

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

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12

13 **Abstract**

14 In October 2017, an extreme wildfire outbreak in the NW of the Iberian Peninsula burned  
15 thousands of hectares, resulting in human deaths and important economic damage. This  
16 paper provides a first comprehensive assessment of the exposure of the local communities  
17 in the Spanish region of Galicia, where forestlands routinely experience fire outbreaks,  
18 as the one that occurred in 14<sup>th</sup>, 15<sup>th</sup> and 16<sup>th</sup> October with more than two hundred fire  
19 incidents. We delimitate the wildfire perimeters, characterize the area burned in regards  
20 to vegetation characteristics, evaluate the affected wildland-urban interface (WUI), and  
21 quantify the population and buildings exposed to wildfires. The burned area was found to  
22 be unevenly distributed, concentrated in the south of the region, and in municipalities  
23 with nearly half of their lands under WUI. This resulted in a high level of exposure in the  
24 affected lands. We estimated that 51 communities were inside fire perimeters. Moreover,  
25 873 communities with more than 87,000 people residing on them, were at a close distance  
26 of less than 1km away. This study demonstrates the importance of understanding extreme  
27 wildfire events and their potential impacts which can guide how best communities can  
28 respond to them. The high number of population exposed to the studied event shows the  
29 necessity of integrating land-use planning with wildfire risk prevention and preparedness.

30

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

## 33 **Introduction**

34

35 The increase in the length of fire weather season due to climate change (Jolly et al. 2015),  
36 and other forest pressures such as urban expansion and unsustainable land uses (e.g.,  
37 Modugno et al. 2016; Radeloff et al. 2018), make the continued increase in frequency and  
38 duration of extreme wildfire outbreaks inevitable (Calkin et al. 2014). These wildfire  
39 events impose large social and environmental costs, often accounted for, on the timber  
40 industry, carbon sequestration, air quality regulation, cultural values, physical and mental  
41 health and human losses (Moritz et al. 2014). In 2017, wildfires had devastating  
42 consequences worldwide (Bladon 2018; Gómez-González et al. 2018; Moreira and Pe'er  
43 2018; McBride and Kent 2019). In the United States, more than 71,000 fires burned 4  
44 million hectares and forced more than 200,000 residents to evacuate their homes; 66  
45 people lost their lives (Balch et al. 2018); in the Austral Summer of 2017, Chile suffered  
46 the biggest wildfire episode in its history, with more than 500 thousand hectares of land  
47 burned, 11 people killed, and 3,000 houses lost (De la Barrera et al. 2018). In the  
48 European Union, wildfires burned over 1.2 million ha of natural land and killed 127  
49 people (San-Miguel-Ayanz et al. 2017); Portugal being the most affected country with  
50 almost 550,000 ha burned, 500 houses destroyed and 112 fatalities registered mostly in  
51 two episodes taken place in June and October 2017 (Comissão Técnica Independente  
52 2017, 2018).

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

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

68 Recent research on wildfire risk exposure has been focused in defining and mapping  
69 Wildland-Urban Interface (WUI) (e.g., Radeloff et al. 2005; Lampin-Maillet et al. 2010;  
70 Johnston and Flanigan 2018), its expansion (e.g., Theobald and Rome 2007; Radeloff et  
71 al. 2018; Bento-Gonçalves and Vieira 2020), and its relationship to social vulnerability,  
72 i.e., the social factors that increases the human susceptibility to the impacts of fires in the  
73 WUI (Wigtil et al. 2016; Oliveira et al. 2018; Badia et al. 2019; Vaiciulyte et al. 2019).  
74 The focus seems to have been on characterization of the hazard at the WUI and the  
75 conditions that contribute to impacts and vulnerability. At the same time, numerous  
76 studies have looked at the need for community protection strategies (e.g., Cova et al  
77 2009), where being exposed to fires has been identified as a key element for public  
78 support of actions for wildfire risk reduction (e.g., McGee et al. 2009). Therefore,  
79 understanding the extent and location of the population that were actually exposed (ex-  
80 post) is important for developing efficient reduction risk strategies by spatially targeting  
81 public investments and prioritization of community protection planning resources (Ager,  
82 et al. 2019; Fisher et al. 2016). In this work, we focus on identifying the location and  
83 number of people, land cover and density of buildings exposed to wildfires, or in close

84 proximity. We extend previous research, which has inventoried population and housing  
85 within burned areas (e.g., Sarricolea et al., 2020; Argañaraz et al. 2017; Thomas and Butry  
86 2014), by analyzing areas beyond the WUI, and focusing on an extreme wildfire event  
87 instead of using historical fires. This is justified by the the indispensable need to gather  
88 information to enhance the communities' preparedness to these type of fire outbreaks  
89 given their overwhelming capacity of control by firefighters (Tedim et al. 2018).

90 This paper focuses on the wildfires that occurred in the Iberian Peninsula in October 2017,  
91 contributing also to the scarce literature on this event, which has focused on Portuguese  
92 fires (Alexander et al. 2018). We investigate the case study of Galicia (north-west Spain,  
93 sharing a border with Portugal), where 393 fire incidents occurred in less than a week, of  
94 which 215 registered in just three days, 14th, 15th and 16th October (Parlamento de  
95 Galicia 2018). In this period, extreme fire meteorology - dry biomass and high  
96 temperatures - was aggravated by storm Ophelia, and a high rate of intentional ignitions  
97 (80%), with simultaneous fires starting at the same time (Parlamento de Galicia 2018).  
98 Moreover, there was a high incidence of large fires (>500 ha), registering 19 out of the  
99 56 large fires that occurred in Spain in the whole year, and affecting nearly 40% of the  
100 total forest area burned by large fires that year (MAPAMA 2018). These events resulted  
101 in 4 people dead, 128 injured and 2,400 evacuated from their homes (Sampedro 2017).  
102 This wildfire episode has been widely covered by the media (Delgado-Arango and  
103 Vicente-Mariño 2019; Pérez Pereiro et al. 2018) and has resulted in intense public opinion  
104 and political debate (Parlamento de Galicia 2018). This has led to the provision of an  
105 extraordinary budgetary fund for wildfire recovery, which offers financial assistance to  
106 repair damage to infrastructure and properties, and to help farmers and ranchers to recover  
107 from production losses (Decree 102/2017, DOG 20 October 2017). However, there has  
108 not yet been detailed information published on the location and extent of the

