

Case Report

Socioeconomic Development, Demographic Dynamics and Forest Fires in Italy, 1961–2017: A Time-Series Analysis

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Received: 15 January 2019; Accepted: 22 February 2019; Published: 1 March 2019



Abstract: Empirical studies investigating long-term trends in wildfires' frequency and severity have been relatively scarce in Europe. Number of fire events, total burnt area and average fire size were studied between 1961 and 2017 in Italy with the aim to identify homogeneous time periods with similar wildfire frequency and severity and correlate them with the background socioeconomic context. Fire attributes had a diverging behavior over time: the number of fires was the highest in the 1970s and the early 1980s; total burnt area was relatively more constant over time with a peak in the 1980s; and, finally, average fire size decreased quite homogeneously from the peak observed in the 1960s and early 1970s. The number of fires and average fire size were significantly influenced by the value of the same variable one year before. Investigating long-term historical outlines of forest fires, a mixed approach based on time-series statistical analysis, multivariate techniques and regressive models intended to define changes in fire regimes and socioeconomic development. In fact, the comparative valuation of the socioeconomic aspects and wildfire trends can reveal a key step to recognizing mitigation and preventive possibilities. Through a multivariate analysis, a substantial difference in the socioeconomic profile can emerge by decade, evidencing a (more or less) rapid socioeconomic development in relation to the evolution of forest fires in Italy.

Keywords: fire history; indicators; exploratory data analysis; Italy

1. Introduction

Having a long fire history, Mediterranean countries, e.g., Italy, are particularly sensitive to wildfires and respond through dedicated legislation, policies and practical measures to increasing fire exposure driven by land-use and climate changes [1–3]. Earlier studies based on the analysis of relatively short time-series data provided mixed evidence toward an overall increase in fire risk, revealing instead more complex spatio-temporal patterns differing between small, medium and large fires [4]. However, growing land vulnerability to large (and mega) fires is a common trend in both peri-urban districts with high human pressure and rural areas experiencing depopulation and land abandonment [5,6].

Around the world, Mediterranean-like ecosystems are probably the most wildfire-prone areas [7–9]. In Europe, according to the Burned Areas Perimeters (BAP) dataset of the European Forest Fire Information System (EFFIS), Spain, France, Portugal, Italy and Greece account for 78% of total burnt area and 84% of the total number of fires recorded in Europe in the 2000–2013 period [7].

Furthermore, the spatial distribution of fire incidence (e.g. number of fires and burnt area) is not spatially homogenous among these countries or within different regions of the same country [7]. However, forest fires can derive multiple explanations, e.g., divergent socioeconomic backgrounds, in different Mediterranean countries. For instance, wildfires, frequently occurring in woodlands, are usually called “forest fires”, depending on type of vegetation being burnt [10–21]. However, in regions such as the Mediterranean basin, both forested and non-forested areas result in being highly fire-prone due to climatic characteristics since fire plays a vital role in the ecosystem structure and function [2,8,22,23].

Based on these premises, a dedicated statistical analysis of longer time-series of fire frequency and severity may refine knowledge of fire behavior advancing strategies containing fire risk and reducing post-fire environmental rehabilitation costs. This study investigates long-term historical patterns of forest fires in Italy (1961–2017) using a mixed approach based on time-series statistical analysis, multivariate techniques and regressive models aimed at defining changes in fire regimes vis à vis socioeconomic development. A comparative assessment of the socioeconomic aspects and wildfire trends can reveal a key step to recognizing mitigation and preventive possibilities [10,11]. Since fires often have an anthropogenic matrix and affect society and the local economy, it is unthinkable to correlate fires to these aspects [24,25]. However, the present work focuses on the temporal component. Often, time is a secondary variable, while in this work it assumes a major role given the long time series (1961–2017) that describe fires in Italy. Time assumed a key importance in this work, although fire risk assessment systems usually offer a spatial assessment of the most relevant components associated with fire occurrence. For instance, fires are constantly judged as human-caused events [26–28]. Socioeconomic development, demographic dynamics and forest fires are, therefore, analyzed based on an extended time period. Moreover, short time frames (as a temporal period used for assessing a specific event) may be satisfactory for evaluating ecosystem dynamics. However, a long time series allows this work to reflect on the long period of the history of fires and their effects in Italy. For that reason, longer time scales are relevant to understanding and managing landscapes with long-lived systems, including forests [29–32].

2. Methodology

2.1. Study Area

The investigated area covers the whole of Italy (301,330 km² with rugged topography: 23% lowland, 42% upland and 35% mountains). The country displays marked disparities in environmental conditions (climate regimes, landscape, vegetation, soils and cropping systems) and socioeconomic factors (income, job market, demographic and socio-spatial structures) between northern and southern regions [33–35]. Recent demographic trends in Italy and a complete outlook of socioeconomic characteristics at national scale were presented in earlier studies [31,36–38].

2.2. Indicators

Long-term forest fire trends were assessed using statistical data on the frequency and severity of fire events in Italy between 1961 and 2017 disseminated by Istat (Italian National Statistical Office) and complemented with additional information provided by Italian Forestry Service. For each year, three indicators were calculated: (i) total number of forest fires, (ii) total forest burnt area (ha) and (iii) average fire size (ha) at national level in Italy. These data were supplemented with detailed information on fire events in non-forest, natural land (pastures, cropland, wetland), available for a shorter time period (1970–2017) from Istat, allowing calculation of the following three variables: (i) total number of non-forest (wild)fires, (ii) total (non-forest) burnt area (ha), and (iii) average (wild)fire size (ha).

