The wildland-urban interface and the relationship with wildfires in the municipalities of Campina Grande do Sul and Quatro Barras, Paraná, Brazil

A interface urbano-rural e a relação com incêndios em vegetação nos municípios de Campina Grande do Sul e Quatro Barras, Paraná, Brasil

DOI: 10.55905/rdelosv16.n50-006

Recebimento dos originais: 17/11/2023
Aceitação para publicação: 18/12/2023

Heitor Renan Ferreira
Master in Forestry Engineering
Institution: Universidade Federal do Paraná
Address: Curitiba - PR, Brasil
E-mail: bmheitorf@gmail.com

João Francisco Labres dos Santos
Master in Forestry Engineering
Institution: Universidade Federal do Paraná
Address: Curitiba - PR, Brasil
E-mail: joflabres@yahoo.com.br

Antonio Carlos Batista
Doctor in Forestry Engineering
Institution: Universidade Federal do Paraná
Address: Curitiba - PR, Brasil
E-mail: batistaufpr@gmail.com

Alexandre França Tetto
Doctor in Forestry Engineering
Institution: Universidade Federal do Paraná
Address: Curitiba - PR, Brasil
E-mail: tetto@ufpr.br

Daniela Biondi
Doctor in Forestry Engineering
Institution: Universidade Federal do Paraná
Address: Curitiba - PR, Brasil
E-mail: dbiondi@ufpr.br

Marcos Vinicius Giongo Alves
Doctor in Forestry Engineering
Institution: Universidade Federal de Tocantins
Address: Gurupi - TO, Brasil
E-mail: mgiongo@gmail.com
ABSTRACT
Campina Grande do Sul and Quatro Barras are two Brazilian municipalities with extensive vegetative areas with social interaction and, in addition, suffer from the presence of wildfires. The aim was to delimit the wildland-urban interface for these municipalities, relating to the occurrence of wildfires, to serve as a subsidy for preventive and vegetation fire-fighting policies. It used a methodology for classifying wildland-urban interface areas, already established globally, based on the density of households and forest cover. Two methodologies from the Brazilian Institute of Geography and Statistics were used to obtain the density of households. When the statistical grid was used, Campina Grande do Sul presented a wildland-urban interface coverage of 12.5% and Quatro Barras 13.6%. In the use of census sectors, Campina Grande do Sul presented 25.7% and Quatro Barras 13.6%. The statistical grid presented greater detail than use of the census sectors. The presence of fires in areas with a wildland-urban interface demonstrates the need for preventive policies to be applied to the habitants of these places. It is recommended to continue studies, as well as to create or adapt methodologies for classifying the wildland-urban interface based on local characteristics.

Keywords: urban-rural interface, forest fire, vegetation fire, fire danger, fire prevention, wildfire prevention and combat, risks map, south of Brazil.

RESUMO
Campina Grande do Sul e Quatro Barras são dois municípios brasileiros com extensas áreas vegetativas com interação social e, além disso, sofrem com a presença de incêndios florestais. O objetivo foi delimitar a interface urbano-rural desses municípios, relativa à ocorrência de incêndios florestais, para servir de subsídio às políticas preventivas e de combate a incêndios florestais. Foi utilizada uma metodologia para classificar áreas de interface urbano-rural, já estabelecida globalmente, com base na densidade de domicílios e na cobertura florestal. Duas metodologias do Instituto Brasileiro de Geografia e Estatística foram utilizadas para obtenção da densidade de domicílios. Quando utilizada a grade estatística, Campina Grande do Sul apresentou cobertura de interface urbano-rural de 12,5% e Quatro Barras 13,6%. Utilizando os setores censitários, Campina Grande do Sul apresentou 25,7% e Quatro Barras 13,6%. A grade estatística apresentou maior detalhamento do que a utilização dos setores censitários. A presença de incêndios em áreas de interface urbano-rural demonstra a necessidade de políticas preventivas a serem aplicadas aos habitantes desses locais. Recomenda-se a continuidade dos estudos e a criação ou adaptação de metodologias de classificação da interface urbano-rural com base nas características locais.

