Sustainable Solutions for Flood: Mapping Risks, Assessing Coping Capacities, and Promoting Rainwater Harvesting Initiatives

Muhammad Qasim[1,2*]

[1] Nova Information Management School, Universidade Nova de Lisboa, Lisbon, Portugal
[2] Remote Sensing, GIS, and Climatic Research Lab (RSGCRL), Department of Space Science, University of the Punjab, New-Campus, Lahore, Pakistan.
Corresponding author: Muhammad Qasim (khanjiqasim@gmail.com)

Abstract

Amid the accelerating frequency of floods in Pakistan, conducting a thorough flood risk assessment has become essential for effective mitigation and resilience planning. This study investigates the application of geospatial technologies in mapping flood-prone areas and identifying rainwater harvesting potential in four districts i.e., Poonch, Rawalakot, Bagh and Muzaffarabad, Azad Kashmir. The research employs GIS, remote sensing, and various datasets to assess flood risks, considering factors like rainfall, topography, soil types, and land use. The methodology involves three main components: Flood Risk Mapping (FRM), Rainwater Harvesting Potential Zonation, and Coping Capacity Layer. Analytical Hierarchy Process (AHP) and weighted overlay operation is utilized for decision-making hierarchies in flood risk assessment and rainwater harvesting potential zonation. Results highlight high flood risks in Muzaffarabad and Neelum districts, with specific vulnerable zones identified. The Rainwater Harvesting Potential Zonation reveals Bagh and Muzaffarabad as districts with high potential for rainwater harvesting, aiding in sustainable water resource management. The study contributes to informed decision-making aligned with Sustainable Development Goals related to sustainable cities, clean water, and climate action.

Keywords: Sustainability, AHP, Kashmir, rainwater, disaster management

1 Introduction

Natural disasters, especially flooding, are significant global concerns, causing extensive damage. Flooding, driven by hydrological changes and precipitation variations, leads to displacement, property damage, and waterborne illnesses (Alkaradaghi et al., 2022). In Pakistan and Kashmir, floods have severe consequences due to geographical features and climate, necessitating comprehensive flood management techniques (Radwan & Alazba, 2022; Sun et al., 2023). Climate change exacerbates flooding risks, emphasizing the need for effective strategies (Bhat et al., 2019).

Geospatial technologies like GIS and remote sensing play a crucial role in mapping flood-prone areas and developing mitigation strategies. Badamasi (2022) integrated hydrological modeling and GIS for sustainable rainwater collection. Siddiqui et al. (2022) assessed disaster resilience in Northern Pakistan using a mixed-method approach. These technologies contribute to enhanced preparedness and resilience. This research aimed to understand flood triggers through historical data and GIS analysis, map flood risks, and enhance resilience to heavy rainfall by implementing rainwater harvesting technologies. The study aligns with Sustainable Development Goals 11, 6, and 13, focusing on sustainable cities, clean water, and climate action.

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2 Study Area

The study area for this research is Poonch and Muzaffarabad Division, Azad Jammu and Kashmir (AJK), Pakistan which is divided into four districts i.e., Neelum, Muzaffarabad, Bagh and Poonch. Below in figure 1 is shown the study area map.

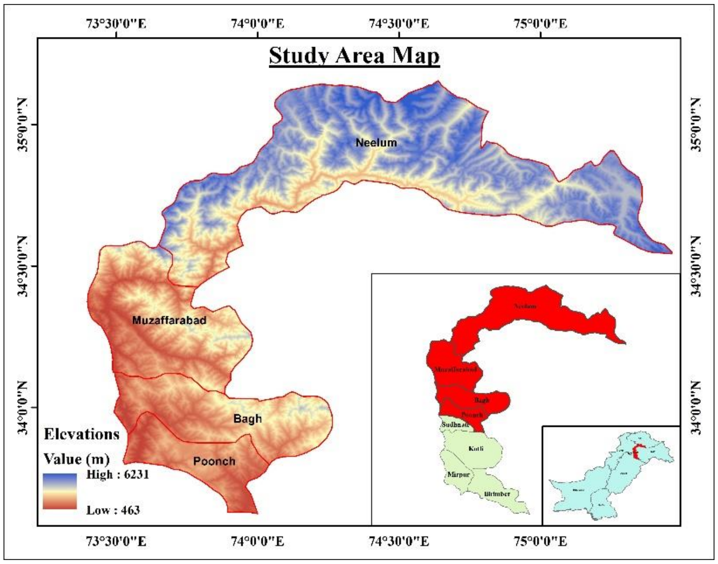

Figure 1. Study Area Map

3 Methodology

3.1 Materials

Different types of datasets were required for flood risk assessment, rainwater harvesting and coping capacity layer. The data further processed in GIS environment (ArcGIS Pro, ArcMap and QGIS), and the final maps were generated from these data sets. The data sets used in this study are shown in the table below.

