Forest Fire Risk in Spain under Future Climate Change

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Forest fires play a dominant role in Spanish landscapes. During the last three decades, there were over 14,000 fires per year, which swept through ca. 200,000 ha. These fires burned a total of nearly 6 Mha, of a forested area of ca. 25 Mha. Fires occurred virtually everywhere throughout the country, except in the valleys of the large rivers, where agriculture landscapes dominate (Moreno et al., 1998) (Figure **1**). Fire incidence, however, varied greatly between regions. Particularly "hot" areas were the North-west (the region of Galicia), and the mountains along the Mediterranean Sea, of the Central System, and of the southern ranges. Based on data from the last decade, most fires are caused by people (Vázquez & Moreno, 1998) (97%), lightning causing only 3%. Of the human-induced fires, the majority of them were lit intentionally (ca. 60%). Negligence and other accidental causes accounted for less than 20% of all fires, and the rest were caused by unknown sources.

Climate is a major determinant of the occurrence of forest fires and of fire regime across the globe. Climate determines the vegetation of any given place, its primary productivity and, in combination with physiographic features, the land-use of the area, which affects the type of human-influenced vegetation apt to burn. For a fire to ignite and spread, the appropriate conditions are critical. These include, high temperatures and low air relative humidity, dry soils and litter, and wind. In Spain, where most of the country has a Mediterranean-type climate, the summer months are particularly critical. This is reflected in the high values of some fire danger indices used by the forest services to alert people to the risk of fire. One index that reflects this risk well is the Canadian Fire Weather Index set of codes. Of these, the drought code (DC, a measure of the seasonal drought effect on fuels) and the FWI (a measure of the intensity of a spreading fire), are highest in summer time (Moreno, 2005) (left-hand side panels of Figure **2**). Accordingly, the majority of fires in the country occur between May and October, with July and August being the critical months. In some areas (North and North-west) fires in spring are also important, and are linked to vegetation burning for pastures. The course of ignitions during the day reflects the course of the daily weather and of the FWI. The peak of fire break-outs occurs at 4 p.m., declining thereafter. However, intentional fire break-outs do not decline markedly until past 10 p.m.

In countries where fires are not natural, man plays a critical role, overriding that of climate (Pausas & Vallejo, 1999) and determining where and when fires occur, since the majority of them are intentionally lit. Indeed, whether a fire will occur or not in an area with very hazardous vegetation or very dangerous weather conditions depends on the availability, intentionally or not, of a source of ignition. And, in areas with vegetation ordinarily not very prone to burn, man can select those few particular occasions when weather is favorable to start a fire. Not surprisingly, the relationship between the number of fires, or the surface burned, and the mean FWI or DC for the fire season (May to October)(both being measures of the susceptibility of an area to sustain fire, given the appropriate vegetation) represented by 50 x 50 km cells in which peninsular Spain can be divided, yields no significant relationships. That is, across the country, fire danger indices do not provide a good basis to infer fire occurrence. This is in accordance with the fact that the region of Spain with the greatest fire incidence is the North-west. This area is characterized by an Atlantic climate, with a cool and moist summer, and non-Mediterranean vegetation (Vázquez et al., 2002). Knowing this, inferring future fire activity in Spain solely from climate is not possible, unless people's behavior can be incorporated in fire-occurrence models. Nevertheless, within a given 50 x 50 km cell the relationship between monthly values of FWI or DC during the fire season (May to October) and fire occurrence through the years yields significant correlations for most cells (85 to 91% for DC and FWI, respectively, and for the number of fires or area burned), albeit in most cells the relationship is fairly weak (mean Spearman non-parametric correlation coefficient of about 0.35 for DC and 0.45 for FWI, for both number of fires or area burned). That is, fire occurrence is partially explained by whether a year is drier (DC) or more dangerous (FWI), even though the potential of any of these indices to explain the total fire activity is low, given the uncertainty linked to the number of ignitions caused by people.

Therefore, for a given area, the larger the FWI or the DC was in previous decades, the more important it was in determining the number of fires that occurred each year, or the total surface burned. One additional point signaling at the role of climate across Spain and its interaction with forest fires was that the relationship between the Gini coefficient of fires, a measure of the inequality in fire sizes, and the FWI for each of the 50 x 50 km cells used was positive. That is, the larger the mean FWI the greater the coefficient, thus the more unequal the size of fires. Most cells (88%) showed high Gini coefficient (>0.5), meaning high inequality in fire sizes, whereas few (12%) cells presented values under 0.5, which means more equality in the distribution of fire sizes. Greater inequality in the size of fires means that more large fires occur. These fires are the ones with greater catastrophic potential and cover most of the area burned per year. Therefore, increases in FWI can severely impact Spanish landscapes by changing the proportion of large fires.