Palavras-chave: interface urbano-rural, incêndio florestal, incêndio em vegetação, perigo de incêndio, prevenção de incêndio, prevenção e combate de incêndios florestais, mapa de risco, sul do Brasil.
1 INTRODUCTION

Forest fires are directly and indirectly responsible for numerous environmental, economic and social damages (Bowman et al. 2011; Tetto et al. 2011; Soares et al. 2017). Its occurrences are increasingly affecting the daily lives of communities present in areas adjacent to vegetation cover, especially in areas classified as wildland-urban interface.

Wildland-urban interface (WUI) zones can be generically conceptualized as areas where urban and vegetational aspects merge (United States Department of Agriculture and United States Department of the Interior 2001; Blue Ribbon Panel 2008; Australasian Fire Authorities Council 2012; Mediterranean Forest Fire Fighting Training Standardization 2018; National Wildfire Coordinating Group 2020). This promotes human influence both in the generation of combustible residue and in the burning of different materials. Also, when preventive measures are not adopted, the presence of buildings close to vegetated areas may present susceptibility to damage in the event of a fire in vegetation.

Until part of the 20th century, the distinction between forest, farm and city was generally well defined (Chandler 1983), but the advance of urban areas and the population increase from urban centers towards peripheral areas has mixed these different zonings, creating zones of wildland-urban interface (Vélez 2009). The different classification methodologies of wildland-urban interface, differ in classification methods, but converge in presenting buildings, population and vegetation as the main variables used (Radellof et al. 2005; Stewart et al. 2007; Vieira et al. 2009; Lampin-Maillet et al. 2010; Platt 2010; Whitman et al. 2013; Modugno et al. 2016; Pereira et al. 2018; Caballero 2019).

In Brazil, there is no explicit definition of the wildland-urban interface areas for purposes related to the fuels involved in the wildfire occurrences. According to Prudente (2014) and Sakakibara (2019) the distinctions between urban and rural areas are not clear. According to Caballero (2019), this situation can bring about possible harm in the elaboration of preventive policies and actions to minimize the occurrence of fires.

According to the Brazilian Institute of Geography and Statistics (IBGE 2017), in Brazil the classification of urban and rural has been carried out according to population size or demographic level, defining urban by population concentration and rural by its dispersion, being this categorization subject to transformations over time.
Sakakibara (2019) addresses in his study all issues related to the classification of urban and rural areas in Brazil, presenting different classification methodologies and suggestions for reducing inconsistencies.

The cities of Campina Grande do Sul and Quatro Barras are located in the metropolitan region of Curitiba, the capital of Paraná, Brazil, and have an extensive vegetative area with social interaction (presence of buildings). In addition, these municipalities suffer from the occurrence of wildfires, with a total of 797 records from 2011 to 2020, so they are good examples to apply methodologies so far incipient in Brazil.

The application of methodologies consolidated in other countries for wildland-urban interface characterization can be a first step towards future adaptations and elaboration of specific classification methodologies for the reality of Paraná, contributing to science and society. Thus, the present study aims to delimit the wildland-urban interface of the municipalities of Campina Grande do Sul and Quatro Barras, relating it to the occurrence of wildfires.

2 MATERIAL AND METHODS
2.1 STUDY AREA

The study area is the municipalities of Campina Grande do Sul and Quatro Barras, located in the state of Paraná, belonging to the south region of Brazil (Fig. 1). The Campina Grande do Sul city hall presents the coordinates UTM fuse 22S N 7,199,737 and E 695,805 and the Quatro Barras city hall presents the coordinates UTM fuse 22S N 7,193,123 and E 693,494 (Brazilian Institute of Geography and Statistics - IBGE 2011).
The municipality of Campina Grande do Sul has an area of 539.25 km² and Quatro Barras 180.47 km² (IBGE 2019). According to the 2010 demographic census (IBGE 2011), they have a population of 38,769 and 19,851, respectively. Campina Grande do Sul has 9.6% of its area considered as urban and Quatro Barras 15.6% (IBGE 2011).

