Fire activity and burned forest lands decreased during the last three decades in Spain

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RESEARCH PAPER

Fire activity and burned forest lands decreased during the last three decades in Spain

Itziar R. Urbieta[1] · Magí Franquesa[1,2] · Olga Viedma[1] · José M. Moreno[1]

Abstract

• *Key message* Fire activity has decreased in the last decades in Spain as a whole and in most provinces. However, fire risk factors have increased. Wildfires are burning preferentially treeless areas. Flammable pine areas burn less, while the less flammable oak forests burn more. This decreasing fire activity coincides with increasing fire suppression resources.

• *Context* Climate and other fire risk factors are changing across the world, including the Mediterranean region. It is important to determine how fire activity is responding to such changes.

• *Aims* To identify spatio-temporal changes in fire frequency and size, main tree species burned, and their association with changes in climate, land-use and land-cover, and fire suppression.

• *Methods* Analysis of trends, breakpoints, and association among the time series of fire variables and fire risk factors during 1980–2013 in Spain at country and provincial levels.

• *Results* Wildfires in Spain have been decreasing in number, burned area, mean, and largest fire sizes. Fires are more frequently burning treeless areas than forests. Pine forests are burning less, while oak forests are burning more. Fire suppression resources, particularly aerial ones, increased significantly. Risk factors like the mean summer fire weather index, and the forested and the artificial areas all increased.

• *Conclusion* Despite increasing fire risk factors, wildfires have decreased at the country as a whole and in most provinces in Spain during the last 34 years.

Keywords Climate change · Fire risk · Fire suppression · Fire weather · Land-use and land-cover change

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1 Introduction

Climate and weather exert major controls on wildfire occurrence, but human factors have influenced fire regimes in different ecosystems across the world (Pausas and Keeley 2009; Bowman et al. 2017). Seasonal fire patterns have been altered due to human pressure (e.g., Benali et al. 2017), often overriding the effect of weather/climate (e.g., Syphard et al. 2017), by modifying ignitions (e.g., Parisien et al. 2016), fuel types and structure (e.g., Andela et al. 2017), and through fire suppression (e.g., Brotons et al. 2013).

In southern Mediterranean European Union countries (EUMed), the economy of the region has been remarkably transformed in the last half century, with the consequent changes in rural population, land management, and other socioeconomic factors, which have affected fire patterns (e.g., Moreno et al. 1998; Pausas and Fernández-Muñoz 2012). The former land-use mosaic and low fuel load were first disrupted by forest expansion and agriculture decline due to rural abandonment (e.g., Moreira et al. 2001; Viedma et al. 2015). Afforestation programs contributed to increase fuel connectivity and accumulation (e.g., Fernandes et al. 2010; Iriarte-Goñi and Ayuda 2018), shifting the fire regime towards higher burned area, particularly during the 1970s–1980s (e.g., Moreno et al. 2014; Fernandes et al. 2014). Nonetheless, in the last decades, urban development and greater investment in fire suppression have modified spatial and temporal fire incidence (Turco et al. 2014; Fréjaville and Curt 2017).

Recent studies at coarse scales showed that fires have been overall decreasing at EUMed (e.g., Urbieta et al. 2015; Turco et al. 2016), consistent with decreasing patterns found globally (e.g., Andela et al. 2017; Earl and Simmonds 2018). These reduced fire activity has been reported in spite of increasing drought (Gudmundsson et al. 2014; Turco et al. 2017), and more severe fire weather (Venäläinen et al. 2014; Jolly et al. 2015). However, we argue that large-scale fire statistics (i.e., global level, country level) might be misleading; fire incidence might be globally decreasing but in some areas, it might be doing the opposite. For example, increased fire activity has been reported for some areas within EUMed, when the scale of analysis varied from countries to regions and provinces (e.g., Rodrigues et al. 2013; Urbieta et al. 2015), municipalities (e.g., Nunes et al. 2016), or grid-cell level (e.g., Silva et al. 2019), particularly for the number of fires, and mostly due to the contribution of small fires (e.g., Rodrigues et al. 2013; Viedma et al. 2018). Fire activity may be declining but not for all fire sizes. Although the number of large fires in the Mediterranean region has exhibited a decline in the last decades (San-Miguel-Ayanz et al. 2013), there are years with large and catastrophic fires, the last being in Portugal in 2017 (Gómez-González et al. 2018). This implies that maximum fire size can still be large under extreme weather conditions, despite the efforts made in suppression, which may have

contributed to the decline of total burned areas (Ruffault and Mouillot 2015).

The spatial distribution of woodland types and structures can determine fire probability (Vázquez et al. 2015; Nunes et al. 2019). However, most studies on fire trends have disregarded what fires burned. Ignitions are not evenly distributed in the landscape (Ganteaume et al. 2013); thus, the spatial variability of fires, and the corresponding vegetation they burn, may change due to alterations in ignition patterns. It is unclear how changes in fire trends are affecting the various dominant forest types in the region. Improved understanding of how fire incidence is spatially changing and whether fires are differentially affecting forest lands is required to address future management needs in a context of more severe fire weather (Bedia et al. 2014; Turco et al. 2018).

Here we analyzed the trends in fire activity, fire risk factors, and firefighting resources at two spatial scales (country and provincial level), during 1980–2013 in Spain. Specifically, we investigated spatio-temporal changes in trends and breakpoints for the time series of the number of fires, burned area, and fire size, as well as the type of burned area (treed and treeless) and main tree species. Furthermore, we explored the relationships of observed fire trends with fire risk factors (fire weather, land-use and land-cover [LULC] changes), and fire suppression resources.

2 Materials and methods

2.1 Data

We used the Spanish National Forest Fire Statistics (EGIF) of the Spanish Ministry of Agriculture, Fisheries and Food, which contains records of all fires at a 10×10 km resolution in a UTM grid. Each record contains information about the fire itself (e.g., fire type, size [total burned area (ha)], type of forest burned area (ha) [i.e., treed or treeless], and the burned area (ha) of the main forest tree species). Additionally, the resources used to contain each fire are recorded, including the type and number of terrestrial and aerial means.

