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Touza, Julia M. orcid.org/0000-0001-8170-1789, Chas-Amil, María Luisa and García-Martínez, Eduardo (2020) Iberian Peninsula October 2017 wildfires:Burned area and population exposure in Galicia (NW of Spain). International Journal of Disaster Risk Reduction. 101623. ISSN 2212-4209

https://doi.org/10.1016/j.ijdrr.2020.101623

Iberian Peninsula October 2017 wildfires: Burned area and population exposure in Galicia (NW of Spain)

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Abstract

In October 2017, an extreme wildfire outbreak in the NW of the Iberian Peninsula burned thousands of hectares, resulting in human deaths and important economic damage. This paper provides a first comprehensive assessment of the exposure of the local communities in the Spanish region of Galicia, where forestlands routinely experience fire outbreaks, as the one that occurred in 14th, 15th and 16th October with more than two hundred fire incidents. We delimitate the wildfire perimeters, characterize the area burned in regards to vegetation characteristics, evaluate the affected wildland-urban interface (WUI), and quantify the population and buildings exposed to wildfires. The burned area was found to be unevenly distributed, concentrated in the south of the region, and in municipalities with nearly half of their lands under WUI. This resulted in a high level of exposure in the affected lands. We estimated that 51 communities were inside fire perimeters. Moreover, 873 communities with more than 87,000 people residing on them, were at a close distance of less than 1km away. This study demonstrates the importance of understanding extreme wildfire events and their potential impacts which can guide how best communities can respond to them. The high number of population exposed to the studied event shows the necessity of integrating land-use planning with wildfire risk prevention and preparedness.

Keywords: wildfire perimeters, wildfire severity, wildfire exposure, wildland-urban interface, Galicia, Spain.

Introduction

The increase in the length of fire weather season due to climate change (Jolly et al. 2015), and other forest pressures such as urban expansion and unsustainable land uses (e.g., Modugno et al. 2016; Radeloff et al. 2018), make the continued increase in frequency and duration of extreme wildfire outbreaks inevitable (Calkin et al. 2014). These wildfire events impose large social and environmental costs, often accounted for, on the timber industry, carbon sequestration, air quality regulation, cultural values, physical and mental health and human losses (Moritz et al. 2014). In 2017, wildfires had devastating consequences worldwide (Bladon 2018; Gómez-González et al. 2018; Moreira and Pe'er 2018; McBride and Kent 2019). In the United States, more than 71,000 fires burned 4 million hectares and forced more than 200,000 residents to evacuate their homes; 66 people lost their lives (Balch et al. 2018); in the Austral Summer of 2017, Chile suffered the biggest wildfire episode in its history, with more than 500 thousand hectares of land burned, 11 people killed, and 3,000 houses lost (De la Barrera et al. 2018). In the European Union, wildfires burned over 1.2 million ha of natural land and killed 127 people (San-Miguel-Ayanz et al. 2017); Portugal being the most affected country with almost 550,000 ha burned, 500 houses destroyed and 112 fatalities registered mostly in two episodes taken place in June and October 2017 (Comissão Técnica Independente 2017, 2018).

Managing wildfire risk also poses important budgetary challenges to governments, with fire suppression costs rising in scale (e.g., Costafreda-Aumedes et al. 2015; Doerr and Santin 2016; Stocks and Martell 2016) due to weather and biomass conditions, but also, very importantly, to the growing presence of houses and population in fire-prone landscapes (e.g., Gebert et al. 2007; Gude et al. 2013; Strader 2018). In 2017, more than half of the U.S. Forest Service's annual budget was associated with fighting wildfires

(Balch et al. 2018), and even before the end of the year, the costs for wildfire suppression had exceeded US $2 billion (Bladon 2018). In Chile, public expenditure to combat fires was more than US $370 million (De la Barrera et al. 2018). Despite these large investments, wildfires can often overwhelm suppression capabilities, causing substantial structure loss and fatalities, especially in the case of extreme of weather conditions like those registered in all the wildfire events described above. Therefore, as the probability of fires and losses grow, so do the arguments for the need of curb these losses through developing policies, investments and community-based strategies to better prevent, prepare for and respond to wildfires (Moritz et al. 2014; Williams et al. 2018).

Recent research on wildfire risk exposure has been focused in defining and mapping Wildland-Urban Interface (WUI) (e.g., Radeloff et al. 2005; Lampin-Maillet et al. 2010; Johnston and Flanigan 2018), its expansion (e.g., Theobald and Rome 2007; Radeloff et al. 2018; Bento-Gonçalves and Vieira 2020), and its relationship to social vulnerability, i.e., the social factors that increases the human susceptibility to the impacts of fires in the WUI (Wigtil et al. 2016; Oliveira et al. 2018; Badia et al. 2019; Vaiciulyte et al. 2019). The focus seems to have been on characterization of the hazard at the WUI and the conditions that contribute to impacts and vulnerability. At the same time, numerous studies have looked at the need for community protection strategies (e.g., Cova et al 2009), where being exposed to fires has been identified as a key element for public support of actions for wildfire risk reduction (e.g., McGee et al. 2009). Therefore, understanding the extent and location of the population that were actually exposed (ex-post) is important for developing efficient reduction risk strategies by spatially targeting public investments and prioritization of community protection planning resources (Ager, et al. 2019; Fisher et al. 2016). In this work, we focus on identifying the location and number of people, land cover and density of buildings exposed to wildfires, or in close proximity. We extend previous research, which has inventoried population and housing within burned areas (e.g., Sarricolea et al., 2020; Argañaraz et al. 2017; Thomas and Butry 2014), by analyzing areas beyond the WUI, and focusing on an extreme wildfire event instead of using historical fires. This is justified by the the indispensable need to gather information to enhance the communities' preparedness to these type of fire outbreaks given their overwhelming capacity of control by firefighters (Tedim et al. 2018).

This paper focuses on the wildfires that occurred in the Iberian Peninsula in October 2017, contributing also to the scarce literature on this event, which has focused on Portuguese fires (Alexander et al. 2018). We investigate the case study of Galicia (north-west Spain, sharing a border with Portugal), where 393 fire incidents occurred in less than a week, of which 215 registered in just three days, 14th, 15th and 16th October (Parlamento de Galicia 2018). In this period, extreme fire meteorology - dry biomass and high temperatures - was aggravated by storm Ophelia, and a high rate of intentional ignitions (80%), with simultaneous fires starting at the same time (Parlamento de Galicia 2018). Moreover, there was a high incidence of large fires (>500 ha), registering 19 out of the 56 large fires that occurred in Spain in the whole year, and affecting nearly 40% of the total forest area burned by large fires that year (MAPAMA 2018). These events resulted in 4 people dead, 128 injured and 2,400 evacuated from their homes (Sampedro 2017). This wildfire episode has been widely covered by the media (Delgado-Arango and Vicente-Mariño 2019; Pérez Pereiro et al. 2018) and has resulted in intense public opinion and political debate (Parlamento de Galicia 2018). This has led to the provision of an extraordinary budgetary fund for wildfire recovery, which offers financial assistance to repair damage to infrastructure and properties, and to help farmers and ranchers to recover from production losses (Decree 102/2017, DOG 20 October 2017). However, there has not yet been detailed information published on the location and extent of the consequences of this event in the region. In this work, we (a) map and delimitate burned areas, estimating burn severity; (b) identify the wildland-urban interface (WUI) areas threatened, as well as the number of communities, people and buildings exposed for their proximity to wildfires; and c) define the types of land cover affected to identify the ecosystems that may suffer higher impacts.