109 consequences of this event in the region. In this work, we (a) map and delimitate burned  
110 areas, estimating burn severity; (b) identify the wildland-urban interface (WUI) areas  
111 threatened, as well as the number of communities, people and buildings exposed for their  
112 proximity to wildfires; and c) define the types of land cover affected to identify the  
113 ecosystems that may suffer higher impacts.

## 114 **Materials and methods**

### 115 **Estimation of burned area and burn severity**

116 Sentinel 2A and its sensor MSI (Multi Spectral Instrument) were selected to identify and  
117 delimitate burned areas over other alternatives, like the Landsat 8 satellite and its sensor  
118 OLI (Operational Land Imager), because of the availability of images immediately before  
119 and after the wildfire wave, corresponding to 12<sup>th</sup> October and 27<sup>th</sup> October respectively.  
120 The best cloud-free Sentinel-2A Level-1C (L1C) MSI images were downloaded from the  
121 Sentinel's Scientific Data Hub (<https://scihub.copernicus.eu/>). Table 1 shows the pre-  
122 /post-fire images employed in this study. Images with more than 27% of cloud content  
123 were discarded to avoid distortions (Biday and Bhosle 2010). This limited the availability  
124 of suitable images only in the province of A Coruña, and affected only 10% of the studied  
125 area (Fig. 1). The atmospheric correction procedure was executed with a Sen2Cor  
126 processor, and complemented with the C-correction method (Hantson and Chuvieco  
127 2011). The spatial resolution used in this study was 20 m.

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

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

#### 149 **Wildland-urban interface and population exposed to wildfires**

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

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

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

#### 169 **Land cover**

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

179 We computed the Jacobs' selectivity index (Jacobs 1974) in order to evaluate wildfire  
180 impact by land cover type, following previous work (Barros and Pereira 2014; Reilly et

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

## 201 **Results**

### 202 **Burned area and burn severity**

203 The total area burned in the one-week wildfires of October 2017 was 42,314 ha (Table  
204 3). This represents nearly 1.5% of the area of the whole region, and 70% of the total area

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

225 Fig. 2, 3 and 4 show a detailed delimitation of the burned area for these key affected  
226 districts, attending to burn severity, and showing the proximity of the area burned to  
227 buildings and main roads in these districts. Note that burn severity of the fires registered  
228 in October 2017 is mainly low to moderate, with only 0.02% of the total area burned  
229 classified as high burn severity, and 46.2% and 50.7% as moderate and low severity,

230 respectively. The highest burn severity was recorded in district VII, A Fonsagrada-Os  
231 Ancares, where 2,729 ha were burned inside the natural park, Biosphere Reserve of Os  
232 Ancares Lucenses, out of the total 3,632 burned in this district (Table 3); but that, as we  
233 examine in the next section, supposed a small risk to the population in terms of area  
234 burned in the wildland urban interface.

### 235 **Wildland-urban interface and population exposed to wildfires**

236 The total area defined as WUI in Galicia is 385,177 ha, representing 13% of the region.  
237 Table 3 shows the share of WUI for the forest districts affected by fires in October 2017,  
238 and the proportion of the WUI that was burned in the studied period. Districts XVII,  
239 XVIII and XIX have the largest proportion of WUI, accounting between 19% and 30%  
240 of their territory. Interestingly, these districts, and XI, were those where the WUI was  
241 most seriously affected, with between 3% and 8% of the burned area in these districts  
242 occurring in the WUI, which corresponds to between 136 ha and 485 ha. Fig. 5 shows the  
243 proportion of burned area in the WUI over different years and compared with this  
244 proportion during the studied days of October 2017, showing the exceptionality of this  
245 event with respect to the WUI affected. In the period 2010-2015, the annual average of  
246 the area burned in the WUI is 1%, whereas it is 3.4% in the studied period. In total, 1,500  
247 ha burned within the WUI in the whole region. A similar pattern occurred at the district  
248 level, for example district XVII and XVIII registered annual averages of 2.1% and 3.7%  
249 respectively of the burned area inside the WUI during the period 2010-15, compared with  
250 8.4% and 5.5% in October 2017 (Table 3). The recurrent pattern observed in district  
251 XVIII, where the highest proportion of burned area in the WUI in each of the years  
252 between 2010 and 2015 was recorded, may be related to the high proportion of WUI as  
253 the highly-populated city of Vigo and its surrounding municipalities have peri-urban

254 characteristics where buildings and forest intermingle (Fig. 4). These municipalities are  
255 among those with the highest proportion of WUI areas in the region, e.g., Nigrán (54%),  
256 Redondela (44%), and Vigo (43%). It was precisely in this district where three casualties  
257 were registered, two in Nigrán during the Chandebrito's wildfire, and another in Vigo.  
258 However, the nearby municipality of Pazos de Borbén was the most damaged with 48%  
259 of its area burned, affecting 11.5% of its WUI area (Fig. 4).

