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# COMPARATIVE FLOOD RISK MODELING AND SOCIOECONOMIC VULNERABILITY ASSESSMENT USING THE 2025 PAKISTAN FLOOD EVENTS ACROSS MULTIPLE PROVINCES

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**Abstract**

*The article presents a comparative flood risk modeling and socioeconomic vulnerable assessment of the 2025 floods in the three largest provinces in Pakistan; Punjab, Sindh, and Khyber Pakhtunkhaw (KPK). The quantitative elements used include intensity of rainfall, extent of flooding and level of poverty to determine the regional difference in the impacts of floods. As the findings reveal, Sindh experienced the highest rainfall (420 mm) that is 38 percent of the total precipitation and the biggest area flooded (7,800 sq km) that is 45 percent of the total inundation. Furthermore, Sindh had the highest level of poverty (37%), which predisposes it to a tremendous degree. Punjab on the other hand recorded the minimal contribution to rainfall (29%), least area flooded (25%), and lowest poverty rate (24%) and this implies that it is not as risky. KPK had moderate values in all the indicators with contribution to rainfall of 33 percent and flooded area and poverty rate of 30 percent and 29 percent respectively. The fact that Sindh was the most vulnerable province (42%), KPK (31) and Punjab (27) was further established in the composite index of the flood risk. The model-based analysis resulted in the estimation of a probability of 78, 65 and 55 floods in Sindh, KPK, and Punjab respectively. The study concludes that the environment and socioeconomic status influence the flood risk. These findings imply that there is a need to have combined flood management strategies that are sensitive to both the physical infrastructure and social susceptibility to enhance resiliency to disasters.*

## 1. INTRODUCTION

Floods are one of the most terrible natural catastrophes that have hit Pakistan and this has caused colossal economic damages, destruction of infrastructure and population displacement(Mumtaz et al., 2026). The floods of 2025 once again highlighted how other provinces were vulnerable to the floods particularly Punjab, Sindh and Khyber Pakhtunkhawa (KPK) due to the variation between the climatic, geographic and socioeconomic factors. Climate change, inadequate drainage and fast urbanization have contributed to extreme rainfall, which can cause floods in these regions(Khan et al., 2023).

Hydrological conditions such as the rainfall and outflow of rivers are not only determinants of the risk of floods, but also social-economic factors such as poverty, infrastructure robustness, and preparedness to deal with disasters. The low land nature in provinces like Sindh is likely to experience the prolonged floods as compared to

KPK which is likely to experience flash floods because of mountainous nature. Punjab is an agriculturally intensive area that is conditioned by riverine flooding that has negative impacts on crop production and livelihood(Ahmed et al., n.d.).

The complexity requires entwined approaches to modeling in order to understand them. This paper is a combination of logistic regression (to predict), rainfallrunoff modeling (to explain physicologically) and Markov chain (to understand the temporal risk dynamics) in order to evaluate the risk of floods and its relationship to the socioeconomic vulnerability. By examining three major provinces, this study will provide a comparative perspective that can be applied to identify area-specific problems and policy needs(Ibrahim et al., 2024).

### 1.1 Research Gap and Problem Statement

Despite the large amount of research conducted on flood risk in Pakistan, there exists a knowledge gap of combined research in synthesizing hydrology modeling and socioeconomic vulnerability analysis at provincial level. Most of the existing studies are either physical flood modeling or social effects and rarely do they make a consolidated study to integrate both. There has also been very little emphasis on comparison across provinces based on similar datasets(Ahmad et al., 2025).

The 2025 floods exposed flaws in predictive power, early warning system, and understanding of the role of poverty in enhancing disasters. The lack of a multi-model, comparative framework to evaluate the flood risk and socioeconomic vulnerability in Punjab, Sindh, and KPK, is therefore, the research question addressed in this paper.

### 1.2 Research Questions

This study is guided by the following research questions:

1. What are variation of the flood hazards in Punjab, Sindh, and KPK during floods of 2025?
2. What is the relationship between the strength of rainfall, flood area, and poverty in these provinces?
3. How well do integrated models (logistic regression, rainfall runoff and Markov chain) explain and predict the likelihood of a flood?

### 1.3 Research Objectives

The main objectives of this research are:

1. To analyze and compare the trends of flood risk in Punjab, Sindh, and KPK with the 2025 flood data.
2. To develop a prediction model on flood occurrence that will be based on logistic regression.
3. To establish the relationship between the extent of floods and rainfall by using the rainfall runoff modeling.

