1. **Lines 143-226: The methodology section should include the rationale for the selection of model parameters and provide a sensitivity analysis to enhance the credibility of the model results.**

We have revised the model section of our methodology to include a detailed rationale for the selection of LAHARZ. This now explains the factors we considered when selecting each parameter including their relevance to the study area and impact on model accuracy. Furthermore, we have incorporated a sensitivity analysis of the DEM on the model's output. This addition enhances the robustness of the results and justify the model's applicability in the context of our research. Please see additions, in italics, to be added to the revised manuscript below:

LAHARZ is a GIS toolkit for lahar hazard mapping and modelling, developed by the USGS to calculate the area of inundation and cross sections based on empirical scaling relationships between area and volume (Schilling., 2014; Iverson et al., 1998). These empirical relationships allow for the creation of realistic inundation areas without a priory knowledge of the rheological parameters. The model simulates a debris flow triggered at a source point located on a digital elevation model and with an initial source volume. The model calculates the flow path downslope of the triggering location then generates a cross-section at each point downslope that represents the depositional volume for that area (Iverson et al., 1998).

We implemented this model using the extension in ArcGIS (USGS., 2007). We used the 30m resolution ASTER DEM as an input, as it is the most reliable of the globally available DEMs. We identified the source areas of 2019 debris flows for Chediguan and Cutou and the 2011 for Xiaojia (Cutou – 351603, 3473449; Chediguan – 350846, 3453894; Xiaojia – 356666, 3439268) from satellite imagery and used these as the triggering locations for our simulations. We then prescribed three input volumes at each of these locations ($10^4\ m^3, 10^5\ m^3$ and $10^6\ m^3$). The flow volumes simulate a range of observed post-2008 debris flows, representing low, high, and extreme debris flows documented in the Fan et al., (2019a) datasets. The volumes we selected reflects the range of similar hazard events in comparable geomorphological settings such as other parts of China and Italy (Wu et al., 2016; Bernard et al., 2019). For catchments with check dams, we added barriers at each check dam location by raising the cell count of the DEM by the height of the check dam obtained from field imagery.

The model was validated by comparing simulated runout extents with observed debris flows from post-2008 events. While a 30m resolution was the only available DEM for our study locations, we tested the sensitivity of DEM resolution on the extent of the final flow. A higher, 10m resolution DEM was available for the Cutou gully and we ran LAHARZ for that catchment. While the 10m DEM created a more effective flow path compared to the mapped data, the flow depositional area was similar in both the 10m and 30m scenario (RMSE 18m). Given the lack of a significant difference between the two DEM resolution we ran 30m scenarios across the three catchments. We note that there is not a strong understanding currently of what controls the maximum size of debris flows within Wenchuan catchments, hence we cannot attribute a particular probability to each scenario.

2. **Could authors further explain how the 'levee effect' influence exposure of large-scale debris flow events?**

We have expanded the explanation of the 'levee effect' in the revised manuscript. This section now describes how levees can alter the natural flow patterns of debris, potentially redirecting flows or causing accumulations in areas that may not otherwise be exposed. We highlight Cutou specifically to demonstrate how the 'levee effect' influences debris flow risk in the context of our study area. This helps to better integrate the theory into our analysis of debris flow exposure and risks. Please see the additions below to be added to the revised manuscript:

The levee effect can influence exposure to large-scale debris flow events by inadvertently increasing risk in areas protected by engineered mitigation structures, such as check dams. This occurs because the perceived safety provided by these structures can encourage development in vulnerable areas, which might otherwise remain uninhabited due to their high-risk nature. This phenomenon is best evidenced in our paper by the Cutou catchment, where the construction of check dams in 2013 coincided with widespread urban expansion, despite ongoing small-scale debris flow activity in the area. Subsequently, building exposure increased by 64% post-2008, underscoring the risk amplification associated with structural mitigation. This observation highlights the necessity of coupling structural interventions with strategies that address residual risks and foster community awareness of long-term hazard vulnerabilities. The 2019 debris flow event exemplified the risks associated with this effect, as the flow overtopped the check dams and used the stored material as a secondary fuel, significantly amplifying the impact. As a result, 40% of surveyed buildings were inundated, demonstrating how the levee effect can potentially escalate exposure to large-scale debris flow events.