260 In total 841 people, residing in 51 human settlements, and 2,124 buildings, were within  
261 the wildfire perimeters. Our results show that the populations inside the three excluding  
262 "donuts" of 100 m, 500 m and 1000 m from wildfire perimeters, were about 11,600,  
263 30,600 and 44,400 people. Overall, wildfires put at risk 873 settlements, 87,425 people  
264 and 80,251 buildings, because they were either inside the wildfire perimeters or less than  
265 1 km from them. This represents 4.5% of the population and 7.4% of the buildings of all  
266 forest districts affected, 3.2% of the total regional population, and 5.7% of the total  
267 number of buildings. Fig. 6 shows the proportion of affected individuals per municipality,  
268 illustrating the significance of overall clustering detected by the Moran's index (0.39, z-  
269 score=13.51, p-value<0.0001). In fact, more than three quarters of the buildings and  
270 population exposed to wildfires were concentrated in districts XI, XVII, and XVIII.  
271 District XVIII had the greatest exposure to wildfire risk with nearly 54,000 people living  
272 within 1 km of fires (11.5% of its total population), followed by district XVII with nearly  
273 15,000 people (28% of its population); and district XI with nearly 3,500 people (8% of  
274 its population). The municipality of As Neves in district XVII (Fig. 3) is worth  
275 mentioning as 48% of its area was burned, 25% of its WUI was affected, 451 people were  
276 residing within wildfire perimeters, and practically all its population (98%) were living  
277 less than 1 km away from wildfires. This high incidence can also be found in other  
278 municipalities of district XI (Fig. 2), Carballeda de Avia (with 94% of the population

279 exposed, 60% of its total area burned and one causality), and Melón (72% of the  
280 population exposed and 37% of its area burned).

## 281 **Land cover**

282 Forest was the ecosystem most affected by wildfires, with 40,509 ha damaged (95% of  
283 the total area burned) (Table 4). This area corresponds to 65.4% of the total forest area  
284 burned during the entire year, 61,902 ha (MAPAMA 2018). Overall, approximately half  
285 of the forest burned was wooded land (20,038 ha) and the other half was shrubland  
286 (20,471 ha). However, within the WUI wooded forest was the land cover with the higher  
287 number of hectares burned, while shrubland was higher outside the WUI (Table 4). In  
288 relation to forest species, mixed forest represented the highest hectares of burned area  
289 inside the WUI, while coniferous forest was highest outside the WUI. Note that even  
290 though only 3.7% of agricultural areas were within the wildfires perimeters, 26% of that  
291 agricultural land burned occurred in the WUI (Table 4).

292 Results from the mean Jacobs' index showed that WUI areas burned less often than  
293 expected given its availability in the Galician territory ( $J = -0.58 \pm 0.0006$ ,  $\alpha = 0.05$ ). Fig.  
294 7 shows these results according to land cover type. Shrubland burned more than  
295 expected based on availability, both in the WUI ( $J = 0.58 \pm 0.0009$ ,  $\alpha = 0.05$ ) and in non-  
296 WUI areas ( $J = 0.26 \pm 0.0008$ ,  $\alpha = 0.05$ ). However, wooded forests burned more than  
297 expected within the WUI ( $J = 0.58 \pm 0.0005$ ,  $\alpha = 0.05$ ), but with a weak or indifferent  
298 preference outside the WUI ( $J = 0.026 \pm 0.0008$ ,  $\alpha = 0.05$ ). In relation to forest species, all  
299 registered values were above zero inside the WUI. This confirms that all wooded types  
300 burned more than expected, with the highest value obtained by eucalyptus forests,  
301 followed by mixed, and coniferous forests; but statistical differences were not found.  
302 Outside the WUI, broadleaved forests were shown to burn less than expected given their

303 presence in the territory ( $J=-0.29\pm 0.0008$ ,  $\alpha=0.05$ ), being significantly different to other  
304 forest type vegetation. Agricultural and artificial areas were the land cover less preferred  
305 by fire in both WUI and non-WUI.

## 306 **Discussion and conclusions**

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

319 Moreover, we have updated the extent of the WUI in Galicia with respect to our previous  
320 work (Chas-Amil et al. 2013), which gives an increment of 140,980 ha in WUI (an  
321 increment of about 60%). This result may be explained because we now use the most  
322 recent building layer, which also has a higher resolution, and the fact a minimum-size  
323 threshold of 500 ha for forestlands was not imposed in the calculation to better capture  
324 the population and land use dispersion (García-Martínez et al. 2015). In this regard, the  
325 findings also show that wildfires spread mainly across dispersed peri-urban residential  
326 areas, with a higher incidence inside the WUI in comparison with evidence registered in

327 annual fires in previous years. This extreme event resulted in a fire exposure of thousands  
328 of buildings (dwellings and non-residential structures) and residents: more than 80,000  
329 buildings and 85,000 people were located within 1 km of the fires. Despite this, we found  
330 that WUI areas burned less than its expected value if this was calculated only based upon  
331 their presence in the region. This is because natural factors, such as fuel load and  
332 continuity (Bajocco and Ricotta 2008), topographic characteristics, and level of forest  
333 management, or in fact, lack of it due to rural abandonment (Silva et al. 2009) influence  
334 the burned area. In this study, burned areas are potentially highly determined by the  
335 firefighting effort, which one may expect to differ within and outside the WUI, because  
336 it is expected that firefighting prioritises populated areas, where houses, infrastructure,  
337 buildings and human lives can be in danger. Therefore, this finding may be in some extent  
338 related to the suppression measures deployed by firefighting crews (and volunteers) in  
339 the WUI.

340 Results suggest that shrublands were burned more than expected based upon their  
341 availability. This is consistent with previous studies in the Iberian Peninsula (e.g., Nunes  
342 et al. 2005; Moreira et al. 2009; Calviño-Cancela et al. 2016) and other Southern  
343 European countries (Oliveira et al. 2013). Regarding forest species outside the WUI, (i)  
344 broadleaves seem to burn less than expected; and (ii) eucalyptus stands and mixed forests  
345 (mainly composed of conifer and eucalyptus), showed the highest fire preference. The  
346 later can be explained because mixed stands are often the result of natural resprouting  
347 after wildfires and harvesting and are usually considered as areas with poor or inexistent  
348 management (Moreira et al. 2009). Inside the WUI, all types of forest cover burned more  
349 than expected. Even though, we recognize limitations mainly associated to the lack of  
350 updating in recent years of the forest data used to extract these results, these findings  
351 suggest that vegetation control and management may be an appropriate prevention

352 strategy through the selection of fire-resistant species (Calviño-Cancela et al 2016, 2017;  
353 Fernandes et al. 2010). Therefore, an evaluation of the current implementation and  
354 enforcement of mandatory vegetation management in the region, making bush clearing  
355 and removal of certain forest species around buildings and populated areas, is needed.  
356 This could be an area for future studies.