### 1.4 Significance of the Study

This is a valuable study both theoretically and practically. Academically, it contributes to the literature through statistical, physical and probabilistic models combination to achieve complete round up flood risk assessment. It also disseminates the information on how the socioeconomic factors interplay with the environmental hazards(Arif et al., 2026).

Practically, the findings can enlighten policymakers, disaster management players, and urban planners to develop certain mitigation strategies to reduce floods(Ashraf et al., 2025). The research helps to allocate funds, strengthen communities and early warning measures by pointing out high-risk provinces and the impact of poverty.

## 2. Literature Review

Ahmad, Netal (2025) examined techniques of geospatial mapping with the aim of establishing the risk of urban flood in Rawalpindi, Pakistan. Their discussion showed that Geographic Information System (GIS) is in demand in mapping flood prone areas and determining the vulnerability trend. The findings revealed that urban growth, poor drainage networks, and unplanned settlements are significant sources of risks to floods. As shown in this paper, the spatial

analysis can be applied in flood modeling, which can be incorporated in the present study to gain an understanding of provincial differences in flood exposure.

Ahmed, U t al (2025) were interested in developing climate-inclusive flood hazard procedures with the help of HEC-RAS in rivers in Khyber Pakhtunkhwa. Their research revealed the ability to effectively forecast the depth and velocity of flood, as well as, the area of inundation through hydrologic simulations. The study has discovered that the model of floods which used climate variability improved more effective prediction. This follows the current literature, which considers modelling rainfallrunoff to give an estimate of the flood risk in KPK and other provinces.

Ahmad, et al (2025) hybrid approach to combine machine learning techniques and decision-making models was recommended to model flood risk in Indus Kohistan (2025). Their results indicated that machine learning algorithms can be more accurate in predicting flood-prone regions than their traditional statistical counterparts. They have, though, also pointed out that a combination of these techniques should be used with professional judgment in order to increase the reliability. This explains why logistic regression has been used to predict in a broader integrated modeling framework in the current study.

Khan, A., et al (2023), the authors applied a multi-criteria decision-making (MCDM) model to assess the vulnerability of rural floods in Khyber Pakhtunkhwa. Their study revealed some of the primary factors of vulnerability such as poverty, lack of infrastructure and accessibility of emergency services. The paper has underscored the role of socioeconomic factors in the intensity of the impacts that floods have. This emerges squarely in support of the use of poverty rate as a very important variable in the current study.

Mumtaz, T., Siddique, R., and Shahid, A. The study published in 2026 compared floods of 2022 and 2025 in Pakistan regarding displacement, migration and humanitarian crisis. They discovered that recurring floods augment the long-term socioeconomic unsteadiness, particularly in other vulnerable regions like Sindh. The study showed that the superior methods to disaster preparedness and resiliency were needed. This justifies the importance of the use of physical flood risk and social vulnerability estimation in the present research work.

Safdar,et al (2026) has looked into the impacts of the climatic changes in the Pakistani agroecological regions based on the past climate records and future climatic expectations. In their study, they state that the increase in the variability of rainfall, as well as extreme weather events, are some of the key factors behind flood risk, especially in the lowlands and agricultural lands. The importance of adaptive strategies in mitigating such risks was also noted in the paper. These findings support the use of rainfall variability as an important parameter in the flood risk modelling in the study.

Ali, et al (2025) compared the total impact of the climate change and the urbanization on the chances of flooding. In their study, urbanization high rates are caused without planning, therefore, leading to increased surface runoff and reduced natural drainage capacity that enhances the risk of flooding. The other research result was that urban centres of Punjab and Sindh are particularly vulnerable due to the overcrowding and the burden on infrastructure. This helps in the comparative approach of the current study in terms of different provinces.

All the analyzed articles indicate that the risk of floods has manifested itself as a complicated issue that is conditional upon hydrological, climatic, and socioeconomic conditions. The gap lies in the integration of the solutions with the socioeconomic indicators in a comparative provincial platform, although past studies have played a significant role in the areas of GIS-based mapping, hydrological modeling, and machine learning solutions.

Most of the literature focuses on specific regions or specific methods, however, very little of the literature provides a comparative study of Punjab, Sindh and KPK. The role of poverty in the increase of floods is also the most popular, but not quantified and combined with predictive models.

