Modelling the vulnerability of urban settings to WUI fires in Chile.

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The authors wish to thank the editors and reviewers for their time and effort in reviewing our manuscript. We hope the changes listed have made the manuscript suitable for publication and we look forward to receiving your response.

We include two versions of the revised manuscript file: a normal one, and one with tracked changes in blue font.

Responses to Comments from Referee Nº1.

Dear Dr. Nolde,

Thank you very much for the helpful comments and suggestions you have made about our manuscript. In the following response, we address each of your comments in detail, identifying referee comments as "RC", and authors' comments as "AC".

RC: The authors identified attributes which determine the probability of build units to be damaged when exposed to WUI fires. The study is comprehensive and conducted thoroughly. The utilized methodology is sound and the conclusions are robust. The work also satisfactorily references other works in the field.

Some minor issues need to be addressed before the work can finally be published. This refers mostly to specific terms requiring further explanation. All comments are included directly in the PDF file.

AR: We thank the reviewer for his generally positive assessment of our work, and for his careful identification of issues that should be clarified or improved. We address each comment in the following paragraphs.

- **Page 2, Line 58.**

RC: A clear definition / differentiation between the terms "hazard" and "risk" would be desirable here. "Hazard" is defined in the next page (so is "risk", but very brieȽfly). These sections should better be placed here.

AC: We appreciate this comment, and agree with the referee that a clear definition of "hazard" and "risk" should be included in the text, and that some reordering of paragraphs is required to improve the clarity and general readability of this section. The revised version of this paragraph is the following (Lines 57-85):

“Wildfire assessments can emphasize different perspectives, including risk, hazard, and vulnerability (Galiana-Martin 2017). In its general definition, the term *hazard* refers to the process or phenomenon that may cause loss of life or injuries, property damage, social and economic disruption, or environmental degradation (Goldammer et al. 2017). The wildfire hazard is a combination of likelihood, defined as the annual probability of ignition in a specific location, and intensity, which refers to the expansion or energy expected from a wildfire (USDA 2024). Usually, wildfire hazard is associated with vegetation or available fuel, topography, weather/climate conditions, ignition likelihood, and suppression capabilities (eg., March et al. 2020b). The assessment of *risk* aims to quantify the potential losses caused by fire and its spread (eg. Jappiot et al. 2009) over a given period and spatial region, and is therefore a product of three components: (1) the hazard, (2) exposure, or inventory of population, built assets, ecosystem services and economic activities exposed to the hazard, and (3) the vulnerability, which represents the propensity of such assets to be damaged if a wildfire occurs (Oom et al. 2022,USDA 2024), and is determined for example by the socioeconomic factors, building conditions, and population demographics of exposed areas.”

Please note that due to the reordering of some paragraphs, and the updating of some literature suggested as well by Referee Nº2, the rest of section 1.2 has experienced other additional changes and improvements.

- **Page 6, L173.**

<u>RC</u>: *So, there is no NIR band information available? At least for vegetated areas, this band is crucial for burnt area assessment. So the lacking of NIR is a drawback that should be mentioned (either here or in the discussion).*

<u>AC</u>: For the drone imagery, only RGB bands are available, and the delimitation of burnt areas was performed manually for each case. However, NIR imaging from Sentinel 2 pre-event observations were used to generate NDVI layers used to represent the distribution of vegetation, and to measure the variable *dist_veg* (as described in Table 2, line 11). To convey this information more clearly, we have added subsection 2.2 describing the generation of burnt area and vegetation layers, as follows:

2.2 Generation of burnt area and vegetation layers.

For each case study, the burnt area was manually delimited based on visual analysis of the drone RGB orthomosaics. In addition, satellite imagery obtained by the Multi Spectral Instrument (MSI) on board Sentinel-2 (S2) were used to characterize the distribution and density of vegetation in each study region through the Normalized Difference Vegetation Index (NDVI; Rouse et al. 1973). This index quantifies the density of plan growth as the normalized difference between reflection at near-infrared (NIR) and optical (red) wavelengths, and in case of MSI/Sentinel-2 data is calculated as where and are the NIR and optical red band, respectively; both with a spatial resolution of 10 m (Drusch et al. 2012). Pixels with were selected to generate a vegetation raster layer (De Fioravante et al. 2021). The details of image dates and tiles used in each case study are given in the last columns of Table 1.”

We have also added a column to Table 1 with the details of the Sentinel 2 images used in each case study.

● **Page 8, Table 2.**

<u>RC</u>: preparedness: It should be stated what identifies as good and poor management, respectively (at least by examples). The same is true for "maintenance".

<u>AC</u>: We agree with the referee that these variables were not clearly defined. We have included in Table 2 a description of what their possible values represent, and also a brief reference to the data sources used to assess them in line 232.

