order to evaluate the effectiveness of the proposed approach.

1 Introduction

The wildfire occurrences in Italy, similar to the others Mediterranean countries, are almost in the totality of the cases related to the human presence; therefore, a reliable study about the causes of wildfires cannot be made without a deep analysis of the land uses in the area of study, the activities present on the territory, and the social and economics characteristics of the local society. In fact, since ancient times, fires have represented a formidable tool used to modify the land use, in order to create new space for agriculture and pasturage; in some regions of Italy (i.e., Sardinia, Calabria, Campania), where the pastoral customs are deeply

[1] DISAFRI Dipartimento di Scienze dell'Ambiente Forestale e delle sue Risorse.
Università degli Studi della Tuscia. Via S.Camillo de Lellis, s.n.c., 01100 Viterbo (Italy).

[2] CIMA Centro di ricerca Interuniversitario in Monitoraggio Ambientale.
Università degli Studi di Genova e della Basilicata. Via Cadorna, 7 – 17100 Savona (Italy).

[3] Presidenza del Consiglio dei Ministri, Dipartimento della Protezione Civile Ufficio Pianificazione Valutazione e Prevenzione dei Rischi. Servizio Rischio Incendi Boschivi. Via Vitorchiano, 7 - Roma

rooted in the society, woodlands are still considered by the rural population as obstacles to the "right" of pasture their flocks and, for this reason, it is not surprising to observe that the presence of wildfires constitutes a seasonal recurrent threaten for the territory. Besides, in the depressed areas, where the unemployment is very high and chronic, the occurrence of a wildfire may (unfortunately) represent an opportunity of employment for the teams of workmen that are usually engaged in the reclamation and reforestation of burnt areas.

The evidence of the strict relationship existing between the use of the fire and the territory is apparent from the hundreds of toponyms and the numerous family names, whose origin is related to the use of wildland fire, quite common and spread over the whole peninsula.

The prevention of the occurrence of wildland fires and their extinction are duties peculiar to the national Forest Service (Corpo Forestale dello Stato), a Corps within the Italian Department of Agriculture, which is also in charge to identify and measure the burnt areas and to collect the data relevant to the events in the *Foglio Notizie Antincendio Boschivo* (Wildfires Daily Journal). This database reports information relevant to each wildfire for which the intervention of some fire fighting resources both of ground and aerial type has been required. Each wildland fire inserted in the database is described by a huge number (in its last version, 296) of fields, related with the physical characteristics of the event (location, geographical coordinates, burnt surface, kinds of fuel, local meteorology, causes of ignition,..) and with the characteristics of the intervention carried out for its suppression (hour of intervention, time of response, kind and number of means, kind and number of personnel, number of drops, accidents, volume of water, and so on.). This document represents the national official source of data needed for the application of the binding force of the law on the area affected by wildfires and, obviously, for the statistical analysis of the phenomenon.

In addition, since 1994 the European Commission has enacted the 804/94 Regulation, related to the activation of a common European information system on forest fires. The Regulation 804/94 defines a set of data that must be present in each European forest fires database. Such "Common Core", is updated systematically in all Member States that are classified at higher risk. At the present time, the Common Core contains information relevant to 319 provinces of the six member states, namely, Germany, Spain, France, Italy and Greece. The Common Core is composed by a minimum set of 10 essential data that are the time and data of the wildfire sighting, the time and data of the first intervention, the time and data of the definitive suppression, the location of the wildland fire, the cause of ignition, the total area burnt, and the kind of burnt vegetation (shrublands, woodlands).

This paper presents a procedure which, starting from the data available from historical wildfire databases, and from a reliable analysis of the crime scene (ignition point of a fire and fire causes), is able to discriminate, in space and time, with reference to a specific region, different wildfire regimes. This in order to better understands the space-time distribution of wildfire risk.

The determination of such distribution may be useful to identify the connections between the ecological features and the land use of certain areas, and their wildfire regimes. Moreover, a deeper knowledge of the space-time risk distribution may be of extreme importance in connection with the sizing and the location of fire fighting resources.

In the remaining of the paper, the proposed procedure will be analysed and discussed with some details. In particular, in the next Section, it will be briefly described the methodology carried out to recognize the ignition point of a fire,

whereas in the subsequent section, the procedure used to characterize the wildfire regimes will introduced and discussed with reference to a specific case study.

