Author Responses to Reviewer 2

General overview

We sincerely thank Reviewer 2 for their careful and constructive review. Your comments are very valuable in helping us identify sections that require clarification, deeper interpretation, and better integration with existing Chaco-specific literature. Below, we provide a structured response organized by topic.

1. Interpretation and contextualization

Reviewer comment: *The manuscript would benefit from a deeper interpretation of results and stronger contextualization within the existing Chaco literature.*

Author response: We fully agree. We will expand the discussion and interpretation of results by referring to additional studies that examine fire ecology, vegetation structure, and land-use dynamics across the Gran Chaco (e.g., Bravo et al. 2010; Argañaraz et al. 2015; Fischer et al. 2012; Naval Fernández et al. 2023). This will help strengthen the regional context and connect our findings to broader ecological and socio-environmental processes.

2. Elevation and slope importance

Reviewer comment: *Elevation appears as the most important variable in the Random Forest models; the explanation is vague and should be explored further. Consider re-running the analysis without elevation.*

Author response: We acknowledge this important comment. In a previous exploratory analysis not included in the manuscript, we had already tested Random Forest models excluding topographic variables (mean elevation and slope) to evaluate the relative importance of the remaining predictors. Those results showed that removing elevation and slope did not substantially alter the ranking of the other variables—the overall order of importance remained nearly identical to what can be visually inferred when disregarding elevation in the results currently presented.

In the revised manuscript, we will repeat the Random Forest analysis excluding elevation using the present dataset and covering all subregions and seasons, in order to formally assess its influence and confirm the robustness of our conclusions. Across all previous configurations, elevation consistently emerged as one of the most important predictors, which we interpret not as a direct causal factor but as a proxy for overlapping gradients in hydrology, vegetation structure, and land-use accessibility—all of which strongly influence final fire size.

We will expand the discussion to clarify this interpretation with concrete regional examples, supported by illustrative figures, such as the examples attached to this response, that could be added as supplementary material.

Some of the different direct and indirect effects of elevation can be summarized with the following examples:

1. Wet Chaco - lowlands and islets (Fig. 1):

In the floodplains of the Wet Chaco, elevation differences of only 10–20 m separate seasonally flooded lowlands from slightly higher islets ("albardones" or "montes" in Spanish) that support woody vegetation. Most fires occur in the lowlands, dominated by herbaceous cover that dries seasonally and sustains surface fires. We see that fires grow large as long as the lowlands are continuous, and that the 10-20 m higher islets act as barriers for fire growth. The tree-covered islets rarely burn, probably because trees form a discontinuous, moister fuel layer that interrupts the spread of low-intensity grass fires. Fires occurring over the islets or small lowlands patches surrounded by islets tend to be smaller than those occurring in large continuous lowlands. Elevation thus indirectly explains the spatial contrast in burned area by delineating zones with and without flammable vegetation.