The climate of Spain by the end of this century will be characterized by much higher temperatures during the summer and reduced precipitation, according to the several regional climate models. These models reproduce the general conditions of present climate in the country reasonably well. The projected changes in climate towards the end of this century (2071-2100) will produce increases in

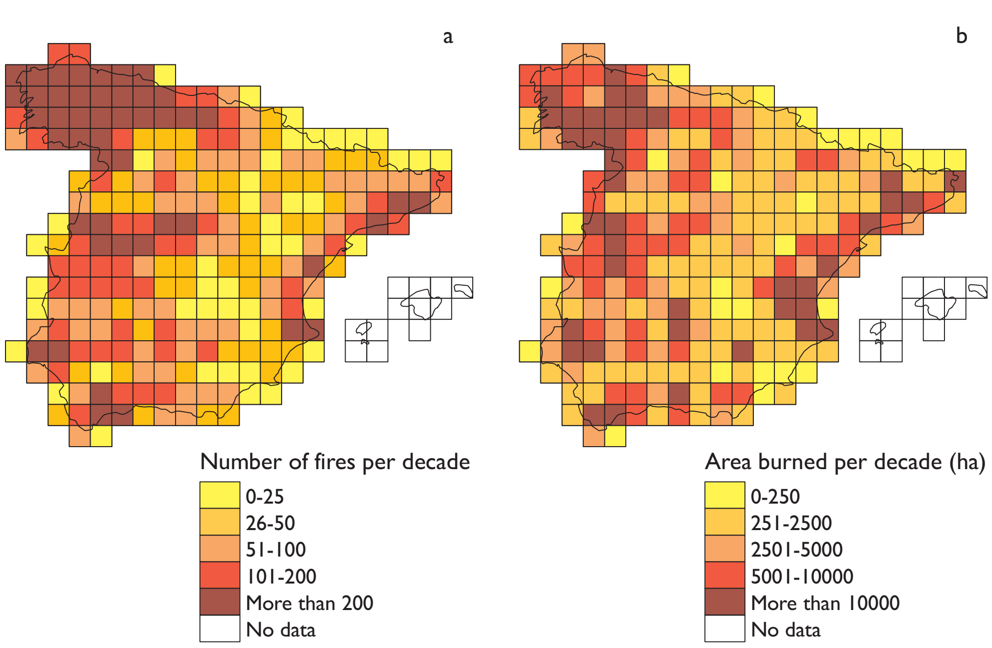

Figure 1. Number of fires/decade (a); and area burned/decade (b) in Spain during the years 1975-2000. Cell size is 50 x 50 km. Source: EGIF Forest Fires Database, Ministry of Environment, Government of Spain.

Details of a large forest fire (12.000 ha), started in Riba de Saelices (prov. of Guadalajara, Spain), on July 16th, 2005, as a result of negligence. When the fire broke out, at 2 p.m. the FWI had a value of 66.6, which exceeded the 95-percentile of the historic series. The fire raced through some rugged terrain, burning a mixture of old and young pine woodlands and shrublands, and caused 11 deaths among fire-fighters. Photos: José Moreno.

the fire danger indices, either of the DC (greater drought on average) or of the FWI (greater fire intensity). This will be the case for lower emission scenarios (B2) or for larger emission scenarios (A2), the differences not being very great (centre and right-hand side panels of Figure **2**). Not only will fire danger indices increase but the length of the fire season will also increase, as shown for the period of alert or the period of risk (Figure **3**). This means that the fire fighting services will have to be in place earlier in the year and until later, and be prepared for a greater number of days of high risk within the fire season.

In summary, anticipating how many fires will occur in Spain as a result of climate change, or the surface they will burn, is difficult given the importance of human activity in providing ignition sources. However, the prospect for increased fire occurrence and fire impacts is quite considerable. A longer and more dangerous season implies that the potential for fires caused by accidents will increase, provided that the same number of ignitions occurs. Therefore, unless efforts are made to effectively deter these sources their capacity to increase fire risk is very likely. Since the potential to have larger fires is related to fire danger indices, the greater they are the more likely to have a large fire, this implies that large fires, which are more catastrophic, will tend to increase. Finally, the extension of a longer and more dangerous fire season into new areas implies that, unless the patterns of ignition are changed, the potential for having catastrophic fires in these areas is possible, thence extending this potential through new areas of the country.