We selected all fires >1 ha occurred in Peninsular Spain and the Balearic Islands from 1980 to 2013 (194657 fires). Earlier data (since 1968) were discarded to ensure maximum homogeneity of the fire database across all administrative units. Missing fire records were detected in many provinces before 1980, and firefighting resources were not reported. Three provinces in the north (Álava, Vizcaya, and Navarra) were not included due to the lack of data for the complete period. We grouped fire records at two spatial scales: whole country and 45 provinces. Then, we calculated annually the total number of fires (> 1 ha), the total burned area (ha) by all fires

(>1 ha), and the median (percentile 50th, P_{50}) and largest (percentile 95th, P_{95}) fire size (ha). For the forest burned area, we aggregated the hectares burned for treed (i.e., tree-covered) and treeless areas (i.e., covered by shrubs or herbs), expressed in hectares and in percentage per year. Moreover, we calculated burned area per year (ha) for each tree species (52 species). Nonetheless, we focused on the most abundant tree species of the genera *Pinus* (*P. halepensis* Mill., *P. pinaster* Aiton, *P. pinea* L., *P. radiata* D.Don, *P. nigra* Aiton, *P. sylvestris* L.) and *Quercus* (*Q. ilex* L., *Q. suber* L., *Q. faginea* Lam., *Q. pyrenaica* Will., *Q. robur* L., *Q. petraea* [Matt.] Liebl.).

Additionally, we calculated changes in fire risk factors at the whole country and for each province, including Fire Weather Index (FWI) of the Canadian system (van Wagner 1987), and main LULC changes. For FWI, we calculated annually the mean FWI of the extended summer months (June-to-September, JJAS), and the 95th percentile (P_{95} FWI), based on daily meteorological data provided by the reanalysis of WFDEI (WATCH-Forcing-Data-ERA-Interim) (Weedon et al. 2014). For LULC changes, we used the European CORINE Land Cover maps of 1987 (CLC90), 2000 (CLC00), and 2012 (CLC12), which included a hierarchical nomenclature in three levels (Heymann et al. 1994). For the first level, we calculated the percentage of change in the area of the main classes of forest, and agricultural and artificial LULC types. For the second and third levels, we focused on changes in forest area between maps including forests, i.e., treed (conifer, broad-leaved, and mixed), and treeless (shrubs and herbs) LULC types. Finally, regarding fire suppression resources, we used the number of terrestrial and aerial means used per fires ≥ 50 ha, and expressed them relative to 100 ha

burned. Then we aggregated data to calculate annually the mean number of resources invested per 100 ha burned.

2.2 Statistical analysis

We applied the modified Mann-Kendall trend test ($p < 0.05$) to analyze temporal changes in fire metrics and fire risk factors, using the R package "fume" (Bedia et al. 2012). This test is more restrictive than the Mann-Kendall test, accounting for the effective sample size and temporal autocorrelation in data (Hamed and Rao 1998). We analyzed the main breakpoints in the time series using the non-parametric Pettitt test (Pettitt 1979) using the R package "trend" (Pohlert 2016).

Finally, we evaluated if, at the provincial level, fire variables among them and in relation to fire risk factors and firefighting resources showed the same trends (negative, positive, or no trend). We used Fisher's exact test to test the association between categorical variables with small sample size. We confronted the type of trends obtained for each variable two by two, to examine the significance of their association (contingency).

3 Results

3.1 Trends in fire activity

In the 34-year period of study, fires affected a large portion of Spain, being more abundant in the northwest, Atlantic north coast, the central mountains, western areas near Portugal, and Mediterranean coast (Fig. 1). At the country level (i.e., aggregating all fires), no trend was found for the number of fires, whereas total burned area significantly decreased
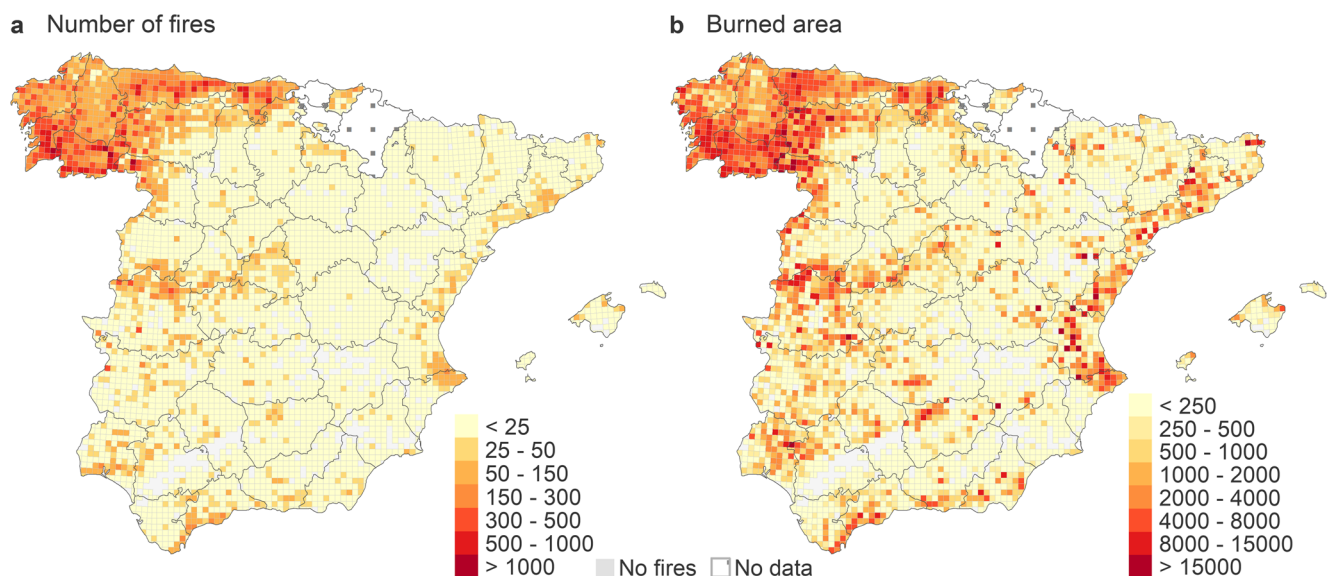

a Number of fires

b Burned area

Legend (a): < 25 | 25 - 50 | 50 - 150 | 150 - 300 | 300 - 500 | 500 - 1000 | > 1000 | No fires | No data

Legend (b): < 250 | 250 - 500 | 500 - 1000 | 1000 - 2000 | 2000 - 4000 | 4000 - 8000 | 8000 - 15000 | > 15000