To illustrate territorial, demographic, socioeconomic and cultural transformations over the study period in Italy, this work adopted 58 contextual indicators (Appendix A) derived from a set of country-scale time-series annual data recently released by Istat. In line with the conceptual

reference framework (the relationship between forest fires, demographic dynamics and socioeconomic development), indicators evaluate five relevant dimensions: (i) territory and environment (7 indicators), (ii) demography (12), (iii) education and labor market (7), (iv) economy and trade (8) and (v) agriculture (24). Indicators were collected and harmonized from multiple data sources (e.g., national census of population, population register, forest/environmental statistics, economic statistics, social statistics provided by Istat) with the aim of investigating post-war socioeconomic and environmental history of Italy. The identification of specific analysis' fields allows indicator sub-sets to be defined suitable for investigating together forest fires' dynamics and socioeconomic development.

2.3. Data Analysis

Based on exploratory thinking, this study evaluates a sufficiently large number of indicators, comparable over the entire study period. The indicators illustrated in Section 2.2 were analyzed using a mixed statistical framework including descriptive analysis, time-series partial auto-correlation and cross-correlation techniques, principal component analysis (PCA), cluster analysis and step-wise multiple regression models. Indicators were standardized prior to analysis.

A classical time-series analysis was run on three indicators (number of forest fires, total burnt area and average fire size) by computing a partial autocorrelation coefficient by lag, considering lags from 1 to 15 over 57 years. Correlation between the number of forest fires and total burnt area was investigated using a scatterplot and cross-correlation coefficients at lags ranging from 0 to 15. Significance was tested at $p < 0.05$ for both partial auto-correlation and cross-correlation coefficients. A specific PCA was run on a shorter time interval (1970–2017) with the aim of comparing temporal trends in forest and non-forest fires in Italy. Five indicators were analyzed together: (i) total number of fires (forest and non-forest), logarithm, hereafter 'Fir(log)'; (ii) total burnt area (forest and non-forest), logarithm, 'Bur(log)'; (iii) average fire size (forest), 'Avg(W)'; (iv) average fire size (non-forest), 'Avg(A)'; and, finally, (v) per cent share of burnt area of forests in total burnt area, 'Wood(%)'. Components with eigenvalues >1 were further analyzed using a biplot that illustrates together component loadings (5 indicators) and scores (48 years), allowing identification of characteristic years and the related fire's attributes.

A cluster analysis (two-way joining) was run to explore intensity of change in basic attributes of forest fires over time (using three indicators: 'Fir(log)', 'Bur(log)' and 'Avg(W)', in relation to socioeconomic development. This technique was run on a data matrix of forest fire's indicators calculated as a 10-year average, producing a central value separately for each of six decades (1961–1970, 1971–1980, 1981–1990, 1991–2000, 2001–2010 and 2008–2017). This value was compared with the corresponding value of 58 context indicators (see in the Appendix A) at the beginning of each time interval (1961, 1971, 1981, 1991, 2001, 2008). Two-way joining is a common multivariate technique analyzing complex data matrices under the assumption that both cases (time intervals) and variables (contextual indicators) will contribute simultaneously to the uncovering of meaningful latent patterns. Two-way clustering produces a graph ordering cases and variables based on similarity patterns. The graph illustrates the distribution of standardized scores (with zero-average) for each case and variable using different colors. Identification of similar (positive or negative) scores for a group of variables and cases allows definition of specific clusters. A PCA was also run on the same data matrix with the aim of classifying indicators in respect of time intervals characterized by different developmental phases in Italy. Components with eigenvalues >1 were extracted and a biplot illustrating together component loadings (6 indicators, one for each decade) and scores (61 indicators, i.e., 3 forest fires' attributes and 58 contextual indicators, see list in the Appendix A) was analyzed.

Multiple regression models were separately run to identify the most relevant predictors of three forest fire's attributes (number of forest fires, total burnt area, average fire size) taken as dependent variables. In each model, predictors were selected from a list of 58 indicators (see in the Appendix A) available each year from 1961 to 2009, by adopting a forward stepwise technique with $p < 0.05$. Adjusted R^2 and Durbin–Watson tests were adopted to evaluate the goodness of fit of each model.

3. Results

3.1. Descriptive Statistics

Forest fires were relatively scarce in Italy during the first decade investigated in this study, ranging between 1000 and 4000 events per year between 1961 and 1970 (Figure 1). The 10-year moving average illustrates a rapid increase in the number of forest fires during the 1970s. A peak in fire events was observed in the 1980s, with the maximum value recorded in 1985 (nearly 18,000 events). Fire frequency was relatively stable during the late 1980s and the early 1990s, and a moderate decline was observed since the mid-1990s. Results of a partial auto-correlation analysis on fire frequency indicate a short-term dependence pattern, with partial autocorrelation coefficients at both lag 1 and lag 3 being significant and positive (respectively $r = 0.67$ and 0.36). In other words, fire frequency has influenced significantly the number of forest fires in the subsequent year, and more slightly, three years later. Total burnt area (forests, ha) followed a particularly volatile time pattern, increasing moderately in the 1970s, stabilizing in the 1980s, reaching a local peak in the 1990s and declining slightly in the 2000s. The largest values were observed in the early 1990s and in the late 2000s. Results of a partial auto-correlation analysis on total burnt area indicate a non-significant time-dependence pattern, reflecting high variability of this indicator over time.