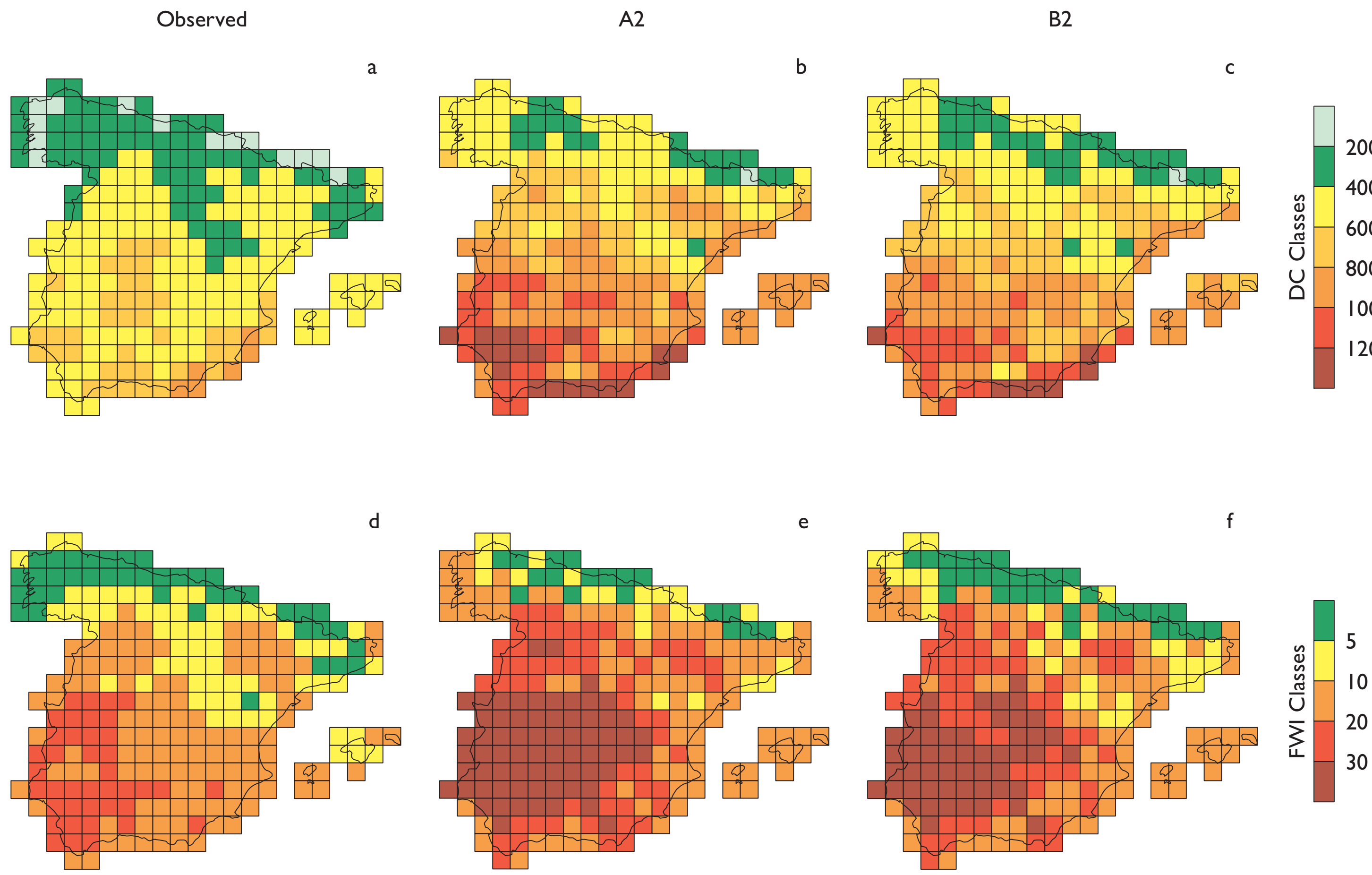

Figure 2. Observed (a, d) and modeled (b, e, c, f) values for the Drought Code (DC)(a, b, c)(a measure of the seasonal drought effect on fuels) and Fire Weather Index (FWI)(d, e, f)(a measure of the intensity of a spreading fire) during a 30 year period for a fixed fire season (May to October) in Spain. Observed values are based on daily data of the MARSSTAT database from the Joint Research Centre of the EC at Ispra (IT), and the period 1975-2004. Modeled data are the median of the A2 and B2 SRES scenarios of 5 Regional Climate Models with daily data for the period 2071-2100, made available by the Spanish Institute of Meteorology (Madrid, Spain). Cell size is 50x50 km.

