Recent climate variability trends and wildfire occurrence in Cantabria (Northern Spain)

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Abstract

Wildfires are a frequent event in Cantabria (Northern Spain), but their seasonality does not match the typical warm season maximum generalized in most of the Iberian Peninsula. They occur at the end of the winter and the beginning of the spring (January to March), being mostly anthropogenically triggered, in conjunction with "Suradas", a weather event which combines high winds and low humidity. In this contribution temporal trends of several climatic variables from meteorological observatories located in Cantabria and neighbour regions are analyzed since 1961 during the highest risk period in order to assess to what extent the occurrence of wildfires may be linked to the recent climatic variability.

Our results show that the regional climate has become warmer and drier, due to the combined effects of increases in temperatures, sunshine duration, and the decrease in relative humidity and precipitation, variables that are likely to play an important role in drought and fire proneness. However, the exception is the frequency of "Suradas", which have reduced. Those regional climatic trends are strongly linked to the recent evolution of atmospheric circulation at regional and hemispheric scale. The higher frequency of anticyclonic cells over the Iberian Peninsula, and conversely, the reduction of the number of Atlantic baroclinic disturbances are consistent with the temporal and spatial evolution of the North Atlantic Oscillation.

Introduction

Wildfires are a common phenomenon in Cantabria (figure 1); during the period 200-2004 there were 487 days and 1560 wildfires; the burned surface, 20155.3 ha, was equivalent to the 5.6 % of the regional forested surface[2] (the corresponding value for Spain was 3.9 %). They affect all kind of surfaces and they are responsible for situations of risk and damages to both the natural environment and the human properties. But, conversely, they constitute a basic tool in the traditional agriculture practices, operative since the beginning of the human settlement in the territory, as it has been proved by many archaeological evidences (Cárdenas, 1989).

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[2] The spanish statistics includes as "forest" not only forest surfaces but also plantations, scrubs and, in general, non cultivated areas.

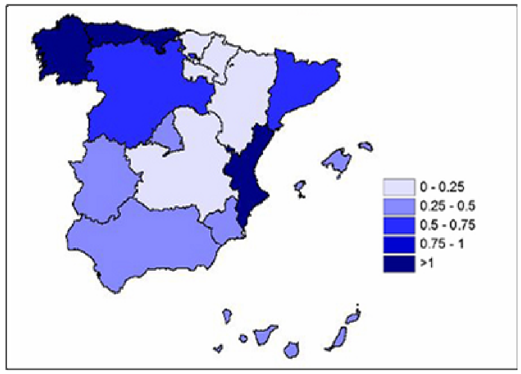

Figure 1—Number of wildfires by year and 1000 ha of forest surface

The burned surface does not show a clear tendency for the last 15 years, but rather a strong inter-annual variability and the relevance of some episodes of above normal fire activity, like the years 1989 and 1990. However, their appearance cannot be related with the seasonal bioclimatic cycles, since their frequency shows a maximum during the January to March trimester, the coolest and one of the wettest periods of the year.

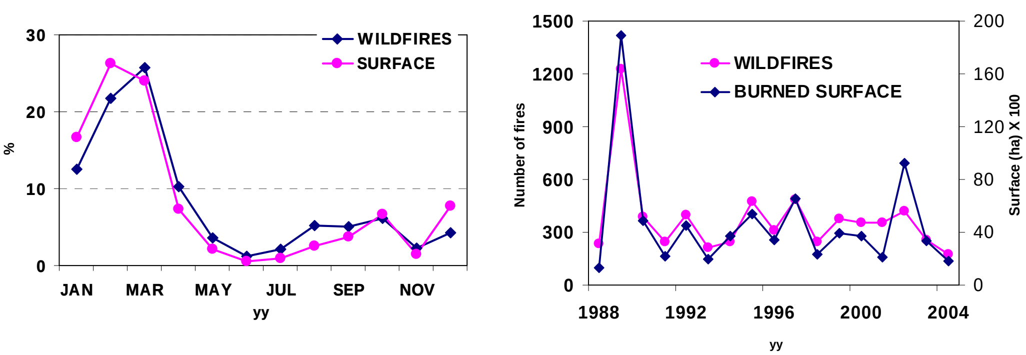

Figure 2—Monthly frequency and inter-annual variability of wildfires in Cantabria (1988-2004)

