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MAPPING COMMUNITY LEVEL VULNERABILITY TO EXTREME CLIMATE EVENTS IN PESHAWAR AND REVIEWING FLOOD MITIGATION EFFORTS

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ABSTRACT

Peshawar, a rapidly urbanizing city in northwestern Pakistan, has become increasingly susceptible to extreme climate events, particularly seasonal flooding due to erratic rainfall patterns, weak governance, and unchecked development along flood-prone corridors. This study maps the community-level flood vulnerability from 2010 to 2022 and critically evaluates the effectiveness of structural & non-structural mitigation strategies executed by relevant authorities. Utilizing a mixed-methods approach, the research integrates climatological data from Pakistan Meteorological Department, Geographic Information System (GIS)-based flood mapping, and field-level insights from stakeholder interviews and community surveys. The findings reveal that 24 union councils are consistently exposed to high flood risks due to their proximity to rivers, seasonal poor drainage infrastructure, and informal settlements. Although structural measures, such as embankments and drainage rehabilitation, exist, their impact is undermined by frequent encroachments, limited maintenance, and a lack of coordination among the municipal, irrigation, and disaster management bodies. This research offers vital recommendations to support sustainable flood resilience and adaptive governance in Peshawar.

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INTRODUCTION

Over the past decade, Peshawar has faced a succession of the climate-related shocks, revealing its exposure to both winter and monsoonal precipitation extremes. Located in a subtropical, semi-arid foothill zone, district experiences four distinct seasons; most intense rainfall occurs from December to March, when western disturbances dominate, and again from July to September with southwest

monsoon (Pakistan Meteorological Department, 2023a). Mean monthly maxima approach 40 °C in May–June, whereas the winter nights can fall to 3 °C, producing sharp thermal gradients that fuel convective storms (PMD, 2023a). These hydro-climatic dynamics have become gradually erratic: a cloud-burst in March 2020 delivered 149 mm of rain, compared with only 5 mm in March 2022 (PMD, 2023b). Hydrological and settlement features amplify meteorological risk. Kabul River, Budhni Nala, and their attendant khwars (seasonal floods) flank or cut through densely populated peri-urban neighborhoods. Pakistan's National Disaster Management Plan ranks Peshawar among the country's highest flood-risk cities, a judgment reiterated in three successive Provincial Disaster Management Authority contingency plans (Provincial Disaster Management Authority Khyber Pakhtunkhwa, 2023).

In the extreme 2010 flood, 22,000 houses were flooded, destroying 5,312 houses and affecting more than 160,000 people across 14 union councils (NDMA, 2011). Even "average" monsoon months now deliver 33–58 mm of rainfall, sustaining threat of over-bank flows (PMD, 2023b). Union-council data show spatially clustered vulnerability. Settlements like Achini Bala, Shahi Bala, and Budhni sit directly on active floodplains where embankments are breached, encroached upon, while others (Chamkani, Urmer Bala) contend with constricted drainage and rapid runoff from adjacent hills (District Administration Peshawar, 2024). Poverty, informal housing, and limited early-warning access further heighten exposure. Although structural countermeasures, embankments, walls and drainage rehabilitation are built, municipal officials acknowledge that weak building-control enforcement and fresh encroachments within riverbeds have eroded their effectiveness (Sena & Michael, 2006). Global risk-reduction research emphasizes that technical defenses must be paired with robust non-structural tools, like land-use zoning, spatial planning legislation, and community-based early warning systems (Rahman & Shaw, 2015; Grieving, Xanthopoulos & Smith, 2016; Shah, Ali & Khan, 2017).