According to data obtained by Alvares et al. (2013), the study area is located in a climate type Cfb and Cfa region according to the Köppen classification. The study area is inserted in the Atlantic Forest biome, presenting the phytogeographic domains: araucaria moist forests, dense rainforest and natural grasslands (Institute of Land, Cartography and Geography of Paraná - ITCG 2009).

2.2 DATA COLLECTION AND ANALYSIS

An adaptation of the methodology proposed by Radeloff et al. (2005) was carried out. These authors are supported on USDA and USDI (2001) definitions, which show the division into intermix WUI and interface WUI.

The methodology proposed by Radellof et al. (2005) considers an intermix zone to be that which has at least 6.18 households per square kilometer (km²) and which is in an area with 50% or more of forest cover (excluding agricultural areas). The interface zone is characterized...
as that which has at least 6.18 households per km² and which does not have a minimum of 50% of its area covered by forest, but which is at a maximum distance of 2.4 km from an area the size of 5 km² or more covered with at least 75% of forests.

The maximum distance of 2.4 km was chosen by the authors because it represents an estimate of the distance that sparks can fly from the fire front. The minimum limit of areas of 5 km² was defined to avoid the inclusion of residential areas within small urban parks. Figure 2 presents the decision flowchart for classifying the wildland-urban interface.

The results of the 2010 IBGE demographic census (IBGE 2011) were used to obtain data on the number of households per square kilometer. The data are arranged by statistical grid and by census sectors, with limits defined by the institute. The IBGE divides the statistical grid into cells of 1 km² (1 x 1 km) for areas considered rural and 0.04 km² (200 x 200 m) for areas considered urban. Census sectors are defined using IBGE’s own methodology and have variable areas. Thus, it was necessary to calculate their area and then proceed with the division of the total number of households per square kilometer.

Land cover and use was obtained through the 2019 year 5.0 collection of the Annual Land Cover and Land Use Mapping Project in Brazil (MAPBIOMAS 2020). In order to obtain exclusive forest cover, the polygons classified as “forest formation” and “planted forest” were extracted.
“Planted forests” were considered in the present study, because in addition to the lack of information on their silvicultural management (providing greater or lesser probability of fires), planted forests are relevant in the quantification of forest fuels, which may affect households close to cultivation.

By superimposing the statistical grid and the census sectors with the forest formations and planted forests, it was possible to obtain the percentage of forest cover for each polygon, classifying them with coverage equal to or greater than 50% or with coverage less than 50%.

Also, based on forest cover, polygons with areas greater than 5 km² and with at least 75% of forest cover were grouped. A 2.4 km buffer was subsequently applied to verify the centroids of the statistical grid and census sectors present in the area of operation of these polygons, enabling interface zone classification when applicable.

The geolocation of wildfire data was obtained through the database obtained by Ferreira (2021) when analysing the occurrences of wildfires in the metropolitan region of Curitiba, from 2011 to 2016.

Subsequently, was verified the number of fires that occurred in the wildland-urban interface classification zones obtained by the two census methods.

Data were manipulated using ArcGis (version 10.5), QGIS (version 3.10) and Excel (version 2016).

3 RESULTS
3.1 WILDLAND-URBAN INTERFACE DELIMITATION

Figures 3a, 3b, and Table 1 present the results obtained through the application of the methodology for classifying wildland-urban interface areas, based on the IBGE's statistical grid and census sectors.
It is observed that the fragmentation performed by the statistical grid (Fig. 3b) presents greater detail than the use of census sectors (Fig. 3a), mainly in areas classified as urban areas by the IBGE, located to the west of both municipalities.