Fire occurrence in Cantabria is mostly determined by human factors, while the surface burned is more related to climatic factors (Carracedo y otros, 2006**),** since it is well known that atmospheric variables affects the spread of wildfires (Pyne y otros, 1996; Westerling y otros, 2004; Pereira y otros, 2005). Changes in climate and consequent changes in fire hazard have been studied in the Alps (Reinhard y otros, 2005), southwestern USA (Crimmins and Comrie, 2004) and mediterranean Spain (Piñol y otros, 1998; Pausas, 2004). Following this topic, the current investigation seeks to establish the most favourable atmospheric conditions to the propagation of wildfires in Cantabria, and to analyze the temporal evolution of such conditions since 1961 in order to establish future strategies of fire management in northern Spain in the framework of the climatic change by the anthopogenic rising of greenhouse gases.

Data and methodology

To analyze wildfires in Cantabria we have used two sources. From 1988 to 1999 daily fire statistics were obtained from the former ICONA (Instituto para la Conservación de la Naturaleza); from 2000 onwards we have worked with "Partes de Incendios", supplied by Dirección General de Montes y Conservación de la Naturaleza (Consejería de Ganadería, Agricultura y Pesca, Gobierno de Cantabria).
The characterization of the atmosphere was undertaken by two complementary methods. The evaluation of fire risk was performed through the calculation of an index (IRIF) following the guidelines of the Spanish meteorological service (INM). This index, suitable to measure rapid changes in the desiccating potential of the atmosphere, is a simplified adaptation of NFDRS (National FIRE Danger Rate System), operatively in the United States years ago. It is based on the calculation of the daily maximum probability of ignition from temperature and relative humidity data at noon. The final value, which classifies the risk of a wildfire in 4 levels (low, medium, high and extreme), is obtained combining probabilities of ignition and wind speed, using tabulated thresholds (INM, 1996; Cádenas y otros, 1997). The Spanish Meterological Office provided us with the meteorological data (temperature, relative humidity, wind speed and direction at noontime) from the airport stations of Parayas (Cantabria) and Sondica (Vizcaya), from which the indices were derived.
The analysis of the regional atmospheric circulation was performed by developing the so-called objective Lamb weather types, also known as the Jenkinson scheme (Jenkinson and Collison, 1977). From daily MSLP data on a regular 5° latitude by 10° longitude grid, we derived the following air flow indices: (1) the direction of the flow; (2) the strength of the flow; and (3) the total shear vorticity, a measure of the rotation of the atmosphere. The values of the three air-flow indices determine the weather type of the day considered. In order to adjust it to the peculiarities of the Iberian climate, we have improved the original scheme (Fernández García et al, 2002). The original source of the daily MSLP data was the REANALYSIS database (Kalnay y otros, 1996).
Time series of the Palmer Severity drought index from Cantabria were provided by the Climate Reasearch Unit (http://www.cru.uea.ac.uk/cru/projects/emulate/; van der Schrier y otros, 2006).

Geographical setting

The study area corresponds to the autonomous region of Cantabria, located in Northern Spain. This is a region with a complex orography, occupying the central sector of the Cantabrian Range (Cordillera Cantábrica), and facing northwards except the southernmost valleys. In spite of the moderate maximum heights of the mountains (2500 m), the proximity to the coast and the energetic fluvial dissection has promoted a mosaic of small valleys and uplands with a diversity of landscapes. Such vigorous relief creates one of the sharpest and well-defined climatological and ecological boundaries of Europe. The climate is a typically west coast temperate Cfb climate (MOUNIER, 1977) with mild and wet winters and cool summers. The orography generates a strong vertical temperature gradient; the coast registers a mean annual temperature of 13–14 ◦C and a vegetative period of almost 12 months, while in the mountains the mean annual temperature is lower than 5ºC. Most of the region might be classified as wet (annual precipitation ranges from 1100 to more than 2500 mm), with some sheltered valleys are considered subhumid (from 600 to 1000 mm). The annual precipitation regime is unimodal, with a maximum at the end of fall and the beginning of winter (355 %), but summers are far from being dry (almost 30% of the annual precipitation). Due to the orography and the presence of the sea, mesoscale and local circulations are common. The small size and location predominantly in the northern slope of the mountains implies that, in general, inter annual climatic variability is uniform throughout the study area, that is, although intra-regional variability can be observed anomalous climatic years are same for the whole study area.