357 Most importantly, the number of exposed people and buildings (in many occasions  
358 homes) that an extreme wildfire event can cause, as evidenced here for the case of 14<sup>th</sup>-  
359 16<sup>th</sup> October 2017, seems to make necessary to develop policies addressing further  
360 residential developments on fire-prone areas in the future. We, therefore, argue for the  
361 high relevance of developing policies that minimize the potential fire exposure to people  
362 and properties by correctly designing the infrastructure and their surroundings, and  
363 integrating wildfire management into spatial planning. This integration is quite rare  
364 worldwide, with some illustrations found in California and some regions of Australia  
365 (Butsic et al. 2015). In Spain, there are still no policies that coordinate land use planning  
366 and wildfire prevention. Moreover, the results make evident the need to develop  
367 communication policies that enhance the population wildfire risk emergency  
368 preparedness. This may be done by direct involvement of local communities and other  
369 stakeholders through participatory processes (e.g., Otero et al. 2018), making them part  
370 of forest fire mitigation measures in order to enhance their capacity to respond.

371 Finally, note that our estimation of area burned provides a conservative estimate, given  
372 the information provided by the Parlamento de Galicia (2018), which reports an estimate  
373 of 48,862 ha burned in 393 wildfires from 8<sup>th</sup> to 17<sup>th</sup> October 2017. This underestimation  
374 of the officially reported burned area in our study may be due to the fact that we discard  
375 burned pixels in the case of mixed patches composed of burned and unburned area, and

376 that our analysis only takes into account wildfires affecting more than 1 ha. In addition,  
377 the use of a standard thresholds of dNBR (Key and Benson 2006) without field  
378 verification can lead to errors in delineating burned areas and severity rating.  
379 Furthermore, many forest stands can be traversed by fire burning the understory without  
380 any damage to the canopy, which will lead to poor representation of the lower strata of  
381 the tree canopy and soil (Arellano-Pérez et al. 2018). The potential error associated with  
382 not accounting for the whole area of the province of A Coruña province is expected to be  
383 minor, as only 752 ha are reported to have been burned in this province (Parlamento de  
384 Galicia 2018).

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606 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

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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 $\geq 10\%$ Structural type: Class 2=1	48.0
Broadleaf	Mainly <i>Quercus robur</i> , <i>Castanea sativa</i> , and <i>Quercus pyrenaica</i> 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 <i>Pinus pinaster</i> in pure and mixed stands. Wooded formations (id_ForArb): 21-23, 25, 46, 58, 61, 62, 64, 65, 392, 393	13.5
Eucalyptus	Mainly <i>Eucalyptus globulus</i> . Wooded formations (id_ForArb): 57	9.6
Mixed forest	Mostly mixed broadleaf with conifer but also broadleaf with eucalyptus, and mixed forest mainly <i>Pinus pinaster</i> with <i>Eucalyptus globulus</i> . It includes acacia wood, mostly <i>Acacia dealbata</i> .  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

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

Forest districts (FD)	Total burned area		Burned area within WUI		
	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

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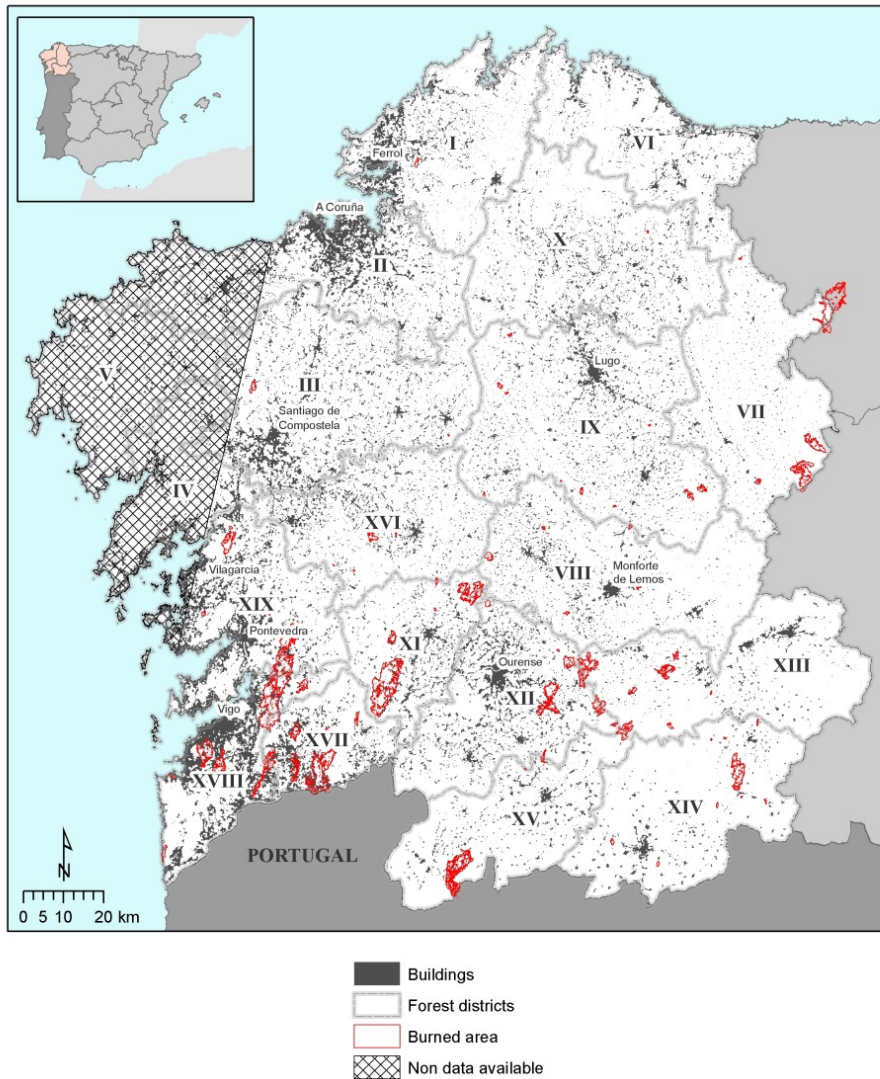
614