Peshawar's current strategy reflects this framing only partially. Short-term action priorities include real-time water-level monitoring through the Water and Power Development Authority and the rapid dissemination of flood bulletins via the PDMA and local administration (PDMA-KP, 2023). Long-term plans call for expanding early-warning networks, designating evacuation centers, and reinforcing embankments; yet, jurisdictional overlaps among revenue, irrigation, and municipal bodies often delay implementation (Sena & Michael, 2006). Against this backdrop, present study pursues two objectives: (a) to delineate hotspot neighborhoods who is physical and socio-economic characteristics render them most vulnerable to extreme hydro-meteorological events, using ten years of rainfall and impact data; and (b) to assess the adequacy of structural and non-structural measures adopted by the government departments and partner organizations to mitigate these vulnerabilities. Therefore, by combining spatial analysis with stakeholder perspectives, the paper provides the evidence-based recommendations for an integrated, community-centered resilience strategy in Peshawar.

Problem Statement

Over the last decade, the city of Peshawar has become increasingly vulnerable to extreme climatic events, particularly seasonal flooding triggered by erratic monsoon and winter rainfall patterns.

Despite repeated incidents of severe floods most notably in 2010, which displaced thousands and caused widespread damage, there is limited progress in developing a comprehensive, community-level vulnerability assessment & mitigation framework. Many areas, especially settlements located near the Kabul River, Budhni Nala, and seasonal streams (khwars), remain exposed to flood hazards due to inadequate drainage systems, unchecked urban expansion, poor spatial planning, and weak coordination among government agencies. While several short- and long-term flood mitigation strategies have been proposed by provincial and local departments, their implementation remains fragmented and reactive rather than preventive. A critical gap exists in understanding the spatial distribution of vulnerability across different communities and evaluating actual effectiveness of mitigation measures. This study aims to map most affected areas using empirical data from 2010 to 2022 and assess institutional responses to support targeted and sustainable disaster risk reduction efforts in Peshawar.

Objectives of Study

1. To identify and map the most vulnerable communities in Peshawar to extreme climatic events, particularly floods, using data from 2010 to 2022.
2. To assess the effectiveness of flood mitigation efforts implemented by relevant government departments and the disaster management authorities.
3. To examine key environmental, infrastructural, and governance-related factors contributing to the flood vulnerability at the community level.

LITERATURE REVIEW

The city of Peshawar, located in northwestern Pakistan, is characterized by the sub-tropical, semi-arid, and sub-mountain climate. It experiences two distinct rainfall seasons: winter rains due to western disturbances and summer monsoon rains (Pakistan Meteorological Department, 2022). Over past decade, this climatic variability, influenced by shifting seasonal precipitation patterns and global climate change, has increasingly exposed Peshawar to the risks of extreme weather events, particularly floods. The monsoon months of July to September pose the greatest threat, with erratic and heavy rainfall often triggering flash floods in both rural and peri-urban settlements (PDMA, 2021). Between 2010 and 2022, rainfall data revealed notable anomalies, including abrupt spikes in March 2020 (149.1 mm) and erratic distribution during the summer monsoons, which often contributed to the overflow of the rivers and drainage nullahs (District Disaster Management Unit, 2023). In this drive, the 2010 floods, among the most devastating in Pakistan's history, had a severe impact on Peshawar.

Approximately 97 villages were submerged, displacing over 164,000 people and damaging over 20,000 homes (PDMA, 2011). These events underscore Peshawar's vulnerability, especially among communities located near river channels and seasonal streams (khwars), such as the Kabul River, Budhni Nala, and Bara Khwarh. The settlements in union councils such as Achini Bala, Jogani, Chaghar Matti, and Mathra were found to be consistently exposed to seasonal flooding risks due to their proximity to floodplains and inadequate drainage infrastructure. Flood risk in Peshawar is not only a consequence of natural hazards but is aggravated by socio-political and infrastructural limitations. According to Sena and Michael (2006), effective flood risk mitigation demands both

structural (e.g., levees, embankments, dams) and non-structural (e.g., zoning, building codes, early warnings) interventions. While structural flood defenses, such as embankments and culverts, exist in Peshawar, they often suffer from poor maintenance, encroachments, and a lack of integration with early warning systems (Shah, Ali, & Mahmood, 2017). Moreover, the local authorities often lack clear jurisdiction.