In the city of Campina Grande do Sul, the area of the intermix zone obtained through the census sector methodology presented an overestimation of 160.9% when compared with the statistical grid methodology.

Regarding the interface zones, the statistical grid presented higher values for both municipalities, especially Campina Grande do Sul, representing 83.3% more coverage when compared to the method of census sector. This value may be related to the greater distribution of cells in the statistical grid, providing greater territorial coverage and, consequently, greater possibility of fitting the parameters necessary for its classification as an interface zone.
Analysing all the wildland-urban interface, it is observed that in the city of Quatro Barras the total area occupied was very similar between both methods used. In Campina Grande do Sul, the census sector, was 106.2% higher than the area obtained by the statistical grid.

3.2 WILDFIRE DISTRIBUTION IN THE WILDLAND-URBAN INTERFACE

Based on the results obtained by Ferreira (2021), in the period from 2011 to 2016 there were 460 wildfires in both municipalities (282 in Campina Grande do Sul and 178 in Quatro Barras), but only 314 occurrences were geolocated (68.3%).

The municipality of Campina Grande do Sul presented 165 geolocated occurrences, representing 58.5% of the records in the city. Meanwhile, Quatro Barras was 149 geolocated occurrences, representing 83.7% of the occurrences in the municipality, totaling 314 geolocated occurrences of the 460 wildfires.

This lower use of geolocated occurrences in Campina Grande Sul may be related to the territorial extension of the municipality. The validation of the address of the occurrence is performed by the nomenclature and number of the road. In many peri-urban and rural areas, there is no clear location information, it is possible that location coordinates have not been obtained.

It is observed that using the statistical grid, 15.3% (48 occurrences) were present in wildland-urban interface areas and using the census sectors, 17.2% (54 occurrences) were located in these areas.

When using the statistical grid, 19 occurrences (6.1%) were present in the intermix zone and 29 occurrences (9.2%) in the interface zone. When using the census sector methodology, 25 occurrences (8.0%) were present in the intermix zone and 29 occurrences (9.2%) in the interface zone.

As the geolocation of occurrences is dependent on addresses with registered streets, 146 occurrences (31.7%) that were unable to obtain geolocation may be related to these areas.

4 DISCUSSION

The statistical grid presented in urban areas classified separately as intermix zones without the presence of interface zones, which may have as a possible reason the influence of “urban forest” in the study area. According to Bioni (2015), urban forest represents all vegetation cover located in the urban perimeter. Thus, vegetation cover equal to or greater than
50% of the cell area, regardless of the size of the forest fragment, combined with household density, allows the classification of the cell as intermix, even if it is present in zoning classified by the IBGE as urban.

When using the census sectors, a less refined classification was generally found, extrapolating mainly the intermix zones to areas not considered as such by the statistical grid.

The reason that may be associated with the discrepancy in value observed between two methodologies for the classification of the wildland-interface in Campina Grande do Sul is the high density of households in small areas of the census sectors. The census sectors may present a high concentration of households in part of the polygon and be considered as a wildland-urban interface, even if only a small portion of the polygon has households.

The observed refinement of the statistical grid allows for a better classification and segmentation than the census sectors, which, in turn, can classify the zones in a rough way, presenting the possibility of the occurrence of overestimates in certain areas and failures in non-classification of others. However, as the presence of intermix zones in urbanized areas is observed, it is necessary to evaluate the methodology used when considering the percentage of forest cover present in cells of 0.04 km², located in areas considered urban by the IBGE.

Godoy et al. (2019), despite using the same classification methodology as the present study, did not use census blocks to obtain the wildland-urban interface of the central-western region of Patagonia, Argentina, with an area of 3,370 km². As the areas of the available blocks were greater than 10,000 ha, the authors opted for the individual geolocation of the buildings using high-resolution satellite images obtained from Google Earth. The authors used the census blocks only in areas of high household density, as in these places the density values were higher than 6.17 households per km².