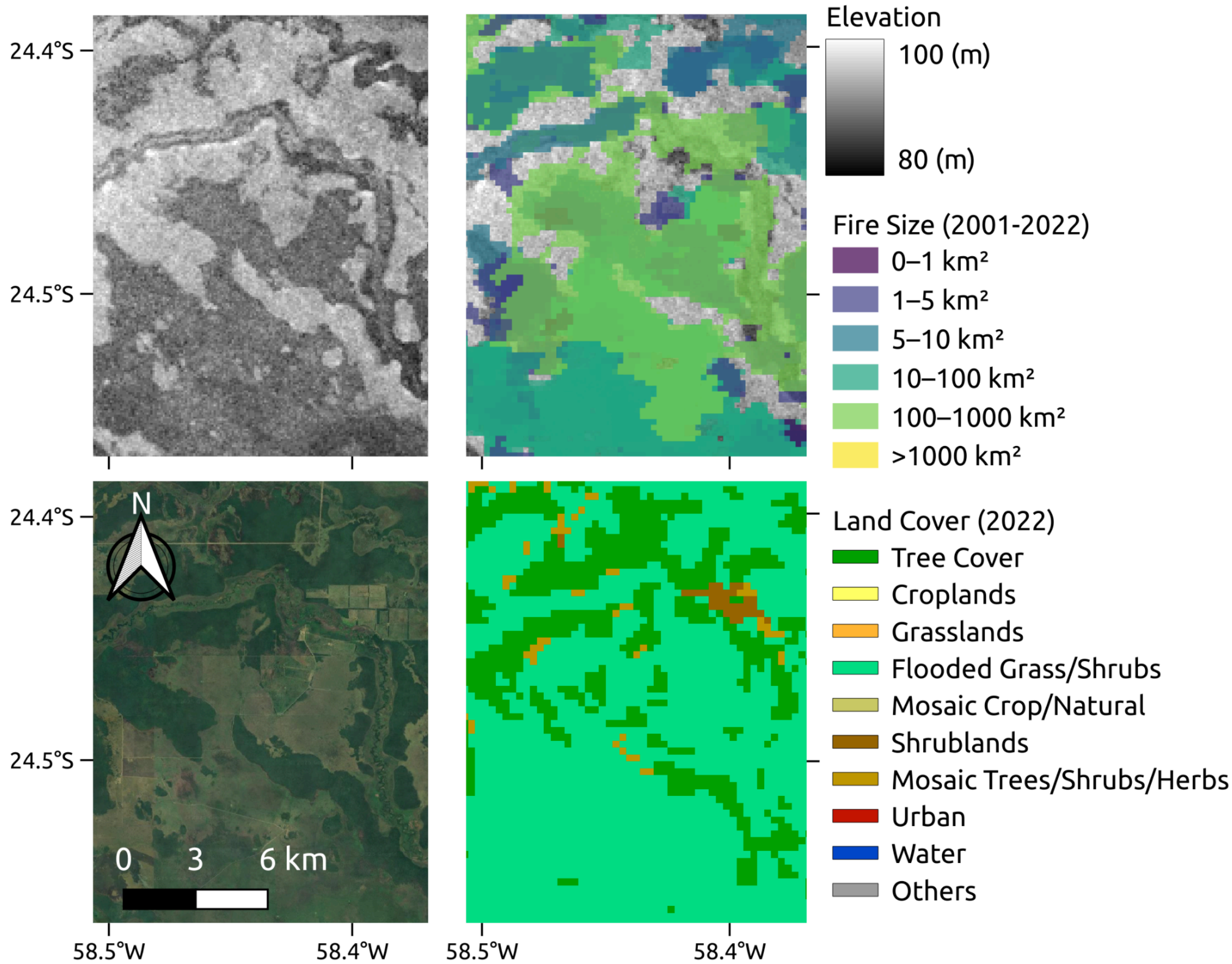

Fig. 1. Topographic and land-cover context of a representative sector of the Wet Chaco. The upper left panel shows the Shuttle Radar Topography Mission (SRTM) digital elevation model at 90 m resolution. The upper right panel displays the same elevation surface overlaid with FRY v2.0 fire polygons (2001–2022) colored by fire-size class. The lower left panel presents a Google Earth high-resolution optical image of the area, and the lower right panel shows the ESA CCI Moderate-Resolution Land Cover (MRLC) map for 2022 (300 m).

2. Wet Chaco - lowlands and islets (Fig. 2):

In some other areas, height differences (usually around 20 m, but up to 60 m) coincide with human settlements established on elevated terrain next to rivers or floodplains —for example, the city of Asunción (Paraguay) or Corrientes (Argentina). These urbanized uplands show very low fire incidence. Although this reflects land use (fast human supression or lack of ignition) rather than topography per se, topography, which originally conditioned urban placement and accessibility, currently still serves as an indirect feature determining fire occurrence and particularly size.