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

Land Cover	WUI		Non-WUI		Total burned area	
	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

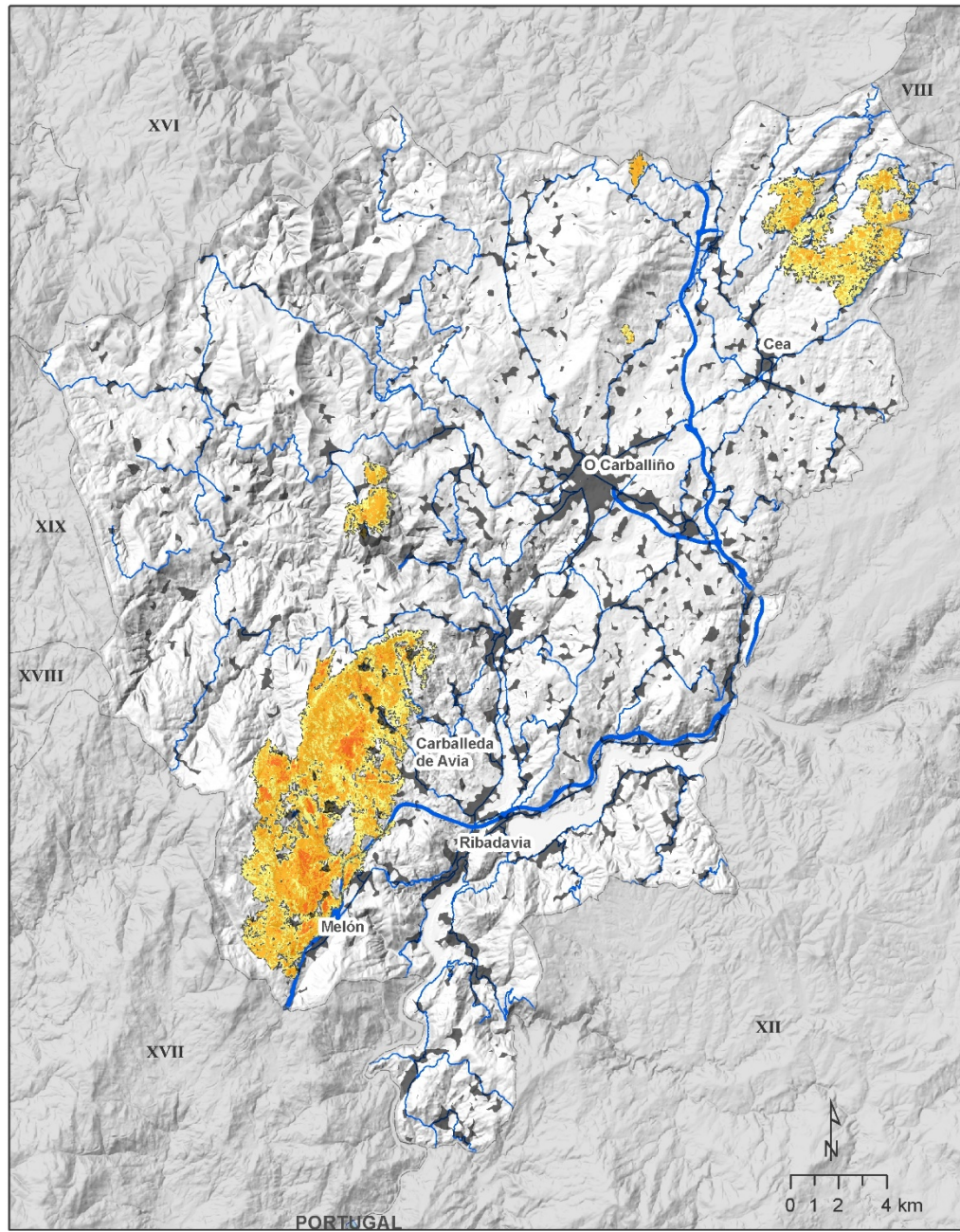
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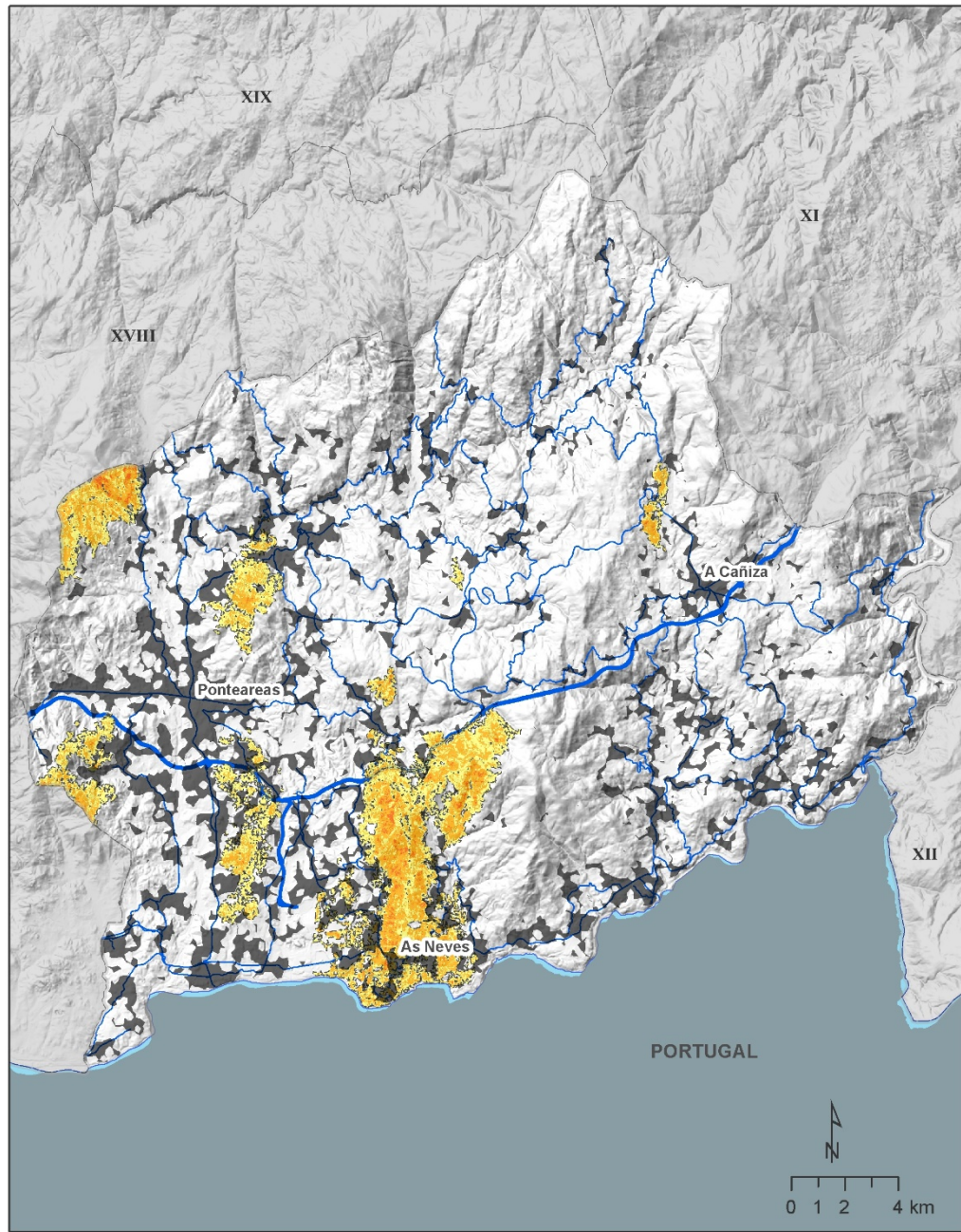
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619 Fig. 1: Delimitation of burned areas caused by wildfires in Galicia in October 2017.



