

1. Introduction

Floods and debris flows are among the most destructive natural hazards in mountainous regions of Central Asia, particularly in southern Kyrgyzstan, where steep slopes and intense rainfall create favorable conditions for rapid runoff and sediment transport. The debris-flow event of 28 June 2024 in the Abshyr-Sai basin (Nookat District in Kyrgyzstan) caused significant damage to houses, roads, and infrastructure, and also resulted in fatalities. Therefore, there is a need to develop reliable methods for flood hazard assessment in data-limited mountainous regions.

2. Study area

The study area is located in the Abshyr-Sai basin in the Nookat District, Osh Region, southern Kyrgyzstan. The basin area covers approximately 278.5 km² and includes several tributary valleys that contribute runoff and sediment to the main channel. The region is characterized by steep mountainous terrain and narrow valleys, which promote rapid runoff and make it highly susceptible to debris-flow hazards. Within this system, the main initiation area of the 28 June 2024 debris-flow event is located in a smaller sub-catchment of approximately 10–20 km², where intense rainfall triggered rapid sediment mobilization.

3. Methodology

This study applies an integrated approach combining GIS-based susceptibility analysis and hydraulic modelling. Debris-flow susceptibility was evaluated using the Analytical Hierarchy Process (AHP) based on six conditioning factors: rainfall (CHIRPS), slope, distance to river, flow accumulation, curvature, and elevation derived from DEM.

Hydraulic simulation was conducted using HEC-RAS 2D to estimate flow depth and velocity. Flood intensity was calculated as:

$$I = D \times V$$

The flood hazard map was produced by combining AHP-based susceptibility and hydraulic intensity results.

4. Results

The debris-flow susceptibility map was generated using six conditioning factors, including rainfall, slope, elevation, curvature, flow accumulation, and distance to river. The results show that rainfall is the main triggering factor, while slope and flow accumulation influence the spatial distribution and concentration of debris flows. **Fig.1**

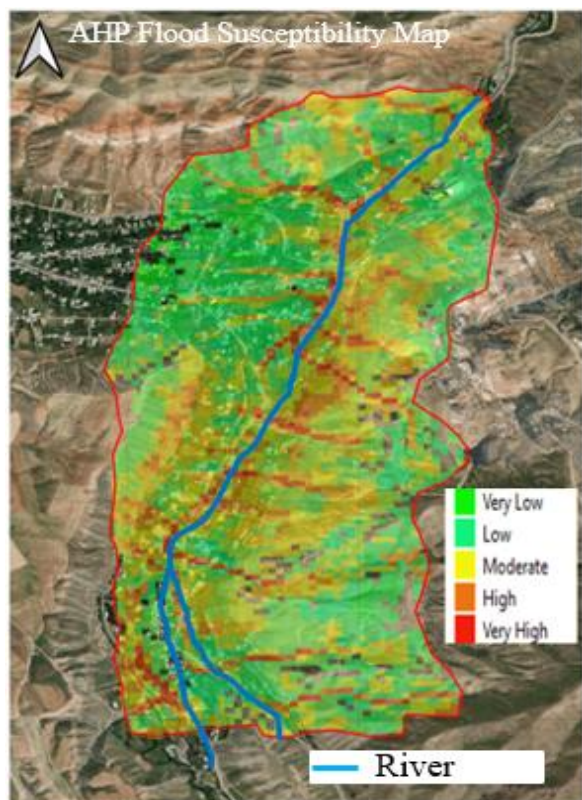


Figure 1: AHP-based flood susceptibility map of the Abshyr-Sai basin showing five classes (very low to very high). High susceptibility zones are mainly located along the main river channel.

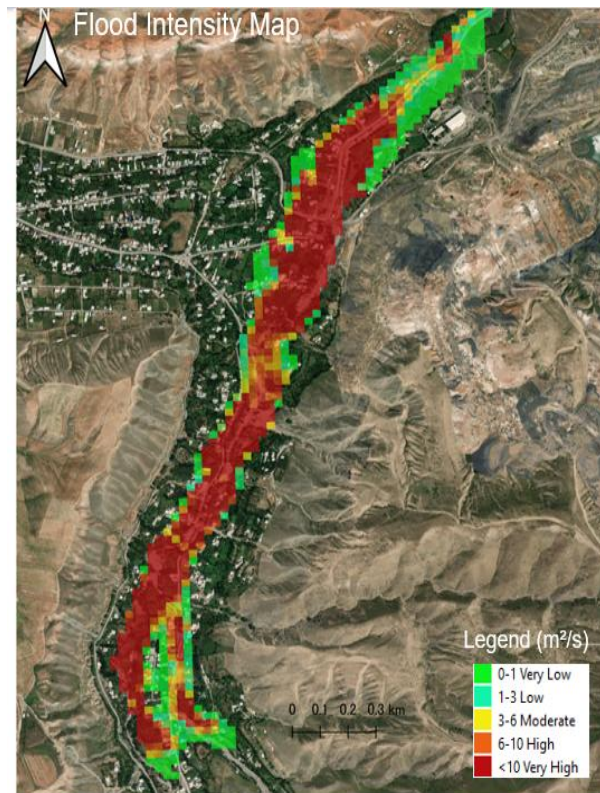


Figure 2: Flood intensity map of the Abshyr-Sai basin based on flow depth and velocity ($I = D \times V$).

