

## Article

# Vulnerability Variables and Their Effect on Wildfires in Galicia (Spain). A Panel Data Analysis

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**Abstract:** This paper studied the effect of the socio-economic variables related to social vulnerability on wildfire characteristics (ignitions, hectares burned, and ratio hectares burned/ignitions) in Galicia, Spain. The study recognized that wildfires present threats to people and communities, so actions might be taken to address vulnerabilities in ways that mitigate the negative impacts of such fires. Our final aim was to identify those variables that are relevant to the starting and spreading of wildfires that can help improve the prevention and mitigation of wildfires. Panel data collected over 15 years (2001–2015) for the municipalities of Galicia were used in this study. The results show that vulnerability-related socio-economic factors affect the number of wildfires and the extent of the destruction they cause. Indeed, the progressive abandonment of rural areas is one of the most important problems that increases the occurrence of wildfires. This abandonment is connected to population factors such as aging or low density of population, economic factors such as the decrease in income or low cadastral value, and territorial factors such as the decrease in rustic hectares and ranches. We conclude that prevention and mitigation focused on areas prone to wildfires could be enhanced by taking into account these variables.

**Keywords:** forest fires; wildfires; socio-economic variables; vulnerability; panel data; Galicia; Spain

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## 1. Introduction

### 1.1. Vulnerability and Wildfires

Vulnerability is a construct that depends on multiple variables and differs over territory and time. For the purposes of this article, it is defined as the capacity of a person or group to avoid or anticipate, cope with, resist, and recover from the impact of a natural hazard [1]. The vulnerability level and the capacity of people to face the risk depend on different social, economic, political, and cultural factors [2].

A hazardous natural phenomenon (e.g., wildfires) that affects a defined place in a specific time is only considered a natural disaster as far as the human population is involved [3,4]. In fact, the importance of a disaster is measured by the damage it causes to a population [5]. In this respect, scholars have commonly analyzed how, when a natural disaster occurs, the most vulnerable people or communities suffer the greatest impact and its consequences [4]. However, it has been much less studied whether the greater or lesser vulnerability of a community can influence the characteristics of certain disasters.

To investigate this question, we followed Faas [6]. This author defines an overall place vulnerability that arises from the interaction of social and biophysical characteristics. Vulnerability affects the occurrence of a disaster, which, in turn, impacts social vulnerability. Therefore, it is important to differentiate pre-disaster vulnerability from post-disaster vulnerability [1,6]. Post-disaster vulnerability is defined by the characteristics of

the population after being affected by a certain disaster. Pre-disaster vulnerability is defined by those variables related to economy, demography, and territory that are a consequence of a previous or existing socio-economic situation. This vulnerability could determine the impact's intensity or the occurrence of a certain disaster.

Moving on to the wildfires issue, it must be taken into account that most wildfires are caused by human activity, fuel availability, and meteorological variables together [7–9]. Therefore, socio-economic variables such as the structure and density of the population, income per capita, or GDP in a territory affected by wildfires become as important as meteorological variables and fuel [6,10,11]. Furthermore, an unfavorable socio-economic situation in such territories (represented by rural abandonment, non-management of the territory, low investment, etc.) could reduce the effectivity of local and regional authorities' prevention and mitigation efforts, [12–14]. In sum, a population and its socio-economic characteristics (such as poverty, aging, rural abandonment, lack of resources, etc.) become paramount factors to be considered for risk management [15].

Additionally, knowing the characteristics that affect the occurrence of wildfires, their extent, and the ratio of extension/occurrence will be very useful in preventing and mitigating wildfires in the future [16].

In this paper, we use fire, wildfire, and forest fire as a description of the same term in an attempt to avoid repetition. These terms are commonly accepted as synonyms [17].

Spain is one of the European countries most affected by forest fires: The Autonomous Community of Galicia (the north-west Spanish region) recorded most of forest fires in the country over the last few decades [11,14]. The vast majority of scholars studying fires in this area have analyzed the influence of meteorological and territorial variables in the region's wildfire production [18,19]; fewer studies have paid attention to the relationship between wildfires and socio-economic variables [14,20,21]; research on socio-economic variables connected to the pre-disaster social vulnerability is even less common. [18].

### *1.2. Social Factors and Wildfire Management*

Although the characteristics of fires (ignition, extension, and ratio hectares burned/ignitions) change over time and vary in response to the interaction and dependencies between fire, people, and biophysical features, the most influential driver of change in fire frequency comes from the population, rather than from the existing climate and flora [7,22]. However, research on social factors and wildfire risk receives less attention than does investigation focused on the effect of climate variability on forest fires [23]. This is due to the higher complexity of the human factors in comparison to the biophysical drivers [22,24].

In any case, as a natural event such as a forest fire becomes a natural disaster only if the human population is affected, knowledge of the territory, the people living within the areas exposed to forest fires, and the social and economic factors related to social vulnerability is essential in determining the magnitude of the event [3,5].

As mentioned before, the determination of vulnerability is complex and depends on the territory and the time frame [6]. Indeed, vulnerability is a construct that can be split into the following dimensions [4,25]:

- Social and population dimension: This includes aspects such as social differences and social organization. Variables related to this dimension are poverty, social marginalization, demographics, and education.
- Economic dimension: This includes variables such as per capita income, GDP, poverty, and property.
- Environmental and territorial dimension: This contains meteorological variables such as temperature, humidity, and wind velocity; where territory is involved, variables such as ranches, rustic hectares, and infrastructures are included.