For instance, drainage channels maintained by the irrigation department often pass-through areas managed by municipal authorities, leading to governance vacuum in enforcement and emergency preparedness (Rahman & Shaw, 2015). Recent studies by Grieving, Xanthopoulos and Smith (2016) emphasize that spatial planning is a vital yet neglected tool in flood management, particularly in developing cities. Despite repeated flood events, Peshawar lacks a robust and enforceable spatial planning framework that can control unchecked urban sprawl in the flood-prone zones. The illegal encroachments continue to proliferate in high-risk areas, and legal or political pressures frequently hinder local efforts to remove them. Additionally, the early warning systems and community-level evacuation planning remain inadequate. These events have intensified in the recent years due to climate change, rapid urbanization, poor infrastructure, and socio-economic disparities. While the PDMA and Irrigation Department have developed short-term flood contingency plans, including the establishment of the observation posts and evacuation centers in schools, their effectiveness is constrained by the weak inter-agency coordination as well as insufficient community engagement (DDMU, 2023).

Research Gap

Although various government documents and academic studies have discussed the diverse climate vulnerability of Peshawar in general terms, there is a lack of community-level spatial mapping that integrates climatic, geographic, and socio-economic data to identify the high-risk zones across the district. The existing research often treats Peshawar as a homogeneous urban unit, overlooking the variations in vulnerability across union councils and settlements adjacent to water bodies. Besides, while structural mitigation strategies have been documented, the effectiveness, implementation status, and sustainability of non-structural measures like community awareness, local governance, and land-use regulation remain underexplored. In this connection, the absence of comprehensive land-use planning and limited public awareness further compounds community vulnerability. This study addresses this gap by identifying the diverse vulnerable neighborhoods through rainfall and the flood impact data (2010–2022) and assessing the performance of mitigation efforts undertaken by local authorities.

RESEARCH METHODOLOGY

To assess the vulnerability of communities in Peshawar to the impacts of extreme climatic events between 2010 and 2022, this study employs a mixed-methods approach, combining qualitative and quantitative data. Secondary information regarding rainfall, flood occurrences, and affected areas was gathered from official sources, including the Pakistan Meteorological Department (PMD), the Provincial Disaster Management Authority (PDMA), and the District Disaster Management Units (DDMU). To map vulnerable communities, Geographic Information System (GIS) techniques were

utilized. These tools were based on flood damage data as well as the closeness of the villages to rivers and seasonal streams (khwars). Additionally, the interviews were conducted with key informants, including officials from the departments of irrigation, meteorology, and disaster management, to assess the effectiveness of the mitigation activities. To enhance the data, field observations and community surveys were conducted in several high-risk union councils. In this drive, these surveys and observations provided insight into the local perspectives and preparation. A thematic analysis was conducted on the collected data in order to identify the patterns of vulnerability and gaps in institutional responses.

FINDINGS OF STUDY

This study provides comprehensive analysis of community-level vulnerability to extreme climatic events in Peshawar and evaluates effectiveness of flood mitigation efforts from 2010 to 2022. The findings are as follows:

Climatic Variability & Rainfall Trends

The analysis of rainfall data from 2010 to 2022 highlights significant variability and irregular precipitation patterns in Peshawar, particularly during monsoon and late winter seasons. Monsoon rainfall, especially in July, August, and September, was found to be highly erratic. For example, in 2020, rainfall peaked at 149.1 mm in March, notable deviation from the expected pattern. Similarly, extreme fluctuations in summer rainfall were noted, for instance, only 5.4 mm in September 2022, compared to 56.2 mm in the same month in 2020. These fluctuations contributed to unpredictable flood events, intensifying risk for communities in low-lying areas. Furthermore, the winter season, influenced by western disturbances, brought substantial precipitation in some years, indicating a dual seasonal threat. The cumulative data shows that rainfall intensity does not certainly correlate with predictable seasons, making flood preparedness gradually challenging. The shifting patterns reflect broader trends in climate change and underscore the need for adaptive flood management systems in the region.

