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Mapping methodological analysis of wildland-urban interface for wildfires in south of Brazil

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Abstract

Wildfires cause several damages to flora, fauna, soil, atmospheric air and human health. The places where there is a concentration of forest fuels in contact or very close to the homes represent a great risk, because the human presence can contribute to the start of fires and can also be drastically affected in the event of a fire. These environments are called wildland-urban interface, represented by places where human beings and anthropic structures meet or mix with vegetation. There are different methodologies for the classification of the wildland-urban interface, aiming to serve as a subsidy for preventive and vegetation fire-fighting policies. In Brazil, discussions about the theme are incipient. Campina Grande do Sul and Quatro Barras are two Brazilian municipalities with an extensive vegetative area with social interaction (areas of wildland-urban interface) and, in addition, suffer from the presence of wildfires. From 2011 to 2020, a total of 797 occurrences were registered in this area. The objective of the present study was to delimit the wildland-urban interface for Campina Grande do Sul and Quatro Barras municipalities, located in the state of Paraná, Brazil, relating to the occurrence of wildfires. To achieve the proposed objective, it was necessary to use a methodology for classifying wildland-urban interface areas, already established globally, based on the density of households and forest cover, dividing into intermix and interface zones. Two methodologies from the Brazilian Institute of Geography and Statistics were used to obtain the density of households (statistical grid and census sectors). The statistical grid presents fixed cells of 0.04 km² for urban areas and 1 km² for rural areas, while the census sectors have variable areas. The results showed that when using the statistical grid, Campina Grande do Sul and Quatro Barras had coverage of 12.5 and 15.2% of the municipal areas classified as wildland-urban interface, respectively. In the use of census sectors, Campina Grande do Sul presented 25.7% and Quatro Barras 13.6% of the areas as a wildland-urban interface. This discrepancy observed when using the census sector may be related to an overestimation of household densities due to the variable size of the census sectors. When distributing the 314 geolocation of fires that occurred in the municipalities from 2011 to 2016, it was observed that when using the statistical grid, 15.3% of these were present in areas of wildland-urban interface and using the census sectors, 17.2% of occurrences located in these areas. Based on the results obtained, it can be concluded that the delimitation of the wildland-urban interface using the method of household information contained in the statistical grid presented greater detail than use of the census sectors. However, it is necessary to evaluate the methodology used to quantify coverage forestry. 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. Finally, it is recommended to continue studies, as well as to create or adapt methodologies for classifying the wildland-urban interface based on local characteristics.

1. Introduction

Forest fires are directly and indirectly responsible for numerous environmental, economic and social damages. 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. 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.

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

The cities of Campina Grande do Sul and Quatro Barras are located in the metropolitan region of Curitiba, 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.

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 (Figure 1). The Campina Grande do Sul city hall presents the coordinates UTM fuse 22S N 7.199.737 and E 695.805 e and the Quatro Barras city hall presents the coordinates UTM fuse 22S N 7.193.123 e E 693.494 (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE, 2011).