Groups with a higher socio-economic vulnerability tend to be located in more dangerous areas and are more exposed to hazardous events and greater damage [26,27]. In

effect, these less favored groups are overrepresented in the rural areas and peri-urban deprived areas that surround the main towns and cities. Rural areas are usually affected by deprivation, principally due to decreasing employment in the primary sector and the subsequent reduction in farm density and livestock [28]. For its part, urban development in forested areas aggravates the risk of wildfire as the wildland–urban interface areas (WUI) increase the wildfire risk and threat to the surrounding population [29].

In disaster management, it is important to minimize the risk of a disaster event; in fact, a local governments' ability to improve prevention is as important as their focus on extinguishing measures [19]. For this reason, it is necessary to identify the factors that could play an important role in prevention and mitigation [15,30–32]. However, there is a lack of integration between social and biophysical systems in community wildfires-protection planning and very few studies describe how prevention could be improved considering the analysis of social and biophysical factors together [7,19,24,33].

Additionally, wildfire studies are dissimilar in the timelines, so there is a great difference in the analytical approach used to investigate pre- and post-fire situations. Both circumstances are closely connected, and the study of socio-economic characteristics related to social vulnerability and climatological variables is equally important [34]. The pre-fire situation, which is determined by socio-economic variables, specifically the ones related to social vulnerability, affects the wildfires' ignitions and behavior (hectares burned and ratio hectares burned/ignitions). The post-fire situation shows the impact of wildfires on the socio-economic variables in a particular area [18]. In other words, when analyzing pre-fire situations, socio-economic variables are the independent variables, while when analyzing post-fire situations, the characteristics of the fire become the explanatory variables.

As mentioned earlier, of the 17 Spanish regions, Galicia is the one most affected by wildfires [14,21,25]; therefore, it is necessary to delve into the effect of socio-economic variables related to social vulnerability on the wildfires' characteristics in Galicia. These effects need to be studied together with the meteorological variables as possible drivers for the risk of origin of wildfires [16].

Although in wildfire research the number of fire ignitions is commonly used as an essential variable, recent studies [35–37] have progressively highlighted the importance of also knowing the other characteristics of fires such as their extension and the ratio of hectares burned/number of wildfires. Some authors [37,38] have used statistical and econometric models (panel data and predictive models) to demonstrate the fire frequency and extension originated by socio-economic variables related to social vulnerability.

Thus, the objective of this research was to study the effects of the socio-economic variables related to social vulnerability over the characteristics of wildfires in Galicia. Specifically, we considered the pre-fire socio-economic characteristics to establish their effect on the ignition, extension (hectares burned), and ratio hectares burned/ignitions of wildfires. For this purpose, we used panel data methods for data spanning 15 years (2001–2015). The identification of these variables and the knowledge of their effect on wildfire characteristics could be used to ultimately improve wildfire prevention, mitigation, and management [30].

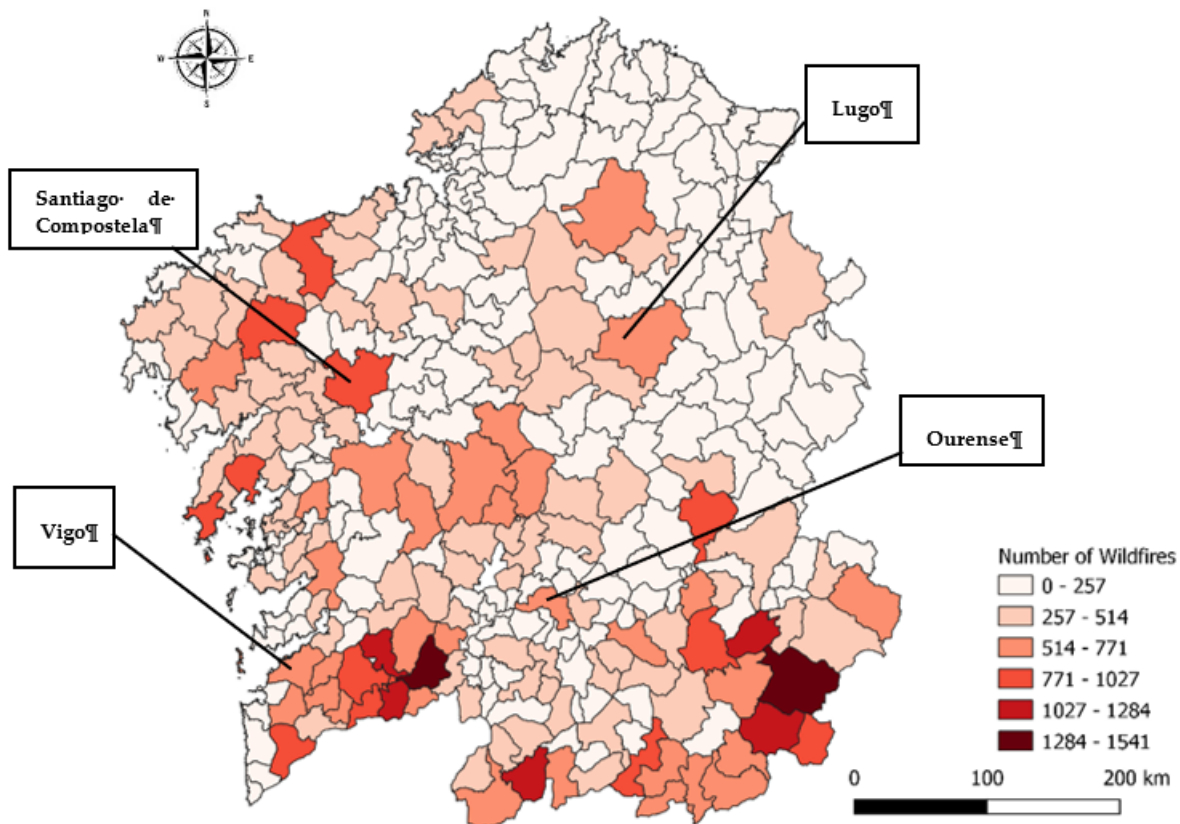
## 2. Materials and Methods

### 2.1. Study Area

Spain is one of the European countries most affected by forest fires. Every year, large areas of forest are burned. Although wildfires in this country are considered natural disasters because they involve forests [39], most of the ignitions (around 96%) are of anthropogenic origin [40].