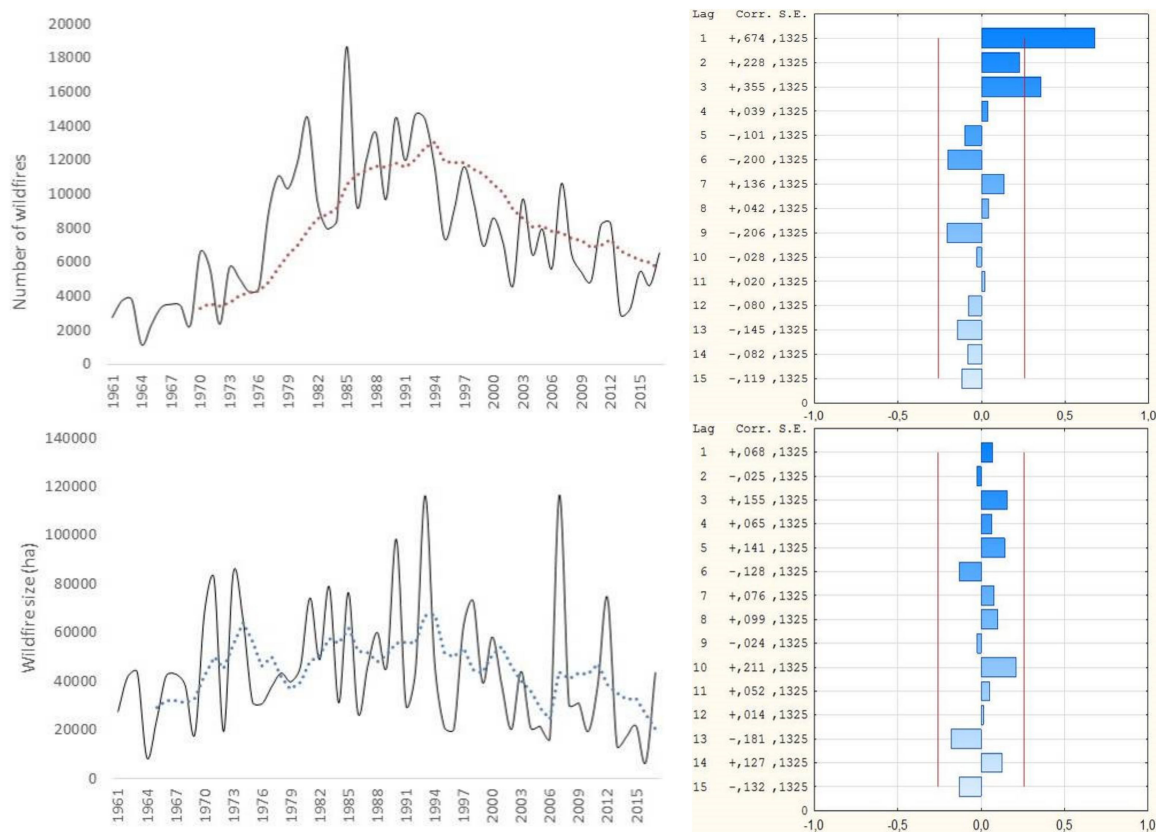


Figure 1. Cont.

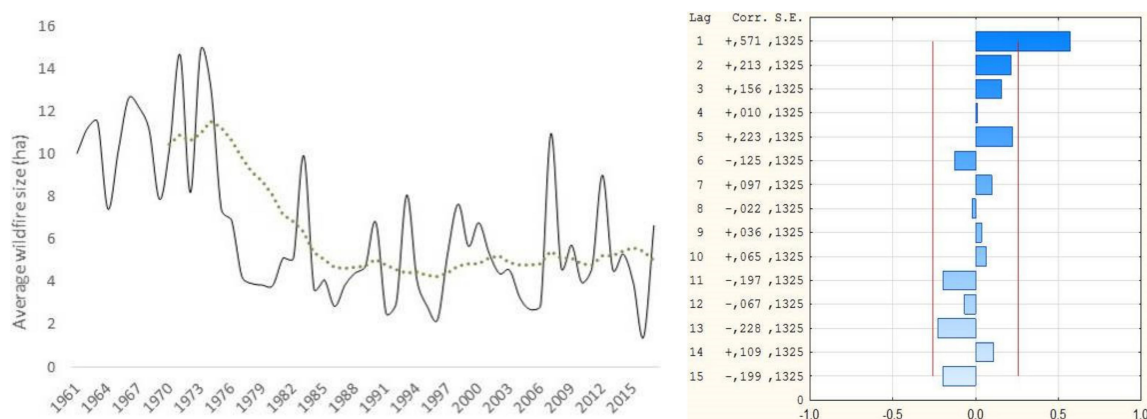


Figure 1. Selected forest fires' attributes in Italy, 1961–2017 (upper: number of wildfires; intermediate: total burnt area; lower: average wildfire size; left: absolute time series—continuous line, and 10-year moving average—dotted line; right: partial autocorrelation coefficients by lag, straight line indicates 95% confidence interval, as it increases by each lag, the colors lighten from shades of dark blue to light blue).

Average forest fire size (ha) was relatively high in the first two decades, declining since the late 1970s and stabilizing to nearly 6 ha in the following decades, while reaching peaks up to 10 ha in exceptional years (e.g., 1985, 2007). A slight increase was finally observed in the last decade. A partial auto-correlation analysis on average fire size indicates a short-term dependence pattern, with a significant, positive autocorrelation coefficient ($r = 0.57$) at lag 1. A correlation analysis was also performed between total number of forest fires and total burnt area in Italy, 1961–2017 (Figure 2). Exceptional years were classified in the upper side of the scatterplot: 1990, 1993 and 2007 had the largest forest area destroyed by fires; conversely, 1985 had the largest number of fires since 1961. Years in the early 1970s were classified in the upper part of the graph (1970, 1971, 1973, 1974). Conversely, early 1990s, 2000s and 2010s years were frequently classified in the lower part of the graph. Synchronic (lag 0) correlation between the two variables was positive and significant ($r = 0.60$). Diachronic correlation patterns (for both negative and positive lags) were non-significant.