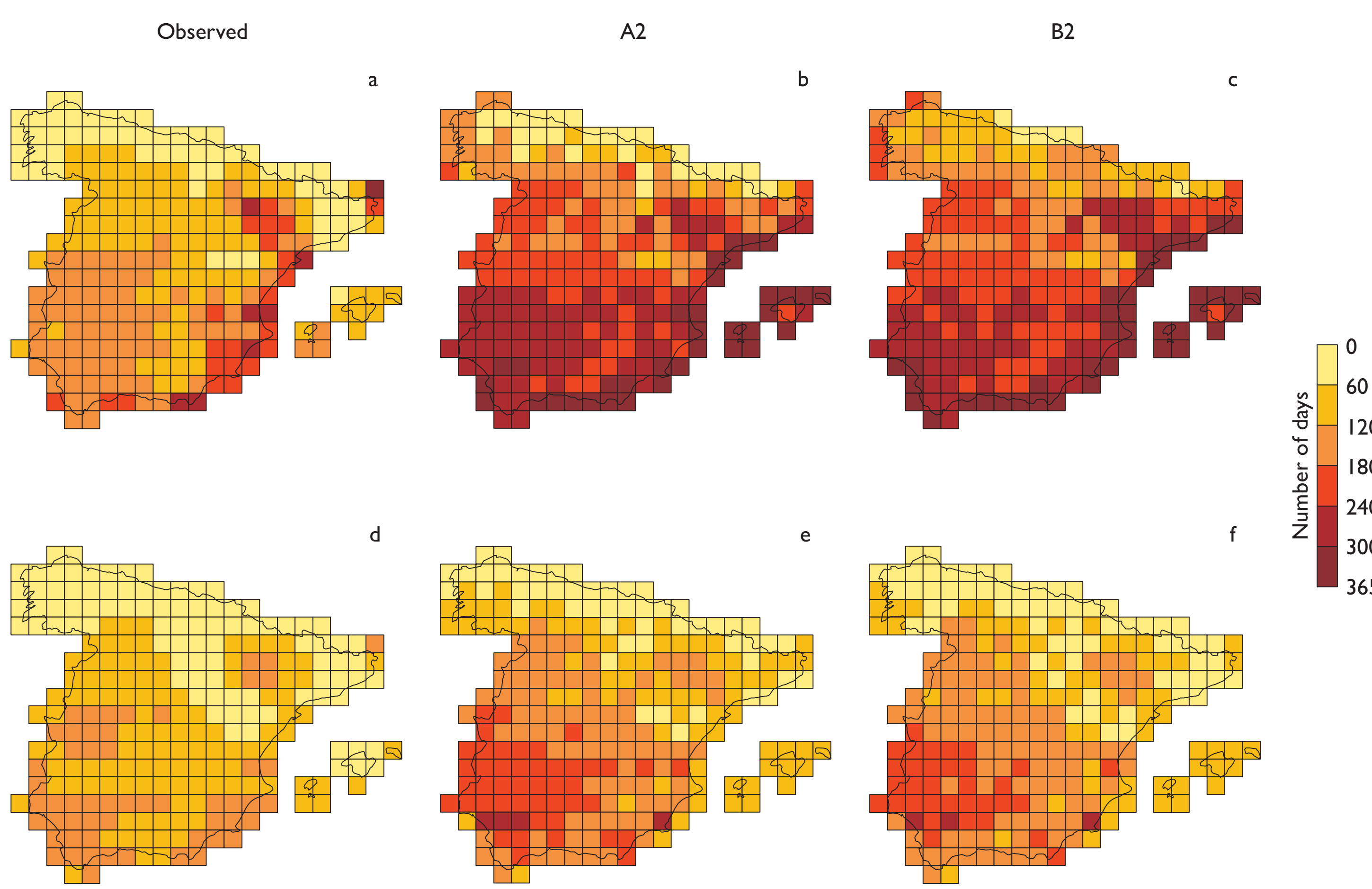

Figure 3. Observed (a, d) and modeled (b, c, e, f) values for the Period of Alert (a, b, c)(number of days between the first and last day during the year that FWI≥15 continuously for a week) and Period of Risk (d, e, f)(number of effective days during the PA in which FWI≥15) during a 30 year period in Spain. Observed values are based on daily data of the MARSSTAT database from the Joint Research Centre of the EC at Ispra (IT), and the period 1975-2004. Modeled data are the median of the A2 and B2 SRES scenarios of 5 Regional Climate Models with daily data for the period 2071-2100, made available by the Spanish Institute of Meteorology (Madrid, Spain). Cell size is 50x50 km.

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