Materials and methods

Estimation of burned area and burn severity

Sentinel 2A and its sensor MSI (Multi Spectral Instrument) were selected to identify and delimitate burned areas over other alternatives, like the Landsat 8 satellite and its sensor OLI (Operational Land Imager), because of the availability of images immediately before and after the wildfire wave, corresponding to 12th October and 27th October respectively. The best cloud-free Sentinel-2A Level-1C (L1C) MSI images were downloaded from the Sentinel's Scientific Data Hub (https://scihub.copernicus.eu/). Table 1 shows the pre-/post-fire images employed in this study. Images with more than 27% of cloud content were discarded to avoid distortions (Biday and Bhosle 2010). This limited the availability of suitable images only in the province of A Coruña, and affected only 10% of the studied area (Fig. 1). The atmospheric correction procedure was executed with a Sen2Cor processor, and complemented with the C-correction method (Hantson and Chuvieco 2011). The spatial resolution used in this study was 20 m.

The near-infrared (NIR) (B8a) and shortwave-infrared (SWIR) (B11) bands (e.g., Fernández-Manso et al. 2016) were used to calculate the Normalized Burn Ratio (NBR) as the difference between NIR and SWIR divided by their sum. The burn severity, as the degree of environmental change caused by fire (Key and Benson 2006), was computed as the difference in the Normalized Burn Ratio before (NBRprefire) and after

(NBRpostfire) the wildfire wave, i.e., dNBR= (NBRprefire-NBRpostfire) (Key and Benson 2006). Following the United States Geological Survey (USGS) classification, dNBR can range between –2.0 and 2.0. However, over natural landscapes, non-anomalous dNBR values typically have a more limited range of about –0.5 to +1.3. In this study, the thresholds of dNBR proposed by Key and Benson (2006) were used, considering five burn severity categories: low (0.1-0.269), moderate-low (0.27-0.439), moderate-high (0.440-0.659), high (>0.660), and unburned (-0.1-+0.099). Finally, note that even though the dNBR measure has been shown to be highly effective to map burn severity in forested areas, it can be less effective in other environments, such as grasslands (Warner et al. 2017). In our study we found many plots with significant spectral changes due to agricultural harvesting, therefore, visual monitoring of a random sample of polygons and all the smallest polygons was performed, to clarify whether or not a wildfire took place. Only isolated burned areas greater than 1 ha were identified and analyzed in this work. Burned areas are represented as mapped patches. Note that this, therefore, does not allow to identify whether each burned area was the outcome of a single or multiple fires within the studied days in October 2017.

Wildland-urban interface and population exposed to wildfires

We identify and map the WUI, defined as the area within a 50 m radius around buildings at a distance of up to 400 m from wildland vegetation, using the most recent layer of buildings from the Galician Topographic Base 1:10,000 (BTG 2016), based on 2014 aerial orthophoto (PNOA ©Spanish Geographic Institute - Xunta de Galicia) with a resolution of 25 cm/pixel, and accounting for all forest polygons of any size to avoid a minimum size restriction imposed in previous works which lead to an underrepresentation of the forest cover (Chas-Amil et al. 2013).

We estimated the area burned within and outside the wildland-urban interface, and identify the population and buildings exposed to wildfires by computing the number of people and buildings inside the wildfire perimeters, and for progressively farther “donuts” around them (less than 100 m, 500 m, and 1000 m). This can be justified because 1 km is a conservative reference of the approximate spotting distance in the case of an extreme wildfire event (Tedim et al. 2018), putting buildings at risk of being burned and influencing protective-action decision making (Cova et al. 2009).

This analysis used the information on the number of inhabitants in the threatened settlements level from the “Nomenclátor” provided by the Galician Statistical Institute. The number of buildings was obtained from the Galician Topographic Base, mentioned above. The Global Moran's I statistics (Anselin, 1995) was used to investigate the spatial clustering of burned areas and population exposure.

Land cover

Land use/land cover type (LULC) of the area burned was obtained using information from the Fourth Spanish Forest Inventory (IFN4), which is based on the cartography of the Forest Map of Spain at 1: 25,000 (MFE25). We grouped the information on the 64 land use types into the following classes (Table 2): forest area, wooded forest, shrubland, agricultural and grassland areas, and artificial surfaces, such as industrial and urban areas. Moreover, wooded forest was classified based on the dominant tree species into four subclasses: broadleaf, conifer, eucalyptus, and mixed forest mostly of conifer and eucalyptus. Humid areas were excluded from this analysis (e.g., continental and maritime waters).

We computed the Jacobs’ selectivity index (Jacobs 1974) in order to evaluate wildfire impact by land cover type, following previous work (Barros and Pereira 2014; Reilly et al. 2018). This index presents the advantage of being easier to interpret than other alternatives (e.g., Savage's forage ratio (Manly et al. 2010)); it takes values between -1 and 1, and is equal to 0 if a land cover burns in proportion to its presence. For instance, if the index is higher (lower) than 0, this indicates that this land cover is burning more (less) often than expected, and can be interpreted as wildfire preference for a given land cover. For this analysis, we include only those parishes, as the smallest administrative unit that divides the territory, affected by wildfires in October 2017, calculating the index as J=$(r-p)/(r+p-2rp)$, where r is the proportion of burned area of each land cover type with respect to the total burned area, and p is the proportion of the area of each land cover type with respect to the total land cover area. We also estimated 95% confidence intervals for the mean selectivity indexes of each land cover type based on 10,000 bootstrap samples. Following Carmo et al. (2011), differences between selectivity indexes for different land cover classes were considered statistically significant when there was no overlap between the respective confidence intervals. Note that given the approach taken here, this selective index does not capture whether fire avoidance of a particular land use is due either to a lack of ignitions in the land use area or to an effective natural resistance to fire spread (Nunes et al. 2005). In addition, no other factors are either considered, such as different fire suppression efforts, the position of fire front relative to the plot, burning under deferring meteorological conditions (day or night) during the course of the fire, etc. All the computations were made with ArcGIS® 10.6.1 by ESRI.

Results

Burned area and burn severity

The total area burned in the one-week wildfires of October 2017 was 42,314 ha (Table 3). This represents nearly 1.5% of the area of the whole region, and 70% of the total area burned in the whole year. This is more than eleven times higher than the average proportion of area burned in the same month (October) over the last 25 years, 6%; and only comparable to October 2011 when fires affected 68% of the area burned in the whole year, although on this occasion the burned area was smaller (29,244 ha). Fig. 1 shows the uneven spatial distribution of the wildfires, with 88% of the total burned area concentrated in the South (provinces of Pontevedra and Ourense). Moran's I index for global autocorrelation (0.16, z-score= 4.17, p-value < 0.0001) confirms this spatial clustering of burned areas. This high concentration is also illustrated in Table 3, which shows these areas burned results by forest districts (FD), which are the administrative units in Galicia to organise firefighting and forest management. The three forest districts (out of the existing nineteen) with the highest incidences of fire, in fact, concentrate 50% of the total burned area of the region: XI-O Ribeiro-Arenteiro (with about 7,300 ha burned, representing 7.6% of FD area and 17% of total area burned), XVII-O Condado-A Paradanta (6,000 burned ha, 8.6% FD area and 14% of the total area burned), and XVIII-Vigo-Baixo Miño (8,000 burned ha, 8.6% FD area and 19% total area burned). At the municipal level, just 13 municipalities (out of the existing 313), with more than 1000 ha burned each, registered 58% of the total area burned. Among them, three municipalities, belonging to the aforementioned forest districts, rank highest in terms of burned area, with around half of their total municipal area burned: Carballeda de Avia (XI), As Neves (XVII), and Pazos de Borbén (XVIII).