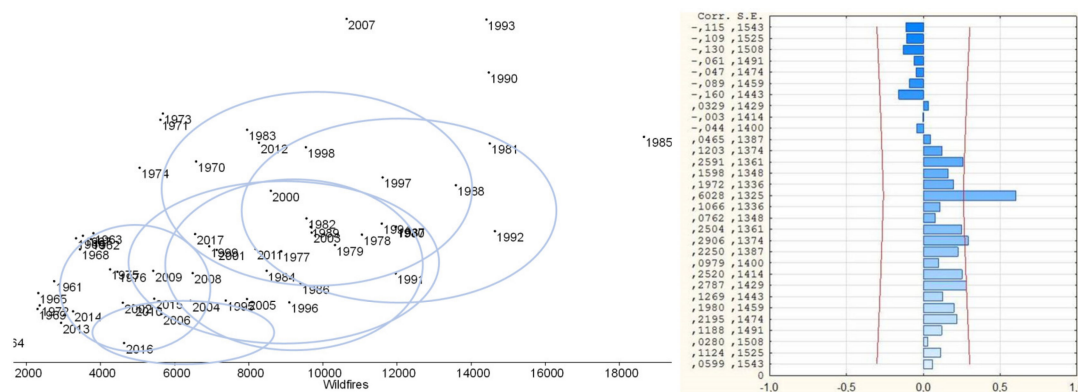


Figure 2. Correlation between the number of forest fires and total burnt area (km^2) in Italy, 1961–2017 (left) and a cross-correlation analysis of the two variables by lag (right).

Considering together forest and non-forest fires over a shorter time period (1970–2017), Principal Component Analysis extracted two axes that explain 82.4% of total variance (Figure 3). The biplot illustrating loadings and scores to components 1 (47.3%) and 2 (35.1%), discriminated fire attributes from fire seasons (i.e., years) within the four quadrants. Years from 1970 to 1976 were clustered together in quadrant IV (negative scores to component 1, positive scores to component 2), being associated with the per cent share of forests in total burnt area and average forest fire size (1999 and 2012 belong to this

quadrant, even if marginally). Quadrant I include years from the 1990s and more sparse years from the 1980s, the 2000s and the 2010s. These years are associated with both total burnt area and average non-forest fire size and are considered as particularly severe years as far as the fire regime is concerned. The total number of fires was associated with component 1. Quadrant II identifies years with a relatively high fire frequency and low percentage of forest land burnt. This group is relatively mixed, including years from the 1990s, the early 2000s and the late 1970s. Quadrant III identifies years with a moderate (or low) fire severity, having together lower-than-average total burnt area and fire frequency. Together with 1995, years of the 2000s and 2010s were more frequently classified in this quadrant.

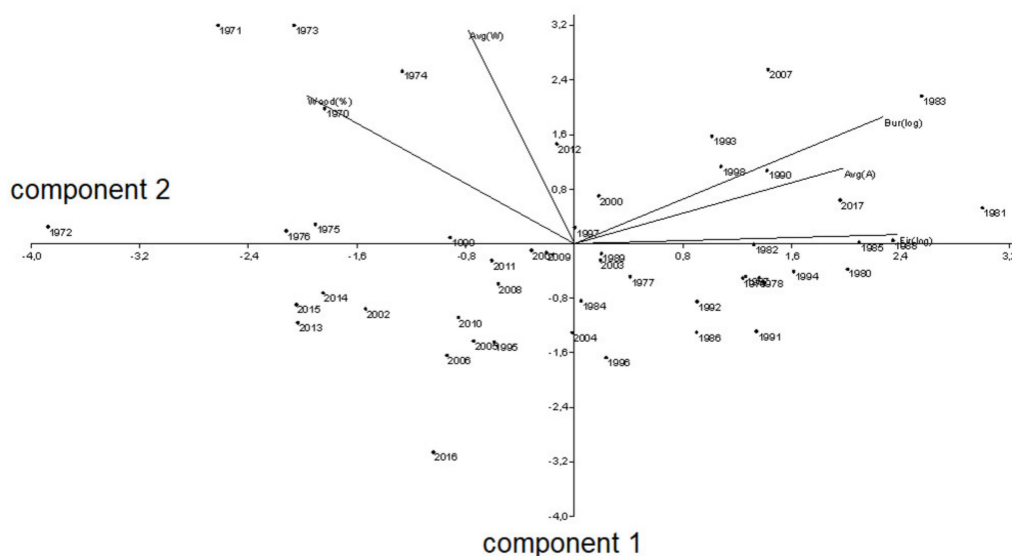


Figure 3. Principal component analysis (PCA) of basic wildfires' attributes in Italy, 1970–2017.

3.2. Clustering and Ordination

Two-way joining indicates a substantial difference in the socioeconomic profile of each decade (Figure 4), evidencing (more or less) rapid changes in forest fires' attributes in relation with socioeconomic development in Italy. The first two decades (1960s and 1970s) were identified with above-average demographic indicators and below-average economic and agriculture indicators. The third decade (1980s) was relatively mixed, displaying some above-average economic and labor market/education indicators. The last three decades were more similar, representing the inherent divide between agricultural indicators (above-average) and demographic indicators (below-average). Figure 4 depicted two-way joining cluster analysis by choosing a color graduation, which starts from the green tones for the lowest values below the average up to the red tones for the values above the average.

Considering forest fires and socioeconomic dynamics (1961–2017), a PCA run on the same data matrix explored by two-way joining (see above) extracted two axes that explain 75.2% of total variance (Figure 5). The biplot illustrating components 1 (55.7%) and 2 (19.5%) discriminated fire/socioeconomic attributes and decades within the four quadrants. The 1960s decade was negatively associated with component 1. The most relevant fire variable associated with this decade was average fire size (reaching in this period the highest values over the whole time series, see Section 3.1) in turn linked with a group of territorial, demographic, agricultural and trade indicators. The subsequent decade was also associated with component 2 and identified a group of variables typically associated with rapid socioeconomic development (reflecting a rising production of specific agricultural products, growing imports, and increasing wealth and savings). The 1980s was a sort of transition period for socioeconomic development, being associated with component 2 and linked to specific forest fires' variables (and especially total burnt area, reaching the highest values in this decade, see Section 3.1). The last three decades were positively associated with component 1. Years in the 1990s were weakly associated to fire frequency and more tightly associated with a group of variables indicating specific

agricultural productions (oil, barley, eggs, wine, tobacco, hazel, livestock), population concentration, urbanization, and specific education variables. The 2000s and 2010s were found to be associated with specific variables, including demographic aspects (migration, ageing), increasing imports from Europe, high-value or niche agricultural productions, and a territorial context characterized by forest expansion thanks to land abandonment and increased environmental protection.

