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CLIMATE CHANGE AND FLASH-FLOOD RISK IN MOUNTAINOUS KHYBER PAKHTUNKHWA: EVIDENCE FROM BAJAUR, BUNER AND SWAT 2025.

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Abstract
Mountainous Khyber Pakhtunkhwa (KP), Pakistan, is highly vulnerable to flash floods, landslides, cloudbursts, and other hydro-meteorological hazards due to steep terrain, narrow valleys, intense monsoon rainfall, rapid runoff, environmental degradation, and expanding settlements. This paper examines climate-related flash-flood risk in Bajaur, Buner, and Swat, focusing on the August 2025 monsoon disaster. Using qualitative secondary data from peer-reviewed studies, NDMA and PDMA reports, government documents, and climate-attribution research, the study finds that extreme rainfall interacted with existing social, environmental, and infrastructural vulnerabilities to produce severe impacts. Buner experienced particularly high human losses, while Bajaur and Swat faced deaths, displacement, infrastructure damage, and livelihood disruption. Progress included emergency response, road restoration, weather monitoring, early warnings, and rehabilitation. However, gaps remain in localized forecasting, warning dissemination, risk mapping, land-use planning, watershed management, resilient infrastructure, and adaptation finance. The paper recommends integrated, community-based, anticipatory, and climate-resilient disaster-risk management.

INTRODUCTION

Climate change is altering the characteristics of hydro-meteorological hazards across many regions of the world. In South Asia, warming is associated with changes in heavy precipitation and increasing risks from pluvial and flash flooding. The Intergovernmental Panel on Climate Change (IPCC) reports that heavy precipitation has increased across much of Asia and that human influence has contributed to the intensification of heavy precipitation at the continental scale. It also projects that heavy precipitation will generally become more frequent and intense with additional warming. IPCC+1

Pakistan is particularly vulnerable because of its exposure to monsoon rainfall, glacial and snowmelt processes, droughts, heatwaves and rapidly changing hydrological conditions. Khyber Pakhtunkhwa is especially exposed because much of the province

consists of mountainous and highly dissected terrain. Steep slopes and narrow valleys allow rainfall to be rapidly converted into surface runoff. Consequently, intense rainfall can produce destructive flash floods with very limited warning time.

Previous research has demonstrated the high vulnerability of communities in flood-prone districts of KP. Shah et al. (2018), using household-level evidence, found substantial vulnerability and differences in resilience among communities affected by floods in KP. Their work emphasizes that disaster impacts depend not only on the physical hazard but also on household socioeconomic conditions, access to resources and institutional preparedness.

Similarly, Nazeer and Bork (2021) demonstrated the importance of local-scale assessment of flood vulnerability in KP and emphasized the value of spatially explicit approaches for understanding variations in exposure and vulnerability. Regional frequency analysis has also demonstrated the importance of understanding flood extremes at multiple hydrological sites throughout KP rather than relying solely on national or provincial averages (Khan et al., 2021).

The August 2025 disaster provides an important recent case for examining these issues. On 15 August 2025, intense monsoon rainfall and cloudbursts triggered flash floods and landslides across several mountainous districts of KP, including Buner, Bajaur and Swat. PDMA's official material identifies Swat, Buner and Bajaur among the districts affected by the event. Pakistan Disaster Management Authority+1

The event is important for climate-risk research because it illustrates the interaction of hazard, exposure and vulnerability. Climate change does not mean that every individual flood can be attributed exclusively to global warming. Rather, warming can alter the intensity or likelihood of extreme rainfall, while local topography, land use, drainage conditions, settlement patterns, infrastructure quality and preparedness determine how that rainfall translates into human and economic losses.

A 2025 climate-attribution assessment found that the maximum 30-day rainfall over a study region covering heavily affected parts of northern Pakistan was approximately 22% more intense in today's climate than it would have been without the observed 1.3°C warming, based on observational analysis. The researchers emphasized uncertainty and differences between observations and climate-model estimates. World Weather Attribution

Therefore, the central argument of this paper is that flash-flood risk in mountainous KP should be understood as a compound climate and development risk. Extreme rainfall is the immediate hazard, but its consequences are shaped by environmental degradation, settlement exposure, infrastructure vulnerability, limited warning time and socioeconomic conditions.

1.1 Objectives of the Study

The study has five main objectives:

1. To examine the relationship between climate change and flash-flood risk in mountainous KP.
2. To document the August 2025 flash-flood event and its major impacts in Buner, Bajaur and Swat.
3. To identify existing progress in disaster preparedness, response and recovery.
4. To identify major institutional, infrastructural and knowledge gaps.
5. To propose climate-resilient recommendations for reducing future flash-flood risk.