Fig. 2, 3 and 4 show a detailed delimitation of the burned area for these key affected districts, attending to burn severity, and showing the proximity of the area burned to buildings and main roads in these districts. Note that burn severity of the fires registered in October 2017 is mainly low to moderate, with only 0.02% of the total area burned classified as high burn severity, and 46.2% and 50.7% as moderate and low severity, respectively. The highest burn severity was recorded in district VII, A Fonsagrada-Os Ancares, where 2,729 ha were burned inside the natural park, Biosphere Reserve of Os Ancares Lucenses, out of the total 3,632 burned in this district (Table 3); but that, as we examine in the next section, supposed a small risk to the population in terms of area burned in the wildland urban interface.

Wildland-urban interface and population exposed to wildfires

The total area defined as WUI in Galicia is 385,177 ha, representing 13% of the region. Table 3 shows the share of WUI for the forest districts affected by fires in October 2017, and the proportion of the WUI that was burned in the studied period. Districts XVII, XVIII and XIX have the largest proportion of WUI, accounting between 19% and 30% of their territory. Interestingly, these districts, and XI, were those where the WUI was most seriously affected, with between 3% and 8% of the burned area in these districts occurring in the WUI, which corresponds to between 136 ha and 485 ha. Fig. 5 shows the proportion of burned area in the WUI over different years and compared with this proportion during the studied days of October 2017, showing the exceptionality of this event with respect to the WUI affected. In the period 2010-2015, the annual average of the area burned in the WUI is 1%, whereas it is 3.4% in the studied period. In total, 1,500 ha burned within the WUI in the whole region. A similar pattern occurred at the district level, for example district XVII and XVIII registered annual averages of 2.1% and 3.7% respectively of the burned area inside the WUI during the period 2010-15, compared with 8.4% and 5.5% in October 2017 (Table 3). The recurrent pattern observed in district XVIII, where the highest proportion of burned area in the WUI in each of the years between 2010 and 2015 was recorded, may be related to the high proportion of WUI as the highly-populated city of Vigo and its surrounding municipalities have peri-urban characteristics where buildings and forest intermingle (Fig. 4). These municipalities are among those with the highest proportion of WUI areas in the region, e.g., Nigrán (54%), Redondela (44%), and Vigo (43%). It was precisely in this district where three casualties were registered, two in Nigrán during the Chandebrito's wildfire, and another in Vigo. However, the nearby municipality of Pazos de Borbén was the most damaged with 48% of its area burned, affecting 11.5% of its WUI area (Fig. 4).

In total 841 people, residing in 51 human settlements, and 2,124 buildings, were within the wildfire perimeters. Our results show that the populations inside the three excluding "donuts" of 100 m, 500 m and 1000 m from wildfire perimeters, were about 11,600, 30,600 and 44,400 people. Overall, wildfires put at risk 873 settlements, 87,425 people and 80,251 buildings, because they were either inside the wildfire perimeters or less than 1 km from them. This represents 4.5% of the population and 7.4% of the buildings of all forest districts affected, 3.2% of the total regional population, and 5.7% of the total number of buildings. Fig. 6 shows the proportion of affected individuals per municipality, illustrating the significance of overall clustering detected by the Moran's index (0.39, z-score=13.51, p-value<0.0001). In fact, more than three quarters of the buildings and population exposed to wildfires were concentrated in districts XI, XVII, and XVIII. District XVIII had the greatest exposure to wildfire risk with nearly 54,000 people living within 1 km of fires (11.5% of its total population), followed by district XVII with nearly 15,000 people (28% of its population); and district XI with nearly 3,500 people (8% of its population). The municipality of As Neves in district XVII (Fig. 3) is worth mentioning as 48% of its area was burned, 25% of its WUI was affected, 451 people were residing within wildfire perimeters, and practically all its population (98%) were living less than 1 km away from wildfires. This high incidence can also be found in other municipalities of district XI (Fig. 2), Carballeda de Avia (with 94% of the population exposed, 60% of its total area burned and one causality), and Melón (72% of the population exposed and 37% of its area burned).

Land cover

Forest was the ecosystem most affected by wildfires, with 40,509 ha damaged (95% of the total area burned) (Table 4). This area corresponds to 65.4% of the total forest area burned during the entire year, 61,902 ha (MAPAMA 2018). Overall, approximately half of the forest burned was wooded land (20,038 ha) and the other half was shrubland (20,471 ha). However, within the WUI wooded forest was the land cover with the higher number of hectares burned, while shrubland was higher outside the WUI (Table 4). In relation to forest species, mixed forest represented the highest hectares of burned area inside the WUI, while coniferous forest was highest outside the WUI. Note that even though only 3.7% of agricultural areas were within the wildfires perimeters, 26% of that agricultural land burned occurred in the WUI (Table 4).

Results from the mean Jacobs' index showed that WUI areas burned less often than expected given its availability in the Galician territory ($J = -0.58 \pm 0.0006$, $\alpha = 0.05$). Fig. 7 shows these results according to land cover type. Shrubland burned more than expected based on availability, both in the WUI ($J = 0.58 \pm 0.0009$, $\alpha = 0.05$) and in non-WUI areas ($J = 0.26 \pm 0.0008$, $\alpha = 0.05$). However, wooded forests burned more than expected within the WUI ($J = 0.58 \pm 0.0005$, $\alpha = 0.05$), but with a weak or indifferent preference outside the WUI ($J = 0.026 \pm 0.0008$ $\alpha = 0.05$). In relation to forest species, all registered values were above zero inside the WUI. This confirms that all wooded types burned more than expected, with the highest value obtained by eucalyptus forests, followed by mixed, and coniferous forests; but statistical differences were not found. Outside the WUI, broadleaved forests were shown to burn less than expected given their presence in the territory (J=-0.29±0.0008, α=0.05), being significantly different to other forest type vegetation. Agricultural and artificial areas were the land cover less preferred by fire in both WUI and non-WUI.

Discussion and conclusions

The high population exposed to an extreme wildfire shown in this work suggests the need to rethink fire risk management for this type of events, enhancing risk prevention, but also strengthening preparedness and capacity of response to support the affected populations (e.g., Moritz et al. 2014; Ager et al. 2019; Craig et al. 2020). This work delimitates, maps and characterizes burned areas in the 14th-16th October 2017 wildfire outbreak in NW Spain, to assess the exposure to this risk of local communities. Area burned (42,314 ha) was spatially concentrated in the south, with just three forest districts suffering most of the damage (80% of the burned area in the extreme event). This meant that a few municipalities had a high percentage of their lands burned. Nevertheless, burn severity was found to be low to moderate which might be related to a number of factors, including wind direction, slope, and aspect (e.g., Viedma et al. 2014; Arellano-Pérez et al. 2018).