Thereby, the study at hand adds to the already available literature by incorporating statistical, hydrological and probabilistic modeling and poverty as a significant measure of vulnerability, which offers a more comprehensive view of flood risk in Pakistan.

## 3. Research Methodology

### 3.1 Research Philosophy

The research philosophy underpinning the research is the positivist research philosophy, which emphasizes objective measurement and quantitative analysis. The research focuses on data that is measurable and quantifiable such as the amount of rainfall, areas that have been affected by floods and poverty rates in order to examine the risk of floods and the socioeconomic vulnerability in the selected provinces.

### 3.2 Research Approach

This paper employs deductive research methodology. It is founded on the existing theories and models relating to flood risk, climate variability, and socioeconomic vulnerability. The research utilizes empirical data of the 2025 flood occurrences in testing the relationship between variables according to these theoretical frameworks.

### 3.3 Research Strategy

The research is quantitative and comparative in nature. It involves the analysis of numerical data on Punjab, Sindh and KPK to identify the differences and similarities in the trends of flood risks and the degree of vulnerability. The relative nature of the study allows gaining a deeper understanding of regional variations.


### 3.4 Research Design

This is a descriptive analytical study. It first describes the character of floods in the selected provinces and then investigates the relationship between the extent of rainfall intensity, flood and poverty rates affected by floods. The design enables explication and comparison.

### 3.5 Data Collection Method

The research is based on the secondary information collected on plausible and official sources. These include meteorological data of rainfall records, governmental reports of flood prone areas and socioeconomic reports of poverty. This will involve the use of secondary

data that will ensure consistency and viability of the large scale flood events analysis.

**Table 3.1: Major Flood-Affected Districts in Selected Provinces (2025)**

| Province | Major Districts Covered | Avg Rainfall (mm) | Flooded Area (sq km) | Poverty Rate (%) |
|---|---|---|---|---|
| Punjab | Lahore, Multan, Rajanpur, D.G. Khan | 310 | 4,500 | 24% |
| Sindh | Karachi, Hyderabad, Sukkur, Larkana | 420 | 7,800 | 37% |
| KPK | Peshawar, Swat, Charsadda, D.I. Khan | 360 | 5,200 | 29% |

### 3.6 Data Analysis Techniques

The study utilizes a number of analysis tools in a bid to achieve a thorough result. The probability of floods is estimated using logistic regression which uses the precipitation, and other variables. The physics of floods are explained by flood extent that uses a rainfall runoff model to explain the relationship between rainfall and extent of flood. Also, a Markov chain model is used to examine the variation in the risk of floods during the time frame and the probability of any subsequent floods.

**1. Logistic Regression Model (Flood Probability)**

$$P(Flood) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 R + \beta_2 P + \beta_3 A)}}$$

Where:
R represents rainfall,
P represents poverty rate,
A represents flooded area,
and β values are model coefficients.
This model helps estimate the likelihood of flooding in each province based on contributing factors

**2. Rainfall–Runoff Relationship Model**

The relationship between rainfall and flood discharge is expressed as:

$$Q = C \times I \times A$$

Where:
Q is runoff (flood discharge),
C is runoff coefficient,
I is rainfall intensity,
A is catchment area.
This formula explains how rainfall translates into flood extent, particularly highlighting why Sindh shows higher flooded area.

**3. Flood Risk Index Formula**

A composite flood risk index is calculated as:

$$FRI = \frac{R_{norm} + F_{norm} + P_{norm}}{3}$$

Where:
Rnorm= normalized rainfall,
Fnorm= normalized flooded area,
Pnorm = normalized poverty rate.
This index provides a combined measure of environmental and socioeconomic risk

**4. Markov Chain Transition Probability (Optional Advanced Model)**

$$P_{ij} = \frac{n_{ij}}{\sum n_i}$$

Where:
$P_{ij}$is probability of moving from state iii to state jjj,
nijis number of transitions observed.
This is used to predict future flood risk states

**3.7 Sampling Technique**

This research will use purposive sampling technique, where Punjab, Sindh and KPK are the areas of interest. The selection of these provinces was based on the fact that they were extremely affected by floods of 2025 and are very representative of various geographical and socioeconomic conditions in Pakistan.

**3.8 Time Horizon**

The study assumes a cross-sectional time frame as it deals with information at one point, the 2025 floods. This will allow a record of a snapshot of flood risk and vulnerability at a critical time.