Table 1 Rainfall Profile of District Peshawar

MONTHS	2020	2021	2022	Average
JAN	47.2mm	0	110.5	52.57 mm
FEB	35.3mm	23.2	35.6	31.37 mm
MAR	149.1mm	79.0	5.2103	77.77 mm
APL	60.9mm	20.2	5.0	28.70 mm
MAY	7.8mm	9.2	19.7	12.23 mm
JUN	10.2mm	0	59.5	23.23 mm
JUL	25mm	79.8	68.0	57.60 mm
AUG	39.2mm	40.8	56.2	45.40 mm
Sep	56.2mm	37	5.4	32.87 mm
Oct	0.8mm	7	18.4	8.73 mm
NOV	63.7mm	0	51.0	38.23 mm
DEC	9.8mm	.4	8.0	6.07 mm

Source: PMD Reports

Table 2 Impacts of the 2010 Flood in District Peshawar

No. of affected Villages	97
Number of Houses Affected	50,067
Destroyed Houses	5,312
Damaged houses	15,202
Total affected households	20,514
Number of people affected	164,112
Loss of Livestock Population	23427
a. Departed	5,406
b. Total affected	18,021

Source: Flood in Pakistan 2010- PDMA Reports

Vulnerable Areas, Communities & Proposed Mitigation Plan

Using spatial mapping and flood impact data, the study identified 24 Union Councils (NCs) across Peshawar that are particularly vulnerable to flooding. In this connection, these areas are located adjacent to the natural waterways, including the Kabul River, Budhni Nala, Shah Alam Khwarh, Zandi Khwarh, Pir Bala Khwarh, and Bara Khwarh. Some of most severely affected communities include: Achini Bala (affected by Achini Khwarh), Mera Surizai Paya & Urmer Bala (Zandi Khwarh), Jogani and Chaghar Matti (Shah Alam River), Kankola and Budhni (Budhni Nala), Kafoor Dehri, Panam Dehri, and Mathra (Pir Bala Khwarh) and Takhatabad, Nahaqi, and Gulbela (Naguman and Hajizai Rivers). These fluctuations contributed to impulsive flood events, intensifying risk for communities in low-lying areas. The 2010 floods, in specific, affected 97 villages, damaging over 20,000 houses, displacing 164,112 people, causing livestock losses. Settlements in floodplain zones suffer from combination of poor drainage, advances, and scarce structure, resulting in high exposure and low resilience.

Short-Term Plans

- ✓ The early warning system for flooding and over-topping of the Warsak Dam, which is implemented by the Water and Power Development Authority (WAPDA) and Irrigation Department.
- ✓ Early transmission of weather predictions and flood warnings through the Public Disaster Management Authority (PDMA), Local Administration, and community-based methods in particular situations.
- ✓ The removal of encroachments along rivers, streams, and drains can be accomplished for the particular purpose in the particular situations and context.
- ✓ We are responsible for the repair and maintenance of the Drainage System, and restoration of damaged flood protection works and their counterparts.

Long-Term Plans

- ✓ To facilitate the acquisition of real-time data on water levels, it is recommended that a network be recognized comprising community-level organization & community volunteers throughout the catchment areas.

- ✓ Additionally, it is recommended that evacuation centers be designated with the support of the education department.
- ✓ The Revenue Department and the Irrigation Department have made arrangements to ensure the rapid broadcast of flood alerts from their respective departments for desired leading outcomes.
- ✓ The Irrigation Department has established several observation posts in locations that are likely to experience flooding. Additionally, it is imperative that the Civil Defense staff and volunteers are fully functional.
- ✓ The construction of dams across the main tributaries of the River Kabul and improvement of flood mitigation measures over the River Kabul are both examples of efforts to mitigate flooding.