<u>RC</u>: dist_fire, there is no explanation as to how this point is determined. As stated in line 112, "fire ignition is mostly associated with human activities", so this information is rather difficult to establish.

<u>AC</u>: The point of ignition was established based on information provided by inhabitants of the burnt areas, and/or by emergency management entities (SENAPRED, firefighters).

We have added this information in the manuscript (Line 229) and in the description in Table 2.

We include here the relevant lines of the corrected version of Table 2:

Table 1: Description of spatial variables evaluated for each housing unit in the study areas.

ID	Variable name	Description	Source	Units/classification
5	*material*	Categorical variable that classifies the dwelling's structural qualities and building materials. We define three categories, *Light*: wood, light wood, other informal materials. *Solid*: concrete, masonry. *Mixed*: combination of light and solid materials.	Field survey	Light Solid Mixed
6	*floor_area*	Ground floor area of each dwelling	Orthomosaic	Square metres
7	*area_parcel_ratio*	Measurement of the dwelling's floor area in relation to the size of the lot/parcel that it is located on	Orthomosaic	Ratio

8	*preparedness*	Binary variable that classifies the management of the dwelling's surrounding area to reduce vegetation and other potentially inflammable materials We define two categories, *Good:* the dwelling's parcel is clear from vegetation or other visible sources of flammable material (e.g. gas tanks). *Poor:* the dwelling's parcel is occupied by vegetation, or other visible sources of flammable material (e.g. gas tanks)	Orthomosaic Google Earth Field survey	Good/Poor
9	*maintenance*	Categorical variable that identifies whether the dwelling is in an acceptable overall material condition. We define two categories, *Good:* the dwelling is clear from surrounding garbage dumps or debris and does not appear to be evidently abandoned. *Poor:* the dwelling is seen to be surrounded by garbage dumps or debris, or looks evidently abandoned.	Orthomosaic Google Earth Field survey	Good/Poor
10	*dist_fire*	Euclidean distance between each dwelling and the likely point of fire ignition, as informed by local inhabitants and/or by emergency management entities.	Orthomosaic Field survey	Metres

- **Page 13, line 291:**

RC: than ⇒ that.

AC: We thank the referee for identifying this typographic mistake and have corrected it in the manuscript.

- **Page 13, line 296:**

RC: Agreed, recall appears to be the better suited metric here since it does not incorporate true negatives and is therefore independent of the size of the study region. The Intersect over Union / Jaccard Index might have been a viable alternative.

AC: We thank the Referee for the suggestion, and we presume that it refers for the Jaccard index for binary classification with a focus on true positives, defined as:

Jaccard=TP/(FN+TP+FP)

wiith TP= true positives, FP=false positives, TN=true negatives, FN=false negatives.

We run our model evaluation code using Jaccard index, and find that the results follow the same trend as those obtained using recall as our performance metric, with values that are in between accuracy and recall. Hence, we believe that including the Jaccard score does not add significant insight to the analysis in section 3.2, but we are nevertheless satisfied to have tested the Referee's suggestion. We also identify in the literature some confusion regarding the use of Jaccard index as classification metric, whereas some references define it relative to positive labels, and others consider both positive and negative labels, which further discourages us from using it.

- **Page 14, line 322**

RC: "Elevation" is expressed relative to the lowest unit in the surveyed area (as stated further down), correct? This plays a significant role, since the absolute elevation has no direvt influence on the damage probability (but secondarily due to vegetation / moisture, as stated some pages below). So this is very prone to be misunderstood and should be clarified.

AC: Correct, elevation is expressed relative to the lowest unit in the surveyed area. We have rephrased as suggested, now the text reads (Line 361):

"...we identified five variables that were consistently more important for predicting damage: the elevation relative to the lowest unit in the surveyed area (elevation), the distance…"

- **Page 14, line 325:**

RC: In line 272, it is stated that "Analysis of the attribute distribution for affected dwellings shows that most of them were built with light materials (~70%)". So this indicates a correlation between the material and the probability of a dwelling to be damaged by fire. The position of this attribute at the end of the list is rather surprising. Or is it just the case that most investigated buildings in the studied regions are build with light materials (as indicated in the discussion)?

AC: Yes, this is precisely the case. In fact, a similar percentage of non-damaged dwellings are built with light materials, We have added a sentence clarifying this point in line 365, as follows:

"The low importance of the *material* feature is explained by socioeconomic context of the studied regions, which correspond to underprivileged developments where a large majority of dwellings (~70-80%) are built from light materials."

Responses to Comments from Referee Nº2.

We thank the referee for his revision, and have pondered his general comments. We'd like to note however that the PDF file submitted has highlighted paragraphs but does not include specific notes or comments, so we were unfortunately unable to respond to more specific concerns or suggestions you may have.

In the following response, we address each of your comments, identifying referee comments as "RC", and authors' comments as "AC".