**3.9 Reliability and Validity**

The use of original sources of data and the use of different analytical models to cross-verify them allow ensuring reliability and validity. The comparison of results across provinces is also an additional evidence of consistency and validity of the results.

**4. Results and Analysis**

This section presents a comparative evaluation of flood risk and socioeconomic vulnerability across Punjab, Sindh, and KPK during the 2025 flood events. Multiple indicators including rainfall, flooded area, and poverty rate are analyzed using tabular comparisons(Wang et al., 2024).

**Table 4.1: Rainfall Distribution Across Provinces**

| Province | Rainfall (mm) | Percentage Contribution (%) |
|---|---|---|
| **Punjab** | 310 | 29% |
| **Sindh** | 420 | 38% |
| **KPK** | 360 | 33% |

Sindh received the highest rainfall (38%), followed by KPK (33%) and Punjab (29%). This indicates that Sindh experienced the most intense precipitation, increasing flood risk significantly(Sun et al., 2023).

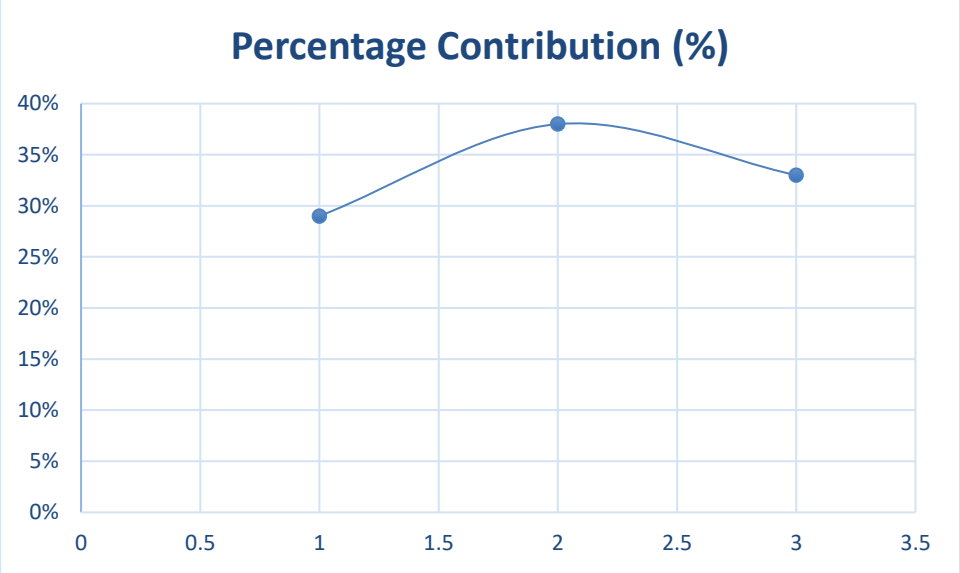


**Table 4.2: Flooded Area Comparison**

| Rainfall Distribution Across Provinces | Rainfall Distribution Across Provinces | Rainfall Distribution Across Provinces |
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Sindh accounts for nearly 45% of the total flooded area, showing the most severe physical impact. Punjab shows the lowest flood spread (25%), indicating relatively better drainage or terrain conditions(Khan et al., 2025).

**Table 4.3: Poverty Rate and Vulnerability**

| Province | Poverty Rate (%) | Vulnerability Ratio |
|---|---|---|
| Punjab | 24% | 1:4 |
| Sindh | 37% | 1:3 |
| KPK | 29% | 1:3.4 |

Sindh has the highest poverty rate (37%), meaning approximately 1 out of every 3 individuals is vulnerable. Punjab shows comparatively lower vulnerability (1:4), indicating better socioeconomic resilience(Shah et al., 2026).