2. Methodology

This paper adopts a qualitative secondary-data research design. The analysis combines four categories of evidence:

- Peer-reviewed scientific literature on climate change, floods and vulnerability in Pakistan and KP.
- Official disaster information from NDMA and PDMA KP.
- Government and humanitarian situation reports concerning the 2025 floods.
- Recent climate-attribution and disaster-risk studies.

The analysis focuses geographically on District Buner, District Bajaur and District Swat. The August 2025 event is used as the principal case study because it provides recent evidence of extreme rainfall, flash flooding, landslides, human losses and infrastructure damage.

Because official casualty numbers changed as missing persons were recovered and records were reconciled, figures are interpreted according to their reporting

date. For example, later NDMA material recorded 20 casualties in Swat and 22 in Bajaur during the 15–25 August 2025 flash-flood and landslide period. Buner experienced substantially greater losses, with subsequent official reporting incorporating additional deaths after missing persons were declared deceased. National Disaster Management Authority+1

The study therefore avoids treating an early situation report as the final disaster total and distinguishes between preliminary and later official figures.

3. Climate Change and Flash-Flood Risk in Mountainous KP

Mountainous flood risk is produced by the interaction of meteorological, geomorphological and socioeconomic processes.

3.1 Increasing Extreme Rainfall

A warmer atmosphere can hold more moisture, increasing the potential intensity of heavy precipitation. The IPCC identifies increasing heavy precipitation as an important consequence of climate change and projects further increases under additional warming. Human influence has contributed to observed increases in heavy precipitation at continental scales, including Asia. IPCC+1

The 2025 climate-attribution assessment for northern Pakistan found that the 30-day maximum rainfall analyzed in the study region was approximately 22% more intense in the present climate than it would have been in a climate without the observed warming, based on observational datasets. The study also emphasized uncertainty in the magnitude of the climate-change contribution. World Weather Attribution

This finding is particularly relevant to mountainous KP because short-duration, high-intensity rainfall can generate extremely rapid runoff.

3.2 Mountain Topography

Bajaur, Buner and Swat contain steep slopes, valleys and numerous seasonal and perennial streams. Mountainous catchments have limited time between rainfall and peak runoff. Consequently, communities located close to river channels, nullahs, alluvial fans and valley bottoms may have only a short period to respond to rapidly developing flash floods.

3.3 Land-Use Change and Environmental Degradation

Climate-related rainfall extremes become more damaging where natural drainage and watershed functions have been degraded. Deforestation, vegetation loss, road construction, slope disturbance and settlement expansion can increase runoff, erosion and sediment transport.

Climate-attribution research has also noted that deforestation and construction in flood-prone areas can increase the consequences of extreme rainfall by increasing exposure and altering runoff processes. World Weather Attribution

3.4 Vulnerable Infrastructure

Roads and bridges in mountainous areas are particularly vulnerable because they frequently cross streams and unstable slopes. When bridges fail or roads are washed away, communities can become isolated precisely when emergency assistance is most needed.

Previous research on KP has shown that flood vulnerability is strongly influenced by local physical and socioeconomic characteristics rather than hazard exposure alone.

4. Event Synopsis: August 2025 Flash Floods

The August 2025 event was characterized by intense monsoon rainfall, localized cloudbursts, flash floods and landslides.

On 15 August 2025, PDMA's daily weather report identified Swat, Buner and Bajaur among the districts expected to receive widespread rain and thunderstorms. It specifically warned that heavy to very heavy rainfall could generate flash floods in local nullahs and streams in Swat and Bajaur, among other districts. RMS PDMA

The event rapidly developed into a major humanitarian disaster. NDMA's later review described widespread flash floods and landslides across northern KP between 15 and 25 August 2025, including Bajaur and Swat. Intense cloudbursts triggered severe flooding and extensive damage to homes, roads and bridges. The review identified Buner, Swabi and Shangla among the hardest-hit districts. National Disaster Management Authority

The event also demonstrated the speed at which localized cloudbursts can transform into destructive flash floods. The combination of intense rainfall, steep terrain, saturated soils and exposed settlements produced cascading impacts across the affected districts.

5. Impacts in District Buner

5.1 Human Impacts

Buner experienced the most severe human losses among the three study districts. Early reports recorded a high number of deaths, while later official reporting incorporated additional fatalities after missing persons were declared deceased. An NDMA situation report specifically recorded 13 missing persons in Buner as subsequently declared deceased. National Disaster Management Authority

The changing casualty figures demonstrate an important methodological issue in disaster research: immediate casualty reports should not automatically be interpreted as final totals.