Moreover, we have updated the extent of the WUI in Galicia with respect to our previous work (Chas-Amil et al. 2013), which gives an increment of 140,980 ha in WUI (an increment of about 60%). This result may be explained because we now use the most recent building layer, which also has a higher resolution, and the fact a minimum-size threshold of 500 ha for forestlands was not imposed in the calculation to better capture the population and land use dispersion (García-Martínez et al. 2015). In this regard, the findings also show that wildfires spread mainly across dispersed peri-urban residential areas, with a higher incidence inside the WUI in comparison with evidence registered in annual fires in previous years. This extreme event resulted in a fire exposure of thousands of buildings (dwellings and non-residential structures) and residents: more than 80,000 buildings and 85,000 people were located within 1 km of the fires. Despite this, we found that WUI areas burned less than its expected value if this was calculated only based upon their presence in the region. This is because natural factors, such as fuel load and continuity (Bajocco and Ricotta 2008), topographic characteristics, and level of forest management, or in fact, lack of it due to rural abandonment (Silva et al. 2009) influence the burned area. In this study, burned areas are potentially highly determined by the firefighting effort, which one may expect to differ within and outside the WUI, because it is expected that firefighting prioritises populated areas, where houses, infrastructure, buildings and human lives can be in danger. Therefore, this finding may be in some extent related to the suppression measures deployed by firefighting crews (and volunteers) in the WUI.

Results suggest that shrublands were burned more than expected based upon their availability. This is consistent with previous studies in the Iberian Peninsula (e.g., Nunes et al. 2005; Moreira et al. 2009; Calviño-Cancela et al. 2016) and other Southern European countries (Oliveira et al. 2013). Regarding forest species outside the WUI, (i) broadleaves seem to burn less than expected; and (ii) eucalyptus stands and mixed forests (mainly composed of conifer and eucalyptus), showed the highest fire preference. The later can be explained because mixed stands are often the result of natural resprouting after wildfires and harvesting and are usually considered as areas with poor or inexistent management (Moreira et al. 2009). Inside the WUI, all types of forest cover burned more than expected. Even though, we recognize limitations mainly associated to the lack of updating in recent years of the forest data used to extract these results, these findings suggest that vegetation control and management may be an appropriate prevention strategy through the selection of fire-resistant species (Calviño-Cancela et al 2016, 2017; Fernandes et al. 2010). Therefore, an evaluation of the current implementation and enforcement of mandatory vegetation management in the region, making bush clearing and removal of certain forest species around buildings and populated areas, is needed. This could be an area for future studies.

Most importantly, the number of exposed people and buildings (in many occasions homes) that an extreme wildfire event can cause, as evidenced here for the case of 14th-16th October 2017, seems to make necessary to develop policies addressing further residential developments on fire-prone areas in the future. We, therefore, argue for the high relevance of developing policies that minimize the potential fire exposure to people and properties by correctly designing the infrastructure and their surroundings, and integrating wildfire management into spatial planning. This integration is quite rare worldwide, with some illustrations found in California and some regions of Australia (Butsic et al. 2015). In Spain, there are still no policies that coordinate land use planning and wildfire prevention. Moreover, the results make evident the need to develop communication policies that enhance the population wildfire risk emergency preparedness. This may be done by direct involvement of local communities and other stakeholders through participatory processes (e.g., Otero et al. 2018), making them part of forest fire mitigation measures in order to enhance their capacity to respond.

Finally, note that our estimation of area burned provides a conservative estimate, given the information provided by the Parlamento de Galicia (2018), which reports an estimate of 48,862 ha burned in 393 wildfires from 8th to 17th October 2017. This underestimation of the officially reported burned area in our study may be due to the fact that we discard burned pixels in the case of mixed patches composed of burned and unburned area, and that our analysis only takes into account wildfires affecting more than 1 ha. In addition, the use of a standard thresholds of dNBR (Key and Benson 2006) without field verification can lead to errors in delineating burned areas and severity rating. Furthermore, many forest stands can be traversed by fire burning the understory without any damage to the canopy, which will lead to poor representation of the lower strata of the tree canopy and soil (Arellano-Pérez et al. 2018). The potential error associated with not accounting for the whole area of the province of A Coruña province is expected to be minor, as only 752 ha are reported to have been burned in this province (Parlamento de Galicia 2018).

Acknowledgments

The work was supported in part by FEDER/Ministerio de Ciencia, Innovación y Universidades – Agencia Estatal de Investigación/ [Grant number ECO2017-89274-R MINECO/AEI/FEDER,UE]. MLCA is also grateful to Ministerio de Economía y Competitividad REFORCE/PCIN-2017-054, and FP7 ERA-NET. The authors would like to thank two anonymous reviewers whose constructive comments have improved this manuscript.

Declarations of interest: None.

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Table 1. Pre-/post-fire Sentinel images employed in this study.

	Acquisition date	Filename of the image
Pre-fire	12/10/2017	S2A_MSIL2A_20171012T112111_N0205_R037_T29TNG_20171012T112713
		S2A_MSIL2A_20171012T112111_N0205_R037_T29TNH_20171012T112713
		S2A_MSIL2A_20171012T112111_N0205_R037_T29TNJ_20171012T112713
		S2A_MSIL2A_20171012T112111_N0205_R037_T29TPG_20171012T112713
		S2A_MSIL2A_20171012T112111_N0205_R037_T29TPH_20171012T112713
		S2A_MSIL2A_20171012T112111_N0205_R037_T29TPJ_20171012T112713
Post-fire	27/10/2017	S2B_MSIL2A_20171027T112139_N0206_R037_T29TNG_20171027T145835
		S2B_MSIL2A_20171027T112139_N0206_R037_T29TNH_20171027T145835
		S2B_MSIL2A_20171027T112139_N0206_R037_T29TNJ_20171027T145835
		S2B_MSIL2A_20171027T112139_N0206_R037_T29TPG_20171027T145835
		S2B_MSIL2A_20171027T112139_N0206_R037_T29TPH_20171027T145835
		S2B_MSIL2A_20171027T112139_N0206_R037_T29TPJ_20171027T145835

Table 2. Description of land-cover types used in this study, and percentage of area they occupy in the region.

Land-cover	Description/MFE25 codes	%
Forest area	It is composed of wooded forest, shrublands and grasslands. Structural type: Class 1=1	68.8
Wooded forest	Vegetation with tree cover ≥ 10% Structural type: Class 2=1	48.0
Broadleaf	Mainly *Quercus robur*, *Castanea sativa*, and *Quercus pyrenaica* in pure and mixed stands. Wooded formations (id_ForArb): 1, 3, 4, 8, 9, 13, 15, 18, 19, 29, 31, 33, 43, 44, 56, 63	14.3
Conifer	Mainly *Pinus pinaster* in pure and mixed stands. Wooded formations (id_ForArb): 21-23, 25, 46, 58, 61, 62, 64, 65, 392, 393	13.5
Eucalyptus	Mainly *Eucalyptus globulus*. Wooded formations (id_ForArb): 57	9.6
Mixed forest	Mostly mixed broadleaf with conifer but also broadleaf with eucalyptus, and mixed forest mainly *Pinus pinaster* with *Eucalyptus globulus*. It includes acacia wood, mostly *Acacia dealbata*. Wooded formations (id_ForArb): 38, 41, 49, 66, 401, 402, 403	10.6
Shrubland	Low and tall shrublands. It also includes sparsely or non-vegetated areas (2.1% of the study area), and natural vegetation dominated by grasses and forbs (0.3% of the study area). Structural type: Class 2= 2+3+4	20.8
Agricultural areas	Crops and diverse agriculture mosaics and pastures. Structural type: Class 1=2	27.7
Artificial areas	Urban, industrial, infrastructures and other artificial areas Structural type: Class 1=3	2.8
Humid areas	Structural type: Class 1=4+5	0.7

Table 3: Total burned area, burned area within WUI, and WUI by forest district.