3. **Expand the analysis of the Xiaojia area to explore the specific reasons for its low exposure changes, such as natural terrain barriers, land-use planning, or building quality.**

We have included an expanded analysis of the Xiaojia area, focusing on the factors contributing to its relatively low exposure to debris flow events. Specifically, we noted factors of natural terrain barriers as well as land-use planning measures, including zoning and construction regulations that mitigate risk. Additionally, we have considered the quality of buildings in Xiaojia, which may influence the ability of structures to withstand debris flow events. These factors are now discussed in greater detail in the revised manuscript. Please see the additions below, in bold italics, to be added to the revised manuscript:

Xiaojia was chosen as the comparative catchment due to the absence of engineered mitigation such as check dams. This analysis of Xiaojia therefore enables comparisons on the effectiveness and limitations of engineering approaches applied to Cutou and Chediguan. In Xiaojia, the lack of engineered dam structures, results in different erosion and deposition patterns compared to the other two catchments. Distinct patterns of upstream erosion and downstream deposition are observed, contrasting with the more controlled environments in the modified gullies, where deposition occurs on the northern channel flank and pronounced erosion on the southern flank. The data availability for building types, quality and spatial distribution was limited to remote sensing images and few literature sources, which restricts our ability to thoroughly assess how specific building characteristics, such as materials, influence the exposure of the built environment to debris flow hazard. This is particularly evident in Xiaojia, where more specific input data would be beneficial for understanding the role of urbanisation and construction practices on risk levels.

Our analysis of Xiaojia unveils no discernible relationship between building development and heightened exposure, particularly to residential and critical infrastructure. This lack of correlation is potentially linked to factors beyond simple urbanisation patterns, like construction quality, building regulations, presence of natural barriers, and effectiveness of mitigation measures. Natural terrain barriers observed in this gully including steep slopes and rocky outcrops, could limit the extent of debris flow impacts by reducing the mobility of debris and offering natural protection to certain areas. To fully understand this observation, further investigation into the above variables is warranted. The absence of significant urban expansion, particularly post-earthquake in Xiaojia may be a key factor in mitigating exposure. This area has experienced less intensive development compared to Cutou and Chediguan, where urban expansion following the implementation of check dams potentially increased exposure to debris flow hazards. Furthermore, the building quality in Xiaojia may play a significant role in *influencing its overall vulnerability. Without more detailed building-specific data, it is possible that buildings in Xiaojia may be of higher structural integrity or designed to withstand environmental stressors better than those in more developed catchments.*

Additionally, detailed mapping of past debris flow events and their impacts on the built environment could provide insights into the specific mechanisms influencing vulnerability in Xiaojia. By conducting a more comprehensive analysis that considers these factors – especially in terms of land-use planning, construction standards and the role of natural terrain features at the local scale, we can gain a better understanding of the complex interactions between building development and exposure to natural hazards in Xiaojia. This, in turn, can inform more effective risk management and mitigation strategies tailored to the unique characteristics of the area. Development in Xiaojia primarily concentrates on the lower slopes (Fig 5(i) and (ii)) at the gully mouth, featuring the construction of major roads and highways (G213 and G2417), alongside the expansion of existing residential areas. Chediguan exhibits a less marked land cover transformation, owing to roads being directed through mountain tunnels. Notably, development in Xiaojia mainly surges post-earthquake up to 2010, with only minor construction activities documented thereafter (Fig 5(iii)).

4. The introduction and conclusion sections should better align with the research objectives.

We have made edits to both the introduction and conclusion sections to better align with the research objectives. In the introduction, we now clearly outline the key research questions and objectives that guide the study. In the conclusion, we explicitly relate the findings back to the original research objectives, ensuring that the main contributions of the study are clearly communicated. This revision strengthens the coherence between the introduction, body, and conclusion of the manuscript, to ensure our study's main contributions are clearly communicated. Please see the changes to be added to the introduction of the revised manuscript in italics below to better align with research objectives:

This study seeks to understand whether the addition of engineered mitigation measures, primarily check dams, have influenced the susceptibility of post-earthquake Wenchuan communities to large debris flows. We compare 3 catchments with similar topography and geology, but different levels of mitigation. We measure the building exposure in two neighbouring catchments with check dams (Cutou and Chediguan) and compare with a third, unmitigated gully (Xiaojia). We examine how infrastructure develops in the basins with time and as a function of check dam measures. By analysing infrastructure development in these catchments, particularly in Cutou and Chediguan in the years following mitigation – will seek to assess how check dam construction has impacted infrastructure growth and the potential exposure to debris flow events of different sizes. Additionally, our analysis will explore whether the presence of these structures has impacted risk perception and/or land-use decisions in 'at-risk' catchments.