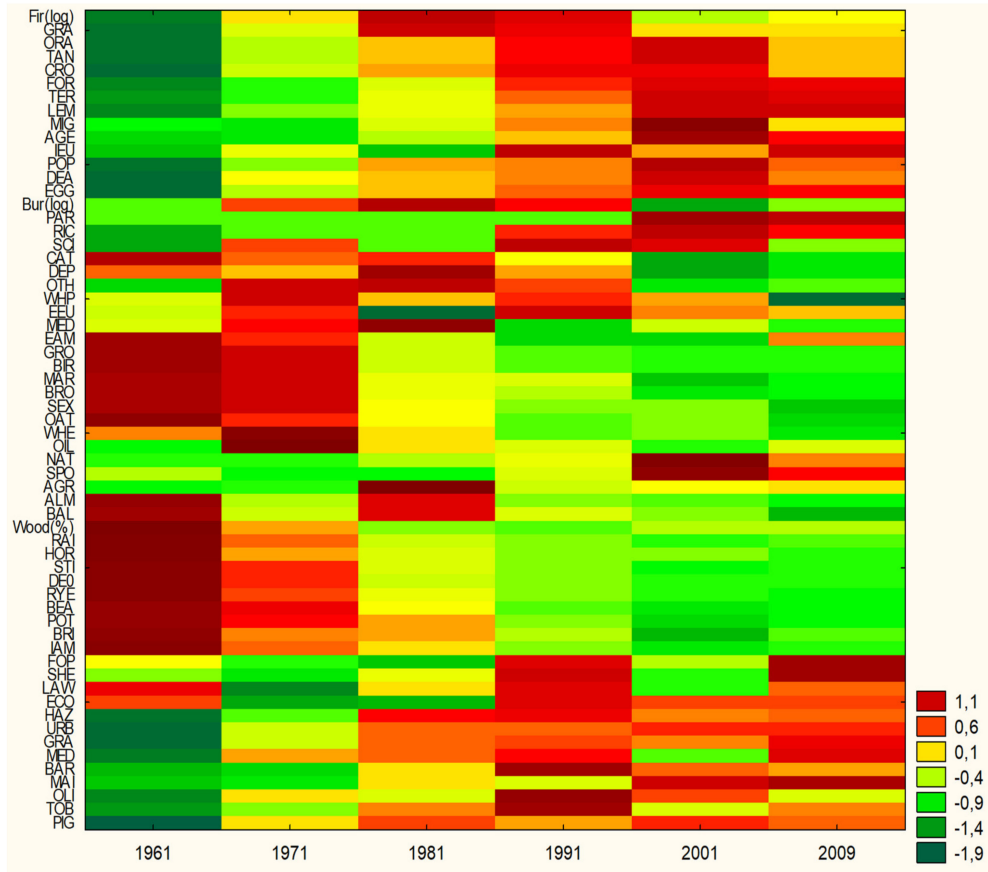


Figure 4. Two-way joining cluster analysis using color graduation from green to red, respectively indicating indicators' value below and above the average.

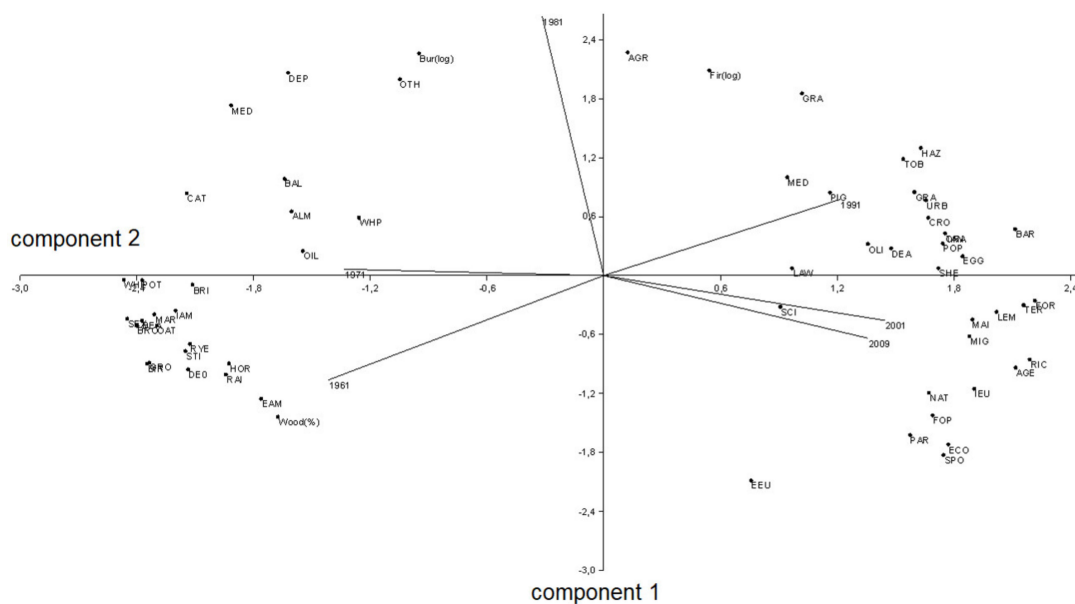


Figure 5. Principal component analysis of basic forest fires and socioeconomic attributes in Italy, 1961–2008.