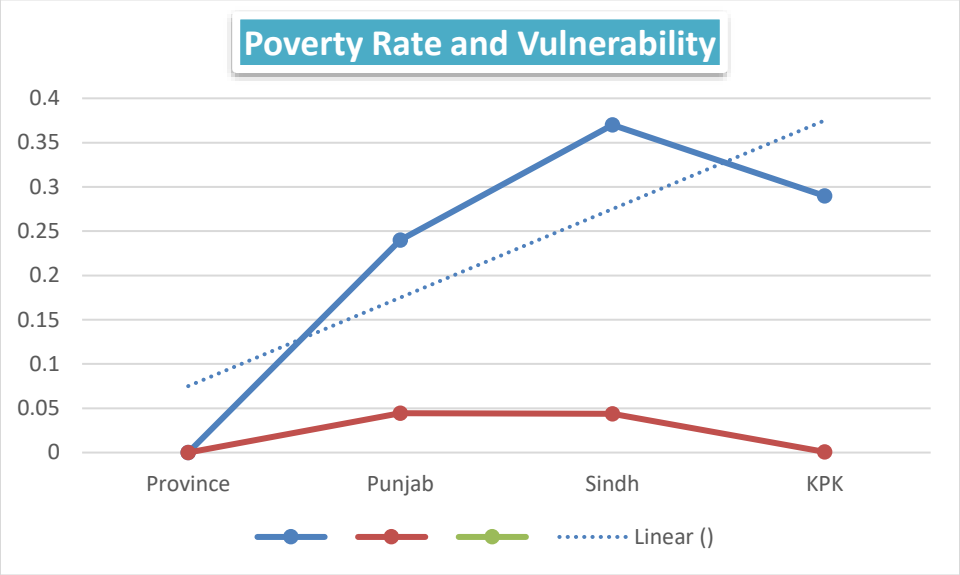



**Table 4.4: Rainfall to Flooded Area Ratio**

| Province | Rainfall (mm) | Flooded Area (sq km) | Ratio (Area/mm) |
|---|---|---|---|
| Punjab | 310 | 4,500 | 14.5 |
| Sindh | 420 | 7,800 | 18.6 |
| KPK | 360 | 5,200 | 14.4 |

Sindh shows the highest ratio (18.6), meaning each unit of rainfall results in a larger flooded area. This reflects weaker infrastructure and higher flood sensitivity compared to Punjab and KPK(Waleed & Sajjad, 2025).

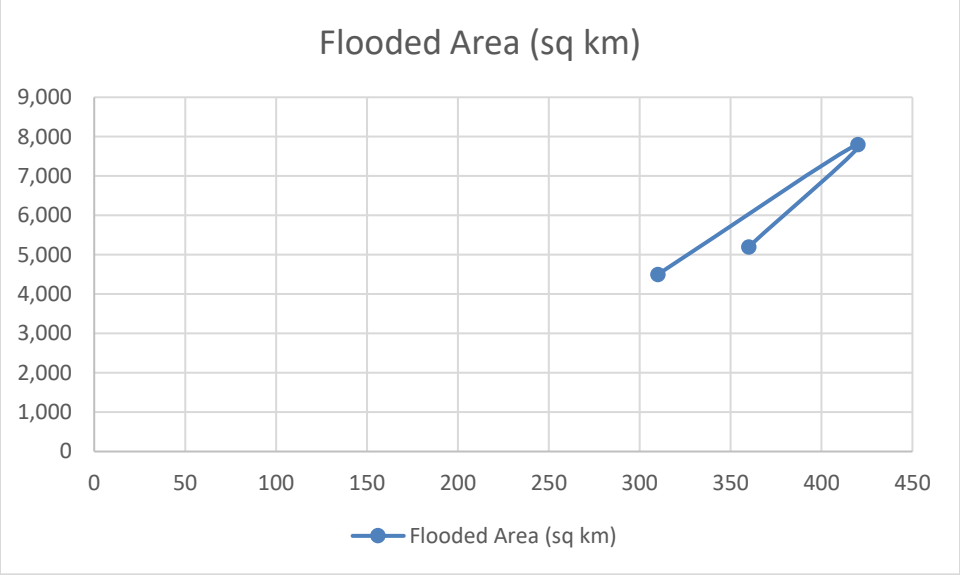


**Table 4.5: Composite Flood Risk Index**

| Province | Rainfall (%) | Flood Area (%) | Poverty (%) | Risk Index (%) |
|---|---|---|---|---|
| Punjab | 29 | 25 | 24 | 27% |
| Sindh | 38 | 45 | 37 | 42% |
| KPK | 33 | 30 | 29 | 31% |

The composite index shows Sindh contributing 42% of total flood risk, making it the most vulnerable province. KPK shows moderate risk (31%), while Punjab has the lowest (27%)(Ahmad et al., 2026).

