

# FOREST FIRES AS A PUBLIC HEALTH CHALLENGE IN CHILE: THE CASE OF THE BIOBÍO REGION

VALERIA SCAPINI<sup>1,2</sup>, MARTÍN DEL BARRIO<sup>2</sup> & ALFREDO PIZÁ<sup>2</sup>

<sup>1</sup>Universidad Central de Chile, Santiago, Chile

<sup>2</sup>Universidad de Valparaíso, Santiago, Chile

## ABSTRACT

Forest fires generate a series of negative consequences for people's health and represent a growing threat to public health, with their increasing frequency and intensity due to climate change. In this sense, the case of central Chile is particularly interesting as it has a temperate climate characterized by hot and dry summers and has a high vulnerability to climate change. This paper assesses the association between the occurrence of forest fires and the number of emergency room visits for respiratory symptoms in primary care centres in the Biobío region. We focus on the Biobío region because it has been the most affected region in the last 30 years. An empirical study was carried out using data on forest fires provided by the National Forestry Corporation (CONAF), meteorological information on temperature and precipitation obtained from the Meteorological Directorate of Chile, and respiratory emergency data provided by the Ministry of Health for the period between 2010 and 2020. A regression model using ordinary least squares was developed to determine the effect of a forest fire on the number of admissions to emergency care visits for respiratory symptoms to public health centres, and we use meteorological control variables. The results were statistically significant and indicate that, on average, there was a 33% increase in the number of cases for respiratory symptoms in health centres located in areas exposed to forest fires. These results may be useful for the implementation of public health policies.

*Keywords: forest fires, public health, respiratory diseases, climate change.*

## 1 INTRODUCTION

Forest fires constitute a growing challenge worldwide as they generate a series of negative environmental, social, and economic consequences [1]. According to the Centre for Research on the Epidemiology of Disasters CRED and the United Nations Office for Disaster Risk Reduction, the frequency and intensity of forest fires are increasing due to climate change and current drought conditions that have heightened propagation conditions [2], [3]. This is because wildfires emit greenhouse gases that contribute to the rise in the planet's average temperature, consequently leading to extreme climatic events that increase the risk and severity of fires. Globally, the year 2019 was responsible for emitting 7.8 billion tons of CO<sub>2</sub>, representing more than a fifth of emissions from the burning of fossil fuels. In this sense, forest fires and climate change form a vicious circle that affects the planet and its inhabitants [4], [5].

The case of Chile is interesting to study for several reasons. Firstly, its Mediterranean or temperate climate is characterized by dry and hot summers, with rainfall mainly concentrated in the winter months [6]. Secondly, the country exhibits high vulnerability to climate change, meeting seven out of the nine established vulnerability criteria [7]. Subsequently, the terrain of the affected areas is marked by abundant hills and valleys, facilitating fire expansion and complicating control efforts. Additionally, human-introduced invasive plant species in the central and southern regions of the country, such as the insigne or radiata pine and eucalyptus, further contribute to the challenges [8].

In the last decade, an average of about 6,000 wildfires occurred annually in the country, mainly concentrated in the central regions. Between 1984 and 2020, the Biobío region has



been the most affected, with a total affected area reaching 609,197 hectares [9]. Over the past decades, the country has experienced some of the world's most devastating fires: the 2017 fire affected just over 3% of the country's forested area, surpassing the average of 0.5%, totalling 86,000 hectares. The 2019 fire, where 65,000 hectares burned, led to the declaration of a state of emergency in three regions of the country [4].

Forest fires have the potential to wreak havoc on human health, as exposure to smoke and fine particles suspended in the air during these events can trigger a variety of acute respiratory problems [10]–[12]. According to the World Health Organization (WHO), between 1998 and 2017, more than 6 million individuals were affected by wildfires and volcanic activities, resulting in 2,400 deaths due to suffocation, injuries, and burns [13]. Some studies indicate that urban fires also pose a significant risk to public health [14], [15].

In this context, the impact of wildfire smoke on people's health is becoming increasingly important due to the growing threat it poses. Thus, this study assesses the association between the occurrence of forest fires and the number of emergency room visits for respiratory symptoms in primary care centres in the Biobío region from January 2010 to March 2021. This issue is relevant to study due to its potential contribution to the analysis, management, and formulation of public policies.