3.3. Multiple Regression

Step-wise multiple regressions were run with the aim of identifying the most relevant predictors of (i) forest fire frequency (ii) total burnt area (forests) and (iii) average fire size (forests). Selected forest fires' attributes assumed as dependent variables are: barley production ('BAR'), per cent share of school graduates in total population ('GRA'), other agrumes' production per 1000 quintals ('OTH'), crude birth rate as percentage on total population ('BIR'), marriage rate ('MAR') and lemon production per 1000 quintals ('LEM') (see in the Appendix A). Step-wise selection of the predictors gave relatively good models (moderate-high adjusted R^2) for dependent variables (i) and (iii). The model for variable (ii) has a rather modest fit and it is not considered here, confirming the large variability over time of total burnt area, that could be better explained with the use of other predictors, including descriptors of climate/meteorological regimes (Table 1). The number of forest fires was positively correlated with barley production ('BAR') and per cent share of school graduates in total population ('GRA'). This model suggests that the highest fire frequency was observed in connection with a phase of rapid socioeconomic changes during the 1980s, with specific agricultural productions and a (more or less) rapid increase in education level. Conversely, average fire size was positively correlated with birth ('BIR') and marriage rate ('MAR') and with lemon production ('LEM'). These variables indicate that the highest values of fire size were observed at the beginning of the observation period, under a specific demographic context ('baby boom') and a more traditional agricultural system dominated by perennial crop.

Table 1. Results of forward step-wise multiple regression models using selected forest fires' attributes as dependent variables.

Predictor	Number of Forest Fires			Burnt Area			Average Fire Size		
	b	SE	t	b	SE	t	b	SE	t
BAR	0.462	0.11	4.2 **						
GRA	0.460	0.11	4.2 **						
OTH				0.313	0.14	2.26 *			
MAR							0.893	0.35	2.58 *
BIR							0.503	0.27	3.88 *
LEM							0.748	0.19	1.83 *
Adj- R^2		0.716			0.079			0.636	
D-W test		2.11			2.11			1.91	

b: standard slope; SE: standard error; Student t statistic testing for non-null regression coefficients at * $p < 0.05$ or ** $p < 0.001$; D-W: Durbin-Watson test of serial autocorrelation, values close to 2 indicate negligible autocorrelation.

4. Discussion

The occurrence and severity of forest fires in each area are fundamental variables when exploring long-term fire dynamics, producing a basic knowledge to evaluate the effectiveness of fire management systems at local, regional and national level [7,22,39]. Understanding past and present fire regimes is, in turn, essential to determining the extent and seasonality of fires, ignition cause and fire behavior [4,40–44]. Earlier studies using a long time-series analysis have demonstrated that fire regimes have shaped landscapes as a function of both climate and human feedbacks [7–11,40–42]. Changes in fire regimes have determined considerable pressures to natural ecosystems and human settlements [45], since fires have frequently led to (more or less) rapid landscape transformations [46]. Comparative investigations of fire history have outlined a high occurrence of fires during the mid to late 19th century [47–49]. Fire regimes occurred between the late 20th and the early 21st centuries were characterized by more volatile climatic and vegetation conditions [1,49,50].

The recurrence of fires turns out to be frequent in recent years, varying meaningfully the current fire regimes. A fire regime can be characterized by the pattern, frequency and intensity of the fires that occurred in a definite area over long temporal phase [40,41]. Fire regime analysis is

particularly interesting for disentangling the role played by anthropogenic pressure on severity and fire frequency [50–57]. Fire severity defines the eco-systemic influence of a fire, e.g., as biomass damage to fire; while, fire frequency outlines the number of fires in a specific place and during a defined temporal period, differing by region as a meaning of both lightning and anthropologic ignitions, with the prerequisite that fuels are adequately dry and significantly combustible to burn [46].

Wildfires seem to be a considerable threat to human and ecological values in the fire-prone areas of the Mediterranean basin, where extreme fire periods are frequent causing human and ecological losses [1,7,10,11,21,58]. In recent years (2000–2009), Italy with other Mediterranean countries in Europe (France, Spain, Greece) experienced about 57,000 wildfires yearly, burning 430,000 ha [1,10,11,59]. More than 90% of fires were produced by negligence, pyromania and agro-pastoral land burning [10]. Wildfires characterized a current concern since it is expected that they will increase in reply to foreseen changes in climate and land-use in the future [60,61].

The latent interplay between socioeconomic development and environmental conditions has been frequently investigated in multifaceted research fields dealing with climate change, land-use, soil degradation and other issues involving global, regional and local spatial scales [62–69]. Being difficult to predict [70], forest fires represent a relevant ecological process in Mediterranean Europe [40,41]. Empirical research on forest fires in southern Europe has increased rapidly since the 1970s [39,71]. Despite mostly volatile and heterogeneous short-term regimes, a comprehensive understanding of forest fires' behavior requires diachronic analysis of multiple fire attributes over enough long temporal scales [72]. In this context, fire history became a specific issue of study, considering territorial specificities and intensifying burning perspectives as a multi-purpose tool [9,73]. Furthermore, especially in Mediterranean Europe, fire history can be easily correlated with anthropogenic activities, which have developed traditional (or advanced) agricultural practices and have directly or indirectly shaped landscapes and land cover [2,74]. For instance, recent trends in landscape transformation [3,49,75–78], models of economic development and lifestyles have directed towards new territorial scenarios for wildfire ignition [9,79]. In addition, climate change and degradation processes (e.g., soil erosion and desertification) have increased the interest on regional vulnerability to wildfires [59–62,80–84].