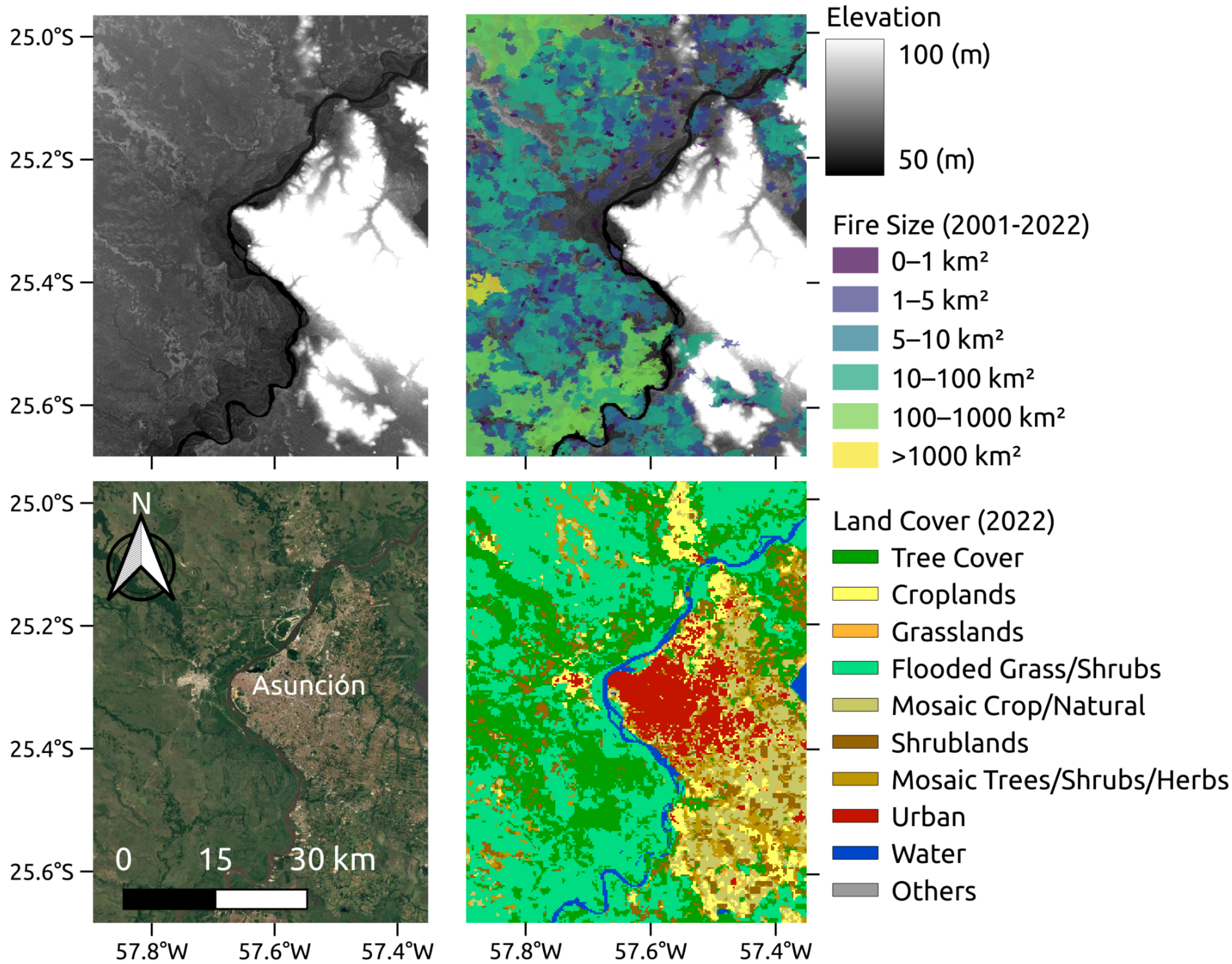

Fig. 2. Topographic and land-cover context over the city of Asunción (Paraguay's capital city). The upper left panel shows the Shuttle Radar Topography Mission (SRTM) digital elevation model at 90 m resolution. The upper right panel displays the same elevation surface overlaid with FRY v2.0 fire polygons (2001–2022) colored by fire-size class. The lower left panel presents a Google Earth high-resolution optical image of the area, and the lower right panel shows the ESA CCI Moderate-Resolution Land Cover (MRLC) map for 2022 (300 m).

3. Very Dry Chaco (mountainous Córdoba region) (Fig. 3):

In contrast, the relationship reverses in the "Sierras". Elevated zones host dense, flammable shrublands with limited accessibility, where large wildfires dominate. The adjacent lowlands are used for agriculture and pastoral activities, where fires are generally smaller and more frequently managed or controlled. Here, slope and elevation enhance fire size through their association with vegetation type and suppression difficulty. Additionally, elevation here is related to orographic precipitation and a very marked difference in humidity on one or the other side of the mountain range running North-South. This difference affects vegetation types on either side of the mountains, thus making topography an indirect driver not only of human presence and activity, but also of vegetation type and soil moisture.