Fig. 1 **a** Total number of fires and **b** total burned area (ha) per 10 × 10 km grid cell accumulated for 1980–2013 in Peninsular Spain and the Balearic Islands. For trend analysis, data were aggregated at the provincial (gray polygons) and country level
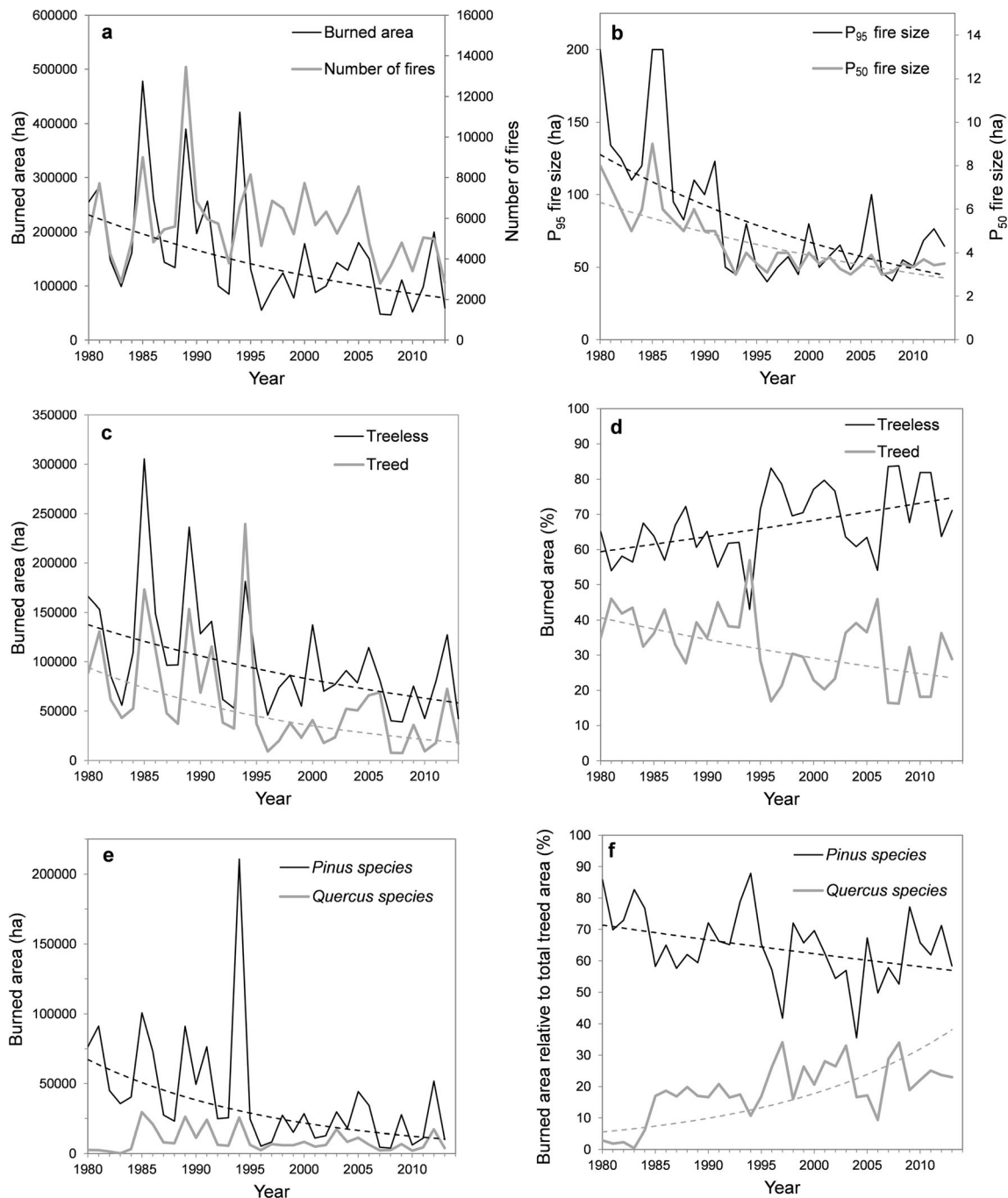
Fig. 2 Fire data annual series for Peninsular Spain and the Balearic Islands (1980–2013). **a** Number of fires and total burned area (ha). **b** P_{50} and P_{95} of fire size (ha). **c** Treed and treeless burned area (ha). **d** Treed and treeless burned area (%). **e** Burned area (ha) of *Pinus* species and *Quercus* species. **f** *Pinus* and *Quercus* burned area (%) relative to total treed burned area. A loess smoothing line is shown for significant trends ($p < 0.05$)

(tau = − 0.35), with a breakpoint in 1994 (Fig. 2a). Significant decreasing trends were detected for both P_{50} (tau = − 0.58) and P_{95} (tau = − 0.41) of fire size, with breakpoints in 1991 and 1992, respectively (Fig. 2b). The type of burned area also decreased for both treed and treeless areas (tau = − 0.35),