The present work outlined the importance of exploring long time-series of forest fire attributes together with a wide-ranging set of socioeconomic indicators. Empirical results outlined significant changes in both frequency and severity of forest fires in Italy. Forest fires were relatively scarce in Italy during the first decade investigated (1961–1970). Subsequently, a rapid increase in the number of forest fires occurred during the 1970s, with a peak in fire events in the 1980s, with the maximum value recorded in 1985. Fire frequency was relatively stable during the late 1980s and the early 1990s, declining since the mid-1990s. Results exposed the fact that fire frequency influenced significantly the number of forest fires in the subsequent year, and more slightly, three years later. Correlation between fire frequency (absolute number of events) and fire severity (total burnt area) identifies fire seasons with a characteristic risk profile, having e.g., above-average fire frequency and severity. Among the main indicators, total burnt area followed a predominantly unpredictable time pattern, (i) increasing moderately in the 1970s, (ii) calming in the 1980s, (iii) reaching a local peak in the 1990s, and (iv) decreasing slightly in the 2000s. Outcomes of a partial auto-correlation analysis on total burnt area exposed a non-significant time-dependence outline, reflecting high variability of such an indicator over time. Fire's behavior over single years evidenced 'risky' characteristics, possibly linked with specific environmental conditions (climate, vegetation, landscape) [83,84]. At the same time, a more general trend over time was observed for all fire's attributes, evidencing different behaviors and background patterns: fire frequency increased up to the mid-1980s and decreased slightly afterwards, and total burnt area was even more volatile. Within this framework, time-series analysis indicates a partial autocorrelation structure characterized by a significant lag-1 positive autocorrelation, suggesting that both fire frequency and average fire size are positively influenced by the level of the same variable one year before. Socioeconomic development was also an important factor explaining the temporal pattern

of forest fires [27,85,86]. In particular, demographic and productive aspects were associated with fire's attributes over time, confirming the key role of human pressure (caused by multiple factors, including e.g., an increase in population density or changes in agricultural productions) in fire risk [42,84,87–92]. For instance, the increasing gap between marginal and highly populated areas is an important aspect leading to a larger unpredictability of fire events. In this regard, areas with more evident processes of land abandonment seem to be more vulnerable to large fires, while fires are smaller and more frequent in peri-urban districts because of high anthropogenic pressure [85,93–98].

Also, the average forest fire size is a significantly indicator since it was comparatively high in the first two decades, declining since the late 1970s and stabilizing to nearly 6 ha in the succeeding decades, while reaching peaks up to 10 ha in extraordinary years (e.g., 1985, 2007). Considering together forest and non-forest fires over a shorter time period (1970–2017), principal component analysis discriminated fire attributes from fire seasons (i.e., years), e.g., years from the 1990s and more sparse years from the 1980s, the 2000s and the 2010s. These years are associated with both total burnt area and average non-forest fire size and are considered as predominantly severe years as far as the fire regime is concerned.

While socioeconomic development is demonstrated to be strongly associated with fire's attributes, mainly frequency and average size, other factors cannot be demised when understanding complex trends in fire risk. The present analysis contributes to shed light on long-term fire risk trends in a Mediterranean country. Proposing a truly comprehensive approach to fire's complexity [23], the originality of this paper is in bringing out and indicating in each decade a considerable change in the socioeconomic profile, demonstrating variations in forest fires' attributes in relation to socioeconomic development in Italy: (i) the first two decades (1960s and 1970s) were recognized as having above-average demographic indicators and below-average economic and farming indicators; (ii) the third decade (1980s) was relatively mixed, exhibiting some above-average economic and labor market/education indicators; and (iii) the last three decades were more similar, on behalf of the inherent division among agricultural indicators (above-average) and demographic indicators (below-average). Furthermore, the recent decades (2000 and 2010) were found to be related to explicit variables, counting demographic aspects (e.g., migration), growing imports from Europe, high-value or niche agricultural production, and a territorial context composed by forest expansion due to land abandonment and improved environmental protection. Analysis of long time-series of fire events unquestionably allows the identification of wildfire scenarios, which represent an indirect approach to accomplishing fire hazard reduction and land management, evaluating together fire events and human-driven activities [39,45].

An integrative concept, including bio-geophysical processes and social structures, can provide a large-scale standpoint appropriate for managing ecosystems and human activities [9,45,47–51]. Although it is a multivariate analysis, a substantial difference in the socioeconomic profile can emerge by decade, evidencing a (more or less) rapid socioeconomic development in relation with the evolution of forest fires in Italy. In this sense, the work proposed allows us to reflect also on recent environmental challenges, e.g., climate regimes which should be better investigated in this line of thinking [1]. Innovative approaches for the integrated management of wildland under changing socioeconomic conditions contributes to a better knowledge of the spatio-temporal dynamics of wildfires in prone areas, suggesting new fire scenarios [102]. In this instance, fire scenarios are useful when they are based both on (i) a location-based approach, referring to the dynamic connotation among fire behavior, ecological issues, socioeconomic aspects and land-use management at a landscape scale [99], and (ii) a time-based approach, which simulates single events regarding alternative temporal pathways for upcoming forecasts of fire risk [100,101]. Thanks to new technologies, multi-temporal databases should be permanently updated and enriched with the final objective of depicting fire history and changing fire regimes in each area [102–107]. Renewed strategies of fire prevention and forecast should be increasingly based on a multi-criteria approach that includes advanced knowledge of a time-series joint analysis of wildfires and socioeconomic development.