Results

Short and long-term climatic forcing on fire activity

Two types of atmospheric phenomena, working at different temporal scales, control the spreading of fires in Cantabria: concurrent weather anomalies, which trigger the fire activity, and antecedent climate anomalies, which precondition an environment prone to fire activity.

Popular belief links most of the fires to the occurrence of a strong downslope windstorm called “Surada”. Some historical facts support such statement, like the fire which destroyed the city center of Santander in 1941 during one of this events. The “surada” is a very characteristic weather type in northern Spain, usually related to the well-known “föhn effect” (Rasilla, 1999); during such events, the coastal plains and inner valleys experience a dramatic temperature rising and below normal humidity. The usual atmospheric conditions reverse between both sides of the Cantabrian Range, being the northern one warmer and drier than the southern. From the synoptic point of view, the circulation pattern comprises a deep low offshore the northwestern coast of the Iberian Peninsula, and a western Mediterranean anticyclone (figure 3). This circulation pattern favours the advection of warm air masses over the Iberian Peninsula, which suffers an additional warming and drying when they descend along the northern slopes of the Cantabrian Range.

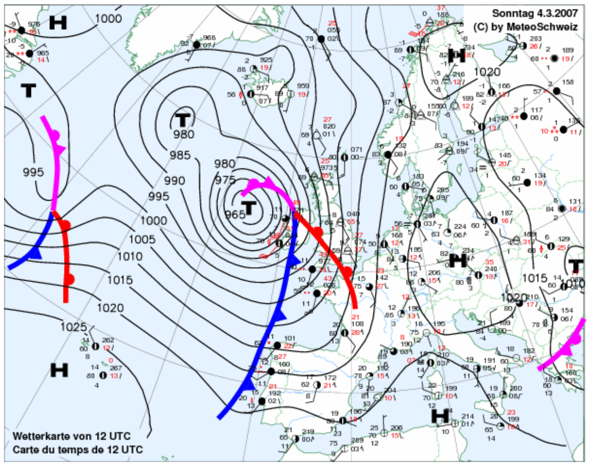

Figure 3—Typical synoptic chart from a "Surada" windstorm in Northern Spain (Source: http://www.meteossuise.com)

Due to the high temperatures (up to 20º C in winter, more than 30ºC in summer), the low relative humidities (below 40 % when the normal values, because of the coastal location, are well above 70 % most of the year) and strong and gusty winds (with gust up to 140 km/h), the "suradas" creates a very dangerous environment, prone to fire propagation. Figure 4 shows the frequency of days with high and extreme fire risk by circulation weather type. In order to account the differences in the seasonal occurrence of each type, the percentage is normalized by the total number of days characterized by each circulation type. Most of the days corresponding to high and extreme risk index values in the JFM trimester appear during synoptic circulations with predominance of southerly and westerly flows (LWT SW, W and SSE). Anticyclonic, easterly and north-northeasterly circulations (LWT A, E and NNE) also contribute, but in a lesser number.

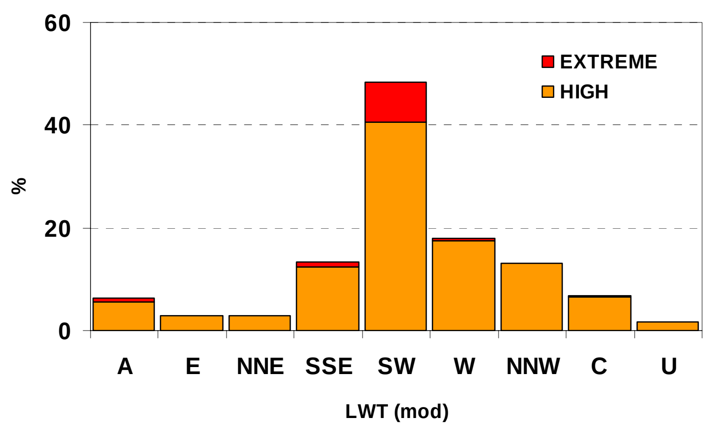

Figure 4—Frequency of high/extreme fire weather conditions by circulation type (JFM period).