particularly after 1991 (Fig. 2c). However, the percentage of what was burned by fires increased for treeless areas (tau = 0.32) and decreased (tau = − 0.32) for treed ones since 1994 (Fig. 2d). Total burned area (ha) of all *Pinus* species decreased (tau = − 0.39), with no trend for *Quercus* species
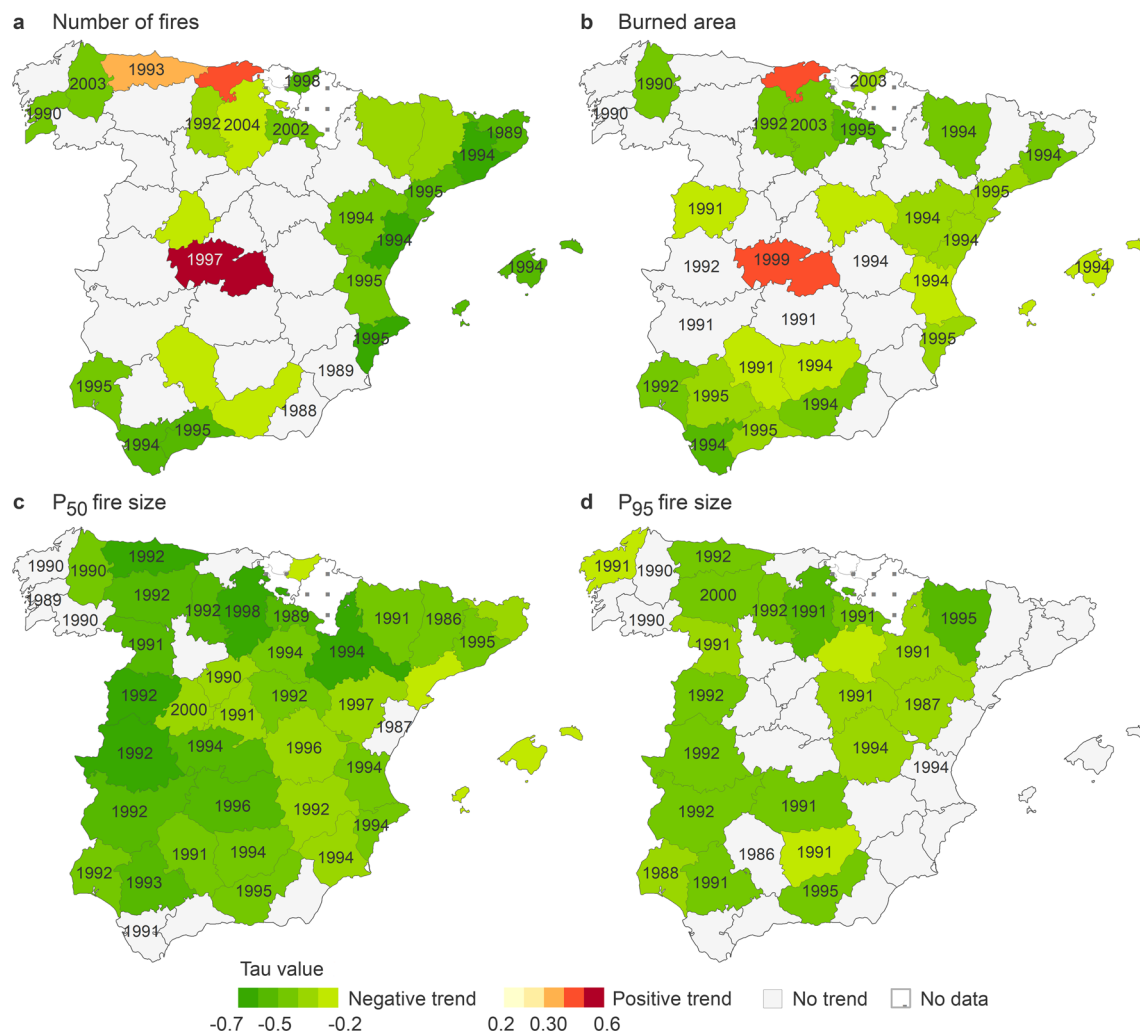
Fig. 3 Fire data trends at provincial level (1980–2013). **a** Number of fires. **b** Total burned area (ha). **c** P_{50} of fire size (ha). **d** P_{95} of fire size (ha). Legend represents modified Mann-Kendall's Tau coefficient with negative trends in green, positive trends in red, and gray no significant trends in the data series ($p < 0.05$). Numbers within each province indicate the breakpoint year in the data series for the corresponding variable

Fig. 4 Trends at provincial level (1980–2013). Burned area (ha) of **a** treed and **b** treeless areas; **c** Ratio of treeless burned area relative to the treed burned area. Legend represents modified Mann-Kendall's Tau coefficient with negative trends in green, positive trends in red, and gray no significant trends in the data series ($p < 0.05$). Numbers within each province indicate the breakpoint year in the data series for the corresponding variable
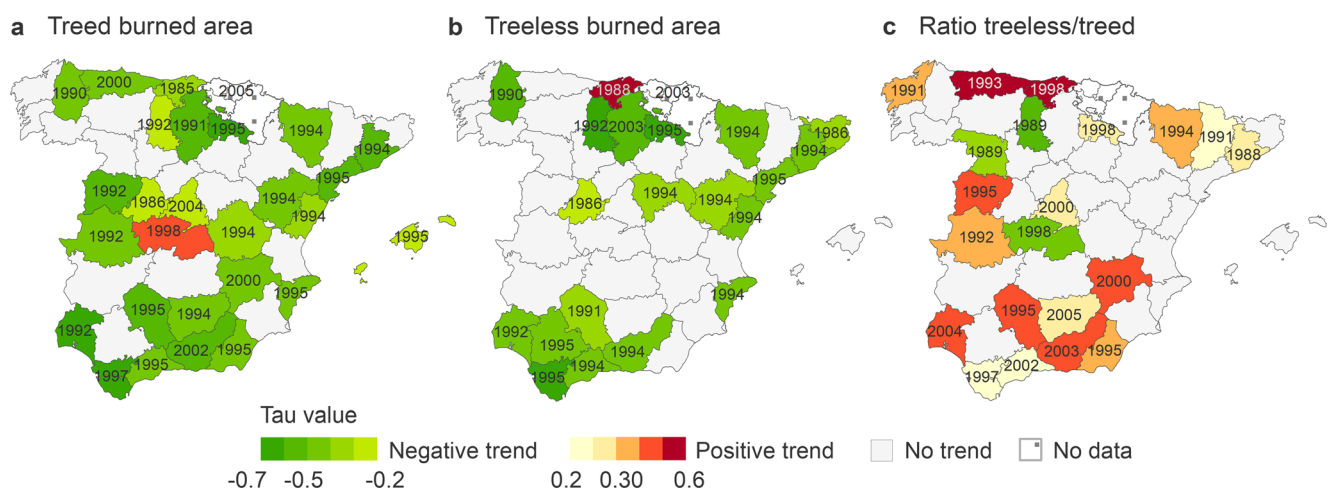
Table 1 Trend analysis results for the burned area of all tree species by province (1980–2013). First column denotes the number of provinces where each species was present according to the EGIF database. Second and third columns denote the number of provinces with significant ($p < 0.05$) positive and negative trends for the burned area of each species, respectively