Table 3 Monsoon Rainfall Profile

	2020	2021	2022	Average
JUL	25mm	79.8	68.0	57.60 mm
AUG	39.2mm	40.8	56.2	45.40 mm
Sep	56.2mm	37	5.4	32.87 mm

Table 4 Vulnerable Areas and Communities in Peshawar & Proposed Evacuation Plan

SN	Name of NCs	Population	Vulnerability Reason	Proposed Evacuation Centers
1	Achini Bala	45,450	Achini Khwarh	GMS Haji Baanda, GMS Achini Bala, GHS Haji Baanda,
2	Mera Surizai Paya	27,286	Zandi Khwarh	GPS Mera suriza payan, GMS Garhi afazal Rahim, GMS GarhiFazal Rahim,
3	Shahi Bala	34,076	Shagai Khwarh	GHS Shahi bala, GPS No. 1 1mera shahi Bala, GPS Juma, GPS Sufaid Sang, GHSS Sufaid Sang
4	Panam Dehri	34,459	Pirbala Khwarh	GPS Hakim khan killi, GPS Panam dheri, GPS Nawab koruna, GHS Hakeem khan killi
5	Jogani	32,222	Shahalam +Hajizai River	GHSSS Chogha Matti, GPS No.1, 2,3 Chaghar Matti, GPS Pir Kallay No.2
6	Chaghar Matti	30,025	Shahalam River	GPS, GHS Chaghi Matti.
7	Chamkani	34,184	Bara khwarh	GHSS Chamkany GHSS Chamkany GPS No.1 and 2 Chamkany GPS Choa Gujar.
8	Budhni	31,918	Shahalam Khwarh	GHS Buddhi, GGHS Buddhi, GMS Sabi, GPS Dalazak, GPS+GHS Guluzai

Table 4A Vulnerable Areas and Communities in Peshawar & Proposed Evacuation Plan

SN	Name of NCs	Population	Vulnerability Reason	Proposed Evacuation Centers
9	Mera Kichori	41,454	Bara Khwarh	GHS Zahir Abad, GPS Mera Kachari, GPS New Qilla,
10	Kankola	42,206	Shahalam Khwarh + Budhni Khwarh	GMS Kankola, GPS Kankola, GPS No.1 & 2 Fatu Abdur Raheema, GPS Daman Hindki

11	Lala	27,845	Bara Khwarh	GPS No.1 & 2 Lala Kallay, GPS Nasir Pur, GHS Tarnab Faram, GMS Tarnab Faram, GPS Masma
12	Khatki	30,134	Naguman + Hajizai river	GPS Mamo Khatki, GPS Banda Payan, GPS No.1 & 2 Bela Barmaid Khel, GPS Qilla Abdul Jalil
13	Urmer Bala	39,121	Zandi Khwarh	GHS Urmer Bala, GMS Urmer Bala, GPS No.1 & 2 Urmer Bala, GMS Ghari Charagh, GPS Ghari Charagh
14	Takhat abad	45,263	Shahalam + Naguman river	GPS Takht Abad Awal, GPS No.1 & 2 Mewra, GMS Mewra, GHS Takht Abad.
15	Mathra	47,189	Pir Bala Khwarh	GHSS Mithra, Degree College Mithra, GPS Budha Kander Khel, GPS No.1 & 2 Mithra
16	Kafoor Dehri	34,806	Pirbala Khwarh	GPS Kafor Dheri, Mera Aka Khel, GHS Kafor Dheri, GPS Killa Jabbar, GPS Zagi Korona,

Table 4B Vulnerable Areas and Communities in Peshawar & Proposed Evacuation Plan

SN	Name of NCs	Population	Reason for Vulnerability	Proposed Evacuation Centers
17	Musazai	28,823	Bara Khwarh	GPS No.1,2 & 3 Musashi. GMS Pandu Payan, GHSS Musazay
18	Haryana Payan	42,305	Badhber Janay Khwarh	GHS Haryana Bala, GPS Muslim Abad (Raam Kishan), GPS Nasapa Payan,
19	Wadpaga	31,305	Bara Khwarh	GHS Wadpagha, GPS Muhammad Zai, GPS Wadpagha,
20	Nahaqi	41,843	Naguman + Shah Alam Khwarh	GCMHS Nahaqi, GHS Mian Gujar, GPS Jala Bela, GPS Daudzai, GPS No.1 & 2 Mian Gujar,
21	Gulbela	40,593	Naguman + Hajizai River	GHS Gulbela, GHS Kareem Daad, GPS Ghari Sharif Khan, GPS Gulbela, GGMS Gul Bela.
22	Khazana	38,111	Shahalam River	GMS Khazanna Shugar Mills, GMS Todda, GPS No.1 Todda, GPS Khazan Sugar, GPS No.2 Toda
23	Pakha Ghulam	32,591	Budhni Nulla	GHS Pakha Ghulam, GPS No.1 & 3 Pakha Ghulam, GPS Duran Pur, GPS ChughalPura
24	Larhama	24,887	Budhni Nulla	GPS Larama, GHS Larama, GPS No.1 Ghari Baloch