So far in the 21st century, the Autonomous Community of Galicia (north-west of the country) is the Spanish region with the highest number of forest fires [11,14]. According to different studies [14,20,41], wildfires are directly related to social and economic factors

mixed with environmental factors. Figure 1 shows the number of wildfires in Galician municipalities within the first 15 years of the 21st century.



**Figure 1.** Number of wildfires in Galician municipalities within the first 15 years of the 21st century.

Galicia has 2,060,453 hectares of forest that cover 69% of the area of the region, 31% of which are non-forestry areas between scrubs and pasture. The forest produces, in most years, about 50% of Spain's timber and about 4.5% of the European Union's timber. Forest territories are divided chiefly among small owners, agricultural use, and a mixture of farmed and forested lands. Additionally, over the past 40 years, there has been an abandonment of rural activities due to a decrease in the rural population and the resultant thinning of population density [42].

Over 96.6% of forestlands in Galicia are privately owned. According to Rodriguez and Marey [43], approximately 700,000 individual proprietors manage 63.7% of these forestlands. Of these forest-land owners, 29.8% are farmers and 19.5% are woodland producers. This is a fire-prone region, and abundant literature points at an anthropogenic origin for the majority of fires [8,11,14,40].

The vast majority of scholars describe Galicia as one of the most deprived regions in Spain. This deprivation is marked by an aging population, abandonment of rural activities, lack of job opportunities in its rural areas, migration of young people to urban areas, significant reduction of the forestry sector, and an increasing social vulnerability of the population that remains in the region [13,21]. All these macro-level characteristics can be translated to the micro-level as they match the description of the typical fire-starter in Galicia: a low-income, low-educated, ailing elderly man, frequently a farmer and land-owner in the wildfire location. Furthermore, this character usually lacks environmental consciousness and does not feel the wildfires are a risk as the forest has no value for them [44].

Defining the social and ecological reasons for wildfires is of paramount importance in developing a realistic and comprehensive framework for estimating the risk of a forest

fire, its reduction, and prevention [23,30,45,46]. Nevertheless, it must be pointed out that there is no detailed information nor data available about prescribed fire management in this area. In addition, the definition of a natural disaster does not talk about the duration, intensity, and frequency; even an isolated event with less than 1 Ha burned is considered in the official fire statistics.

## 2.2. Source of Data and Data Analysis

Panel data models are used when there are repeated observations of a sample of individual units over time. It can be said that for a variable “Yit,” there are ... N individuals observed along  $t = 1 \dots T$  periods [47]. This technique is not often used in wildfire research. However, some authors have already demonstrated it as a useful tool for risk analysis [32,38,48].

Panel data were used with the intent to explain the effect of the socio-economic variables related to social vulnerability on the characteristics of wildfires that took place over 15 years in Galician municipalities (314 in total). To capture the dynamics of forest fires, a balanced panel dataset for the 314 municipalities was produced for the 2001–2015 period. The municipalities were chosen as the observational unit since they are the smallest entity of information on forest fires. In addition, municipalities are the smallest territorial division for which accurate and consistent socio-economic information related to social vulnerability is available. We also selected updated data covering the period 2001–2015. These data are compiled every five years by the Ministry of Agriculture, Fisheries, and Food ([https://www.miteco.gob.es/es/biodiversidad/estadisticas/Incendios\\_default.aspx](https://www.miteco.gob.es/es/biodiversidad/estadisticas/Incendios_default.aspx)) and are the most accurate and comprehensive statistical data on wildfires. A decision was taken to extend the research timeframe beyond those used in previous studies. Different and shorter time spectrums were used in past studies: 2001–2006 used by Barreal et al. [21], 2001–2009 used by Barreal et al. [21], 2006 used by Balsa and Hermosilla [20], and 2001–2010 used by Loureiro and Barreal [14].

The dataset includes three dependent variables—number of wildfires (N° WF), hectares burned (HaBur), and ratio of hectares burned/number of wildfires (Ha/I) (the most commonly analyzed dependent variables in wildfire research [18])—and 16 explanatory variables (Table 1). These panel data allow for the visualization of statistics for every municipality for each year and the information allows us to observe changes over time [49,50].

**Table 1.** Variables selected for the models.

Dimension	Explanatory Variables	
Social and Population [14,20,43]	Population > 64 *	Population > 64 years
	Density *	N° of people divided by Has
	I.active * (active population)	Population between 40 and 64 divided by population between 15 and 39
	I.Replacement * (replacement index)	Population between 60 and 64 divided by population between 15 and 19
	P.Foreign * (percentage of foreigners)	Foreign population divided by total population
Economic [6,51]	Livestock *	Cattle heads per municipality
	IncCap *	Gross income per inhabitant
	DebtHab * (debt per inhabitant)	The debt of the town councils' divided by the number of inhabitants in each municipality
	GDP *	Gross domestic product
Meteorological [41]	TSum	Average summer temperature
	HuSum	Average summer humidity
	WiSum	Average summer wind velocity

Territorial [33]	ParcelVal * (parcel value)	Plots in thousands of Euros divided by people registered in the Real Estate Cadastre
	DisCenter * (buildings and dwellings)	Buildings and dwellings of a singular entity divided by set of towns with less than ten buildings, which form streets, squares, or other urban roads
	RusticHa * (rustic hectares)	Rustic Has per municipality
	Ranch *	Livestock farms per municipality

\* Logarithms were used to normalize these variables.