Table 1 Datasets used in this study.

Dataset Name	Source	Format	Use
DEM (30×30m)	https://dwtkns.com/srtm30m/	raster (tiff)	Hydrological uses (slope, aspect etc.)
Rainfall	https://crudata.uea.ac.uk/cru/data/hrg/	netcdf	Rainfall Map, Curve Number
Lithological Data	GLiM, Hartmann and Moosdorf, 2012	Shapefile (polygons)	Lithology Map
Soil Data	FAO	shapefile (polygons)	Soil types map
Sentinel 2	Copernicus	raster (tiff)	NDWI
Flood Inventory	On ground Survey	Shapefile (point)	Flood Inventory Map

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3.2 Flowchart of methodology

This study involves various geospatial techniques i.e., interpolation, Euclidean distance, weighted overlay, raster calculator, classification, digitization, reclassification etc. Flowcharts for flood risk map and rainwater harvesting potential zonation are given below.

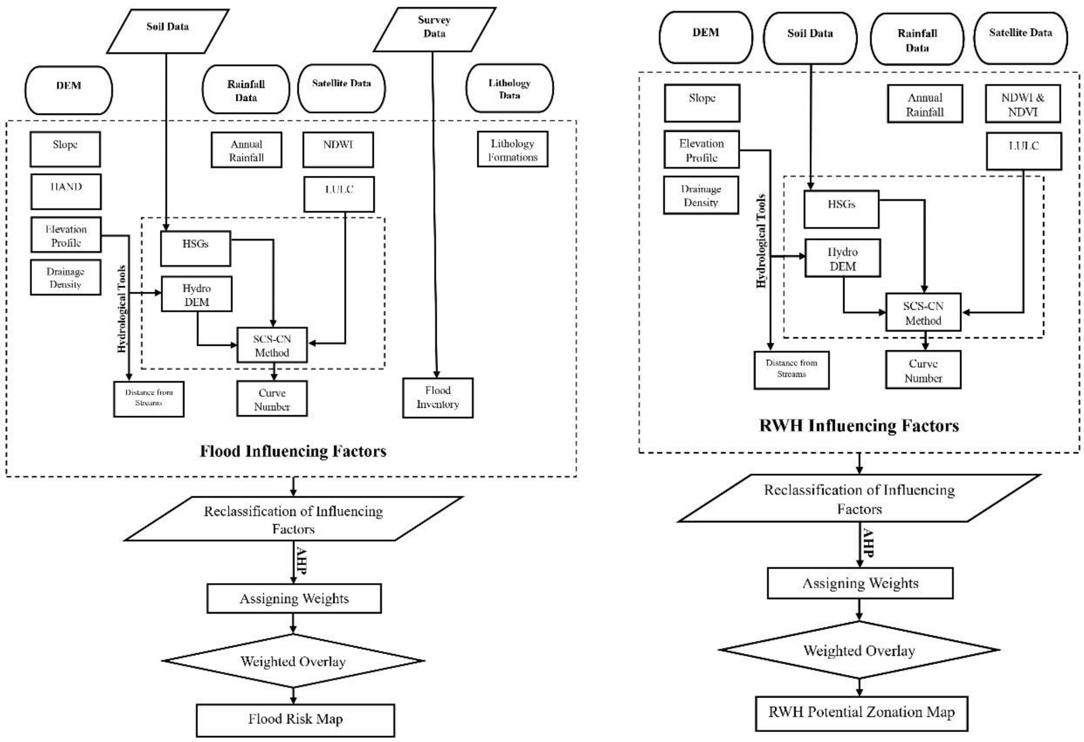

Figure 2. Flowcharts for FRM and RWH Potential Zonation Map

4 Results

Weighted Overlay, a GIS technique, combines raster layers using specific weights to represent the combined influence of various factors.