	Total burned area		Burned area within WUI		
Forest districts (FD)	ha	% /total FD area	ha	% /total FD burned area	%WUI /total FD area
I. Ferrol	129.6	0.08	0,4	0.31	16.06
III. Santiago Meseta Interior.	233.1	0.10	2.2	0.94	16.01
VII. A Fonsagrada-Os Ancares	3,632.3	2.10	25.7	0.71	4.45
VIII. Terra de Lemos	626.0	0.32	5.3	0.85	8.91
IX. Lugo-Sarria	673.1	0.26	4.2	0.62	11.35
X. Terra Chá	18.5	0.01	0.0	0.00	10.64
XI. O Ribeiro- Arenteiro	7,292.2	7.61	259.0	3.55	11.99
XII. Miño-Arnoia	3,366.6	2.22	43.1	1.28	17.01
XIII. Valdeorras-Trives	2,701.0	1.58	15.9	0.59	5.82
XIV. Verín-Viana	1,971.6	1.12	3.0	0.15	5.03
XV. A Limia	3,011.0	2.26	13.3	0.44	6.70
XVI. Deza-Tabeirós	559.0	0.38	8.8	1.57	12.85
XVII. O Condado-A Paradanta	5,812.7	8.57	485.4	8.35	19.42
XVIII. Vigo-Baixo Miño	8,020.2	8.60	438.3	5.46	29.87
XIX. Caldas- O Salnés	4,267.1	3.04	136.1	3.19	24.96
Galicia	42,314.0	1.43	1,440.7	3.40	13.00

Table 4. Burned area by land cover type in WUI and non-WUI areas.

	WUI		**Non-WUI**		**Total burned area**	
Land Cover	**ha**	**%/total**	**ha**	**%/total**	**ha**	**%**
Forest land	982.1	2.42	39527.0	97.58	40,509.1	95.73
- Wooded	750.4	3.74	19288.1	96.26	20,038.5	47.36
Broadleaf	112.5	2.53	4325.9	97.47	4,438.3	10.49
Coniferous	204.4	3.07	6461.8	96.93	6,666.2	15.75
Eucalyptus	184.9	3.58	4978.7	96.42	5,163.7	12.20
Mixed forest	248.6	6.59	3521.6	93.41	3770.2	8.90
- Shrubland	231.7	1.13	20238.9	98.87	20,470.6	48.38
Agricultural areas	405.3	25.96	1156.2	74.04	1,561.5	3.69
Artificial area	52.5	22.79	177.9	77.21	230.4	0.54
Humid areas	0.6	4.62	12.4	95.38	13.0	0.03
Total	1,440.5	3.40	40873.5	96.60	42,314.0	100.00

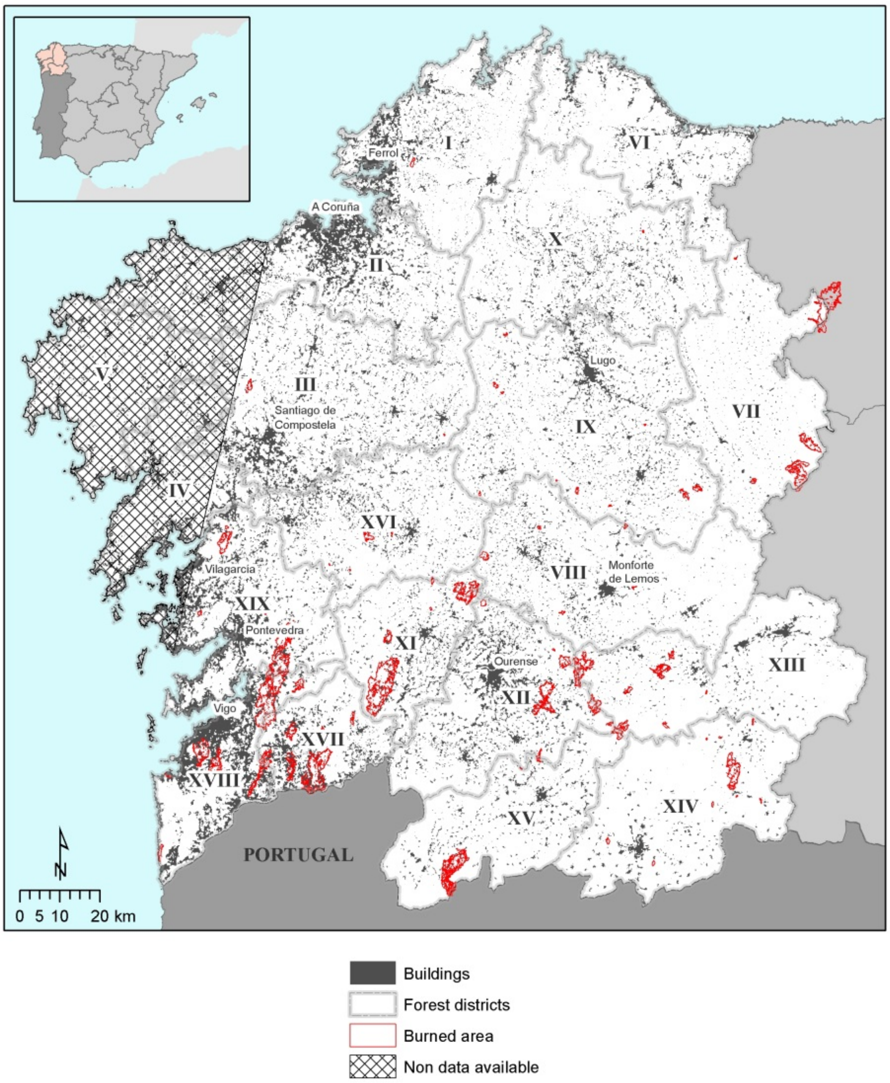

Fig. 1: Delimitation of burned areas caused by wildfires in Galicia in October 2017.