It must be pointed out that the factors that mostly influence the ratio of hectares burned/number of wildfires have to do with particular types of vegetation and soil characteristics [36,52]. As this article is focused on socio-economic factors and not on a particular fire behavior, these vegetation- and soil-related variables were excluded from the model, though we included land use variables among the independent variables, as explained in the literature review section [4,25].

The socio-economic explanatory variables related to social vulnerability were extracted from the analyzed literature about wildfires in Galicia [14,20,21]; they were also selected depending on their availability in statistical sources for the observational unit selected (municipalities). Socio-economic variables included the population over 64 years of age, density, active population, replacement index, and percentage of foreigners representing the population dimensions of social vulnerability [14,20,43]. Economic variables related to social vulnerability were also used, such as livestock, income per capita, debt per inhabitant, and GDP [6,51]. The territorial dimension of vulnerability is also important in wildfires; therefore, variables such as parcel value, buildings and dwellings, rustic hectares, and ranches were selected [34]. Finally, meteorological variables were added to the dataset, as these are common, important drivers for wildfire characteristics [41].

The first step was to gather the data available using different information sources and databases—IGE (Galician Institute of Statistics) and INE (National Institute of Statistics)—and variables of different types and formats. To ensure uniformity, completeness, and accuracy of the available data, a process of screening and quality assurance was conducted. Every variable added to the database was carefully substantiated by the literature and subject to a standardization process of units and meanings, codified, and re-codified, if considered necessary. First, we divided certain variables by the total population or the total Ha of the municipality; second, we used logarithms to normalize those variables that showed higher variation ranges, non-linear behaviors, or skewed right distribution (specifically, logarithms were used for the following variables: population > 64, density, I.Active, P.Foreign, ParcelVal, DiCenter, RusticHa, Ranch, Livestock, DebtHab, and GDP, as shown in Table 1).

In addition, robust standard deviations [53] were used to solve the heteroscedasticity problems (ordinary least squares estimators are not optimized) and to allow for a correct inference on the  $\beta$  calculation. It is also important to mention that the principal limitation of this research is related to the available data. We tried and failed to obtain information about wildfire prevention funds in the Galician municipalities. The authors repeatedly (and unsuccessfully) attempted to contact regional and municipal authorities. It would also have been useful to obtain information about the sources of wildfires, because the official reports do not include accurate evidence on these issues, or simply do not provide this information at all.

Panel data are useful when there is evidence that the dependent variable is influenced by non-observable independent variables that are correlated with the observed independent variables. If these non-observable independent variables are constant over time, the real effect on the selected fire variables can be determined [54]. The panel data model is represented as follows [49,50,55]:

$$y_{it} = \alpha + x_{it}\beta + u_{it} \quad i = 1, \dots, N; t = 1, \dots, T$$

$i$  subscripts denote the independent variables (cross-section dimension) and  $t$  subscripts denote the time-series dimension (years).

$y$  represents the dependent variables: the number of wildfires, hectares burned, and intensity (hectares burned/number of wildfires). Therefore, the three models are run.

$x$  is the  $i$ th observation on  $K$  explanatory variables.

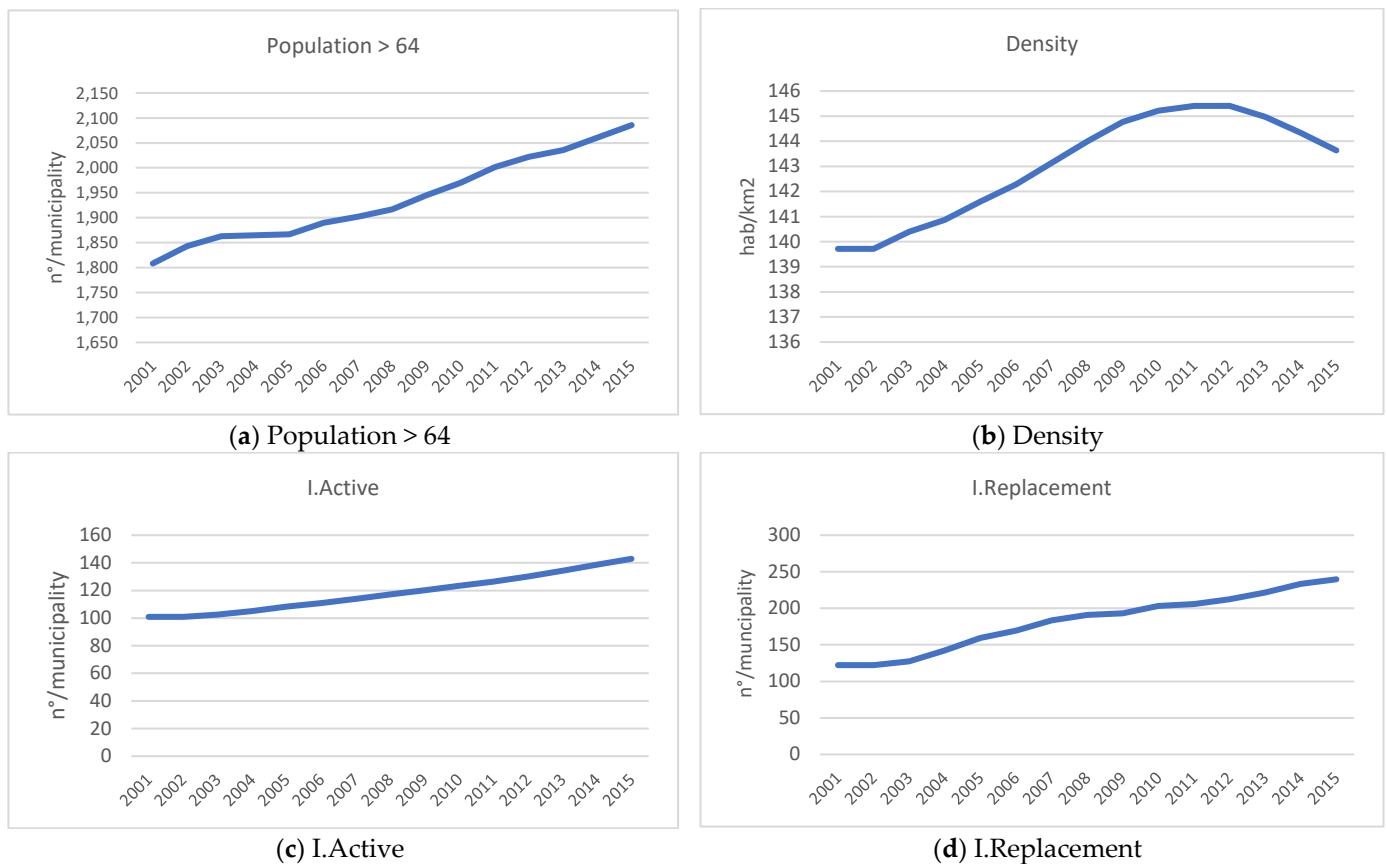
$u$  denotes the unobservable individual-specific effect.