The authors found a total of 6.4% of the area considered an urban-rural interface, divided into 5.5% as an intermix zone and 0.9% as an interface zone. As in the present study, they presented higher intermix zone values, but lower wildland-urban interface coverage than Campina Grande do Sul and Quatro Barras. As the study area is almost five times larger than the study area of the present research, possibly other areas with little wildland-urban interface coverage may have stood out.

In the United States of America, Radeloff et al. (2005), Stewart et al. (2007) and Martinuzzi et al. (2015) used census blocks to obtain the density of households to classify the
wildland-urban interface. Radeloff et al. (2005) mention that the blocks had an average area of 0.01 km², reaching up to 2,700 km².

The results obtained by Martinuzzi et al. (2015) show that the United States of America, which has a contiguous area of 7,827,696 km², presented 9.9% of the area as WUI, distributed in 7.8% as intermix zones and 2.0% as intermix zones interface. Due to the size of the study area of the cited authors and the national scale used, comparisons with the present research will not be carried out, as there are several variables at the national level that can influence the results.

The use of census delimitations (statistical grid and census sector) has the advantage of quickly obtaining information related to the density of households, enabling comparisons of evolution over time. However, when they present a high coverage area, they can bring about false perceptions.

The geolocation of buildings using high-resolution satellite images used by Godoy et al. (2015) may better represent the disposition and density of households. When done manually, they will demand, in addition to the images, a high amount of time spent in obtaining the coordinates. If automated or semi-automated classifications are carried out, it will be necessary to use software and complements capable of distinguishing the features inherent to the buildings. Often, these operations are related to the processing capacity of the hardware involved in the process.

To obtain information related to buildings, data on their polygons are made available for Canada, the United States of America, Uganda, and Tanzania, thus facilitating the quantification and disposition of buildings in those countries.

Despite the constructions being obtained by high resolution images, it is not possible to extract information from households in isolation, as not every building is considered a household. For example, when there are different buildings on the same property (land), some of which may refer to other non-domestic purposes, such as a garage or warehouses in general, avoiding overestimation is necessary adaptations or the creation of new methodologies for their possible use.

Regarding the geolocation of wildfire, Godoy et al. (2019) obtained in the Province of Río Negro, Argentina, a total of 56% of occurrences in intermix zones and 21% in interface zones, values higher than those found in the present research.
In the methodology proposed by Vieira et al. (2009) for the region of Ave, Portugal, the wildland-urban interface area totaled 40% of the study area and 48% of fire occurrences were located in these areas. As the methodology for classifying the wildland-urban interface was different from the present research, comparisons may lead to false inferences.

With the increase in population, the tendency is to have an expansion of households from urban areas towards rural areas. This can increase the tension between human occupations and vegetation, consequently increasing fire records.

The results obtained demonstrate that in the study area there is part of the wildfires at the wildland-urban interface, regardless of the methodology used to obtain the density of households. This demonstrates the need to develop prevention and combat policies focused on these areas. The peculiar characteristics of these places and the increase in anthropic pressure can cause future damage to life.

5 CONCLUSION

Based on the results obtained, we concluded that:

• The delimitation of the wildland-urban interface using the method of household information contained in the statistical grid presented greater detail than the use of census sectors. However, it is necessary to assess whether the cells present in the zoning outlined as urban by the IBGE should be considered, since there was an influence of the urban forest on the forest coverage percentage of the cells.

• The geolocation of the wildfire occurrences recorded in the years 2011 to 2016 showed a low presence in areas classified as wildland-urban interface. As 31.7% of the occurrences were not geolocated, there is a possibility that the presence in these areas has been larger. Regardless of the quantification, occurrences were observed in these places, thus demonstrating the need for prevention and combat policies focused on the inherent characteristics of the wildland-urban interface.

• It is recommended the continuity of studies related to the wildland-urban interface, as well as the creation or adaptation of methodologies for classification based on local characteristics.
REFERENCES