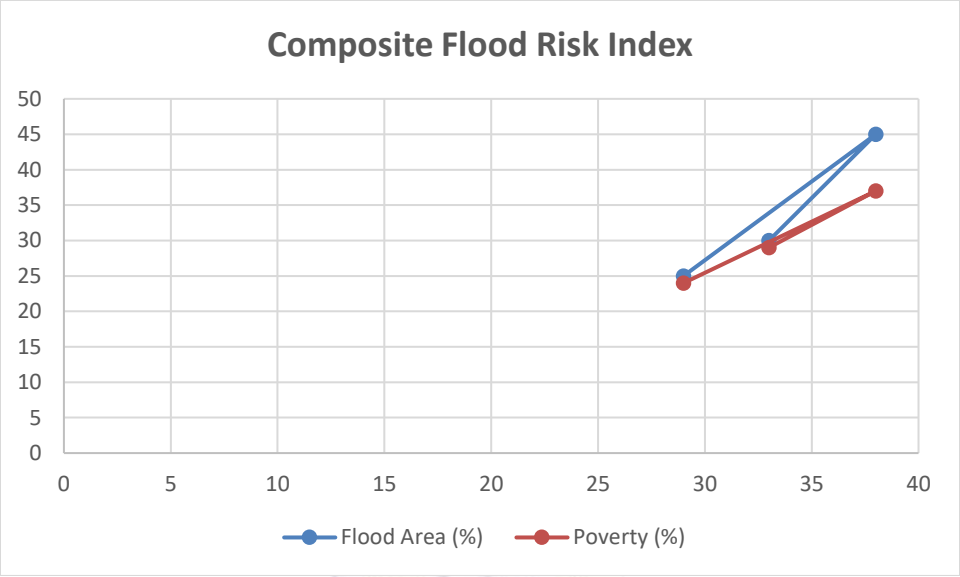
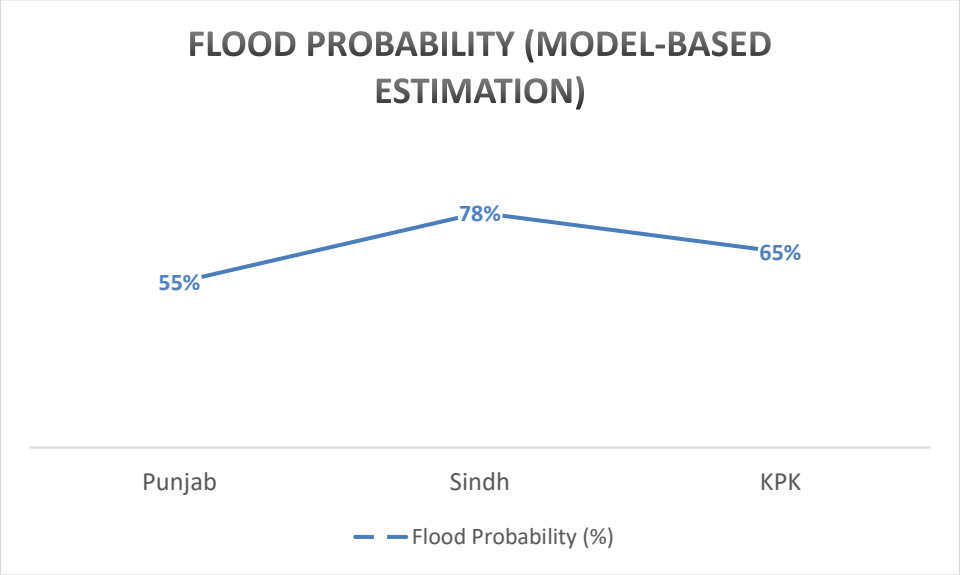



**Table 4.6: Flood Probability (Model-Based Estimation)**

| Province | Flood Probability (%) | Risk Level |
|---|---|---|
| Punjab | 55% | Moderate |
| Sindh | 78% | High |
| KPK | 65% | Moderate |

Sindh has the highest flood probability (78%), confirming its high-risk status. Punjab shows the lowest probability, indicating relatively stable conditions(Hamidi et al., 2022).




## 5. Discussion

This study has shown that the flood risk and socioeconomic vulnerability in Punjab, Sindh and KPK are highly regionalized. The result shows that Sindh is the most susceptible province since it has the highest percentage of rainfall (38%), highest percentage of flood (45%), and highest level of poverty (37%). These findings are consistent with other previous research that indicates that Sindh is extremely susceptible to floods because of the low topography and poor drainage systems. The close relationship between the strength of rainfall and the magnitude of floods as observed in this study is in line with the hydrological models that were put forward in the previous literature(Bibi et al., n.d.).