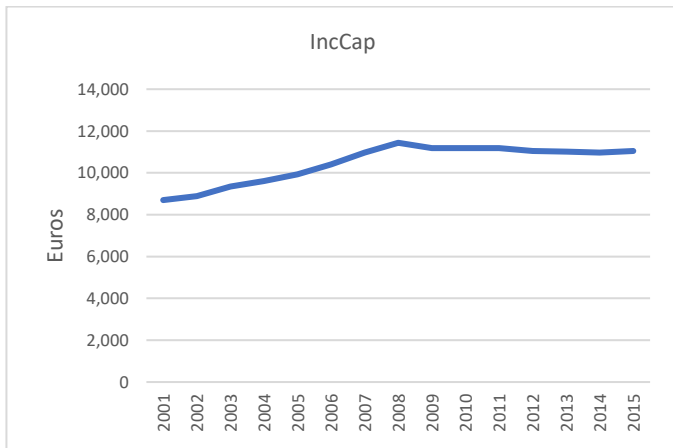
$\alpha$  is a scalar and  $\beta$  is the variable coefficient.

The software STATA.16 was used to run the three-panel data models, establishing the data as cross-sections of individuals observed over time. We selected this software as it is the most suitable for panel-data methodology. Panel data models turn out to be very useful when applied to long time-periods and enable examination of changes over time [49]. The models were run for three different dependent variables, namely, number of wildfires ( $N^\circ$  WF), hectares burned (HaBur), and hectares burned/number of wildfires (Ha/I).

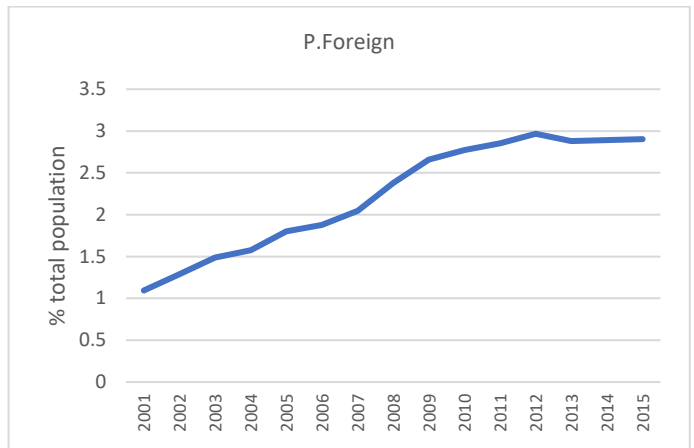
### 3. Results

The 16 selected independent variables were the ones most commonly used in scientific articles related to wildfires in Galicia, provided they were available in the municipality information [14,20,21]. Figure 2 shows the evolution of these independent variables over time. This figure represents the aggregated average annual values of all municipalities for each variable.