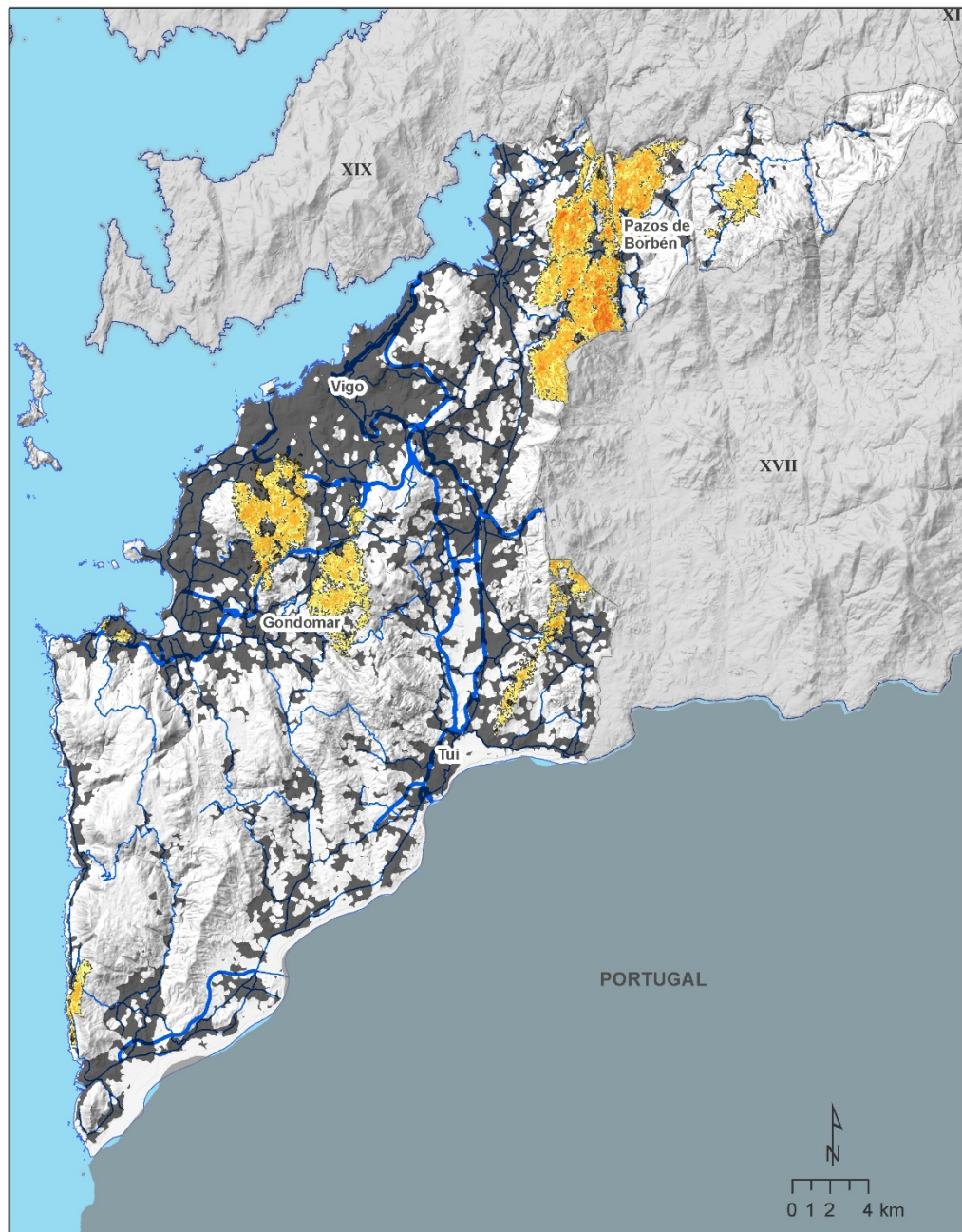
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621 Fig. 2: Burned area and burn severity for October 2017 wildfires in Forest District XI  
 622 (Galicia).