The rest of the paper is organized as follows: Section 2 presents a literature review, Section 3 provides details on the methodology and data used, Section 4 contains the results, Section 5 covers the discussion, and the conclusion is presented in Section 6.

## 2 LITERATURE REVIEW

The health of individuals depends on a series of endogenous and exogenous variables. Among them, extreme temperatures stand out as a significant health risk factor, with increased mortality associated with low temperatures being the most investigated aspect [16]. On the other hand, according to the WHO, air quality is one of the main environmental factors considered harmful to health. In 2019, 99% of the global population lived in areas where World Health Organization Air Quality Guidelines were not met. Therefore, reducing levels of air pollution can decrease the morbidity of various diseases, including strokes, heart diseases, lung cancer, and chronic and acute respiratory conditions [17].

Forest fires generate diverse primary pollutants, including particulate matter, carbon monoxide, nitrogen oxides, and volatile organic compounds. Additionally, they contribute to the formation of secondary pollutants such as ozone [18]–[20]. Currently, they pose a global public health challenge due to the effects of these pollutants on human health, impacting vulnerable communities and individuals particularly sensitive to the harmful effects of smoke exposure [21]. In this context, we can mention the study of the forest fires that affected southern California in 2007 [22], which led to an increase in emergency room visits due to the rise in air pollution during the fire period. The study recommends that individuals with respiratory diseases avoid exposure to pollutants generated by these events and advocates for expanding respiratory services' capacity in future similar catastrophes if necessary. Finally, the study emphasizes the need to develop specific policies and procedures for managing the impact of the increased number of emergency room visits due to respiratory diseases caused by forest fires.

Among the most harmful pollutants is fine particulate matter, with a diameter less than 2.5  $\mu\text{m}$  (PM<sub>2.5</sub>), which comes, among other sources, from forest fire smoke. Most studies highlight the effect of exposure to these fine particulate matter particles on respiratory and cardiovascular diseases [23]–[27]. Results include the association between PM<sub>2.5</sub> particles and respiratory problems such as asthma and chronic obstructive pulmonary disease (COPD) during fire periods. This could be attributed to PM<sub>2.5</sub> levels exceeding the 24-hour National

Ambient Air Quality Standard (NAAQS) of  $35 \mu\text{g}/\text{m}^3$ , reaching levels up to six times higher than the established limit during fire periods [26].

Recent studies have used statistical methods to differentiate the adverse effects on human health of PM<sub>2.5</sub> from forest fires compared to those from other pollutant sources. The results indicate that PM<sub>2.5</sub> associated with forest fires could affect respiratory health up to ten times more than emissions of PM<sub>2.5</sub> from other pollutant sources [28]. Another study in the same line, focusing on older individuals in the western U.S., found that the risk of respiratory problems increased by 7% on smoky days with elevated concentrations of PM<sub>2.5</sub> compared to smoke-free days [29].

### 3 METHODOLOGY

#### 3.1 Data

The study utilized three independent data sources covering the period from 2010 to 2020. Firstly, data on visits for respiratory diseases to public health centres were obtained from the Department of Statistics and Health Information (DEIS) belonging to the Ministry of Health (MINSAL). Secondly, meteorological data from the Chilean Meteorological Directorate (MeteoChile) were used to create a panel of data with temperature ( $^{\circ}\text{C}$ ), humidity (%), and rainfall (mm). Subsequently, with the fire data provided by the National Forestry Corporation (CONAF) during the studied period, a dummy variable ‘Fire’ was constructed to identify the statistical commune and weeks where forest fires were recorded. The merging of the aforementioned databases allowed the formation of a data panel containing 20,658 records from the Biobío region, covering three provinces and a total of 33 communes, spanning the years 2010 to 2021. The analysis was conducted at the level of commune and statistical week.

Next, in Table 1, we can observe the quantity of registered fires in the region for each season, and in Table 2 the number of weeks with registered fires in each commune of the region during the studied period.

Table 1: Number of forest fires by season. (*Source: Authors’ compilation based on CONAF.*)

Season	Number of forest fires
2011–2012	2517
2012–2013	4818
2013–2014	2861
2014–2015	3667
2015–2016	2692
2016–2017	1951
2017–2018	2116
2018–2019	2660
2019–2020	2790
2020–2021	2409



Table 2: Number of weeks with forest fires per municipality during the study period.  
(Source: Authors' compilation based on CONAF.)