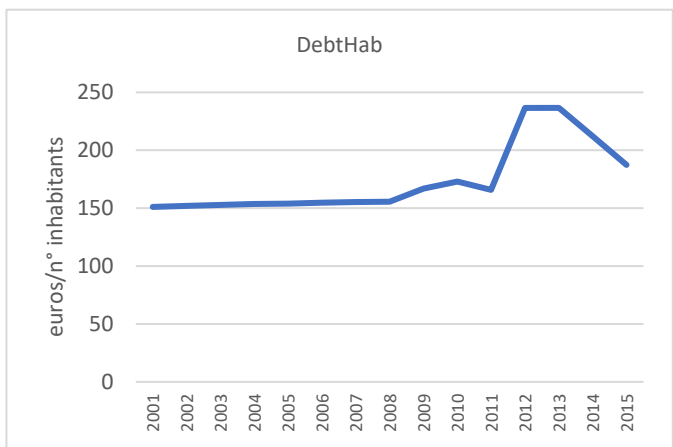




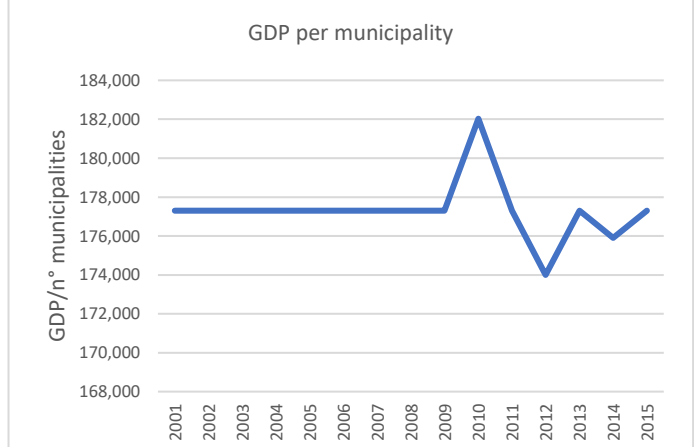
(e) IncCap



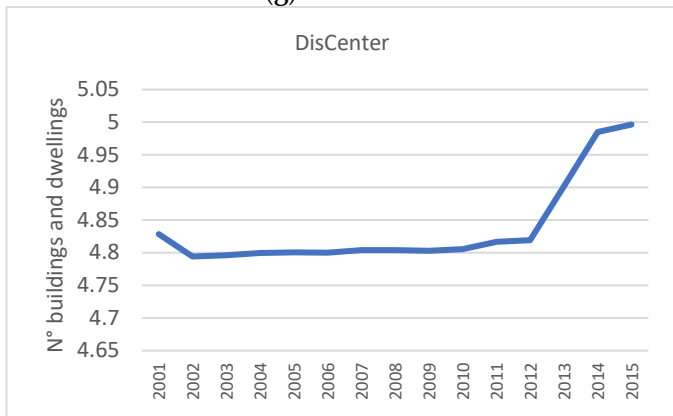
(f) P.Foreign



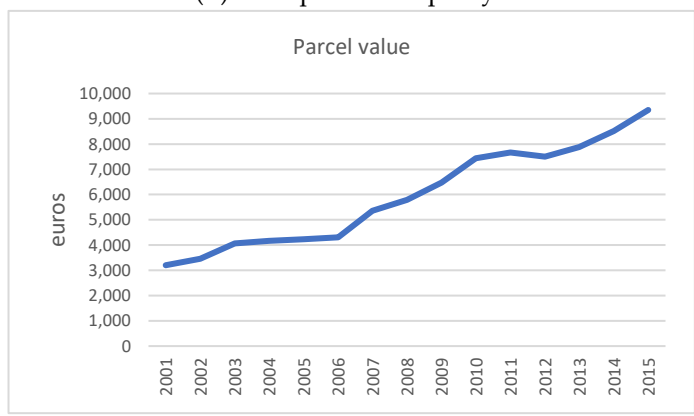
(g) DebtHab



(h) GDP per municipality



(i) DisCenter



(j) Parcel value





**Figure 2.** Time evolution of the variables selected between 2001 and 2015 in the Galicia region. **Source:** IGE (Galician Institute of Statistics).

The insights to be gleaned from Figure 2 are that some variables are mutually and indirectly related, such as ranches and livestock. During the 15 years under consideration, while ranches significantly decreased in number, the average number of livestock increased (though not significantly), indicating a more intensive livestock farming [55]. In the case of the population in the 64-and-older group, the 15-year increase pattern is similar

to that of the Spanish trend during the past decade, but according to the time series analysis, it is not significant [52]. The growing value of density is consistent with the increasing urban population, while rural areas show diminishing density. However, this value is not significant over time [28]. There are other variables, such as the percentage of foreigners, buildings, and dwellings or the meteorological variables (summer temperature, summer humidity, and summer wind velocity), whose evolution over time is not remarkable but that emerge as significant in the time series analysis. Therefore, these small changes turn out to be useful in panel data analysis where the models compare every municipality every year, so the former variation is usually bigger [55,56].

The results of the multivariate models are shown in Table 2. These models show the effect ( $\beta$ ) of the 16 selected variables on the characteristics of wildfire (number of wildfires (N° WF)), hectares burned (HaBur), and hectares burned/ignitions (Ha/I). In the case of the number of wildfires, we chose a fixed-effect model, but for the two other variables (hectares burned and hectares burned/ignitions), random-effects models were selected. The decision to use fixed effects was based on the contrast of Hausmann [49], which demonstrated that fixed effects, in this case, are better than random effects. Fixed effect panel data models identify the effects of explanatory variables based on within-municipality variation, while random panel data models assume that the overall effect of omitted variables is randomly distributed over time and municipalities and is therefore uncorrelated with other explanatory variables [57].

**Table 2.** Models. N° WF: Number of wildfires (using fixed effects). Ha Bur: Hectares burned and Ha/I:Hectares burned/Ignitions (using random effects).