Species	Provinces	+ Trend	− Trend
Abies alba Mill.	10		
Abies pinsapo Boiss.	3		
Acer sp.	8		
Alnus glutinosa (L.) Gaertn.	26	1	
Betula sp.	18	4	
Castanea sativa Mill.	24		3
Chamaecyparis lawsoniana (A.Murray bis) Parl.	1		
Corylus avellana L.	6	2	
Cupressus sp.	31		
Erica arborea canaria	1		
Eucalyptus camaldulensis Dehnh.	20		2
Eucalyptus dalrympleana Maiden	2		
Eucalyptus globulus Labill.	22	2	1
Eucalyptus nittens Maiden	6		
Other *Eucalyptus*	22	1	
Fagus sylvatica L.	19	1	2
Fraxinus sp.	34	3	
Ilex aquifolium L.	4	2	
Juglans regia L.	23		
Juniperus oxycedrus L.	25		
Larix sp.	4		
Olea europaea L.	25	1	1
Phoenix dactyliphera L.	2		
Picea excelsa Link	3		
Pinus canariensis C.Sm. ex DC.	12		
Pinus halepensis Mill.	41	1	9
Pinus nigra Aiton	41	1	7
Pinus pinaster Aiton	45		20
Pinus pinea L.	42	4	8
Pinus radiata D.Don	26	1	6
Pinus sylvestris L.	36		15
Pinus uncinata Ramond ex DC.	15		
Populus alba L.	41	7	
Populus nigra L.	39	5	
Populus tremula L.	25		
Populus canadensis Moench	24	7	
Other *Populus*	36		
Pseudotsuga menziesii (Mirb.) Franco	13	1	
Quercus faginea Lam.	34	1	
Quercus ilex L.	44	10	1
Quercus petraea [Matt.] Liebl.	22		2
Quercus pyrenaica Will.	34	5	2
Quercus robur L.	28	2	
Quercus rubra L.	9	1	
Quercus suber L.	30		
Other *Quercus*	38	1	
Salix sp.	34	6	
Sorbus sp.	8		
Tilia sp.	2		
Ulmus sp.	28	2	
Other conifer species	30		
Other broad-leaved species	39	2	

(Fig. 2e). Moreover, the percentage of burned area for *Pinus* decreased (tau = − 0.25), while that of *Quercus* increased (tau = 0.43) (Fig. 2f).

At the provincial level, either the number of fires or burned area showed no trend in almost half of the Spanish provinces (Fig. 3a, b). However, some negative trends were detected, particularly in areas with historically high fire occurrence:

some provinces in the northwest (Galicia), Mediterranean (Cataluña, Valencia), and south (Andalucía). Conversely, three provinces showed positive trends: two at the north coast (Asturias, Cantabria), and one at the center (Toledo). Eighty percent of the provinces showed negative trends for P_{50} of fire size (Fig. 3c). However, for large fire sizes (P_{95}), 47% of the provinces showed negative trends and the rest of the

provinces, particularly those with historically high fire occurrence, had no trend (Fig. 3d). Most of the breakpoints found in the fire variables corresponded to the 1990–1995 period.

Regarding the type of burned area, about half of the provinces showed negative trends for treed burned area (ha) (57% of the provinces), and treeless burned area (ha) (44% of the provinces) (Fig. 4a, b), with no significant trends in the rest. However, the proportion (%) of treeless burned area relative to treed burned area showed positive trends in 40% of the provinces (Fig. 4c). We did not find significant trends for most of the more flammable species (e.g., *Eucalyptus* sp.), except for *Pinus* (see Table 1 for the analysis of all tree species). *Pinus* species showed negative trends in many of the provinces in which species were present: *P. sylvestris* (in 42% of provinces), *P. pinaster* (44%), *P. radiata* (23%), *P. halepensis* (22%), *P. pinea* (19%), and *P. nigra* (17%) (Fig. 5a). Only *P. pinea* showed also an increase in the burned area in 10% of the provinces. Conversely, most *Quercus* species showed no trend in burned areas. Nonetheless, two oaks showed positive trends, i.e., have been increasingly more affected by fires: *Q. ilex* (23% of provinces) and *Q. pyrenaica* (15%), in the north and northwest of the country (Fig. 5b).

3.2 Trends in fire risk factors and fire suppression resources

At the country level, summer FWI values (mean and P_{95}) showed a significant increase (tau = 0.34), with a breakpoint in 1997 (Fig. 6a). Regarding LULC changes, agricultural areas have decreased, while forest and artificial areas have increased, particularly from 2000 to 2012 (Fig. 6b). In relation to fire suppression resources, both the number of terrestrial (tau = 0.22) and, particularly, aerial (tau = 0.80) resources have increased (Fig. 6c).

At the provincial level, mean summer FWI has increased in 58% of the provinces (Fig. 7a), particularly in the center, east, and south, showing a very similar pattern for extreme P_{95} FWI (Fig. 7b). Most of the breakpoints found in the FWI corresponded to the 1992–1998 period. According to CLC level 1, forest and semi natural areas increased in 75% of the provinces (Fig. 7c), while agricultural areas decreased in most provinces (82%) (Fig. 7d), except in the southwestern provinces, which showed the opposite trend (i.e., increment of agricultural areas at the expense of forests). An increment of artificial areas
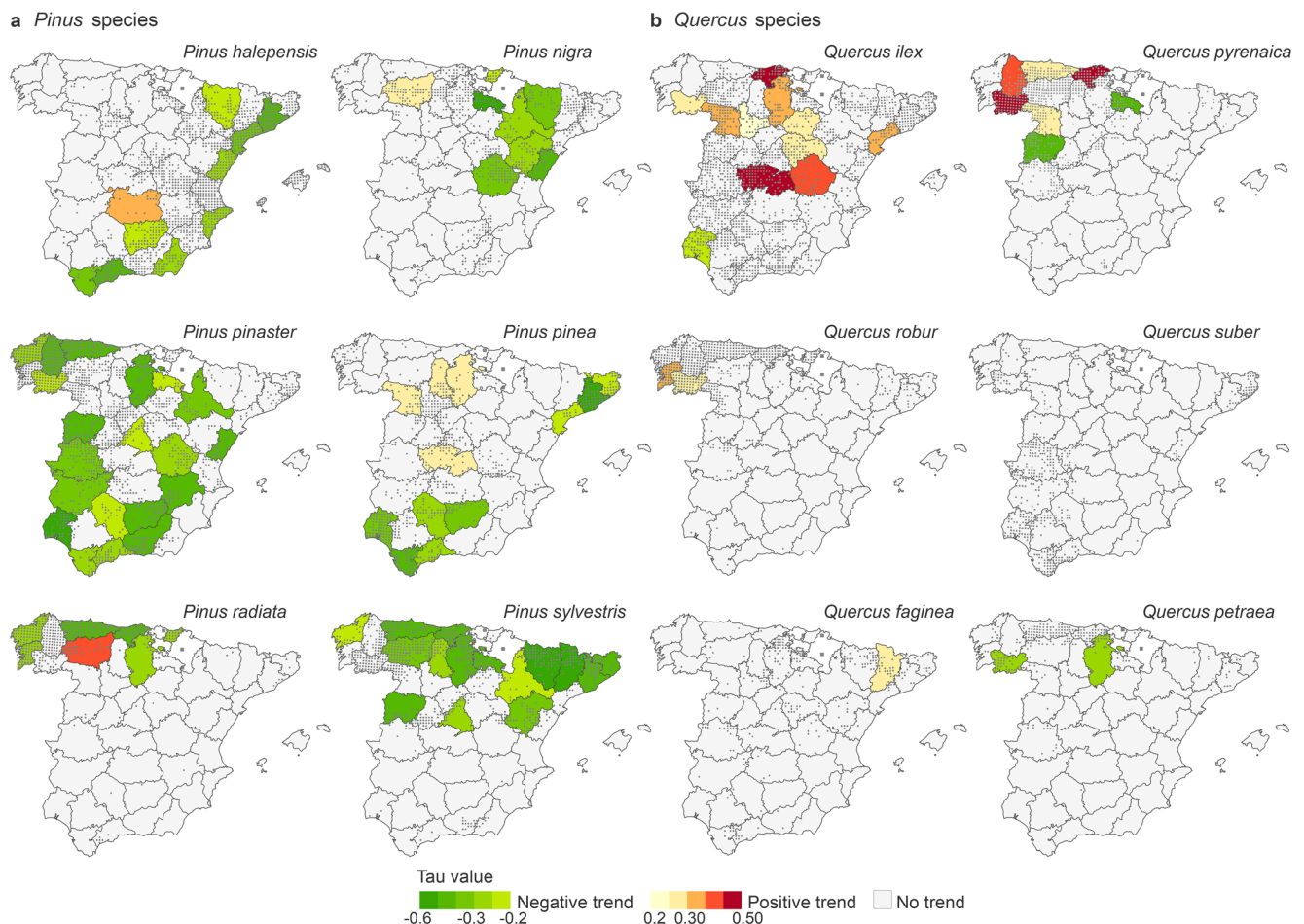
Fig. 5 Trends of burned area (1980–2013) by province for **a** *Pinus* species (left maps), and **b** *Quercus* species (right maps). Legend represents modified Mann-Kendall's Tau coefficient. Dots indicate the presence of each species according to EGIF fire database