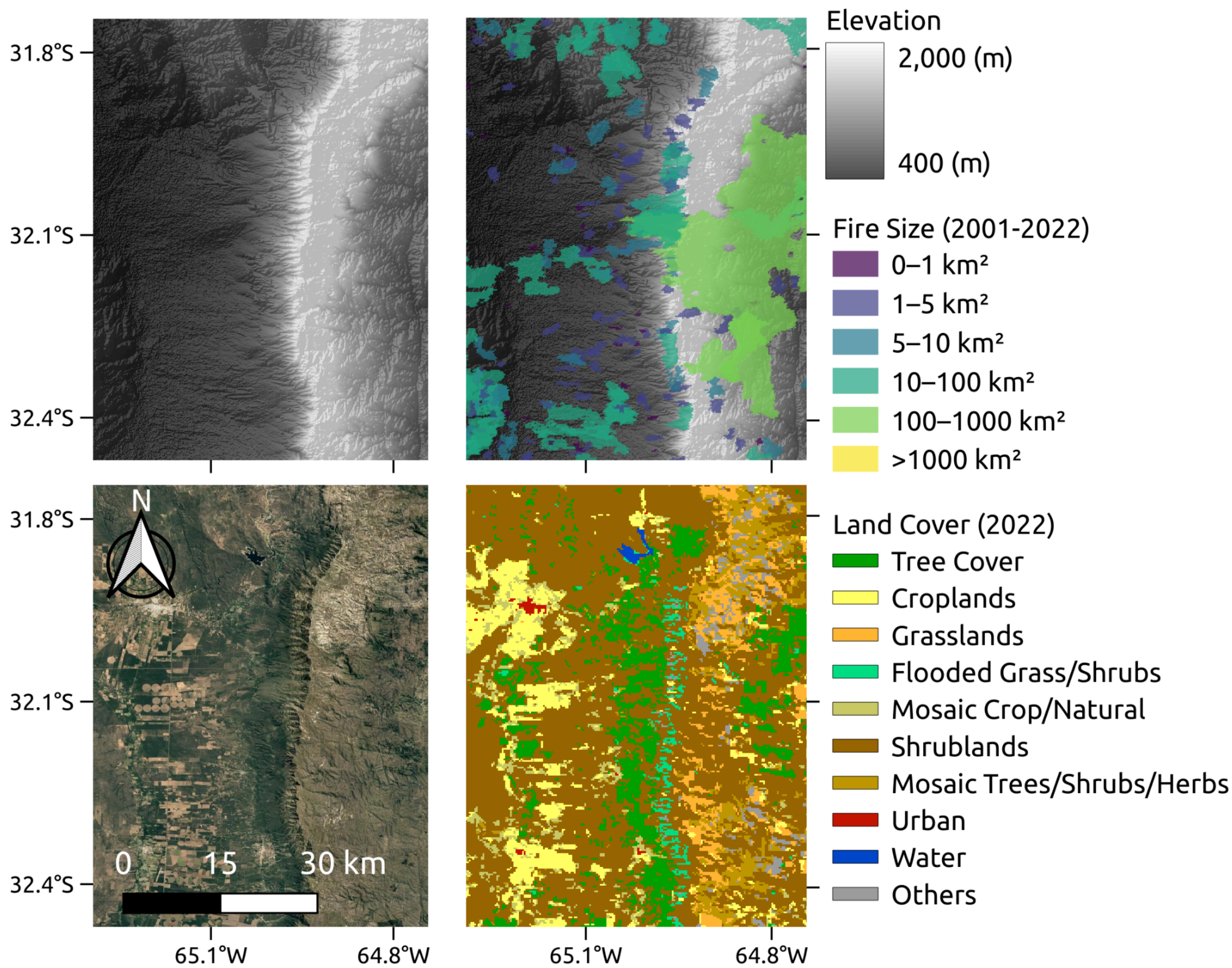

Fig. 3. Topographic and land-cover context over the "Sierras de Córdoba" in the Very Dry Chaco (Argentina). The upper left panel shows the Shuttle Radar Topography Mission (SRTM) digital elevation model at 90 m resolution. The upper right panel displays the same elevation surface overlaid with FRY v2.0 fire polygons (2001–2022) colored by fire-size class. The lower left panel presents a Google Earth high-resolution optical image of the area, and the lower right panel shows the ESA CCI Moderate-Resolution Land Cover (MRLC) map for 2022 (300 m).

4. Dry Chaco deforestation and agricultural fires (central Dry Chaco) (Fig. 4):

In the gently undulating forested plains, elevation seems to play a minor role. Fires here mostly occur in deforested agricultural areas where fuel continuity is governed by land use rather than topography. The very gradual east–west elevation gradient has a less important ecological meaning for fire spread in this subregion.