Variables	Description of Variables	N° WF ( $\beta$ )	HaBur ( $\beta$ )	Ha/I ( $\beta$ )
const		324.70	463.38	24.43
LnPopulation > 64	-Population > 64 years	9.184	34.38 *	-0.06
LnDensity	-N° of people/Has Population between 40 and 64/population between 15 and 39	-13.95	-70.15 ***	-2.34 ***
LnI.Active	Population between 60 and 64/population between 15 and 19	-43.07 ***	-137.35 ***	-7.52 **
I.Replacement	Foreign population/total	-0.013	-0.12 **	0.00
LnP.Foreign	Plots in thousands of Euros/people registered in the Real Estate Cadastre	-1.12	-2.60	-1.14 **
LnParcelVal	Buildings and dwellings of a singular entity/set of towns with less than ten buildings, which form streets, squares,	-1.90	-25.47 ***	-0.01
LnDisCenter		-0.99	-17.40 ***	-0.38 **

	or other urban roads			
LnRusticHa	Rustic Has per municipality	−5.28 ***	15.03 *	1.06 **
LnRanch	Livestock farms per municipality	8.84 ***	4.30	−0.15
LnLivestock	Cattle heads per municipality	−2.80 **	−10.86 *	−1.12 **
IncCap	Gross income per habitantinhabitant	−3.25	−2.87	0.10
LnDebtHab	The debt of the town councils/habitantinhabitants of each municipality	0.08	−1.84	−0.06
LnGDP	Gross domestic product	−3.86	8.08	0.62
T°Sum	Average summer temperature	−0.22 ***	4.92 ***	0.21 ***
HuSum	Average summer humidity	−0.14 ***	0.93 ***	0.07 ***
WiSum	Average summer wind velocity	0.36 **	−1.26	0.29

\*\*\*: significant at 1%, \*\*: significant at 5%, \*: significant at 10%.

The results demonstrate this effect and also illustrate the importance of meteorological variables, considering that wildfires are caused by human activity as well as by natural phenomena [7].

The wildfires in Galicia are mostly caused by human activity. Therefore, the effect of the selected variables that relate to social vulnerability (the variables that describe population characteristics in the pre-fire situation) is paramount in understanding the fire dynamics in this region. Those relevant variables are useful to possibly improve wildfire preventive actions [30,56,15]. The coefficients' ( $\beta$ ) sign shows direct or inverse relations with the dependent variables. Significant relations are highlighted with asterisks in Table 2. However, there are differences among the models.

In the case of the **number of wildfires (N° WF)**, all meteorological variables are significant, but the one that stands out is the inverse relationship between temperature ("T°Sum") and wildfires (which is direct for the other two dependent variables). In other words, if the temperature is lower, there are more wildfires. Insofar as forests are naturally prone to wildfires when the temperature rises [10,58], in this case, the explanation may rely on the high percentage of intentional wildfires in Galicia: more than 84% of wildfires in this region is deliberately started, compared to 33% for the rest of Spain [59].

Furthermore, the variables related to rural areas such as ranches and livestock are significant. Their effect is due to the management and control of bush and pasture. The direct effect of ranches has been proven in that if the stakeholders do not manage them, these areas tend to have bush and pasture [43]. This kind of vegetation is, specifically, more prone to wildfires [60–62]. Nevertheless, the effect of livestock is in inverse proportion because grazing on vegetation helps control wildfires [63]. Rustic hectares also cause the same issue.

Finally, the relationship between the size of the active population and the number of wildfires is inverse. In other words, when the younger population, which is the active population, diminishes (due to lowering employment in the primary sector), the number

of wildfires increases. Probably, this is due to two important factors: first, the disconnection of the young population from their natural surroundings so that their collaboration in mitigation and prevention efforts decreases, and second, the prevailing (land-burning) cultural behavior of the proportionately increasing aging population. [11,20].

When the dependent variable is **hectares burned (HaBur)**, the significant determinants are those related to the management of the territory (parcel value, buildings and dwellings, and rustic hectares) and the population of these areas (population aged 64 years or more, density, and the active population). The relation between these variables is connected to the abandonment of rural areas, which is reflected in the direct relationship with the population over 64 and the rustic hectares and the inverse relation with the rest of the variables [33,63,64]. In other words, lands are more prone to big wildfires because of a lack of management of forest areas [65]. This rural depopulation is a consequence of the lack of job opportunities in these regions [12]. The main reason for this is the industrial-scale market, which damages small-scale traditional agricultural businesses run by poor rural landowners [66].

In the case of **hectares burned/ignitions (Ha/I)**, the results are similar to those for hectares burned, although the foreign population is noteworthy. This may be because foreigners (mostly migrant people) have a lower economic capacity and therefore live in deprived places such as rural areas. In addition, these areas are populated largely by aged people, the proportion of the active population is low, and the overall density of population is low. As a result, the lands are not properly managed or are abandoned [67]. This leads to a situation of fuel increase, which results in a greater probability of high-intensity wildfires [40].

In summary, some socio-economic variables related to social vulnerability stand out among the three models that were run. Most of them are connected to the abandonment of the territory, which results in a lack of management of the lands. There are also some variables linked to the population, which point to the problem associated with the increasing proportion of elderly inhabitants in rural areas due to factors as a scarcity of job opportunities that cause the youth to leave the area. The variables related to social vulnerability form a complex situation in Galicia, the identification of the variables that are relevant to the occurrence of wildfire production will possibly help to improve wildfire prevention and mitigation measures.

#### 4. Discussion

This research has revealed the effect of the socio-economic variables related to social vulnerability on the characteristics of wildfires in Galicia, such as the number of wildfires, hectares burned, and fire intensity. As mentioned before, previous research on wildfires has not delved into socio-economic variables related to social vulnerability [18]. Therefore, knowledge of these key variables that affect the characteristics of wildfires could be used to improve wildfire prevention management and mitigation [30,45].