2. Recognition of the Ignition Point of a Wildfire

The identification of the exact ignition point of a wildfire is a major step forward in the detection of the causes. According to the European Commission Rule n°804 1994 every wildfire must be classified within one of the following four groups:
- Unknown-origin wildfire;
- Natural-origin wildfire;
- Unintentional-origin wildfire due to lack of attention. This origin is related with human activity but it doesn't show any specific intention to destroy the natural space;
- Intentional-origin wildfire caused by the clear intention to destroy a forest or wildland space for several purposes.

This classification aimed to improve statistics on fire causes, which may help fire prevention and contrasting strategies.

The National regulation of 21 November 2000 n°353 is the law in force to prevent and cope with severe wildland fires, reduce their impacts on wildlife and communities, and plan suitable fire fighting capabilities at regional and national level. The application of law 353 imposes to all the Italian Regions to produce peculiars Regional Plans for the prediction, the prevention, and the extinction of wildland fires. Such Plans are revised each year, and must include the following key components:
a) an analysis relevant to the main causes of wildland fires;
b) the maps relevant to the areas burnt by wildfires in the previous years;
c) the maps of the areas more exposed to wildfire risk along with information on the vegetation cover;
d) the periods that present a higher risk, along with the data relevant to the wind direction and intensity;
e) the selected risk indexes and the methodology carried out for their implementation;
f) the prediction-prevention actions which will be carried out in the area;
g) the number, the typology, and the localization of the available resources (trucks, barracks, roads, water reservoirs, firebreaks, ..), along with the current protocols of intervention;
h) the hazardous fuel reduction plans foreseen in the area;
i) the economic action plan, the structures for personnel training and information dissemination within the communities.

The application of the law 353 stressed the importance of prevention (art. 4 paragraph 2) and it introduced within the Penal Code the crime of wildfires ignition (art. 423 bis).

Since 2001, national Forest Service has been charged by the Italian Government with the first National Cognitive Investigation on the causes of fires, which may be considered as a milestone for any further methodological study carried out on this subject. In order to issue qualitative and quantitative databases, this investigation was carried out by grouping the fire events according to the former national classification (natural, intentional, unintentional, unclassifiable).

The application of the methodology highlighted the necessity to focus on anomalous behaviours at the origin of wildfires. In 2003, the Italian Forest Service charged the Department of Environmental Sciences and Forest Resources of Tuscia University (Italy) with the experimental application of the fire-cause detective

method, which has been already and successfully tested in other countries (Porrero-Rodriguez, 2001).

A better knowledge on the fire causes is the result of the application of this objective method based on verifiable elements to recognize the ignition point of a fire. Owing to the application of this methodology, statistics of fire occurrences have greatly changed both all over Italy and in those regions where the research and the Forest Service training were carried out. The most important changes were founded in the fire occurrences classified as doubts, which have significantly decreased, whereas the culpable and fraudulent ones have increased.

Year	Natural	Accidental	Negligent	Intentional	Unknown
1998	1	0,6	12,6	50,7	35,1
1999	0,6	0,2	11,2	48,9	39,2
2000	0,9	0,5	11,8	57,7	29,1
2001	1,1	0,5	34,4	60	4
2002	0,7	0	17,7	59,2	22,3
2003	2,7	0,7	14,2	61,5	20,9
2004	1	0,6	13,3	61,7	23,4
2005	0,6	0,9	19,6	64,5	14,4

Table 1 – Percentage distribution of wildland fires classified for cause of ignition. (Forest Service).

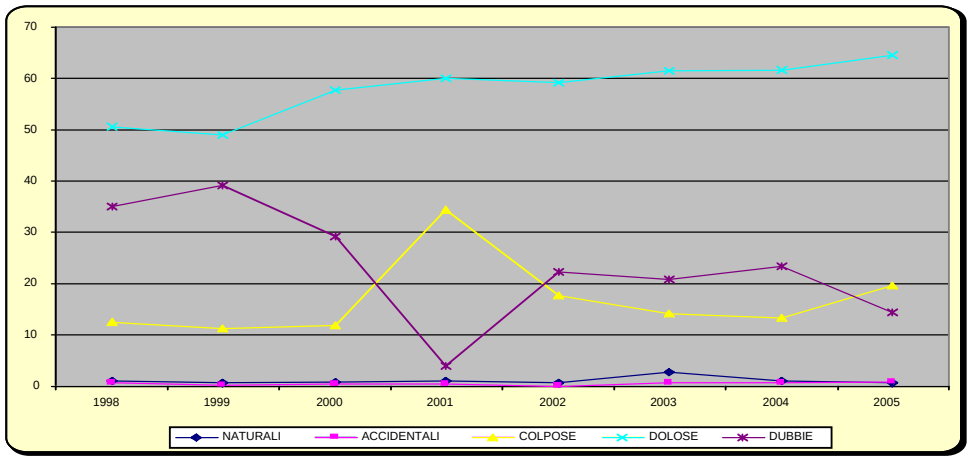

Figure 1 – Percentage distribution of wildland fires classified for cause of ignition. Natural = *Naturali*; Accidental = *Accidentali*; Negligent = *Colpose*; Intentional = *Dolose*; Unknown = *Dubbie*. (Forest Service)

From Table 1 and Figure 1 it became apparent the change in classification. Such a behaviour can be explained through the better knowledge of the occurrence related to the local community.