623

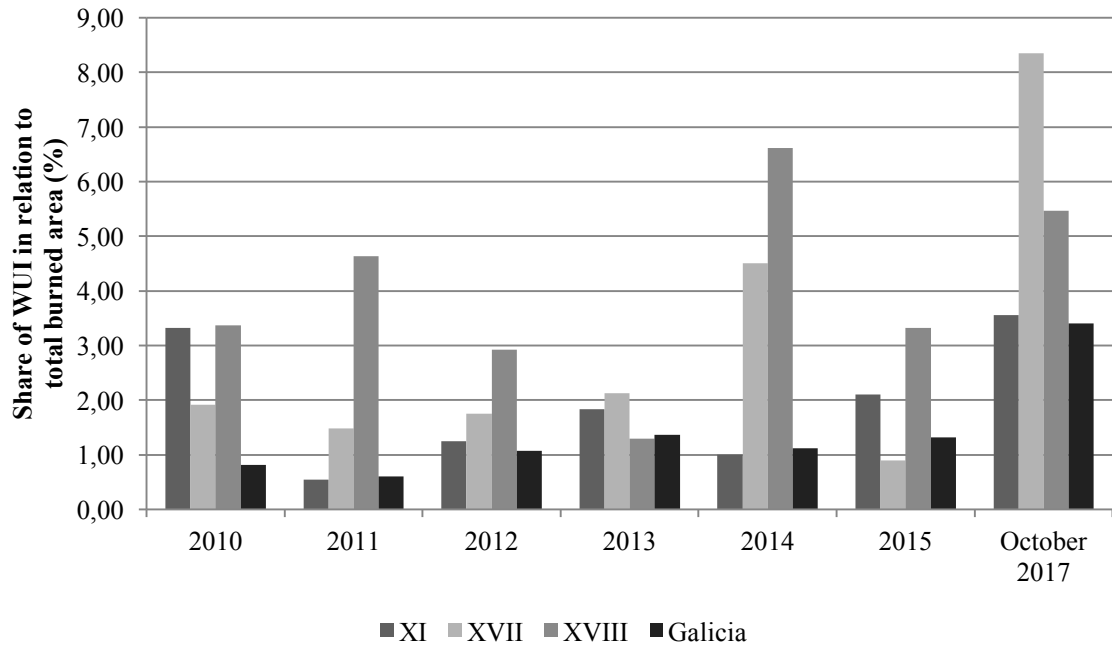
624 Fig. 3: Burned area and burn severity for October 2017 wildfires in Forest District XVII  
 625 (Galicia).



626

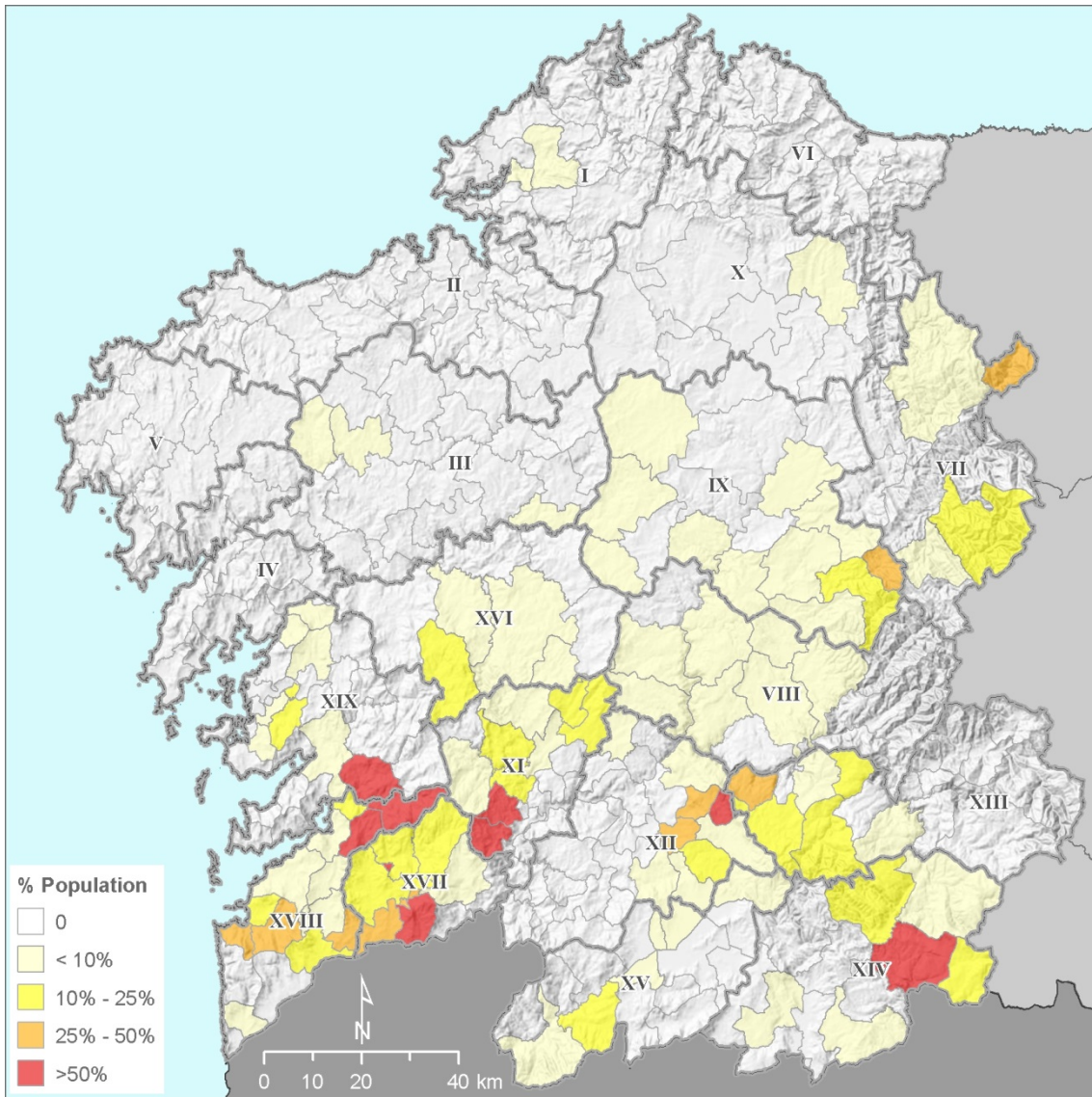
627 Fig. 4: Burned area and burn severity for October 2017 wildfires in Forest District XVIII