In order to check the hypothesis of the relationship between fire, risk indices and downslope windstorms, we examined the correspondence between synoptic circulation, risk indices and large wildfires, since most of burned surface is the result of a small number of episodes of generalized burnings. For that reason, we first select those days which the burned surface was above 90 ha; this threshold corresponds to the upper 95th percentile of the daily burned surface.

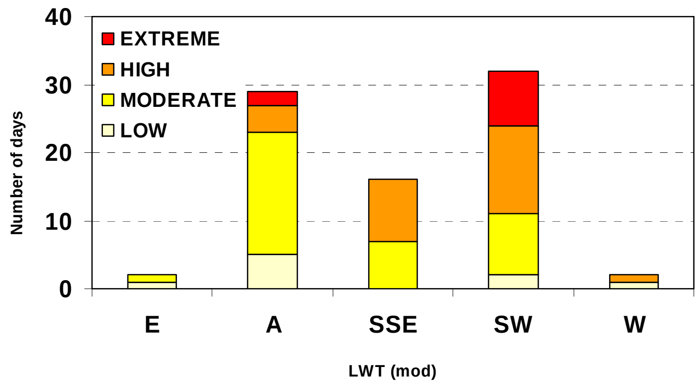

Figure 5—Frequency of fire weather conditions by circulation type during the top 5 % days of burned surface in Cantabria.

The most relevant fact is that, high fire risk conditions do not assure the spreading of wildfire; even, some of those relevant episodes occur without an appropriate atmospheric environment. In some cases such discrepancy might be related to days inserted into a long episode of generalized fire activity (for example, when a weak frontal system crosses the region interrupting briefly a windstorm); although the weather conditions are not suitable for burning, since the wind direction veers to a westerly component and the relative humidity rises, the fires maintain their activity if there is no rain. But some cases the fires spread through the region because of the concurrence of other atmospheric conditions, such as warm temperatures, moderate humidity and high sunshine in combination with a severe drought. To characterize the magnitude of the droughtness, we have compared the number of fires and the surface burned with the values of the PSDI (Palmer Severity Drought Index; van der Schrier y otros, 2006), a usual proxy of such conditions worldwide and commonly used to relate drought and fires (Keeley, 2004; figure 6).

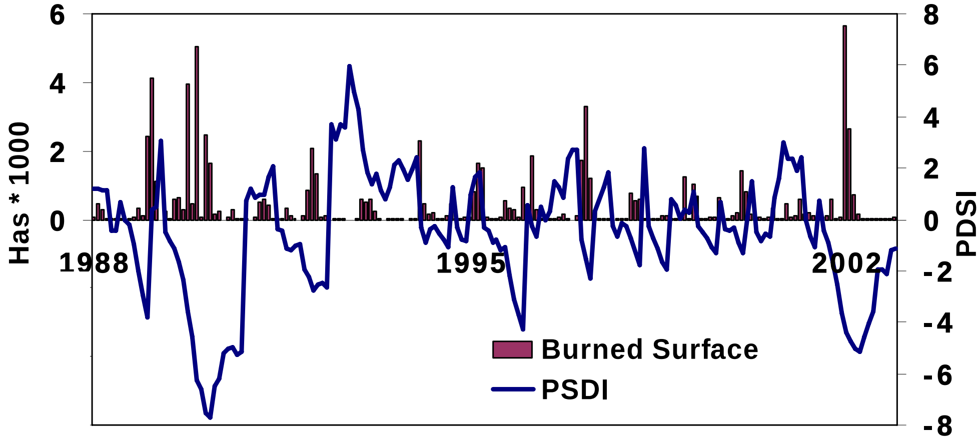

Figure 6—Monthly frequencies of burned surface in Cantabria and the PDSI (1988-2004)

The most severe drought episode took place between 1988 and 1990, with a climax during the trimester January to March 1990 (figure 7). The persistence of high pressures on the Western Mediterranean leaded to the predominance of southerly flows over the Iberian Peninsula. This type of atmospheric pattern characterizes very intense, but spatially localized episodes of drought at the Cantabric area and Southern France, while in the rest of the Iberian Peninsula the conditions were normal, because the same flow steers humid Atlantic air masses.