5. Conclusions

Despite Mediterranean countries being strongly sensitive to fire risk, few researches have focused on long-term fire risk trends, especially related to socioeconomic development. The present study offers an integrated time-series analysis along a long temporal series (1961–2017) exploring forest fires in Italy and the relative socioeconomic and demographic dynamics. Among the numerous indicators, number of fire events, total burnt area and average fire size were studied with the aim of identifying homogeneous time periods with similar wildfire frequency and severity and correlating them with the background socioeconomic context. Investigating trends of forest fires over the last decades, a mixed approach was based on time-series statistical analysis, multivariate techniques and regressive models, proposed at defining variations in fire regimes and socioeconomic development. The comparative assessment of the socioeconomic aspects and wildfire trends revealed a key step to identifying mitigation and preventive possibilities. As regards current concerns, e.g., climate changes and regimes, a truly comprehensive approach to fire's complexity is necessary [47], offering wildfire scenarios, which embody an ancillary approach to achieving fire hazard reduction and land management, assessing both fire events and human-driven activities [39]. The present work focused on temporal data, without defining a precise place definable in space: the lack of spatial linkage among fire occurrence points, regions and descriptive information is a weakness, which could be filled by future studies. However, a substantial difference in the socioeconomic profile can arise by decade, proving a (more or less) rapid socioeconomic change in relation with the development of forest fires in Italy. An integrative approach can offer a large-scale perspective, which can be very appropriate for managing the future of fragile ecosystems and human activities [9,32].

Author Contributions: Conceptualization, A.C. and M.C.; methodology, L.S.; software, I.Z.; validation, I.Z.; formal analysis, L.S.; investigation, M.C.; resources, M.C.; data curation, A.C.; writing—original draft preparation, L.S.; writing—review and editing, L.S., M.C.; visualization, I.Z.; supervision, A.C.; funding acquisition, L.S.

Funding: This research was funded by two projects: SMART4Action (grant no. LIFE13 ENV/IT/000813) financed by European Union and CRISIS, a Sapienza University grant to M.C.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Indicators adopted in the present study by thematic domain.

Theme	Acronym	Indicator	Source
Territory	FOR	Forest land (% in total land)	Forest statistics
	FOP	Per-capita forest area (m ² per inhabitant)	Forest statistics
	GRO	Population growth rate (% per year)	Demographic statistics
	POP	Resident population (logarithm)	Demographic statistics
	PAR	Protected area (% in total land)	Environmental statistics
	RAI	Railway network (km/1000 inhabitants)	Economic statistics
	URB	Population residing in urban centers (% in total popul.)	Demographic statistics
Demography	SEX	Sex ratio (males <i>vs</i> females)	Demographic statistics
	BIR	Crude birth rate (% in total population)	Demographic statistics
	DEA	Crude death rate (% in total population)	Demographic statistics
	MIG	Migration rate (% in total population)	Demographic statistics
	NAT	Natural birth rate (% in total births)	Demographic statistics
	STI	Still birth rate (% in total births)	Demographic statistics
	BRI	Age difference between groom and bride (years)	Demographic statistics
	MAR	Marriage rate (% in total population)	Demographic statistics
	SPO	Average age of the groom at the marriage (years)	Demographic statistics
	AGE	Median age at death for males (years)	Demographic statistics
	MER	Difference in female vs male median age (years)	Demographic statistics
DE0	Death at age 0–4 years (% in total population)	Demographic statistics	

Table A1. Cont.

Theme	Acronym	Indicator	Source
Education	TER	Third-level graduated (% in total population)	University statistics
	GRA	Second-level graduated (% in total population)	School statistics
	SCI	Enrolled at the university in science faculties (%)	University statistics
	MED	Enrolled at the university in medicine faculties (%)	University statistics
	AGR	Enrolled at the university in agrarian faculties (%)	University statistics
	ECO	Enrolled at the university in economy faculties (%)	University statistics
	LAW	Enrolled at the university in law faculties (%)	University statistics
Agriculture	WHP	Wheat production (per 1000 quintals)	Agricultural statistics
	RYE	Rye production (per 1000 quintals)	Agricultural statistics
	BAR	Barley production (per 1000 quintals)	Agricultural statistics
	OAT	Oat production (per 1000 quintals)	Agricultural statistics
	RIC	Rice production (per 1000 quintals)	Agricultural statistics
	MAI	Maize production (per 1000 quintals)	Agricultural statistics
	BRO	Broad bean production (per 1000 quintals)	Agricultural statistics
	BEA	Bean production (per 1000 quintals)	Agricultural statistics
	POT	Potatoes production (per 1000 quintals)	Agricultural statistics
	TOB	Tobacco production (per 1000 quintals)	Agricultural statistics
	GRA	Wine grapes production (per 1000 quintals)	Agricultural statistics
	OLI	Olive production (per 1000 quintals)	Agricultural statistics
	ORA	Orange production (per 1000 quintals)	Agricultural statistics
	TAN	Tangerine and clementine production (per 1000 quintals)	Agricultural statistics
	LEM	Lemon production (per 1000 quintals)	Agricultural statistics
	OTH	Other agrumes' production (per 1000 quintals)	Agricultural statistics
	ALM	Almond production (per 1000 quintals)	Agricultural statistics
	HAZ	Hazel production (per 1000 quintals)	Agricultural statistics
	CRO	Per capita agricultural production (quintals)	Agricultural statistics
	CAT	Total density of cattle and buffaloes (animals)	Agricultural statistics
	SHE	Total density of sheep and goats (animals)	Agricultural statistics
	PIG	Total density of pigs (animals)	Agricultural statistics
HOR	Total density of horses (animals)	Agricultural statistics	
EGG	Total number of eggs produced (per 1000 units)	Agricultural statistics	
Economy	IEU	Imports from Europe (% in total import)	Trade statistics
	IAM	Imports from north America (% in total import)	Trade statistics
	EEU	Exports to Europe (% in total import)	Trade statistics
	EAM	Exports to north America (% in total export)	Trade statistics
	DEP	Bank deposit amount/total loan amount	Economic statistics
	OIL	Imported oil/imported carbon	Trade statistics
	WHE	Wheat production/wheat import	National accounts
BAL	Total import/total export	Trade statistics	

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