2.1 Wildfire Causes Detective Method

The adopted method, namely the MEF (*Metodo delle Evidenze Fisiche*, Physical Evidence Method) allows tracking the fire development through evidences (signs and tracks) that the propagation of a fire has left behind along its path in order to classify the originating cause. The method is made of the following steps:

1. Reckoning of the fire geometry;
2. Tracking of the fire development;
3. Location of the fire path and recognition of the ignition area;
4. recognition of the fire ignition point;
5. Recognition of the cause-related physical evidences.

The application of the MEF method improved the capacity to obtain information from the analysis of the crime scene in order to track the fire development and to detect its originating cause. During the detective phase, a major effort has been devoted to the acquisition of objective evidences that the fire propagation left on vegetation and soil. The careful analysis of these evidences gets important information on fire propagation, heat intensity and rate of spread of the fire front. In this way it is also possible to recognize the ignition points of a fire, that is the main purpose of the whole detective procedure.

The validation of the methodology has been done on the basis of the ignition area location compared to the reliable witnessing gathered from local population and/or from the fire-fighters intervened on the fire. Once recognized the ignition point along with the most important evidences, it is eventually possible to outline the fire occurrence in order to issue a reasonable assumption on the fire cause to be compared to witnessing and validated. The implementation of MEF provide Forest Service officers with a greater capacity on analyzing the fire event and it allows to recognize either the local characterization or the crime responsible.

The MEF method, based on the objective and verifiable recognition of the fire ignition point, provides a fast investigative instrument and, consequently, a greater skill in determining the cause and focusing on responsibilities. Moreover the systematic gathering of undoubted and incontrovertible elements, useful to detect the fire cause, contributed to identify the crime responsible.

Focusing on the considered case of study, i.e., the Province of Savona (Italy), it is worth observing that the application of MEF on 70 wildfires burnt during the year 2006 lead to identify the exact ignition point of 47 events, that is the 67% of the whole set. Besides, for 10 of such wildfires it was possible to ascertain the responsible of the crime. It is also important to point out the benefits attainable by National Forest Service from the implementation of MEF within a more general resource planning. In fact, the characterization of the territory on the basis of the causes of ignition, allows Forest Service to relocate the resources in a more effective way. The use of an objective method, as the MEF, improved the detective skills of the research strongly reducing - or even definitely excluding –evaluation mistakes.

3. An analysis on the ignition causes in the Province of Savona (SV)

In this section it will be presented the results obtained from the application of a procedure that, starting from the data available from historical wildfire databases, is able to discriminate, in space and time, a set of different areas, which are characterized by different wildfire regimes. This in order to better understands the space-time distribution of wildfire risk. The determination of such distribution may be useful to identify the relationships between the ecological features and the land use of certain areas, and their wildfire regimes. Moreover, a deeper knowledge of the space-time risk distribution may be of extreme importance during the phase of sizing and location of the fire fighting resources.

Several works, appeared in recent years in the literature (Malamud and Turcotte, 1998; Ricotta et al., 1999; Song et al., 2001; Turcotte and Malamud, 2004; Telesca et al., 2005; Malamud et al., 2005), proposed the so-called power-law (scale invariant) statistical distribution applied to heterogeneous examples of data set referring to natural hazard case studies. In brief, such distribution states that the expected number of events having a certain magnitude, within a given time interval and a given geographical area, is proportional to a power of that value of magnitude. Particularly, in the case of wildfires, the magnitude of the event can be represented by the burnt area (Malamud et al., 1998). The wildfire regime in a homogeneous area is defined by the inter-event time per given burnt area, resulting from the values of parameters characterizing the distribution of fire numbers per given burnt area (power law). The application of such procedure to a wide set of data and its heuristic nature, might lead to approximations that must be carefully considered. The quantitative evaluation of the partition homogeneity can be obtained through the parameters variances characterizing the power law distribution. Thus, it is possible to use the following expression as “quality” index of a partition q composed by K_q homogeneous areas

$$\Psi_q = \frac{1}{K_q}\sum_{i=1}^{K_q}\Theta_{q,i} \qquad (1)$$

where $\Theta_{q,i} = \sigma^2_{\beta_{q,i}} + \sigma^2_{\log\alpha_{q,i}}$ represents the “quality” indicator of every single zone i belonging to the q^{th} partition.