Socioeconomic & Infrastructural Vulnerability

The study found that socio-economic status plays a critical role in determining flood vulnerability. Most high-risk communities are composed of low-income households with limited access to safe housing, early warning systems, and evacuation services. Many reside in unplanned or informal settlements built along riverbanks and drainage channels. Field visits and surveys revealed that several vulnerable areas lack even basic stormwater management systems. Residents reported frequent waterlogging, even during moderate rainfall. Drainage systems are often clogged, broken, or insufficient in capacity, particularly in union councils such as Mathra, Chamkani, and Kankola.

often damaged, destroyed during monsoon flooding, disrupting mobility and access to emergency diverse services.

Institutional & Governance Challenges

The interviews with officials from PDMA, Irrigation Department, WAPDA and local administrations tinted systemic issues in the disaster management governance. Key challenges identified include: Overlapping jurisdiction between departments (e.g., municipal vs. irrigation vs. revenue), Lack of enforcement of building codes and zoning laws in flood-prone areas, Inadequate maintenance of embankments and flood protection infrastructure and Absence of integrated flood risk maps to guide planning and response. The efforts to remove illegal settlements along rivers and khwars are often met with legal, political resistance, making enforcement difficult. In many cases, authorities admitted to lacking real-time flood nursing systems or actionable community-level data for rapid response planning.

Mitigation Efforts: Status and Limitations

While the government has introduced both short-term and long-term mitigation plans, their impact on reducing flood risk remains limited. Some key initiatives include: Early warning systems via WAPDA and meteorological departments, evacuation plans involving the local schools and community halls, maintenance, rehabilitation of drainage systems & construction of embankments in flood-prone zones

Mitigating Vulnerabilities

According to Sena and Michael (2006), mitigation is the process of anticipating and responding to possible catastrophes to minimize property loss and casualties. The flooding and its effects can be lessened by implementing structural modifications. Flood levees and embankments are often promoted as effective ways to mitigate flood hazards, despite their inherent limitations. To reduce flooding, Peshawar has considered adopting a strategy in floodplains, where relevant authorities have constructed embankments across river and Nullah (a canal fed by rivers, streams originating from higher elevations). This subject focuses on both non-structural mitigation measures, such as inadequate building regulations, intrusions into embankments, and ambiguous responsibilities and jurisdictions, as well as structural mitigation measures, such as proper drainage canal cleaning and embankment construction (see Figure). The findings of present study are shown in the figure, which indicates that the community members and municipal authorities think embankments should be strengthened or increased.

Illustrates how non-structural mitigation techniques might be used to lessen possible residual flood dangers in four distinct locales. Building control is the most effective way to reduce the danger of disaster. In this connection, regulations are in place to limit and direct building away from known dangers. Government officials and residents in flood-prone areas generally agreed that the local government was not doing a good job of controlling rural expansion. New encroachments appeared in the riverbeds when the most recent flooding subsided. Threats of legal action, however, resisted the authorities' attempts to demolish this criminal encampment. The local governments must take down dangerous and unlawful constructions. They are unable to demolish unauthorized buildings

on revenue or irrigation department property, examines efficacy of existing flood mitigation efforts. Since the nation lacks both regional and spatial legislation, localized regulation is insufficient to restrict sprawl, is impaired by geographical extent of floods that impact regions under jurisdiction of several authorities.