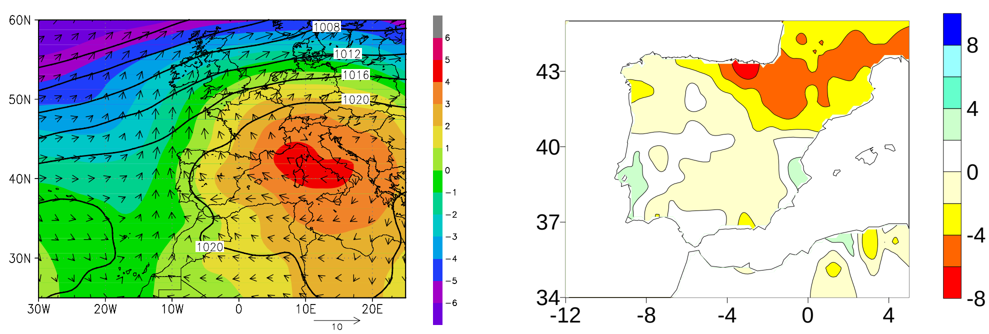

Figure 7— Sea level pressure and wind anomalies between November 1989 to March 1990 and spatial pattern of the PSDI over the Iberian Peninsula (March 1990)

Recent climatic trends and fire susceptibility

Once the short and long term atmospheric factors favourable to the occurrence of wildfires have been defined, the next step is to analyze how those factors have been progressing in last decades.

In order to analyze the temporal evolution of the short term forcing (mostly "suradas") we have compared the frequency of "suradas" with the frequency of days classified by fire risk index. This allows us to observe a divergent tendency (figure 8): the days characterized by medium, high and extreme risk are decreasing, while the lower risk days experience the opposite tendency, towards a higher occurrence.

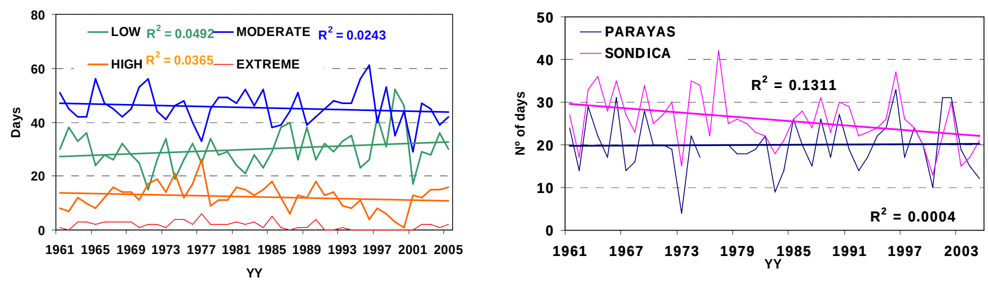

Figure 8—Temporal evolution of days characterized by status of fire risk (EFM, 12 UTC) and "Suradas" since 1961 in Northern Spain

Such temporal evolution of the days with the higher risk of fire seems to be in closed agreement with the decreasing trend in the occurrence of "Suradas" since 1961 during the trimester January to March.

However, the explanation of the increasing trend of low risk days should be to take in account other climatic processes. First of all, the risk of drought has increased in Cantabria, like the evolution of the PSDI index reveals (figure 9). While prior to 1979 there are discontinuous episodes of weak below normal conditions; after that date the index displays a larger inter annual variability with several episodes of drought, more intense and longer than previously.

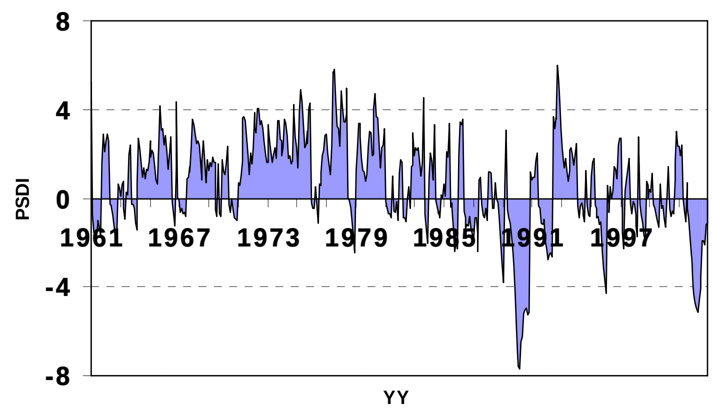

Figure 9—Evolution of the PDSI index between 1961-2005 in Cantabria.