The application of (1) is therefore possible to compare different partitions defined by indicators referred to the specific studied area, i. e., and the land-use.
The Province of Savona (Italy) has been considered since it seems very interesting in order to understand the complex social, economic and ecological interactions, which determine the wildfire regimes. The selected partitions were defined on the basis of the strict relationship between rural activities and wildfires.

A first global analysis has pointed out a strong space-time correlation between the ignition points density and the land use of the considered area. This assumption is supported by the ignition points experimental analysis carried on the wildfire occurrences in 2006.

A first partition was carried out with reference to agricultural land-use. In particular, the following four main classes of land-use has been considered in the paper:

1. Olive grown;
2. Abandoned olive grown;

3. Grassland;
4. Vineyards and other plantations.

On this basis, the partition reported in Figure 2 has been obtained; the percentages of each land-use classes with respect to the whole considered area are reported in Table 2.

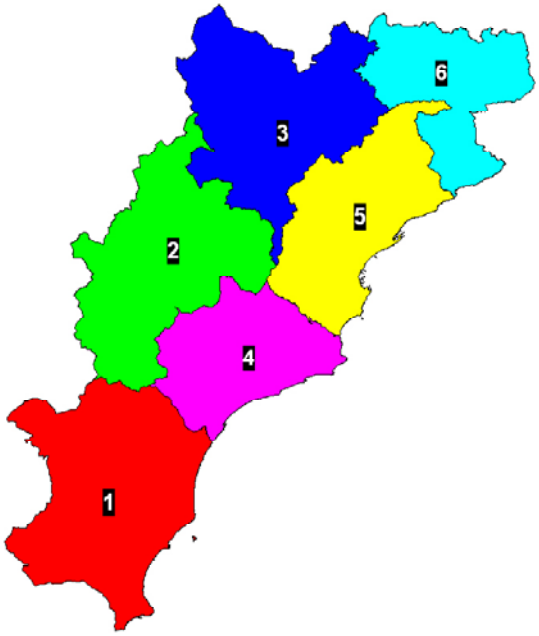

Figure 2. The 6 zones obtained from the partition of the province of Savona basing on a land-use classification.

Zona	oliv_c	oliv_a	vigneti	prato
1	6.72	2.45	11.57	1.78
2	0.02	0.00	6.08	2.56
3	0.00	0.00	18.22	3.48
4	5.12	1.11	9.31	0.69
5	3.69	0.34	7.81	1.36
6	1.11	0.20	5.97	7.06

Table 2 – Percentage of agricultural land-use for each different zone.
Olive grown = *oliv_c*; abandoned olive grown = *oliv_a;* vineyards = *vigneti*; grasslands = *prati.*

The power law parameter values and the inter-event times obtained for each zone belonging to the partition shown in Figure 2 are reported in Table 3.

zona	beta	alfa	correlazione	qualità	n	area	tr > 1 ha	tr > 100 ha
1	-1.369	-2.680	0.986	0.0027	452	336.9	18.6	101.8
2	-1.375	-3.387	0.939	0.0324	89	303.4	104.1	585.8
3	-1.360	-3.252	0.913	0.0485	100	296.4	80.3	421.4
4	-1.318	-2.719	0.973	0.0062	210	191.7	39.0	168.4
5	-1.351	-2.700	0.966	0.0096	314	234.6	28.9	145.7
6	-1.328	-2.808	0.946	0.0168	172	179.6	50.4	227.7

Table 3 - For each zone are referred the Power Law parameter values (α, β), the quality index value (*qualita*), the number of wildfires (*n*), the burnt area (*area*) and, finally, the inter-event time in days per burnt area estimated greater than 1 hectare (*tr >1 ha*) and greater than 100 hectares (*tr > 100 ha*).