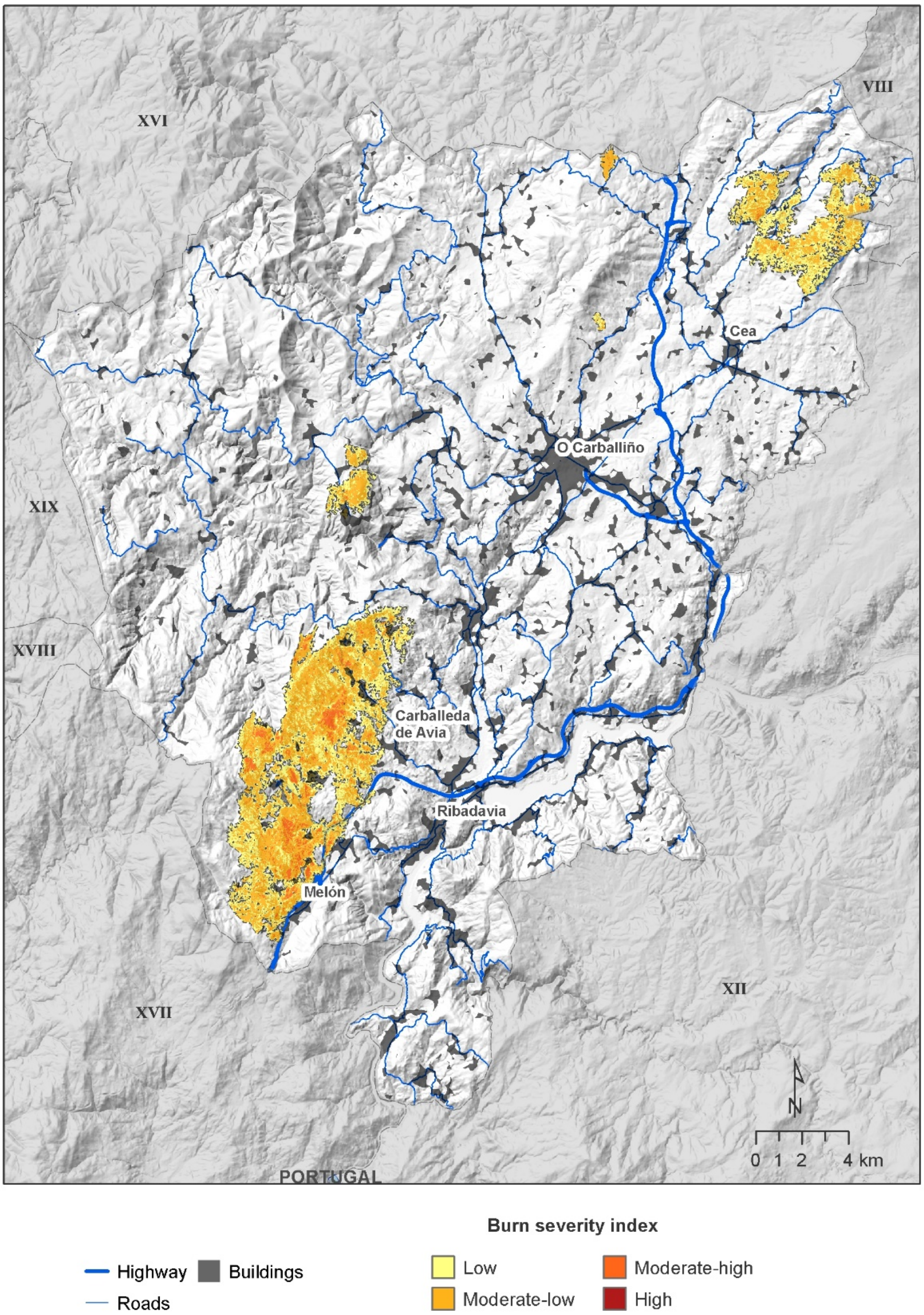

Fig. 2: Burned area and burn severity for October 2017 wildfires in Forest District XI (Galicia).

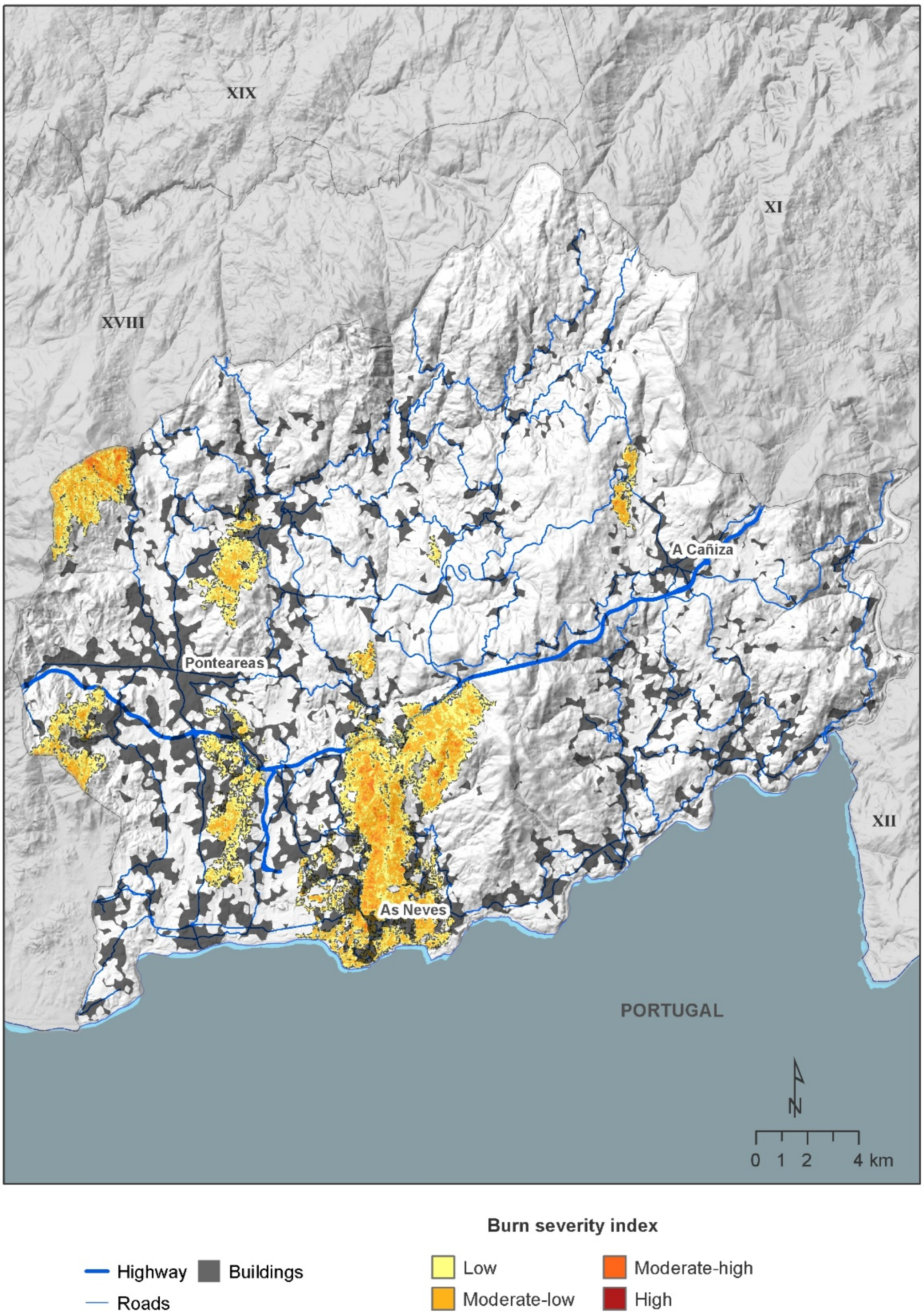

Fig. 3: Burned area and burn severity for October 2017 wildfires in Forest District XVII (Galicia).

