

## **Reviewer Comments:**

The manuscript “Dynamics and Impacts of Monsoon-Induced Geological Hazards: A 2022 Flood Study along the Swat River in Pakistan” offers an insightful analysis of geological hazards and flooding in northern Pakistan. It effectively explores the spatial distribution of these events, their hydro-meteorological triggers, and their impact on mountainous landscapes. While the study fits well within the scope of NHESS and is well-written, with strong results and discussions supporting the conclusions, minor revisions are needed to enhance clarity and robustness.

This work is significant because it detailed examines monsoon-induced hazards and their implications for disaster management and risk mitigation. Publishing this study in NHESS will provide valuable insights for the scientific community and policymakers, particularly regarding climate change, deforestation, and the interaction of extreme weather events.

The following detailed concerns should be addressed point by point:

**Abstract:** It would be better to reduce the abstract to focus on the main points and avoid repetition.

**Introduction:** The authors effectively convey the study's significance in the introduction. However, they should cite more relevant studies to highlight the study's significance and worth further.

### **Some minor concerns are highlighted below:**

The introduction states, “The registration of economic losses and human casualties due to extreme phenomena is higher in developed countries than in developing countries (Atta-Ur-Rahman, 2010).” This contradicts the subsequent statement, “Developing countries are hot spots for catastrophe events.” Could you clarify whether the registration of losses refers to absolute numbers or the proportion relative to population and GDP?

The introduction mentions various statistics and data points from different sources and years (e.g., CRED, German Watched, NDMA). Could you specify the sources more clearly and consistently? Ensure the data is recent and relevant to support the discussion of trends.

Line 47: Please check whether the reference conveys the correct information.

The terms “Flush flood” and “flash flood” are both used. Please make it consistent by using the standardized term “flash flood.”

Lines 52 and 53: Please review the sentence for clarity.

L56 to L58, please make it clear the sentence is confusing

**Study Area:** The section briefly overviews the Swat River's course and surrounding geography. However, more detail on the Swat Valley's specific topographic and hydrological characteristics would help readers better understand the context of the floods and geological hazards.

For example, how do elevation changes and river gradients influence flow patterns and flood risks?

The text mentions that the Swat River is nourished year-round by glacier streams. Can you elaborate on how seasonal variations and climatic factors, such as monsoon rainfall and glacial melt, affect the river's flow patterns and potential for flooding? How do these factors vary throughout the year, and what are the regional disaster preparedness implications?

**Methodology:** The methodology outlines using GPS to document landslides and debris flow locations with an accuracy of 1m. How was this accuracy verified? Were any challenges encountered in ensuring this precision in rugged and inaccessible terrain? Additionally, what measures ensured the consistency and reliability of data collected from different sites?

L130: "The positions of each debris flow dam and meticulously measured the dimensions" to "The dimensions of each debris flow dam were also measured and documented comprehensively."

L136: conducted to performed

L163: for "Land Use and Land Cover (LUC)" throughout the section using consistent terminology and format.

The study spans 20 years and is divided into four intervals for LUC mapping. Can you provide more detail on how the specific intervals (2002, 2009, 2016, and 2022) were chosen?

**Results:** Section 4.1: The results highlight the role of rainfall intensity and antecedent rainfall in triggering debris flows. Can you elaborate on how these factors were quantified and analyzed to establish a correlation with debris flow events? How did the return period of the flood (estimated at 425 years) influence the interpretation of the data and flood risk assessment in the study area?

Figure 1: Please check the X-axis of the panel (d). What does "Dig." mean? Please explain in the caption.

Section 4.2: Please state how flood levels were measured at different locations in one sentence. The results show a decline in vegetation cover and an increase in barren land. How do these changes correlate with the increase in debris flow events? Were any specific land use practices or human activities identified as key contributors? How do fluctuations in cropland affect slope stability and the likelihood of landslides or debris flows?

Section 4.3: Along with topographic factors, consider discussing how geological factors contribute to the occurrence of hazards in the region.

Figure 3: Use the standardized abbreviation "Land Use Cover Change (LUC)." The figure is shown as LUCL; please correct this.

Figure 3: Please also check the spelling of "Sawat" in the figure.

Figure 3: Move the legend below the bar graphs for better presentation.

Figure 3: Change the scale bar to kilometres (KM).

Figure 3: Clarify the X-axis labels for the bar graphs (0 to 50).

Line 193: Please correct the sentence.

Line 197: Please review this sentence.

Ensure consistent terminology throughout the manuscript when numbering debris flows. Some sections refer to "DF 1," while others use "DF 01."

Line 220: Please review this line.

The font size in Figure 4 is inconsistent. The Y-axis in panel (b) looks narrow—please revise. Also, in the DEM panel, the names of the catchments and debris flows are cluttered; please check and enlarge the font size.

Figure 4: Panel (a) has no heading, while panel (b) does. Consider adding more photos of the debris flow fan. Overall, the quality of the figure should be improved.

Figure 5 (b and c): The font size is unreadable—please review. Also, add a north-direction indicator.

Figures 6 and 7: The font size is also unreadable—please check and improve it.

Section 4.7: The results show significant changes in debris flow depth and velocity over time, particularly when merging with the Swat River. How do these variations impact downstream flood dynamics and hazards? Can you explain the factors contributing to the rapid increase in velocity and depth, especially in residential areas?

L325 and 326: the lines should need to be rephrased

L334 and 335: replace to "The debris flow depth reaches its peak between 45 and 60 minutes, ranging from 36 to 40 m, while the velocity reaches a maximum of 17 to 18 m/s, as shown in panels d-e and i-j, respectively."

Section 4.8: The section presents the information well. However, given the damage to infrastructure, particularly bridges and buildings, what specific design flaws were identified as contributing to their failure during the floods? How can future constructions in the Swat region be improved to withstand such events, especially considering lessons from previous incidents like the 2010 flood?

L522: change was observed to was recorded

L524: change "catalyzed" to triggered

Figure 9: Please add an overview map as panel (a) to indicate the damage locations. This will improve readability, as shown in Figure 10, where locating damaged sites is easy. Consider doing the same for Figure 9.

Why are some panel legends in Figure 10 bold while others are not? Please ensure consistency.

**Discussion:** The discussion is thorough and well-structured, connecting the key findings to broader literature and contextualizing them within global climate change and local environmental challenges. The clear presentation of data, particularly the integration of meteorological factors, deforestation, and land use, strengthens the argument.

Can you elaborate on how the numerical simulation data was validated, particularly regarding the debris flow velocities and depths? Clarifying this would enhance the reliability and accuracy of the findings.