Fig. 6 Trends of fire risk factors for Peninsular Spain and the Balearic Islands (1980–2013). **a** Summer (JJAS) mean FWI and P_{95} FWI. **b** LULC changes (%) based on CORINE Land Cover (CLC) maps for forest and semi natural, agricultural, and artificial areas. **c** Average number of terrestrial and aerial fire suppression resources invested per 100 ha burned for fires $\geq$ 50 ha. A loess smoothing line is shown for significant trends ($p < 0.05$)
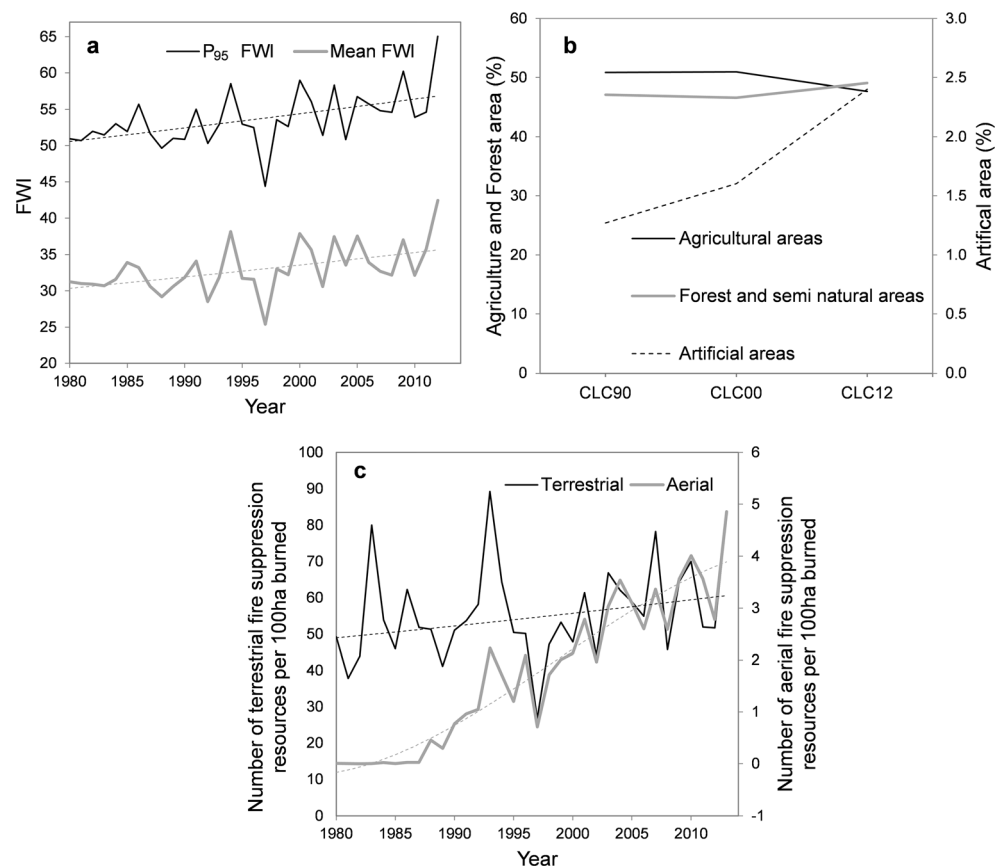
occurred in all provinces (Fig. 7e). CLC level 2 showed that, within forests and semi natural areas, treed areas increased in most provinces (84%), while the overall extension of shrubs and herbaceous vegetation decreased (67% of the provinces) (Fig. 8, maps not shown). At CLC level 3, broad-leaved forests increased more (in 84% of provinces) than coniferous and mixed forests (c.a. 50%) (Fig. 8). Finally, regarding fire suppression resources, aerial means clearly increased in all provinces (Fig. 7f), while terrestrial resources increased in 40% of them (map not shown).

3.3 Association between trends in fire activity, fire risk factors, and fire suppression

At the provincial level, we observed that most fire variables showed negative trends (i.e., reduced fire activity) or no trend, while fire risk factors showed positive trends, except for agricultural areas that mostly decreased (Fig. 8). Based on the Fisher's exact test, we found the following significant ($p < 0.05$) associations in trends between variables (Fig. 8): (i) the number of fires increased, decreased, or did not change in the same provinces than total burned area and treed burned area (see Figs. 3a, b and 4a); ii) total burned area followed a

similar pattern to the trends of treed and treeless burned areas (see Figs. 3b and 4a, b); (iii) treed burned area showed a negative association with the ratio of treeless/treed burned area: provinces that decreased their treed burned area increased the proportion of treeless burned area (see Fig. 4a, c); (iv) the ratio treeless/treed burned area showed a negative association with forest change (CLC level 1) (see Figs. 4c and 7c); (v) mean FWI and P_{95} FWI showed a positive association (see Fig. 7a, b); and (vi) forest and agricultural changes showed a negative association in their trends: provinces that increased their forest area decreased their agricultural one, and vice versa (see Fig. 7c, d).