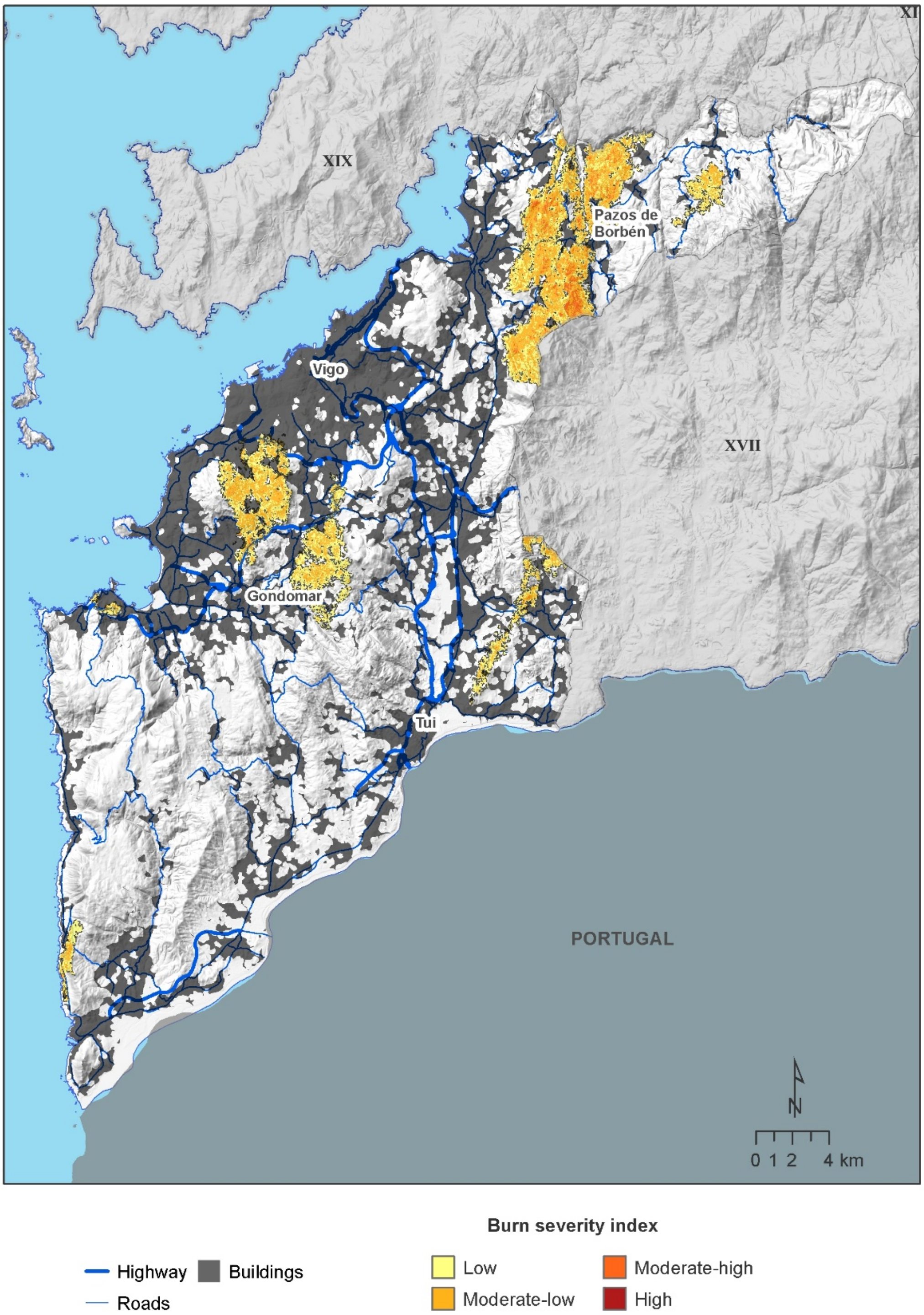

Fig. 4: Burned area and burn severity for October 2017 wildfires in Forest District XVIII (Galicia).

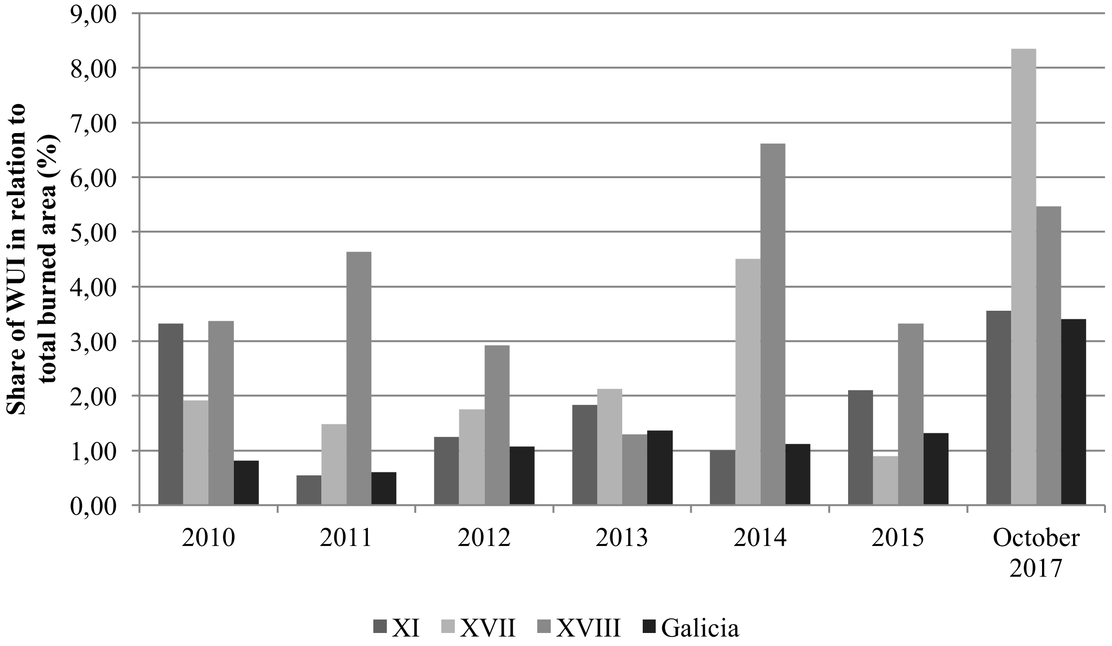

Fig. 5. Percentage of burned area in the WUI during October 2017 wildfires in the most affected forest districts and in Galicia.