Therefore, spatial planning regulations and procedures can be used to mitigate non-structural flood risk to a great degree. Additionally, work of several academics has supported this (Rahman & Shaw, 2015; Grieving et al., 2016; Shah et al., 2017). However, the implementation is inconsistent and often reactive. The lack of regular drain cleaning, poor embankment design, and insufficient community engagement all contribute to reduced overall effectiveness. Moreover, non-structural measures, such as land-use regulation, community training, and awareness campaigns, are either absent or not institutionalized at the local level lack of drainage infrastructure, and limited access to emergency services. Residents expressed concerns in limited communication of flood warnings, mainly in rural areas. Evacuation centers, yet designated, lack basic facilities such as bedding, food supplies, or medical kits.

Community Awareness and Preparedness

Surveys and interviews with residents in flood-prone areas indicate low levels of awareness about flood risks and preparedness. Most respondents had not participated in any community disaster training or evacuation drills. Many people rely on informal sources, such as neighbors, local leaders, or social media, for flood warnings. This informal system often fails during emergencies, particularly at night or in the event of rapidly developing floods. Despite these challenges, the study observed examples of local-level resilience, including volunteer groups in areas like Musazai and Haryana Payan, have organized basic response systems. Still, these initiatives are limited in scale and lack institutional support.

Spatial Planning and Legal Gaps

A critical finding of the study is the absence of enforceable spatial and regional planning laws in Peshawar. Illegal construction continues in high-risk areas due to unclear land ownership, weak regulatory enforcement, and political interference. The local authorities admitted that no unified land-use policy exists to guide the flood-safe development across the district. This aligns with the broader national context, where disaster risk reduction (DRR) is not effectively integrated into the urban planning. The study confirms the conclusions of previous scholars (Rahman & Shaw, 2015; Grieving et al., 2016) that localized legislation along with spatial tools are urgently needed to reduce future risk.

CONCLUSION

Drawing on the rainfall records (2010-2022), flood-impact data, GIS mapping, and interviews, the study demonstrates that Peshawar's flood vulnerability is both climate-driven and human-made. The 24 most at-risk union councils lie on or near active floodplains, where drainage is inadequate and building control is weak. Structural defenses embankments and rehabilitated drains offer partial relief but are compromised by encroachments and maintenance lapses. The non-structural measures, like zoning, early warning dissemination & community preparedness, remain piecemeal.

Thus, poverty, informal housing, and limited access to official alerts amplify residents' exposure, especially in peri-urban settlements. Overall, without coordinated planning, robust governance, and ordinary engagement, Peshawar will continue to face rising flood hazards. Despite ongoing mitigation efforts, Peshawar remains highly vulnerable to flooding. The failure to mix structural and non-structural measures, especially the community engagement, has led to fragmented and reactive responses. Governance challenges, including overlapping departmental roles and a lack of enforceable spatial planning, hinder the sustained reduction of flood risk. Communities are often left uninformed, unprepared, and unsupported, particularly in most exposed areas. There is urgent need to reframe disaster risk management as a community-centered process rather than a purely administrative task.

Recommendations

a. Structural and Planning Measures:

1. Reinforce the embankments and drainage systems in the flood-prone zones, with regular inspection and maintenance.
2. Establish a single coordinating authority for land-use planning and flood control to avoid overlapping jurisdiction.
3. Enforce zoning laws and prevent encroachments in high-risk floodplains through clear and consistent legal actions.

b. Community-Based Measures:

4. Form community disaster management committees in high-risk union councils to improve preparedness and response.
5. To conduct regular awareness campaigns, evacuation drills, and training programs in collaboration with local schools, mosques, and civil society.
6. Empower local volunteers to monitor water levels and report hazards, supported by real-time alerts from WAPDA and PDMA.
7. To involve the communities in identifying and managing evacuation centers to ensure accessibility, supplies, and shelter standards.

c. Governance and Policy:

8. To develop and implement district-wide spatial planning laws that integrate flood risk zoning and disaster preparedness.
9. Improve coordination among municipal, irrigation, and disaster management departments to avoid delays in emergency response.
10. Institutionalize community feedback mechanisms to update risk maps and improve local policies continually.

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