The Zone 1, which presents the largest area of olive grown along with a great presence of vineyards and other cultivations, shows the shortest inter-event time. On the other hand, zone 2 and zone 3, where there are almost no agricultural activities, the inter-event time per wildfires larger than 100 hectares is about 2 years. The importance of olive cultivation in wildfire regimes suggested the definition of a new partition based only on grown olive zones. In Figure 3 the partition of the Province of Savona into 5 different zones is reported. This partition was defined classifying the 69 Municipalities of the Province in connection with the number of grown olive hectares (see Table 4) according to the following steps:

Zone 1 Municipalities with no grown olives;
Zone 2 Municipalities with less than 50 hectares of grown olives;
Zone 3 Municipalities with less than 100 hectares of grown olives;
Zone 4 Municipalities with less than 200 hectares of grown olives;
Zone 5 Municipalities with more than 200 hectares of grown olives.

zona	olivo	olivo_abb	olivo_tot
1	0.00	0.00	0.00
2	1.42	0.26	1.68
3	3.88	1.69	5.57
4	5.47	2.10	7.58
5	8.56	1.45	10.00

Table 4 - Olive area percentage on the total area amount in every zone.
Olive grown = *olivo*; abandoned olive grown = *olivo_abb;* total percentage of olive grown (*olivo_tot*)

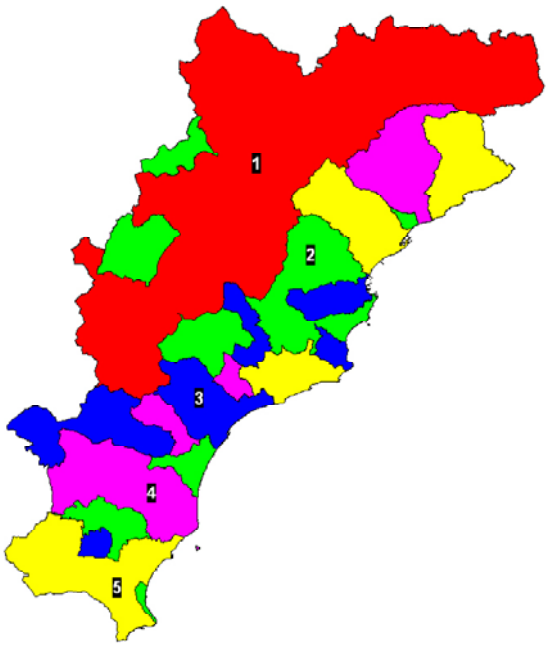

Figure 3 – The partition obtained for the Province of Savona on the basis of olive grown zones.

Even in this case the minimum quality index value is obtained considering the total amount of wildfires occurred in every season.
The power law parameter values and the inter-event times per zone belonging to this new partition are referred in Table 5.

zona	beta	alfa	correlazione	qualit	n	area	tr > 1 ha	tr > 100 ha
1	-1.54	-3.58	0.96	0.0189	275	675.2	49.1	588.9
2	-1.32	-2.81	0.97	0.0063	197	231.5	39.8	172.3
3	-1.30	-2.75	0.98	0.0040	170	179.1	45.3	182.4
4	-1.31	-2.57	0.96	0.0082	292	198.5	26.9	110.5
5	-1.37	-2.64	0.98	0.0050	403	258.3	22.4	120.9

Table 5 - For each zone are referred the Power Law parameter values (α, β), the quality index value (*qualita*), the number of wildfires (*n*), the burnt area (*area*) and, finally, the inter-event time in days per burnt area estimated greater than 1 hectare (*tr >1 ha*) and greater than 100 hectares (*tr > 100 ha*).

From Table 5 is apparent that the inter-event times are strongly correlated with the grown olive area percentage. Such a relationship is weaker in zone 2 and zone 3. In these two zones it can be assumed a more complex wildfire regime probably due to the presence of arsonists.

3. Conclusions

The exact identification of the ignition point of a wildfire has a twofold effect. Firstly, it allows to better discriminate among the different causes of ignition, decreasing the number of wildfires, whose origin was classified as unclear or uncertain. Secondly, allows highlighting the complex interactions between wildfire

regimes and land-use. In fact, at least in Mediterranean countries, the ignition of a fire is nearly always attributable to human activities (either as a voluntary action or as an involuntary consequence of some practice) and, therefore, not recognizable as a natural event. In this connection, it is apparent the benefits attainable by territorial planners and local administrators from the knowledge of the different wildfires regimes characterizing a given region. Such information can be conveniently used to define new urban or territorial plans or to modify the existent ones.

Furthermore, from an operational point of view, it is worth remarking the importance of a reliable partition of the territory based on the causes of ignition. In fact, such information can be used during the preventive phase, since the exact knowledge of the causes of recurrent wildfires allows Forest Service to organize an effective and timely patrolling aimed to decrease the number of fires due to unintentional or negligent reasons.

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