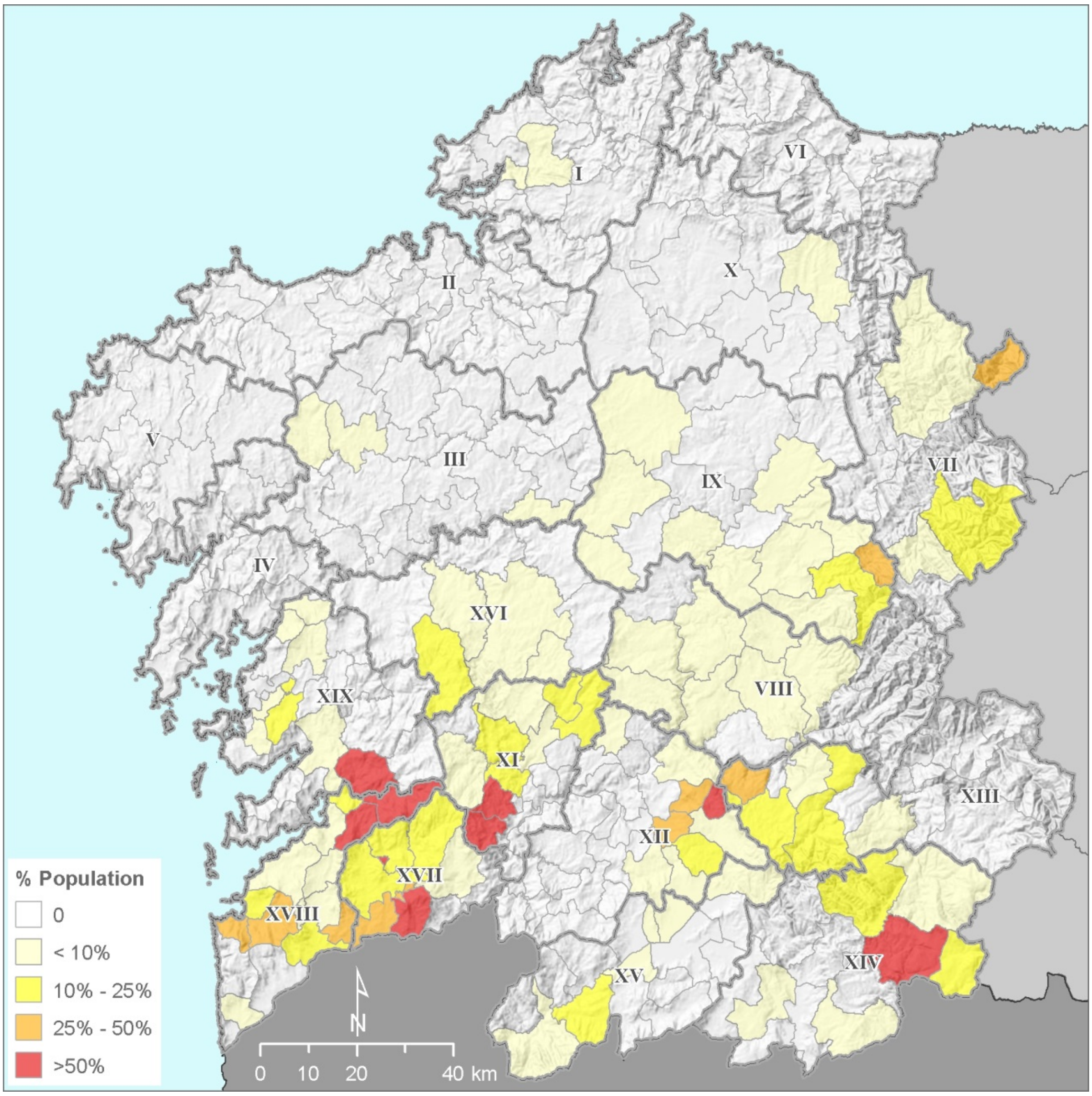

Fig. 6. Proportion of people living within wildfires perimeters, and up to 1000 m, by municipality.

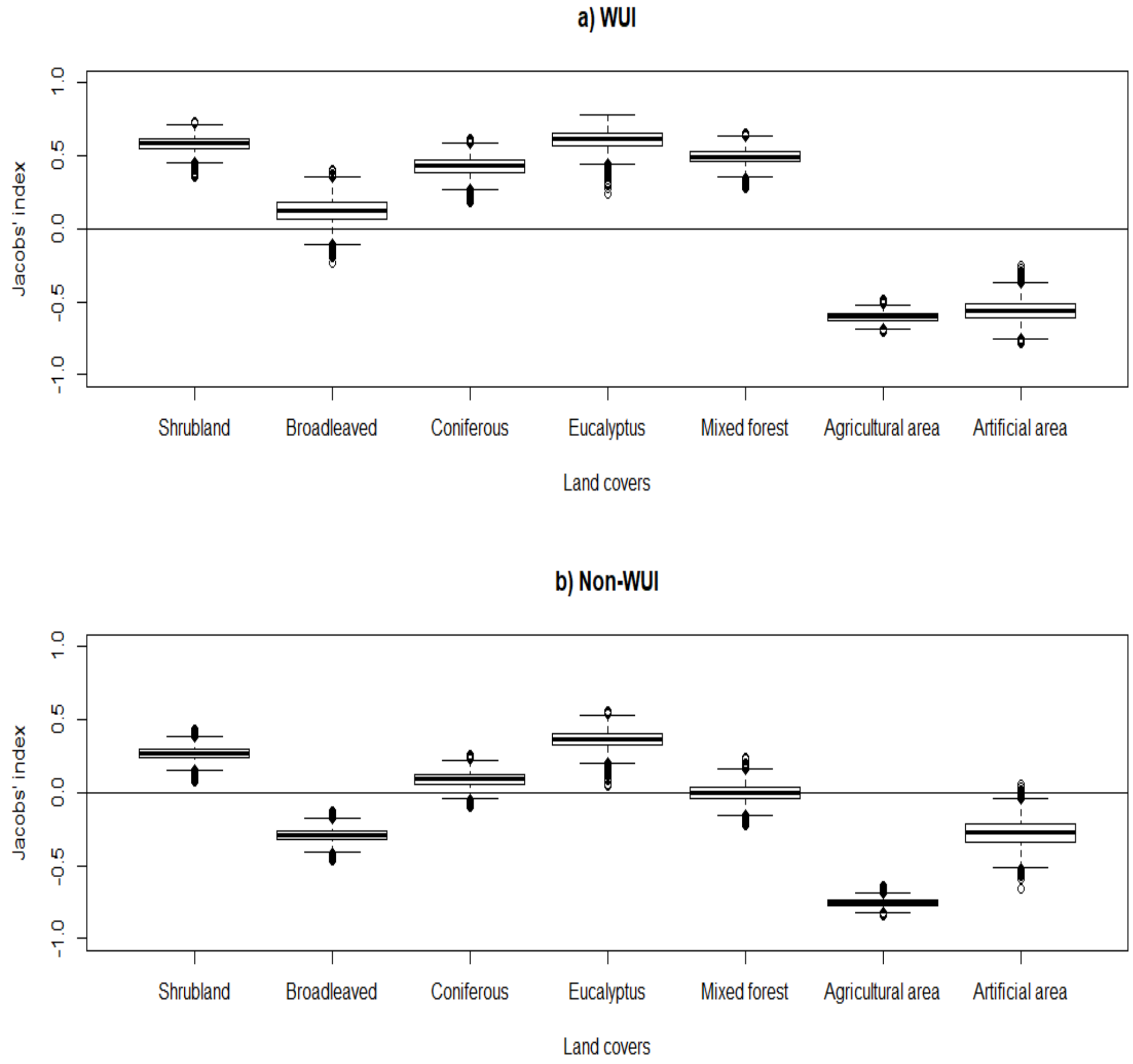

Fig. 7. Jacobs' selection index (J; mean ± 95% confidence interval) with values of 0, 1 and -1 corresponding to indifference, preference and avoidance, respectively by land cover types in (a) WUI and (b) non-WUI areas.