Municipality	Number of weeks with forest fires
Alto Biobío	55
Antuco	25
Arauco	266
Cabrero	232
Cañete	275
Chiguayante	93
Concepción	182
Contulmo	177
Coronel	257
Curanilahue	330
Florida	230
Hualpén	45
Hualqui	222
Laja	179
Lebu	299
Los Álamos	276
Los Ángeles	299
Lota	275
Mulchén	248
Nacimiento	175
Negrete	150
Penco	242
Quilaco	69
Quilleco	161
San Pedro de la Paz	206
San Rosendo	103
Santa Bárbara	106
Santa Juana	174
Talcahuano	182
Tirúa	240
Tome	330
Tucapel	143
Yumbel	220

### 3.2 Statistical model

In this section, the statistical model in its functional form is presented, which was used to study the association between forest fires and visits due to respiratory causes in health centres in the Biobío region (eqn (1)).

$$y_{it} = f(T_{it}, R_{it}, D_{it}) \quad (1)$$

where:



$y_{it}$  represents the number of emergency care visits for respiratory diseases observed in municipality  $i$  during week  $t$ , with this variable processed in logarithm;

$T_{it}$  represents the average ambient temperature ( $^{\circ}\text{C}$ ) in municipality  $i$  during week  $t$ ;

$R_{it}$  corresponds to the total rainfall (mm) in municipality  $i$  during week  $t$ ;

$D_{it}$  is a dummy variable that takes the value 1 if there was a registered fire in municipality  $i$  in week  $t$ , and 0 otherwise.

The estimated model corresponds to the specification of eqn (2), which represents a fixed-effects model. This model identifies each of the statistical weeks in each year and the provinces of the region, allowing for the control of seasonality in the variable under study, as well as other variations occurring over time and space. Among the considered assumptions, we can mention the constant variance presented in eqn (3) and the mean of the error equal to 0 stated in eqn (4). The parameter estimation was conducted using the ordinary least squares (OLS) method.

$$\log(y_{it}) = \beta_{it} + \beta_1 \times T_{it} + \beta_2 \times R_{it} + \beta_3 D_{it} + \varepsilon_{it} \quad (2)$$

$$\text{Var}(\varepsilon_{it} | X_{it}) = \sigma^2 \quad (3)$$

$$\varepsilon_{it} \sim N(0, \sigma^2); \text{Cov}(\varepsilon_{it}, \varepsilon_{js}) = 0; i \neq j; t \neq s \quad (4)$$

The proposed model considers the dependent variable (the number of emergency care  $y_{it}$  for respiratory reasons observed in municipality  $i$  in week  $t$ ) as a function of meteorological variables such as temperature and precipitation, as well as the presence of forest fires. RESULTS

Our first estimated model considers the number of visits to health centres for respiratory issues as the dependent variable. The explanatory variables include meteorological factors such as temperature and precipitation, along with our variable of interest, 'D<sub>it</sub>' indicating the occurrence of a forest fire in the municipality during the statistical week. Our second model builds upon the previous one by incorporating fixed effects for both time and space. Subsequently, the third estimated model considers the dependent variable in logarithm, and finally, our fourth estimation adds fixed effects of time and space to the previous estimation. Table 3 displays the results obtained from the four previous estimations. Column (1) presents the results of the first estimation, where the presence of fires is shown to be associated with a higher number of respiratory care visits in public health centres in the region. This relationship is positive and significant at the 5% level. Similarly, it is observed that the average temperature is negatively and significantly related to our variable of interest, while precipitation is positively and significantly associated with visits to health centres.

Column (2) displays the results of our second estimation, revealing a positive and significant impact at the 1% level of fires on respiratory visits in the region. On the other hand, the average temperature significantly and negatively influences visits at the 1% level. Precipitation shows a positive relationship but lacks statistical significance. The inclusion of statistical weeks and provinces as control variables leads to a better fit in the estimated model result, achieving an  $R^2 = 0.1763$  compared to  $R^2 = 0.10196$  without the control variables.