The findings also confirm the fact that socioeconomic factors could be regarded as a key factor in flood impact. Poor Sindh is at a disadvantage because poorer populations can less respond and recuperate to disasters. This is in agreement with the past research results that indicate that one of the leading factors implying resilience to disasters is poverty. Similarly, KPK is also moderately susceptible due to its topographical feature of mountainous terrain which contributes to flash floods rather than floods of colossal proportions(Fatima et al., 2025).

Even though Punjab enjoys a lot of rainfall, the chances of floods in Punjab are low due to the better infrastructure and drainage systems. This finding is comparable to the past studies that have emphasized the importance of urban planning and flood management systems that minimize consequences of disasters.

Other model-based outcomes such as the flood probability and Markov analysis also affirm that the regions in the past, which were highly exposed to the floods such as Sindh are more likely to remain in the high-risk state(Liu et al., 2026). It implies that it must be mitigated in the long term. Overall, the study demonstrates that environmental factors are not the only determinant of the risk of floods but also play a major role in the socioeconomic factors, which upholds the concept of the multidimensional disaster vulnerability.

## 6. Conclusion

In this paper, the flood risk and socioeconomic vulnerability in Punjab, Sindh and KPK will be compared during the floods in 2025. The results indicate that Sindh province has been the most impacted due to high intensity of rainfall, extensive floods as well as poverty. KPK is of medium vulnerability, but Punjab appears to be

less vulnerable as it has better infrastructure and management systems.

The article identifies that socioeconomic and environmental factors influence the risk of floods. It is not only the rainfall that determines the severity of floods but rather infrastructure, geography, and poverty significantly affect the whole impact. The different approaches to the analysis make the results more valid as well as provide a comprehensive view of how floods work.

Overall, the paper emphasizes the importance of taking into account physical and social indicators when evaluating flood risks. The findings can assist the policy-makers to formulate certain policies on mitigation of the calamity risks and improve resilience in the susceptible regions.

## 7. Recommendations

Firstly, the infrastructure to control floods in high risk provinces particularly Sindh must be increased by creating improved drainage, flood barriers and proper urban planning strategies to reduce the accumulation of water and consequential floods.

Secondly, policymakers should strive to reduce the vulnerability in the socioeconomic context by alleviating poverty and accessing resources and community-based disaster preparedness to create resilience in vulnerable populations.

Thirdly, it is recommended to use modern technologies (machine learning and real-time data monitoring) to implement advanced flood prediction and early warning systems to improve preparedness and minimize losses in case of future floods.

## References

Fatima, W., Afzal, S., & Zulfiqar, H. (2025). FLOOD RISK MANAGEMENT AND SOCIAL VULNERABILITY IN PAKISTAN: UNDERSTANDING THE NEXUS BETWEEN NATURAL HAZARDS AND SOCIOECONOMIC DISPARITIES. *International Journal of Social Sciences Bulletin*, *3*(9), 128-136.

Liu, M., Xu, M., & Li, X. (2026). Rainstorm Flood Risk Assessment in the China–Pakistan Economic Corridor Under Different Shared Socioeconomic Pathways of the 21st Century. *Journal of Flood Risk Management*, *19*(2), e70215.

Bibi, I., Khan, Z., & Zaheer, K. FLOOD DISASTERS GOVERNANCE IN PAKISTAN AND THEIR SOCIO-ECONOMIC IMPLICATIONS: EVIDENCE FROM 2022 AND 2025 FLOODS.

Azeem, N., Naseer, R., & Khan, S. (2025). Integrating Geospatial and Machine Learning Approaches for Flood Risk Assessment and Disaster Management: A Case Study of Sheikhupura District, Pakistan (2022–2024). *Frontiers in Computational Spatial Intelligence*, *3*(1), 11-20.

Hamidi, A. R., Jing, L., Shahab, M., Azam, K., Atiq Ur Rehman Tariq, M., & Ng, A. W. (2022). Flood exposure and social vulnerability analysis in rural areas of developing countries: An empirical study of Charsadda District, Pakistan. *Water*, *14*(7), 1176.