For Flood Risk Assessment, the formula used for weighted overlay is given below,

Flood Risk Map = D2S*30.1 + RF*22 + DD*14.2 + CN*9.4 + HAND*7.8 + SLOPE*4.7 + DEM*4.7 + LITHOLOGY*3.2 + LULC*2. 2 + NDWI*1.7

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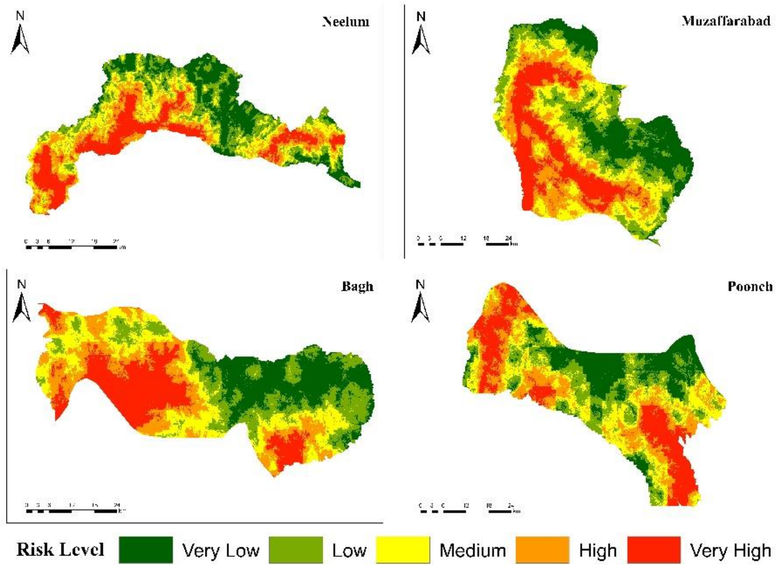

Figure 3. Flood Risk map

The generated flood risk map highlighted Muzaffarabad and Neelum districts as particularly high-risk areas, attributed to infrastructure near riversides, the presence of low-lying villages, glacier melting from climate change, and the impact of high rainfall leading to flash floods.

For Rainwater Harvesting Potential Zonation, formula used is given below,

RWH Potential Zonation = Rainfall*31.2 + CN*22.1 + DD*15.2 + LULC*10.3 + D2S*6.8 + SLOPE*4.4 + DEM*4.4 + NDVI*2.8 + NDWI*2.8

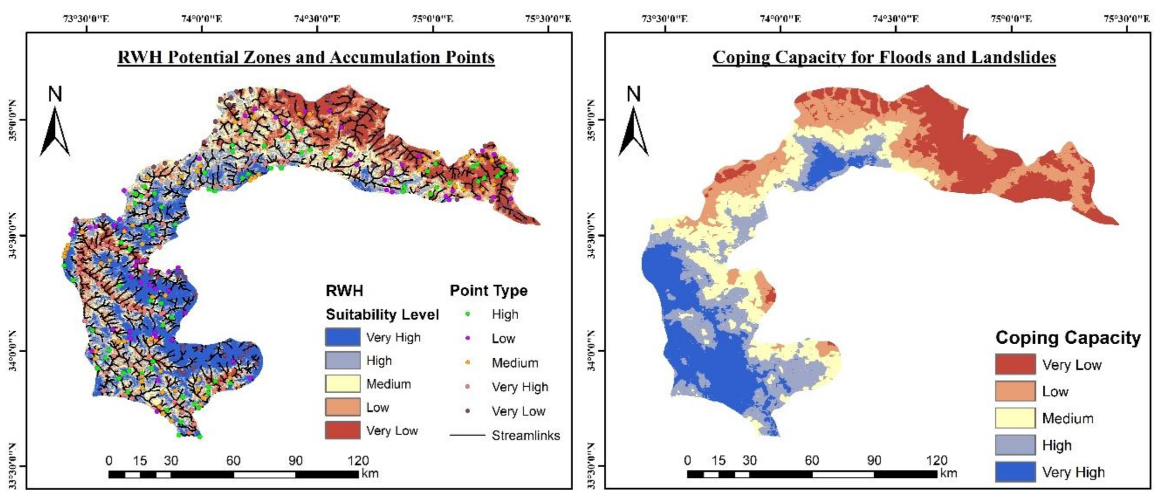

Figure 4. **Left**: Rainwater Harvesting Potential Zonation Map with accumulation points, **Right**: Coping Capacity of the region