5.2 Housing and Infrastructure

Flash-flood waters and debris damaged or destroyed houses and local infrastructure. Roads and bridges were particularly vulnerable, limiting access to affected settlements and complicating rescue operations.

The wider KP response involved large-scale deployment of rescue and relief personnel and the restoration of damaged transport links. PDMA also reported emergency monitoring and coordinated relief activities following the disaster. Pakistan Disaster Management Authority

5.3 Livelihood Impacts

The destruction of homes was accompanied by losses of livestock, household possessions and productive assets. Rural households dependent on agriculture, livestock, small businesses and daily wage employment are particularly exposed because a single disaster can simultaneously destroy housing and income-generating assets.

5.4 Health and Social Impacts

The displacement of households created immediate requirements for shelter, drinking water, sanitation, food and health services. Such impacts can continue after floodwaters recede because damaged infrastructure and disrupted livelihoods slow the recovery process.

6. Impacts in District Bajaur

Bajaur experienced severe flash flooding and landslides during the August 2025 event. NDMA's later review recorded **22 casualties in Bajaur** during the 15–25 August disaster period. National Disaster Management Authority

The impacts included:

- Loss of human lives.
- Injuries and displacement.
- Damage to homes and community infrastructure.
- Flash-flood and landslide impacts on roads and access routes.
- Loss of livestock and household assets.
- Disruption of access to health, education and markets.
- Increased need for emergency shelter and food assistance.

The Bajaur experience demonstrates the importance of village-level early warning. In cloudburst situations, provincial or district warnings may not provide sufficient lead time unless information reaches communities through local communication networks, mobile alerts, volunteers, mosques and community emergency committees.

7. Impacts in District Swat

Swat is particularly exposed because the district contains the Swat River and numerous tributary streams and mountainous settlements.

NDMA's later disaster analysis specifically documented a **flash flood in Swat on 15 August 2025**. Heavy monsoon downpours caused extensive road blockages and submerged low-lying areas. The analysis identified inadequate drainage as an important factor contributing to flooding of roads and developed areas. National Disaster Management Authority

A second event on **18 August 2025** resulted in severe road erosion associated with soil saturation and instability. Prolonged waterlogging weakened the road base, creating hazards for transport and relief operations. National Disaster Management Authority

NDMA's later review recorded **20 casualties in Swat** during the 15–25 August 2025 flash-flood and landslide period. National Disaster Management Authority

The impacts in Swat included:

- Loss of life.
- Damage to roads and transport infrastructure.
- Flooding of low-lying settlements.
- Road erosion and slope instability.
- Disruption of tourism and local commerce.
- Damage to houses and community infrastructure.
- Isolation of communities following road blockage.
- Increased risks to relief and emergency personnel.

The Swat case demonstrates that flood risk is not limited to riverbank inundation. Roads, bridges, drainage systems and unstable slopes can become important pathways through which a rainfall event produces cascading impacts.

Comparative Impacts

Impact Category	Buner	Bajaur	Swat
Human casualties	Extremely severe; later official reporting recorded very high losses	Severe; NDMA later recorded 22 casualties	Severe; NDMA later recorded 20 casualties
Flash flooding	Very severe	Very severe	Severe
Landslides/slope instability	Significant	Significant	Significant
Housing damage	Extensive	Significant	Significant
Road/bridge damage	Extensive	Significant	Extensive
Community isolation	Severe	Severe in affected localities	Severe
Livelihood disruption	Agriculture, livestock, businesses and daily employment	Agriculture, livestock and household assets	Agriculture, tourism, transport and local commerce
Emergency response	Rescue, relief distribution and infrastructure restoration	Search, rescue and relief operations	Rescue, infrastructure restoration and relief operations
Key risk issue	Extremely high exposure and rapid flood response requirements	Short warning time and remote settlements	River/tributary flooding, drainage and slope instability
Impact Category	Buner	Bajaur	Swat
Human casualties	Extremely severe; later official reporting recorded very high losses	Severe; NDMA later recorded 22 casualties	Severe; NDMA later recorded 20 casualties

The comparison indicates that the three districts share common climate and environmental risks but differ in the pathways through which hazards become disasters.

9. Progress in Disaster Management and Climate Adaptatio

Despite the scale of the disaster, several areas of progress can be identified.

9.1 Early Warning and Weather Monitoring

One important area of progress is the development of weather forecasting and early-warning mechanisms.

PDMA's 15 August 2025 weather report provided district-level warnings for Swat, Bajaur and other vulnerable districts and specifically identified the possibility of flash flooding in local streams and nullahs. RMS PDMA

This demonstrates that meteorological information can be translated into district-level hazard warnings. However, the effectiveness of such systems ultimately depends on whether warnings reach exposed communities and result in timely protective action.