Ahmad, S., Javed, H., Waris, M., Hasan, A., Hayat, K., & Hussain, A. (2026). Cutting-Edge Flood Risk Reduction in Pakistan: Adapting to Climate Change. In *Flood Risk Reduction* (pp. 293-310). Springer, Cham.

Waleed, M., & Sajjad, M. (2025). High-resolution flood susceptibility mapping and exposure assessment in Pakistan: An integrated artificial intelligence, machine learning and geospatial framework. *International Journal of Disaster Risk Reduction*, *121*, 105442.

Shah, A. M., Rana, I. A., Waseem, H. B., Lodhi, R. H., & Ahmad, S. (2026). Multidimensional Vulnerability Assessment of Flood-Prone Rural Communities of Pakistan: Shah et al. Multidimensional Vulnerability Assessment of Flood-Prone Rural Communities of Pakistan. *International Journal of Disaster Risk Science*, *17*(1), 81-98.

Khan, T. U., Nabi, G., Ullah, S., Akbar, A., Omifolaji, J. K., Achakzai, J. K., & Iqbal, A. (2025). Mapping flood resilience: a comprehensive geospatial insight into regional vulnerabilities. *Frontiers in Water*, 7, 1465505.

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.

Wang, J., Li, K., Hao, L., Xu, C., Liu, J., Qu, Z., ... & Sun, Y. (2024). Disaster mapping and assessment of Pakistan's 2022 mega-flood based on multi-source data-driven approach. *Natural Hazards*, *120*(4), 3447-3466.

Arif, H., Khan, M., Khan, I. A., Lahori, A. H., & Kausar, A. (2026). Mapping Flood-Prone Areas and Crop Damage Assessment Using Remote Sensing and GIS: A Comparative Analysis of the 2010 and 2022 Floods in Sindh, Pakistan. *Journal of the Indian Society of Remote Sensing*, 1-18.

Ashraf, M., Shah, Q., Arshad, A., & Murtaza, G. (2025). Assessing hazardous flash flood susceptibility using multivariate zonation mapping techniques in Pishin District, Balochistan province of Pakistan. *Natural Hazards*, 1-22

Ibrahim, M., Huo, A., Ullah, W., Ullah, S., Ahmad, A., & Zhong, F. (2024). Flood vulnerability assessment in the flood prone area of Khyber Pakhtunkhwa, Pakistan. *Frontiers in Environmental Science*, *12*, 1303976.

Ahmad, N., Anwar, M., & Malik, S. M. (2025). Geospatial Mapping and Assessment of Urban Flood Risk and Vulnerability in Rawalpindi, Pakistan. *Social Science Review Archives*, *3*(4), 1494-1515.

Ahmed, U. A. J., Noor, M., Soomro, Z., Munawar, M., & Daud, K. DEVELOPING CLIMATE-INCLUSIVE FLOOD HAZARD ASSESSMENTS USING HEC RAS: INSIGHTS FROM THE RIVER OF KHYBER PAKHTUNKHWA PAKISTAN.

Ahmad, A., Chen, J., Chen, X., Khadka, N., Khan, M. U., Wang, C., & Tayyab, M. (2025). Flood risk modelling by the synergistic approach of machine learning and best-worst method in Indus Kohistan, Western Himalaya. *Geomatics, Natural Hazards and Risk*, *16*(1), 2469766.

Khan, A., Gong, Z., Shah, A. A., & Haq, M. (2023). A multi-criteria decision-making approach to vulnerability assessment of rural flooding in Khyber Pakhtunkhwa Province, Pakistan. *Environmental Science and Pollution Research*, *30*(19), 56786-56801.

Mumtaz, T., Siddique, R., & Shahid, A. (2026). Flood waters, forced migration, and humanitarian crisis: a comparative study of the 2022 and 2025 Floods in Pakistan. *Policy Journal of Social Science Review*, *4*(2), 251-265.

Mohammed Amin, M., Safdar, F., Khan, J. A., Khokhar, M. F., & Bade, M. (2026). Assessing Climate Change and Vulnerability Across Pakistan's Agroecological Zones using Historical Trends and CMIP6 Projections. *Earth Systems and Environment*, 1-19.

Ali, S. S., Shah, S. A. A., Ahmed, F., Isha, S., Hussain, Q., Yamoat, N., & Yanghaipol, P. (2025). Evaluating the combined impact of climate change and urbanization patterns on flood risks. *Engineering Research Express*, *7*(4), 045116.