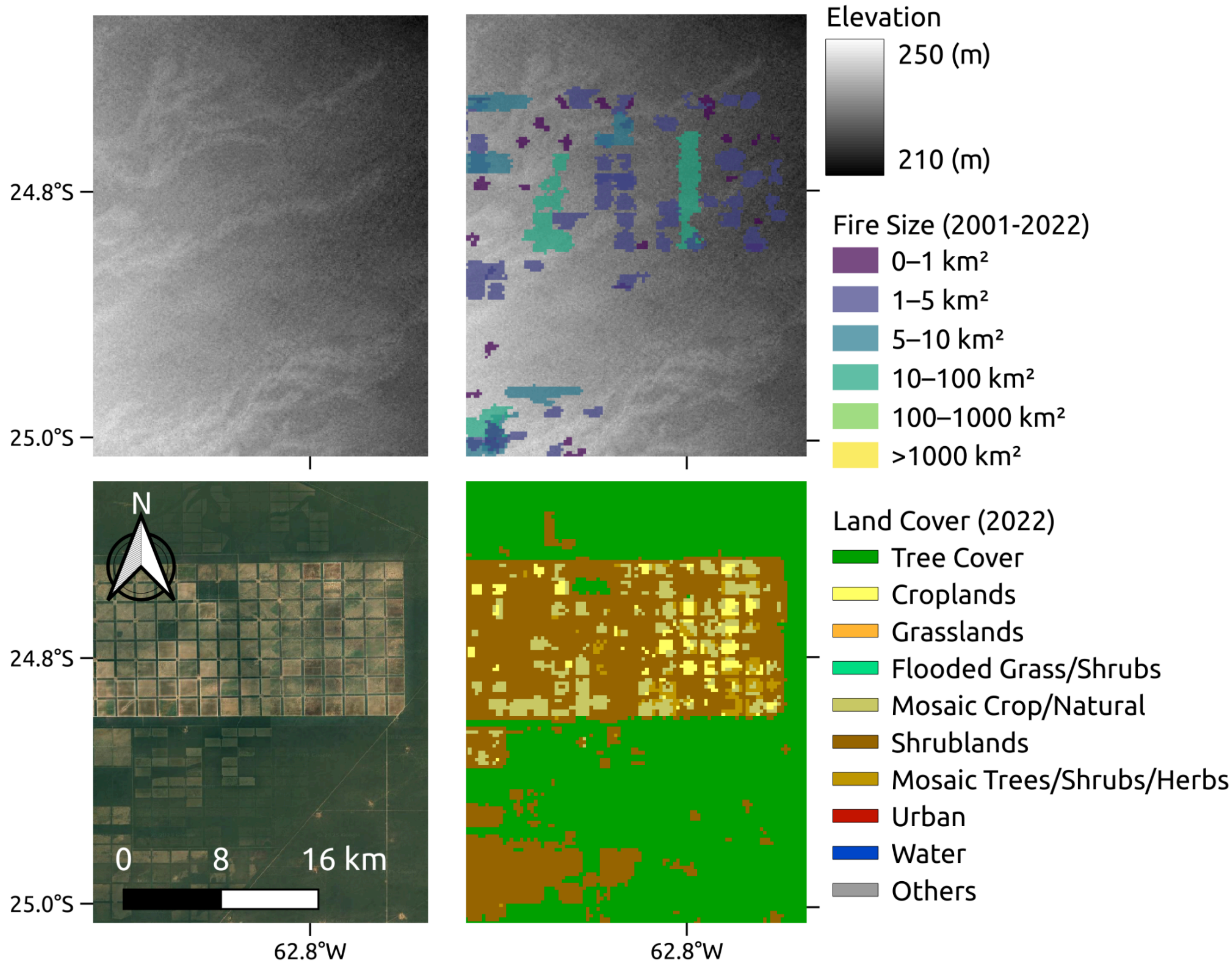

Fig. 4. Topographic and land-cover context over a deforested area within the Gran Chaco forest in Argentina. The upper left panel shows the Shuttle Radar Topography Mission (SRTM) digital elevation model at 90 m resolution. The upper right panel displays the same elevation surface overlaid with FRY v2.0 fire polygons (2001–2022) colored by fire-size class. The lower left panel presents a Google Earth high-resolution optical image of the area, and the lower right panel shows the ESA CCI Moderate-Resolution Land Cover (MRLC) map for 2022 (300 m).