Hydraulic simulation using HEC-RAS 2D provided spatial distributions of flow depth and velocity. Flood hazard intensity was calculated as $I = D \times V$, representing the destructive power of the debris flow. Areas with high depth and velocity values correspond to zones of high hydraulic impact **Fig.2**.

Validation using official damage data suggests that many of the affected houses are located in areas identified by the model as having elevated hazard levels, particularly along the main flow paths. The dataset includes different levels of damage, total observed houses 499 with 4 destroyed houses, 28 severely damaged, 93 with minor damage, and 374 with no damage. A noticeable concentration of damaged houses can be observed in zones following the spatial pattern of the simulated flow paths and areas of increased hydraulic influence. This result suggests a general spatial correspondence between the modelled hazard distribution and the observed impacts, although some differences may be related to local conditions and data limitations. **Fig. 3**.

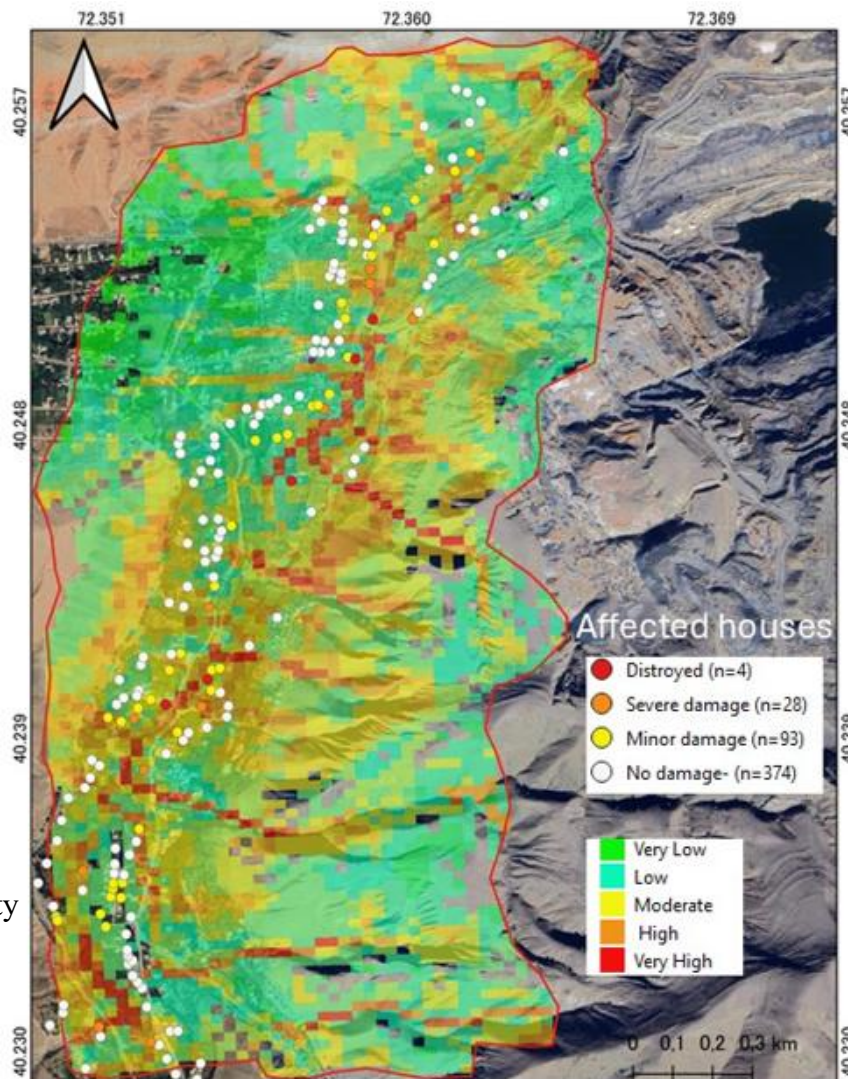


Figure 3: Validation of the flood susceptibility map using observed house damage. Affected houses are mainly distributed along the identified flow paths, showing a spatial correspondence with the model results.

5. Discussion

The integration of AHP-based susceptibility analysis and hydraulic modelling improves the accuracy of hazard assessment compared to using a single method. The results confirm the importance of rainfall as a trigger and slope as a controlling factor, which is consistent with previous studies in mountainous regions. However, uncertainties remain due to limited hydrological data and simplifications in model assumptions.

6. Conclusion

This study demonstrates that combining GIS-based susceptibility analysis with hydraulic modelling provides an effective and practical framework for flood hazard assessment. The approach is particularly useful for data-scarce mountainous regions such as southern Kyrgyzstan and can support disaster risk reduction and planning.

7. References

- Shahgedanova, M., et al. (2024). Climate and hydrological hazards in Central Asia. (*Regional study*). Flood susceptibility mapping using GIS-based methods. *Journal of Hydrology*, 512, 332–343.
- Costache, R., Pham, Q.B., Sharifi, E., Linh, N.T.T., Abba, S.I., & Vojtek, M. (2020). Flash-flood potential mapping using GIS. *Science of the Total Environment*, 698, 134211.
- Kalashnikova, O.Yu., et al. (2023). Hydrological modelling of debris flow processes in the Alai region in Kyrgyzstan.