4 Discussion

During the last decades, fire activity in Spain has declined at the country and provincial level, despite the increase in fire risk factors. Average and extreme summer FWI conditions have increased during this period, reflecting observed regional climate change (EEA 2017). Additionally, forest and semi natural areas, together with artificial uses, have expanded at the expense of agricultural lands. However, no clear relationships were found between fire risk factors and actual fire
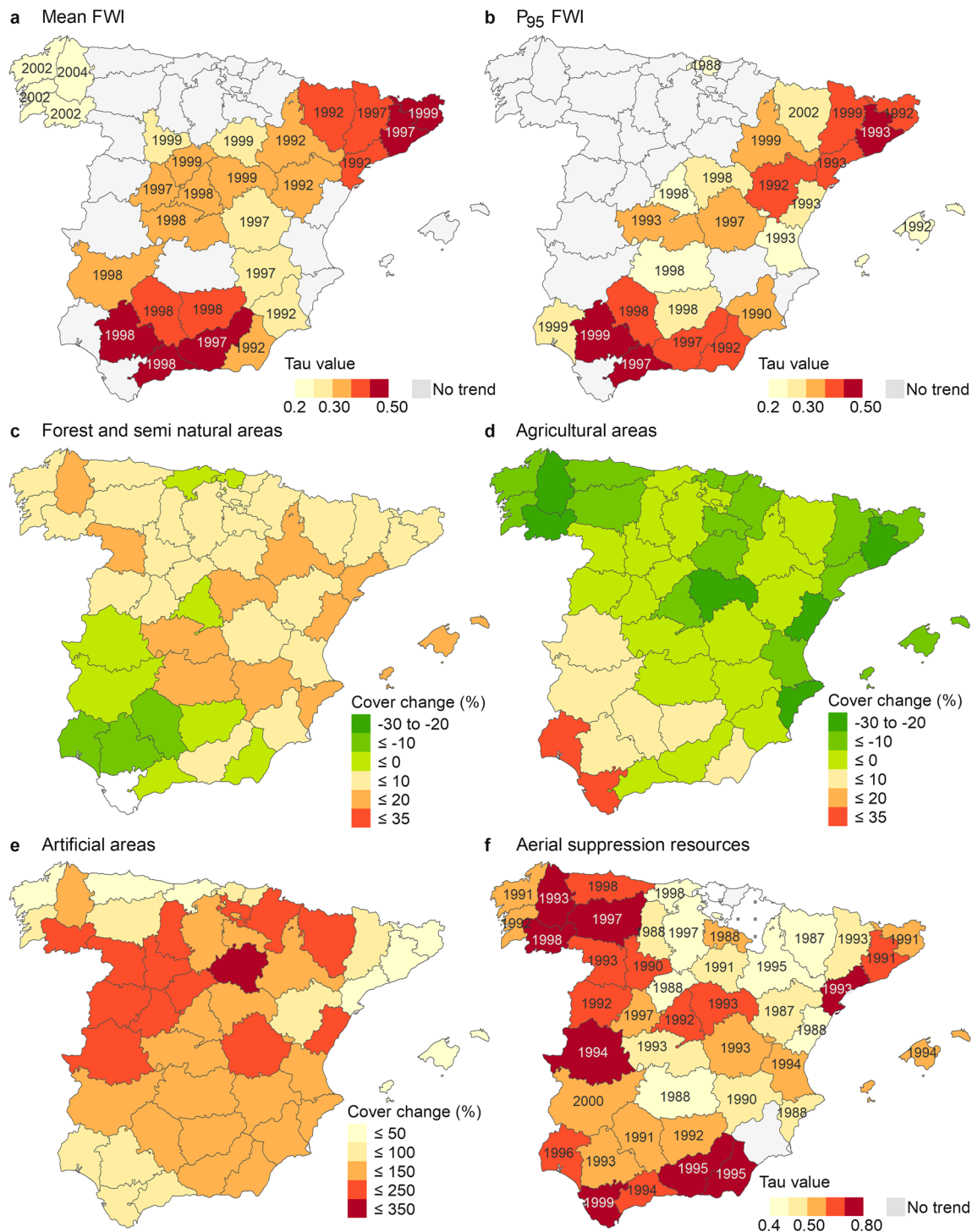
Fig. 7 Trends of fire risk factors by province (1980–2013). **a** Summer (JJAS) mean FWI. **b** P$_{95}$ FWI; LULC changes (%) from CORINE Land Cover (CLC) maps of 1990–2012 for **c** forest and semi natural, **d** agricultural, and **e** artificial areas. **f** Average number of aerial suppression resources used per 100 ha burned. Numbers within each province indicate the breakpoint year in the data series for the corresponding variable

trends, indicating that trends in fire activity were decoupled from trends in climate and LULC.

Decreasing trends in the number of fires and burned area were significant in provinces with historically high fire occurrence (except for the northwest [Galicia]) (see Chas-Amil