9.2 Provincial Disaster Management Planning

The Provincial Disaster Management Authority has increasingly emphasized disaster preparedness, response and resilience. PDMA describes the 15 August 2025 event as a major disaster affecting Swat, Buner, Bajaur and Swabi and highlights the need for greater preparedness for climate-related hazards. Pakistan Disaster Management Authority

Disaster management is increasingly being approached as a continuous process involving:

- Risk assessment.
- Prevention and mitigation.
- Preparedness.
- Emergency response.
- Recovery.
- Climate adaptation.

This approach is particularly relevant to Swat because disaster risk cannot be addressed only after a flood occurs.

9.3 Contingency Planning

Seasonal contingency planning allows authorities to identify vulnerable areas, prepare emergency resources, coordinate departments and establish response procedures before extreme weather occurs.

For mountainous districts such as Swat, Bajaur and Buner, contingency planning is especially important because road closures can rapidly affect the movement of rescue teams, food, medicines and other relief supplies.

9.4 Anticipatory Action

Another important development in disaster-management policy is the increasing focus on **anticipatory action**.

Anticipatory action means taking protective measures before a disaster occurs when forecasts indicate that a dangerous event is likely. Such measures can include:

- Pre-positioning rescue equipment.
- Warning communities living near rivers and streams.
- Preparing evacuation routes.
- Temporarily closing dangerous roads or bridges.
- Moving livestock and valuable equipment to safer locations.
- Preparing emergency shelters and medical supplies.

For Swat, anticipatory action could substantially reduce losses if forecasts are translated into locally appropriate action before extreme rainfall occurs.

10. Climate Adaptation in District Swat

Climate adaptation means adjusting infrastructure, institutions and community practices so that society can cope better with climate-related hazards.

10.1 Climate-Resilient Infrastructure

Roads and bridges are extremely important for Swat because many communities depend on transport connections through mountainous terrain.

Future infrastructure development should consider:

- Higher flood levels.
- Stronger bridge foundations.
- Proper drainage systems.
- Protection against riverbank erosion.
- Landslide-resistant road construction.
- Alternative routes for isolated communities.

Infrastructure should be designed using updated hazard and climate-risk information rather than relying only on historical rainfall patterns.

The 2025 Swat events demonstrate the importance of drainage and road resilience, as NDMA documented both flooding associated with inadequate drainage and subsequent road erosion from saturated soils. National Disaster Management Authority

10.2 River and Watershed Management

Protection of river corridors and watersheds is another important adaptation measure.

Deforestation and uncontrolled construction can increase runoff and erosion. Reforestation, slope stabilization and watershed conservation can help reduce some of these risks.

Adaptation should therefore combine engineering solutions with ecosystem-based approaches.

10.3 Community-Based Disaster Risk Management

Local communities are usually among the first to experience a disaster. Therefore, community participation is essential.

Village-level disaster committees can be trained in:

- Early-warning interpretation.
- First aid.
- Evacuation procedures.
- Search and rescue.
- Emergency communication.
- Protection of children, older people and persons with disabilities.

Community-based disaster management can make official warning systems more effective because warnings must ultimately lead to appropriate action at household and village level.

10.4 Risk-Sensitive Land-Use Planning

Construction in flood-prone riverbeds and unstable slopes can increase disaster losses.

Future development in Swat should therefore consider hazard maps before approving new residential, commercial or tourism-related construction.

Risk information should be integrated into development planning so that new infrastructure does not unintentionally increase exposure to future hazards.

11. Major Challenges

Despite progress, several challenges remain.

11.1 Rapid Onset of Flash Floods

Flash floods can develop very quickly, particularly after intense rainfall in mountainous areas. Even when a weather warning is issued, communities may have limited time to evacuate.

11.2 Difficult Mountainous Terrain

Swat, Bajaur and Buner contain mountainous areas where landslides and damaged roads can isolate communities and delay rescue teams and relief supplies.

11.3 Settlement Near Rivers and Streams

Settlements and infrastructure located close to waterways are particularly exposed to sudden increases in water flow.

11.4 Communication Gaps

An early warning is useful only if it reaches people in an understandable form and at the right time. Remote communities may face difficulties with mobile connectivity, electricity or access to official information.

11.5 Limited Local Capacity

District-level disaster management requires trained staff, equipment, rescue resources and adequate financial resources. Local capacity needs to be continuously strengthened rather than expanded only after a major disaster.