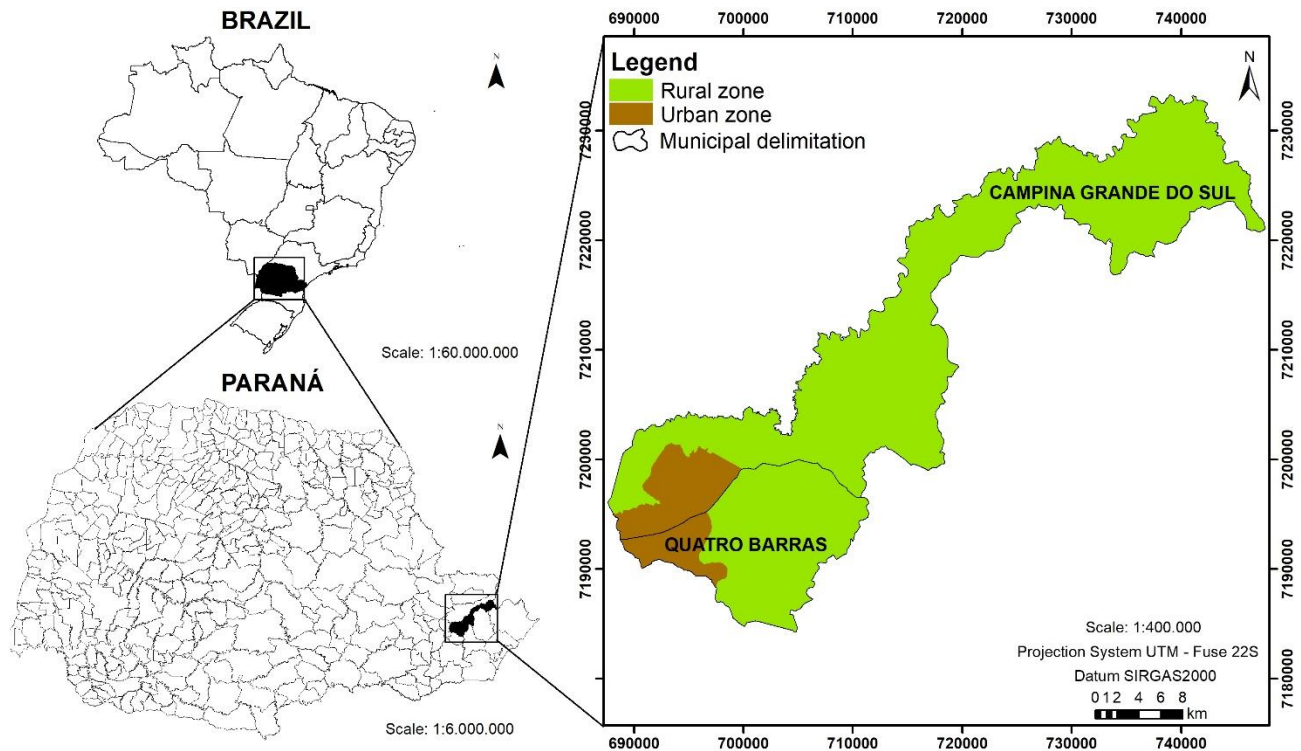


Figure 1- Localization map

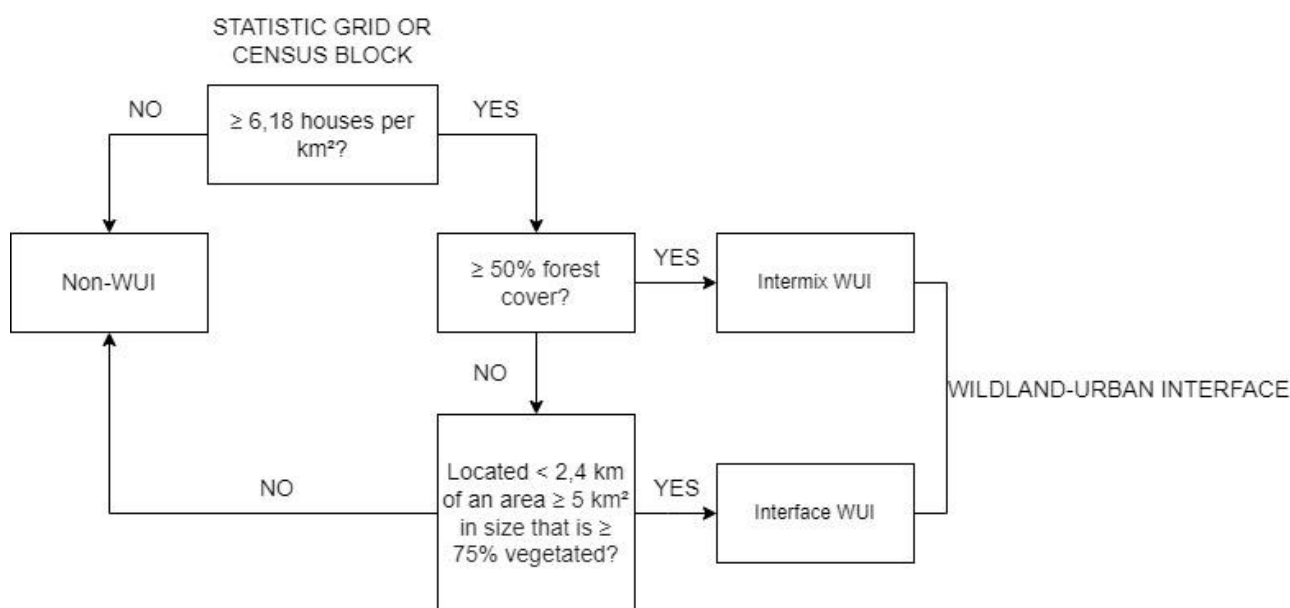
The municipality of Campina Grande do Sul has an area of 539.25 km² and Quatro Barras 180.47 km² (IBGE, 2019). According to the 2010 demographic census (IBGE, 2011), they have a population of 38,769 and 19,851,