Taken together, these examples show that elevation functions as an integrative variable capturing multiple mechanisms—hydrological, ecological, and anthropogenic—that differ among Chaco subregions. Its high importance in the Random Forest models reflects its ability to summarize several latent gradients rather than a direct physical control on fire spread.

Additionally, to better represent human accessibility, we will incorporate a more detailed road-network dataset to refine the calculation of road density within fire polygons. This improvement will provide a stronger proxy for human influence and allow us to test whether the prominence of elevation partly results from the current limitations of anthropogenic indicators.

Overall, these new analyses and supporting figures will clarify why elevation and slope appear as key predictors of fire size in our models and will directly address the reviewer's request for a deeper interpretation of their ecological meaning.

3. Methodological details and performance metrics

Reviewer comment: *The paper should better connect with local literature and clarify methodological details, such as Random Forest performance metrics.*

Author response: We will strengthen the discussion with key Chaco-specific studies and add model-performance metrics (e.g., out-of-bag R^2, RMSE, which were inadvertently excluded) in the Results section to reinforce our results. The Methods will also clarify variable definitions, collinearity checks, and consistent terminology (e.g., using "fire counts" instead of "ignitions").

4. Clarity and citations (L42–69)

Reviewer comment: *Revise the link between exotic grasses and fire intensity; ensure cited studies support the statements.*

Author response: We will refine several sentences to ensure each claim is directly supported by cited literature. In particular, we will clarify the discussion on exotic grasses and their influence on fire intensity. We will note that such invaded areas are spatially limited within the Chaco and adjust the phrasing to avoid overgeneralization.

5. Terminology and consistency (L192 ff.)

Reviewer comment: *Standardize terminology throughout the manuscript.*

Author response: We will standardize terminology (e.g., "fire patches" instead of "fire polygons," "meteorological" instead of "climatic," and "fire counts" instead of "ignitions") to maintain coherence throughout the text.

6. Data sources and resolution (L155–158)

Reviewer comment: *Explain why ESA CCI Land Cover was used instead of MapBiomas Chaco.*

Author response: We selected ESA CCI Land Cover (300 m) because it provides a consistent, globally validated, and temporally continuous dataset directly compatible with FireCCI51 and FRY products. This ensures coherence between the fire and land-cover components of our analysis. MapBiomas Chaco dataset, although valuable, still shows some regional classification uncertainties and requires non-trivial extraction procedures through Google Earth Engine, which complicates reproducibility and temporal analysis. For our multi-year, regional-scale work, ESA CCI LC offers a robust and harmonized framework. This justification will be made explicit in the Methods section.

7. Figures and tables

Reviewer comment: *Improve readability of figures and captions.*

Author response: Figure and table captions will be expanded for clarity, color schemes harmonized, and all morphology indices explicitly defined in the Methods. We will also avoid opening sections with figures or tables.

8. Fire Weather Types and morphology (L492 ff.)

Reviewer comment: *Clarification about FWTs and fire morphology.*

Author response: We will expand the interpretation of how Fire Weather Types (FWTs) relate to fire morphology. Wind-driven fires tend to display higher elongation and compactness. This will be clearly discussed in the Results and Discussion.

9. Discussion enrichment and literature integration (L583–669)

Reviewer comment: *Strengthen the Discussion by connecting with additional Chaco-specific research.*

Author response: We will discuss our results in light of the regional studies suggested, some of which were already referenced in the introduction and some that will be added (e.g., Bravo et al. 2010; Argañaraz et al. 2015, 2016, 2018; Bianchi et al. 2014; Fischer et al. 2012). We will also correct the section on prescribed burning.

10. Figures 10, 11, and 15

Reviewer comment: *Improve interpretability and consistency across figures.*

Author response: We will enhance visual clarity (consistent color schemes, transparency for overlapping points). Figure 15 will explicitly describe the elevation and slope ranges of the selected data used for the Random Forests.

Summary of planned revisions

- Improved figure readability and consistent design.
- Clear justification for using ESA CCI Land Cover (300 m).
- Revise the introduction and discussion sections with recommended references
- Clarified discussion of informal versus prescribed burning in the Chaco.
- Revised Random Forest analysis excluding elevation, with added model-performance metrics. Improve the discussion of
- Evaluation of a more detailed road dataset to refine road-density estimation and check the robustness of topography as the main predictor for fire size.

We thank Reviewer 2 once again for the detailed and constructive comments, which will help to clarify our scope, improve methodological transparency, and strengthen our results.