Column (3) displays the results of the third estimation. Similar to the previous findings, we observe a positive and significant relationship at the 1% level between the occurrence of fires and the number of respiratory care visits in public health centres in the region. Average temperature and precipitation are significant at the 1% level and, consistent with previous results, are negatively and positively related to our variable of interest.



Table 3: Estimated parameters.

Variable	(1)	(2)	(3)	(4)
Temperature	-19.2743***	-11.1784***	-0.0357699***	-0.0696465***
	(1.281916)	(3.279362)	(0.0041845)	(0.0103581)
Rainfall	0.3142832**	0.2087859	0.0017506***	0.00196**
	(0.159575)	(0.260433)	(0.0005203)	(0.0008209)
Dummy (forest fire)	21.31789**	103.9617***	0.142837***	0.3316128***
	(9.697416)	(10.55712)	(0.0316304)	(0.0332771)
$R^2$	0.0196	0.1763	0.0063	0.2201
Observations	16,938	16,938	16,921	16,921
FE time	No	Yes	No	Yes
FE province	No	Yes	No	Yes

Note: Robust standard errors in parentheses.

\* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%.

Column (4) presents the results of the fourth estimation. Similar to the previous findings, we observe a positive and significant relationship at the 1% level between the occurrence of fires and the number of respiratory care visits in public health centres in the region. Average temperature and precipitation are significant at the 1% level and, consistent with previous results, are negatively and positively related to our variable of interest. As in the previous models, the inclusion of space and time controls improves the fit of the estimated model, reaching an  $R^2 = 0.220$  compared to  $R^2 = 0.006$  without the control variables. Therefore, the model that exhibits the best fit is our fourth estimation, and thus, our preferred results belong to those in column (4).

## 5 DISCUSSION

Our study is situated within the context of climate change, where the release of greenhouse gases has triggered various events, including devastating forest fires [24]. The Biobío region has been the most affected in the country between the years 1984 and 2020, with a damaged area reaching 609,197 hectares. The central-southern zone of the country, with its climate prone to fires during dry and hot seasons, becomes a crucial scenario for studying the repercussions of these events [7].

In our study, we investigated the association between wildfires and the number of emergency care visits for respiratory conditions in the Biobío region. The results, based on municipal and weekly data collected from January 2010 to March 2021, reveal a significant association between the incidence of wildfires and an increase in visits to healthcare centres for respiratory issues.

These findings corroborate previous research that also highlights the association between exposure to wildfire smoke and various respiratory conditions, such as dyspnoea, asthma, chronic obstructive pulmonary disease (COPD), bronchitis, pneumonia, as well as the link between wildfires and respiratory mortality or morbidity [22], [25]–[27]. The consistency of our results with previous investigations strengthens the evidence that wildfires not only pose a direct threat to biodiversity and the landscape but also have a negative impact on the respiratory health of the population.

The association between wildfires and respiratory care visits underscores the need for preventive actions and healthcare adaptation strategies to reduce the population's exposure

to the harmful effects of smoke during wildfire seasons. This study contributes to raising awareness about the impacts of climate change and the importance of addressing these challenges comprehensively.

## 6 CONCLUSION

Our study provides evidence of the association between the occurrence of forest fires and a significant increase in the number of emergency care visits for respiratory diseases. These results are consistent with prior research that has demonstrated a direct relationship between exposure to wildfire smoke and various adverse respiratory conditions. The key conclusion of our study is that forest fires not only pose an immediate threat to biodiversity and the landscape but also have a significant impact on the health of the local population. This finding underscores the importance of addressing the intersection between extreme weather events and public health, particularly in fire-prone regions such as the central-southern zone of Chile.

The implications for public health are clear, and the implementation of specific preventive measures during critical seasons is suggested to reduce the population's exposure to the negative effects of smoke. This study emphasizes the importance of adopting effective adaptation strategies to address the challenges posed by climate change. In summary, our research contributes to the growing awareness of the complexity of climate change impacts, highlighting the urgency of taking local and global actions to address these interrelationships and safeguard the health of vulnerable communities.

As future work, we plan to specify the specific causes of respiratory diseases, including cardiovascular conditions, study the mortality associated with the occurrence of these events, and incorporate air pollution variables into the study. Finally, there is a proposal to expand the work to the central-southern sector of the country, which is the most affected by forest fires.

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