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 (*INSTITUTO DE TERRAS, CARTOGRAFIA E GEOGRAFIA DO 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. Figure 2 presents the decision flowchart for classifying the wildland-urban interface.



SOURCE: MARTINUZZI *et al.* (2015), adapted by the authors.

Figure 2 – Decision flowchart for wildland-urban interface classification

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 *Projeto de Mapeamento Anual de Cobertura e Uso de Solo do Brasil* (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 and discussion

3.1. Wildland-urban interface delimitation

Figures 3a and 3b 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.

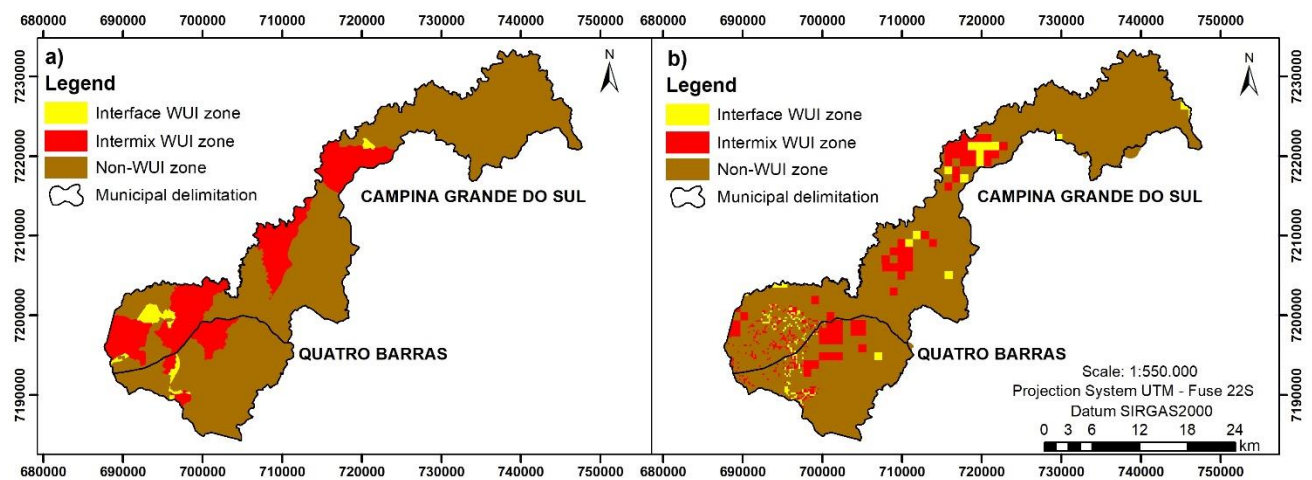


Figure 3 – Classification of wildland-urban interface areas according to: a) census sectors e b) statistical grid

It is observed that the fragmentation performed by the statistical grid (Figure 3b) presents greater detail than the use of census sectors (Figure 3a), mainly in areas classified as urban areas by the IBGE, located to the west of both municipalities.

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 Biondi (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.

In the city of Campina Grande do Sul, the intermix zone presented a total area of 129.17 km² through the census sector methodology, and when comparing with the statistical grid methodology (49.41 km²), an overestimation of 160.9% is observed. In the city of Quatro Barras, the census sector showed 21.51 km² and the statistical grid 23.27 km² for that zone.