Together with other research [33,63,58], this paper demonstrates that the progressive abandonment of the rural areas is one of the most important factors that boosts wildfires. This abandonment is related to population factors (aging or low density), territorial factors (a decrease in rustic hectares and ranches), and economic factors (low GDP due to low cadastral value). In turn, all these factors, which are strongly related, contribute to people's social vulnerability [6].

Population variables, such as aging, low population density, and a decreasing population of young people, have become a problem in some areas of Galicia. Aging becomes particularly relevant in a contradictory way: On the one hand, some harmful traditional behaviors of the senior population (for example, scrub-burning) turn out to be closely related to the origin of wildfires [11,20]. On the other hand, traditional burning practices may tend to prevent catastrophic fires by burning off the fine fuels before they became dangerous; and it is often the older people who have the skills to burn in a safe and effective way [68–70].

The involvement of the aged people in raising awareness campaigns and prevention plans could be effective because, as they represent the majority of Galician landowners, they could participate both actively and directly in preventive measures to improve mitigation. Furthermore, the preservation of traditional burning in a more modern, regulated, and professional way might be implemented to decrease vulnerability [70].

Variables related to territory increase the challenges of fire management in areas with a scattered population. This is the case in Galicia where rural properties are mostly small-holdings, thus complicating fire control and control of wildfire ignitions [21]. Furthermore, the values of parcels are generally low, so the owners put little effort into minimizing the risk of wildfires. As indicated before, land management, particularly to control the accumulation of fuel, is critical to limit the impact of wildfires [38]. In addition, municipalities with higher GDP tend to have more individual houses; this means larger WUI extensions [71]. In this regard, fuel control and land management contribute to the improvement of management of these WUI areas and make them less prone to wildfires [29,59]. Additionally, it is crucial to maintain a balance between the number of ranches and livestock. Controlling bush and grasslands could have a positive effect on wildfire characteristics [55], but it also could have a negative effect because owners tend to burn forest areas to expand pasture areas [28].

Concerning the economic variables, the most relevant challenge in rural areas (in terms of reducing the impact of wildfires) is the necessity to improve the quality of life, the level of education, and income per capita [66]. These recommendations could sound naive or simple; however, the Galician reality leads to the adoption of these measures in the medium–long term. As explained in previous sections of this paper, the typical fire-starter in the region is a low-income, low-educated man, frequently a farmer and landowner in the wildfire location. Therefore, this socio-economic challenge could be met by improving land management through the reduction of rural abandonment [32]. Education becomes important as it opens more job opportunities in these rural areas. It is also relevant for adding to the value of the forest. This could be achieved through measures such as agroforestry and mosaic systems and investments in forest improvement, for example, mixing resinous and deciduous species, that efficiently reduce fire risk [60]. As already mentioned in the literature [58], if people can derive something valuable from the forest, they might be more inclined to protect it. Consequently, enhancing the quality of rural life in the affected areas would predictably and positively improve job opportunities and land management, cut rural abandonment, and reduce the incidence of forest fires.

Therefore, the best way to preserve the economic, social, and environmental characteristics of an area is to work on disaster prevention and mitigation [4]. Considering these socio-economic variables together might be useful for the improvement of wildfire prevention, mitigation, management, and policymakers' decision-making. In this vein, the Galician regional government is currently preparing a new law for defense against forest fires that will come into force in 2022. This regulation has been prepared following a participatory process that involved all the relevant actors in the wildfire prevention arena. The new law intends to define multilevel cooperation mechanisms and preventive actions for the territory to raise society's awareness; actively involve citizenship in the prevention and extinction of fires; enhance the economic structure of rural areas; guarantee the future of the region; and pay special attention to the professional and continuous training of the personnel, to dissemination of information and, especially, to investigation [72].

Indeed, preventive actions go beyond just emergency improvement. They are also related to the implementation of policies to improve social wellbeing in some areas. As pointed out above, to enhance prevention and mitigation it is important to focus, as a medium and long-term solution, on education, the spread of risk awareness, and participation of the population in the implementation of the policies [20,32].

## 5. Conclusions

The results of this study demonstrate the adverse effect of the aging population and the lack of young residents on the occurrence of wildfires. Therefore, it may be concluded that, concerning socio-economic variables, it is necessary to involve different social groups [33] and promote interactions among various sections of the population and age cohorts. Variables related to the territory are also important. Some of these variables are complex and comprise a duality that is at times difficult to measure. For example, livestock controls the fuel available in most of the territories, but sometimes the ranch owners burn forest areas intentionally to expand the pasture. Finally, raising a population's awareness on the value of the forest and on land management becomes paramount.

It is necessary to increase public spending on the prevention and mitigation of wildfires and to develop anticipation strategies. This should be the priority in contrast with the more common practice of prioritizing emergency actions [66]. Climatic, environmental, and natural variables are not the only important issues. To reduce the risk of a disaster, the focus should be put on those aspects from which such disasters arise. Prevention and mitigation might be focused on wildfire-prone areas and take into account their vulnerability-related, socio-economic variables, which, as has been demonstrated in this paper, influence wildfire characteristics.

## 6. Limitations and Future Research

This article has revealed some relevant issues related to people's attitudes about fire, raising questions such as why landowners do not believe in the intrinsic value of the forest, or what their understanding is of how wildfire affects communities.

These questions are of paramount importance and frequently appear in the media [73]. Regrettably, no statistical sources provide information about attitudinal variables. Therefore, the most effective way of solving this unknown is to use a qualitative approach. The research team that conducted this study were not able to obtain qualitative information (or at least not all the information that would have been necessary to extract significant conclusions). In any case, these results help us demonstrate the importance of this approach when the subjects of study are wildfires and their relationship with the population.

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