The reason for such prevalence of more dry conditions can be related to the decrease of rainfall (do not shown) and the relative humidity, and the generalized increase of temperature along the year (figure 10).

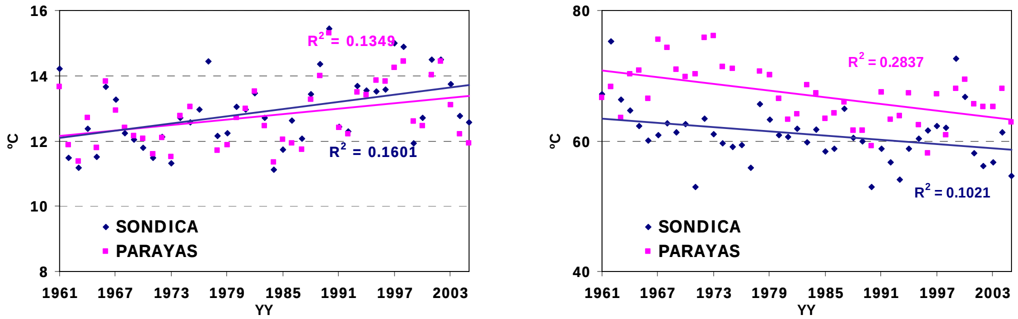

Figure 10—Trends of daily maximum temperature and relative humidity at 12 UTC since 1961 (JFM)

The local climatic evolution in Northern Spain is strongly linked to the atmospheric circulation anomalies at regional and hemispheric scale. Using a synoptic catalogue, we have obtained decreasing trends of the synoptic patterns responsible for the “Suradas” and most of the higher risk days, while there is a clear trend to the patterns favourable to stable conditions (“fair weather”), days characterized by a predominance of low risk conditions (figure 11).

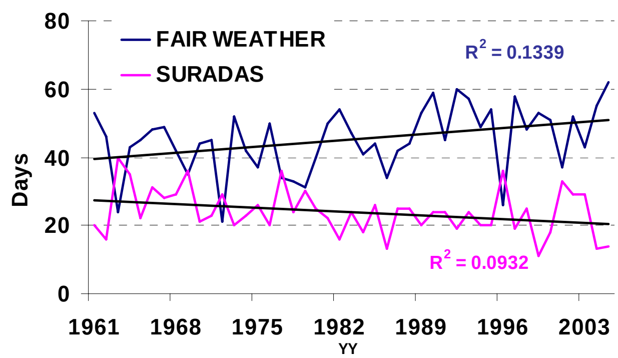

Figure 11—Frequency of different synoptic circulation patterns (1961-2005)

And, consequently, the regional atmospheric circulation over the Iberian Peninsula is strongly linked to one of the most relevant low frequency patterns of the Northern Hemisphere, the North Atlantic Oscillation. The replacement of the negative phase, active during the 60’s by a positive phase in the 80´s and 90s’ has increased not only the frequency of the fair weather situations, but also has warmed up the same situations, contributing to the increase of low risk days.

		FREQ	TEM	HR
FAIR WEATHER	PARAYAS	0.59	0.51	-0.23
	SONDICA		0.44	-0.29
			TEM	HR
SURADAS	PARAYAS	-0.56	0.11	-0.18
	SONDICA		0.21	-0.37

Table 1—*Correlation (Pearson´s r) between the NAO index and frequency and surface climatic parameters by weather type*

CONCLUSIONS

Although wildfires are a frequent event in Cantabria (Northern Spain), but their seasonality does not match the typical warm season maximum generalized in most of the Iberian Peninsula. They occur at the end of the winter and the beginning of the spring (January to March), because of a combination of specific meteorological conditions ("Suradas", a weather event which combines high winds and low humidity) and the agricultural practices (preparation of pastures for the cattle).

The analysis of meteorological data suggest a reduction of the number of "Suradas", and consequently, a reduction of the high fire risk events, because a reduction of the number of baroclinic disturbances crossing the Iberian Peninsula, due to the predominance since 1980 of a positive phase of the NAO pattern. But, conversely, the generalized warming and drying of the region, because of more anticyclonic conditions, has increase not only the events of low risk, but also has intensified the episodes of drought in the two last decades, thus creating a more favourable environment to wildfire spreading.

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