628 (Galicia).



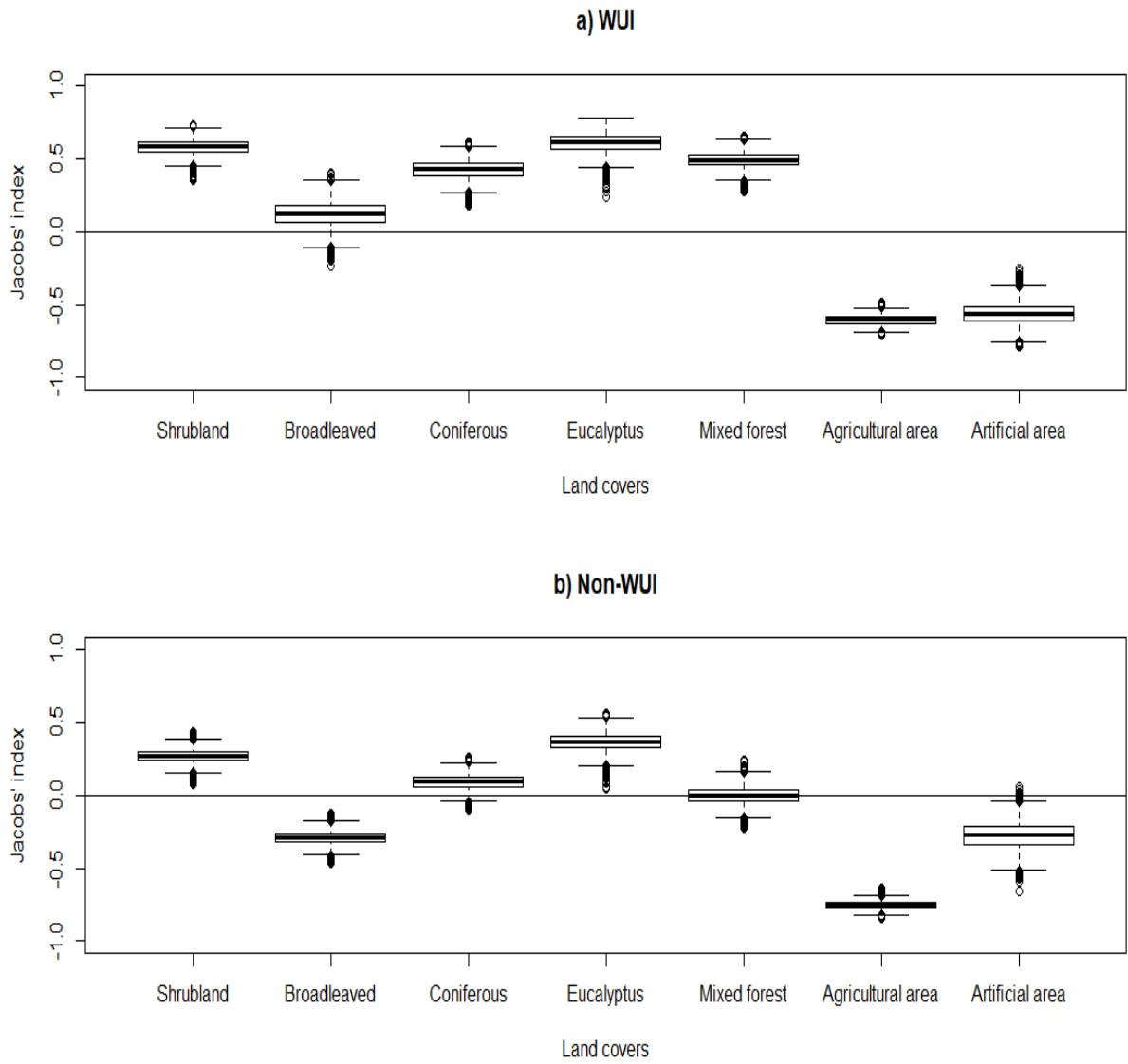
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630 Fig. 5. Percentage of burned area in the WUI during October 2017 wildfires in the most  
 631 affected forest districts and in Galicia.



632

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



635

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

639