11.6 Climate Uncertainty

Climate change does not produce identical changes everywhere. Complex mountainous terrain and monsoon dynamics introduce uncertainty in local projections. Consequently, disaster-management planning requires updated climate, weather and hazard information rather than reliance on historical averages alone.

12. Impacts on Local Communities

Extreme rainfall and flash floods can affect communities in several ways.

12.1 Social Impacts

These include displacement, deaths, injuries and disruption of family and community life.

12.2 Economic Impacts

Economic losses can include damage to houses, shops, agricultural land, livestock, roads and tourism-related businesses.

12.3 Infrastructure Impacts

Important infrastructure can include:

- Roads.
- Bridges.
- Electricity systems.
- Water-supply systems.
- Communication networks.
- Schools and health facilities.

12.4 Environmental Impacts

Environmental impacts can include riverbank erosion, landslides, soil loss, sediment deposition and damage to forests and agricultural land.

These impacts can be particularly serious for low-income households because they often have fewer resources to recover after a disaster.

13. Recommendations

Based on the vulnerabilities demonstrated by the 2025 monsoon season, the following measures are recommended for Bajaur, Buner and Swat, with particular attention to mountainous communities in Swat:

1. **Strengthen local early-warning systems** and ensure warnings reach villages through multiple communication channels.
2. **Develop detailed hazard maps** for flash floods, landslides, riverbank erosion and other relevant hazards.
3. **Improve evacuation planning** at village and union-council levels.
4. **Strengthen bridges and roads** using climate- and hazard-resilient engineering standards.
5. **Improve drainage systems**, particularly around roads, settlements and other developed areas in flood-prone locations.
6. **Control construction in high-risk areas**, particularly floodplains, river corridors and unstable slopes.
7. **Increase community disaster-management training**, including first aid, evacuation drills and emergency communication.
8. **Improve coordination** between PDMA, district administrations, Rescue 1122, local government, meteorological authorities and communities.
9. **Pre-position emergency equipment and supplies** before the monsoon season.
10. **Increase watershed restoration and reforestation** in vulnerable mountainous areas.
11. **Integrate climate-risk information into development planning** rather than treating disasters only as emergency events.
12. **Strengthen tourism safety systems in Swat**, including weather warnings, evacuation arrangements and emergency communication for visitors in vulnerable valleys.
13. **Develop systematic district-level disaster databases** that record deaths, injuries, infrastructure damage, livelihood losses and recovery costs.
14. **Use post-disaster assessments to update contingency plans** and infrastructure standards.
15. **Increase investment in anticipatory action**, allowing authorities to take protective measures before forecast extreme rainfall becomes a disaster.

14. Conclusion

The 2025 monsoon disasters demonstrated the continuing importance of disaster preparedness and climate adaptation in mountainous areas of Khyber Pakhtunkhwa. Bajaur, Buner and Swat share a combination of steep terrain, rivers and streams, exposed settlements and intense rainfall that creates significant flash-flood and landslide risks.

The August 2025 event also demonstrated that disaster impacts are not determined by rainfall alone. Extreme rainfall interacts with topography, environmental conditions, settlement patterns, infrastructure quality, drainage systems, socioeconomic vulnerability and disaster preparedness. Climate change adds another dimension by increasing the potential intensity of heavy precipitation. The IPCC finds that human influence has contributed to observed intensification of heavy precipitation across Asia, while the 2025 Pakistan attribution assessment provides additional evidence that warming contributed to the intensity of heavy monsoon rainfall in northern Pakistan. IPCC+1

There has been progress in Pakistan and Khyber Pakhtunkhwa through weather monitoring, early warnings, emergency response, contingency planning, infrastructure restoration and disaster-management planning. The 15 August 2025 PDMA warning for Swat and Bajaur demonstrates that

district-level hazard information was available before the event. RMS PDMA

However, significant challenges remain. Warning information must reach communities quickly, infrastructure must be designed for future climate risks, drainage and watershed systems need improvement, and district-level preparedness must become more participatory and locally informed.

For District Swat in particular, the 2025 floods highlight the importance of combining early warning, resilient infrastructure, improved drainage, watershed management, risk-sensitive land-use planning and community preparedness. Similar measures are relevant to Bajaur and Buner.

The experience of 2025 provides an important lesson: **disaster management and climate adaptation must be continuous processes rather than activities that begin only after a disaster occurs.** A shift from predominantly post-disaster relief toward anticipatory, locally informed and climate-resilient risk reduction can help reduce future losses and strengthen the resilience of mountain communities.

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The National Disaster Management Plan emphasizes proactive disaster preparedness and early-warning systems (National Disaster Management Authority [NDMA], 2025a).

The August 2025 floods caused extensive damage across affected districts (National Disaster

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