Regarding the interface zones, the statistical grid presented higher values for both municipalities, especially Campina Grande do Sul, which obtained a total area of 17.87 km², representing 83.3% more coverage when compared to the method of census sector (9.55 km²). 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, with values of 27.5 km² for the statistical grid and 24.62 km² for the census sector. In Campina Grande do Sul, the census sector, with an area of 138.73 km², was 106.2% higher than the area obtained by the statistical grid, which presented an area of 67.28 km².

The reason that may be associated with this discrepancy in value observed 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.

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%).

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.

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.

4. 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.

5. References

- ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, Stuttgart, v. 22, n. 6, p. 711-728, 2013.
- BIONDI, D. Floresta urbana. In: BIONDI, D. *Floresta urbana*. Curitiba, 2015. 202 p.
- CABALLERO, D. **Utilización, interpretación y limitaciones del índice de interfaz WUIX**. Madrid, 2019. 65 p. Série: Cadernos Técnicos.
- CHANDLER, C.; CHENEY, P.; TRABAUD, L.; WILLIAMS, D. **Fire in forestry**. Volume II – Forest fire management and organization. Canada: John Wiley & Sons, 1983.
- FERREIRA, H. R. **Análise das ocorrências de incêndios em vegetação na região metropolitana de Curitiba-PR, no período de 2011 a 2016**. 137 f. Dissertation (Master in Forestry Engineering) - Universidade Federal do Paraná, Curitiba, 2021.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Censo demográfico de 2010: características da população e dos domicílios – resultados do universo. Rio de Janeiro, 2011. In: <<https://www.ibge.gov.br/estatisticas/sociais/saude/9662-censo-demografico-2010.html?edicao=9673&t=downloads>>. Access: 05 set. 2020.
- _____. Malha municipal. 2019. In: <<https://www.ibge.gov.br/geociencias/organizacao-do-territorio/15774-malhas.html?=&t=downloads>>. Access: 05 nov. 2020.
- INSTITUTO DE TERRAS, CARTOGRAFIA E GEOCIÊNCIAS (ITCG). Mapa de fitogeografia do Estado do Paraná. 2009. In: <http://www.itcg.pr.gov.br/arquivos/File/Produtos_DGEO/Mapas_ITCG/PDF/Mapa_Fitogeografico_A3.pdf>. Access: 20 mar. 2020.
- MARTINUZZI, S.; STEWART, S. I.; HELMERS, D. P.; MOCKRIN, M. H.; HAMMER, R. B.; RADELOFF, V. C. **The 2010 Wildland-Urban Interface of the Conterminous United States**. 2015. 123 p.
- PROJETO DE MAPEAMENTO ANUAL DE COBERTURA E USO DE SOLO DO BRASIL (MAPBIOMAS). Coleção 5.0 da Série Anual de Mapas de Cobertura e Uso de Solo do Brasil. 2020. In: <<https://mapbiomas.org/>>. Access: 20 nov. 2020.
- PRUDENTE, L. T. O lugar da interface rural-urbana no planejamento territorial: estudo de caso da região metropolitana de Porto Alegre/RS. **1º Congresso brasileiro de geografia política, geopolítica e gestão territorial**, p. 1258-1269, 2014
- RADELOFF, V. C.; HAMMER, R. B.; STEWART, S. I.; FIRED, J. S.; HOLCOMB, S. S.; MCKEEFRY, J. F. The wildland-urban interface in the United States. *The ecological society of America*, Washington, v. 15, n. 3, p. 799-804, 2005.
- SAKAKIBARA, G. M. **Classificação de áreas urbanas e rurais no Brasil: uma discussão a partir do território municipal**. 165 f. . Dissertation (Master in Geography) – Universidade Federal do Rio Grande do Sul, Porto Alegre, 2019.
- UNITED STATES DEPARTMENT FOR AGRICULTURE (USDA); UNITED STATES DEPARTMENT OF THE INTERIOR (USDI). Urban wildland interface communities within vicinity of Federal lands that are at high risk from wildfire. *Federal Register*, v. 66, n. 3. p. 751–777, 2001.
- VÉLEZ, R. La protección contra incendios en la interfaz urbano-forestal. In: VÉLEZ, R. (Coord.) **La defensa contra incendios forestales: fundamentos y experiencias**. 2.ed. Madrid: McGraw-Hill, 2009. p. 282-287