et al. 2015), suggesting that fire suppression efforts might have been more effective in these areas, particularly after the 1990–1995 peak fires (e.g., Moreno et al. 2014). Three provinces showed positive trends in the number of fires or burned area, and two of them (in the north coast) were the ones with
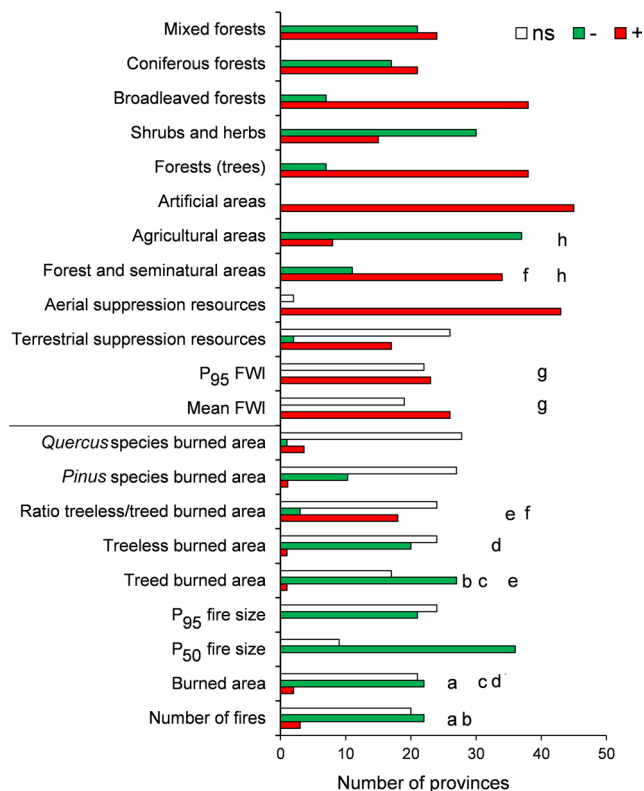
Fig. 8 Number of provinces showing the different types of trends (positive (red), negative (green), or non-significant (blank)) for each fire variable, fire risk factor, and fire suppression resources. The upper eight variables correspond to CORINE data and they represent change in time (negative or positive) but not trends. Variables sharing the same letter indicate that they were significantly associated according to a contingency Fisher's exact test

the lowest figures in suppression resources per fire (Costafreda-Aumedes et al. 2016). Not only fire activity decreased, but also fire size patterns changed. The median (P$_{50}$) and extreme (P$_{95}$) fire size tended to show a negative trend, i.e., towards smaller size. The major transition points were located in the first half of 1990s, when the greatest large fire episode occurred in Spain (Moreno et al. 1998). Nonetheless, provinces with historically high fire occurrence showed no significant trends in P$_{95}$ fire size, indicating that inter-annual variability is high, and peaks of large fires occur. This suggests that fire suppression can reduce or stabilize fire activity (e.g., Moreno et al. 2014; Fréjaville and Curt 2017), but could affect less the incidence of large fires driven by extreme weather (e.g., Fernandes et al. 2016).

Landscapes became more hazardous with time, since land abandonment led to an increase in forest area. Treeless areas burned proportionally more than treed ones in many provinces. Fires in southern Europe have more preference for shrublands than for flammable forest types (Moreira et al. 2009; Oliveira et al. 2014), but may vary among locations (Moreno et al. 2011). This could be due to a change in the ignition patterns owing to shifts in the wildland-agricultural

and wildland-urban interfaces (Rodrigues et al. 2014; Modugno et al. 2016). Ortega et al. (2012) found that the most vulnerable landscapes were those with a high diversity of land uses, with forest-agriculture mixtures. Similarly, Viedma et al. (2018) showed that, in central Spain, fires lost the links with the initial fire-prone areas (conifers), and became more associated with lower altitude and less forested (treeless) areas. Nonetheless, land cover and forest type may not totally align with fuels and overall fire hazard. Forest composition can account for a small variation in fuel loading and other fuel characteristics (Fernandes et al. 2019).

Fire trends could also be affected by changes in the cause of ignition. In Spain (and in EUMed), a minor percentage of fires are caused by lightning, and most are caused by people. Fires of these two sources tend to occur at different locations (Vázquez and Moreno 1998), which could affect the vegetation they burn and the difficulty of extinction. However, no changes between these two sources have been observed (Ganteaume et al. 2013). Regarding people-caused fires, the majority of them are voluntary, followed by negligence. In recent times, negligence fires are increasing and voluntary ones decreasing (Ganteaume et al. 2013). Whether this is differentially affecting the fire trends, by way of the vegetation they burn or the point of ignition, is something that needs research.

Flammable species, like most *Pinus*, were expected to be positively related to fire activity, since large and high-severity fires have been associated with these species, whereas broad-leaved forests showed negative selectivity and lower severity (e.g., Fernandes et al. 2010; Moreno et al. 2011; Barros and Pereira 2014). Our results, however, showed that trends in burned areas of *Pinus* species were mostly negative. In contrast, species less flammable, like *Quercus*, notably the deciduous ones, were expected to not have a trend, which was generally true. However, species like *Q. ilex* and *Q. pyrenaica* are burning increasingly more frequently in the center and northwest of their distributions. A significant positive relationship between forest fires and the afforested areas has been found in Spain, especially 30–35 years after plantations (Iriarte-Goñi and Ayuda 2018). However, conifer plantations have been reduced in the last decades, as attested by CORINE data. This could be due to a change in ignition patterns (e.g., Viedma et al. 2018), or to the leverage of previous burning (Price et al. 2015). In contrast, broad-leaved forests, mostly *Quercus*, are increasing according to CORINE, as a likely reflection of abandonments. Abandonment of grazing of old *dehesas* (open oak woodlands with pastures) might have led to encroachment by shrubs, hence facilitating ignitions and fire spread (Torres et al. 2012; Salis et al. 2019). Moreover, *Quercus* species are invading many pines stands (Urbieta et al. 2011), and when burned, these may turn into oak forests (Torres et al. 2016). Recurrent fires could have more negatively affected pines (seeders) than oaks

(resprouters). For example, *P. nigra*, *P. sylvestris*, and *P. pinea* (seeders that produce few seedlings) usually change to other vegetation types after high-severity fires without proper management to reestablish them back (Rodrigo et al. 2004). Moreover, *P. halepensis* and *P. pinaster* forests have very low resilience when burned frequently, and may turn into shrublands (e.g., Viedma et al. 2006; González-De Vega et al. 2016).

5 Conclusion

Wildfires in Spain are decreasing in number, burned area, mean fire size and, in most provinces, also in the largest fire size. Wildfires are burning preferentially treeless than treed areas. Moreover, *Pinus* forests are burning less, while *Quercus* forests are burning more. This has occurred despite that fire risk factors have been rising: weather conditions became more severe, and landscapes more hazardous, owing to greater forest cover. Decreasing fire activity can largely be justified by the increase in firefighting resources, particularly aerial ones, which showed positive trends.

Data availability The datasets analyzed during the current study are available from the corresponding author on reasonable request. The data can be requested from the following sources: Spanish National Forest Fire Statistics (EGIF) from the Spanish Ministry of Agriculture, Fisheries and Food; Daily meteorological data from the reanalysis of WFDEI (WATCH-Forcing-Data- 111 ERA-Interim) (Weedon et al. 2014); LULC data from CORINE Land Cover Project at https://land.copernicus.eu/pan-european/corine-land-cover.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

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