RC: The manuscript lacks novelty and originality. Novelty is the primary criterion that a manuscript should have in order to be published to a scientific journal. The specific manuscript is not presenting anything new except for conventional methods.

AC:
We do believe that our paper contributes to an emerging field of research in wildfire risk reduction in WUI areas, which is the quantitative assessment (based on statistical analyses of post-disaster surveys) of detailed-scale physical characteristics of settlements and structures, and how these features contribute to the probability of loss. As authors like Dossi et al. (2022) and Papathoma-Köhle et al. (2022) point out, there is a lack of studies focusing on this topic. Moreover, we propose a sample size of 6,061 built units (collected across seven case studies and three years of work), significantly larger than most of the studies currently available in the literature. Also, unlike several articles that focus on one or two types of physical variables, we assess three types of them: those that characterize the built unit itself, those that address the relationship between this built unit and its immediate surroundings, and those that examine the location of the built unit in its larger neighbourhood context. Finally, it is worth pointing out that we deliver the first study of this type for Latin America and Chile, an area that is expected to be severely affected by climate change in the following, one of which consequences will be more frequent and severe wildfires.
To make the novelty and contributions of our paper more clear to the reader, we have reworded and improved part of section 1.4.

RC:

The introduction should be more updated in the probabilistic assessment of vulnerability (see the references below).

AC:

Unfortunately the references suggested by the referee were not attached to his post, but we have taken into account his request to update the discussion of probabilistic vulnerability, and we do agree that some relevant works had been missed in our original version, in specific:

Caggiano, Michael D., Todd J. Hawbaker, Benjamin M. Gannon, and Chad M. Hoffman. 2020. “Building Loss in WUI Disasters: Evaluating the Core Components of the Wildland–Urban Interface Definition.” *Fire* 3 (4): 73. https://doi.org/10.3390/fire3040073.

Calkin, D., O. Owen Price, and M. Salis. 2019. “WUI Risk Assessment at the Landscape Level.” In *Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires*, edited by Samuel L. Manzello, 1184–95. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-52090-2.

Goldammer, Johann, Ioannis Mitsopoulos, Giorgos Mallinis, and Martine Woolf. 2017. “Words into Action Guidelines: National Disaster Risk Assessment Hazard Specific Risk Assessment 6. Wildfire Hazard and Risk Assessment.” https://www.undrr.org/publication/wildfire-hazard-and-risk-assessment.

Mitsopoulos, Ioannis, Giorgos Mallinis, and Margarita Arianoutsou. 2015. “Wildfire Risk Assessment in a Typical Mediterranean Wildland–Urban Interface of Greece.” *Environmental Management* 55 (4): 900–915. https://doi.org/10.1007/s00267-014-0432-6.

Oom, D., D. de Rigo, H. Pfeiffer, A. Branco, D. Ferrari, R. Grecchi, T. Artés-Vivanco, et al. 2022. “Pan-European Wildfire Risk Assessment.” Luxembourg. https://doi.org/10.2760/9429.

Sakellariou, Stavros, Athanassios Sfougaris, Olga Christopoulou, and Stergios Tampekis. 2022. “Integrated Wildfire Risk Assessment of Natural and Anthropogenic Ecosystems Based on Simulation Modeling and Remotely Sensed Data Fusion.” *International Journal of Disaster Risk Reduction* 78 (August): 103129. https://doi.org/10.1016/j.ijdrr.2022.103129.

San-Miguel-Ayanz, J., E. Chuvieco, J. Handmer, A. Moffat, C. Montiel-Molina, L. Sandahl, and D. Viegas. 2017. “Climatological Risk: Wildfires.” In *Science for Disaster Risk Management 2017: Knowing Better and Losing Less*, edited by K. Poljanšek, M. Marín Ferrer, and T. Clark, I. De Groeve, 294–305. Publications Office of the European Union. https://purl.org/INRMM-MiD/c-14445352.

Tampekis, Stergios, Stavros Sakellariou, Palaiologos Palaiologou, Garyfallos Arabatzis, Apostolos Kantartzis, Chrisovalantis Malesios, Anastasia Stergiadou, Dimitrios Fafalis, and Evangelos Tsiaras. 2023. “Building Wildland–Urban Interface Zone Resilience through Performance-Based Wildfire Engineering. A Holistic Theoretical Framework.” *Euro-Mediterranean Journal for Environmental Integration* 8 (3): 675–89. https://doi.org/10.1007/s41207-023-00385-z.

Zong, Xuezheng, Xiaorui Tian, and Lei Fang. 2022. “Assessing Wildfire Risk and Mitigation Strategies in Qipanshan, China.” *International Journal of Disaster Risk Reduction* 80 (October): 103237. https://doi.org/10.1016/j.ijdrr.2022.103237.

A critic revisit our of introduction, as well as some suggestions for Referee N°1, lead us to rewrite paragraphs in section 1.2.