Rainfall and curve number were identified as the most sensitive layers in RWH potential zonation, with rainfall assigned the highest weight of 31.2 and curve number receiving the second-highest weight of 22.1. The resulting suitability map classified the study area into Very High, High, Medium, Low, and Very Low suitability classes. Bagh and Muzaffarabad emerged as districts with the highest potential for rainwater harvesting, especially in areas with seasonal snowfall and subsequent meltwater. The study's detailed spatial distribution analysis provides valuable insights for identifying optimal locations for RWH structures like tanks and check dams, contributing to sustainable water resource management in the region.

Coping capacity, representing a region's ability to manage natural disasters, was assessed based on four factors: proximity to government buildings (30%), roads (30%), health sites (30%), and distance from streams (10%). Poonch emerged with the highest coping capacity, attributed to its smaller size and abundant resources. Bagh followed as the second highest, with Muzaffarabad ranking third, while Neelum exhibited the lowest capacity due to limited resources.

5 Conclusion

Addressing the rising risks of floods in Pakistan requires a concerted effort in disaster management. Utilizing GIS and remote sensing, this study emphasized the significance of risk maps for informed decision-making and the potential of rainwater harvesting to alleviate both water scarcity and disaster impacts. Despite limitations in obtaining accurate datasets, the findings highlighted the importance of improving data integration, validating models, enhancing public awareness, implementing sustainable land use planning, and establishing monitoring systems. By acting upon these recommendations, the study contributed to a more resilient and prepared community, laying the foundation for effective disaster management strategies in the face of evolving climate challenges.

References

Alkaradaghi, K., Hamamin, D. F., Karim, H., Al-Ansari, N., Ali, S. S., Laue, J., & Ali, T. B. B. T. (2022). Geospatial Technique Integrated with MCDM Models for Selecting Potential Sites for Harvesting Rainwater in the Semi-arid Region. *Water, Air, & Soil Pollution*, *233*(8). https://doi.org/10.1007/s11270-022-05796-2

Badamasi, H. (2022). A review of GIS-based hydrological models for sustainable groundwater management. In *Current directions in water scarcity research* (pp. 183–200). https://doi.org/10.1016/b978-0-323-91910-4.00012-1

Bhat, M. S., Alam, A., Ahmad, B., Kotlia, B. S., Farooq, H., Taloor, A. K., & Ahmad, S. (2019). Flood frequency analysis of river Jhelum in Kashmir basin. *Quaternary International*, *507*, 288–294. https://doi.org/10.1016/j.quaint.2018.09.039

Mahmood, K., Qaiser, A., Farooq, S., & Nisa, M. U. (2020). RS- and GIS-based modeling for optimum site selection in rainwater harvesting system: an SCS-CN approach. *Acta Geophysica*, *68*(4), 1175–1185. https://doi.org/10.1007/s11600-020-00460-x

Radwan, F., & Alazba, A. A. (2022). Suitable sites identification for potential rainwater harvesting (PRWH) using a multi-criteria decision support system (MCDSS). *Acta Geophysica*, *71*(1), 449–468. https://doi.org/10.1007/s11600-022-00895-4

Siddiqui, T., Saadat, A., & Ameen, A. M. (2022). Devastating flood emergency in Pakistan- a recent threat to country's health care system. *Annals of Medicine and Surgery*, *82*. https://doi.org/10.1016/j.amsu.2022.104633

Sun, X., Jin, K., Tao, H., Duan, Z., & Gao, C. (2023). Flood Risk Assessment based on Hydrodynamic Model—A case of the China–Pakistan Economic Corridor. *Water*, *15*(24), 4295. https://doi.org/10.3390/w15244295

Zakaullah, U., Saeed, M. M., Ahmad, I., & Nabi, G. (2012). Flood frequency analysis of homogeneous regions of Jhelum River Basin. *International Journal of Water Resources and Environmental Engineering*, *4*(5), 144–149. https://doi.org/10.5897/ijwree12.013

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