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Geospatial Modeling of Urban Flood Susceptibility under Rapid Urban Expansion in Pakistan

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Abstract

Rapid urbanization in Pakistan, occurring at an annual rate of approximately 3%, has dramatically increased urban flood susceptibility through uncontrolled sprawl, encroachment on floodplains, blockage of natural drainage networks (nullahs), and widespread conversion of permeable surfaces to impervious cover. This study synthesizes geospatial modeling approaches to map and predict urban flood risk under these dynamic land-use changes, drawing on multi-criteria decision analysis (Analytical Hierarchy Process AHP), machine learning algorithms (Random Forest, XGBoost, CNN), and remote sensing data (Sentinel-1 SAR, NDVI, NDBI, TWI). Key conditioning factors elevation, slope, drainage density, distance to rivers, land-use/land-cover (LULC), and rainfall intensity are integrated to generate high-accuracy susceptibility maps (AUC 0.92–0.99 in validated models). Case studies from major cities (Karachi, Lahore, Islamabad, Quetta) reveal that urban expansion has eliminated critical natural waterways, reduced infiltration capacity, and exacerbated pluvial and flash flooding, as evidenced by record-breaking events in 2010, 2022, and 2025. The analysis highlights the limitations of traditional models in capturing non-stationary climate extremes (cloudbursts, GLOFs) and underscores data gaps (high-resolution DEMs, localized rainfall records). Findings emphasize that unchecked impervious surface growth disproportionately amplifies runoff in low-lying and high-density zones, threatening infrastructure, public health, and economic stability. Policy recommendations include mandatory risk-sensitive urban planning, restoration of natural drainage, separation of stormwater and sewage systems, scaling nature-based solutions (urban green infrastructure, sponge city principles), and integration of real-time AI/GIS monitoring for early warning. Transitioning to resilient, adaptive urban development is essential to mitigate escalating flood risks in Pakistan's rapidly growing cities amid climate change.

Keywords: Urban Flood Susceptibility, Geospatial Modeling, Rapid Urbanization, Impervious Surfaces, Analytical Hierarchy Process (AHP), Machine Learning, Remote Sensing, Land-Use Change, Flood Risk Management, Pakistan, Drainage Networks, Climate Extremes

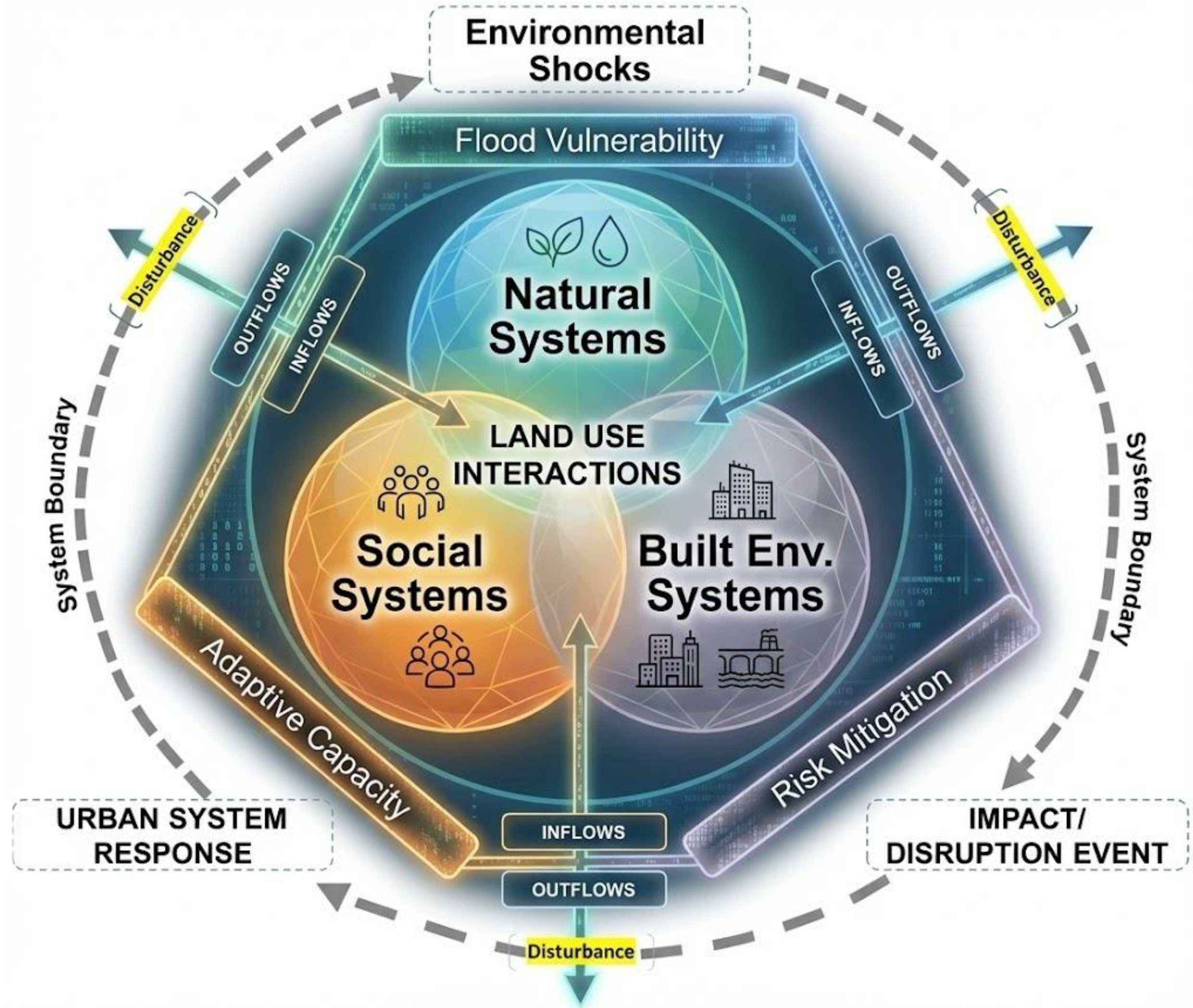
1. Introduction

The contemporary landscape of Pakistan is undergoing a profound transformation characterized by one of the highest rates of urbanization in South Asia, currently estimated at an annual growth of 3% (Office of the Auditor General of Pakistan, 2022). This demographic shift, driven by both natural population increases and a relentless rural-to-urban migration, has significantly outpaced the developmental capacity of urban infrastructure, particularly in terms of drainage and flood management (Zia et al., 2023). As the country transitions towards a manufacturing and service-based economy, the expansion of built-up areas is frequently unplanned, leading to the encroachment of natural floodplains and the systematic dismantling of historical hydrological networks (Sohail et al., 2023). The resulting urban flood susceptibility is no longer a peripheral environmental concern but a primary threat to national economic stability and public health, exacerbated by a climate regime that is becoming increasingly volatile (Mukhtar et al., 2024; Ullah, 2024).

2. Theoretical Framework of Urban Flood Dynamics

In the context of rapid urban sprawl, flood susceptibility is defined by the interaction between static geo-environmental conditioning factors and the dynamic increase in impervious surfaces (Khan et al., 2025). The conversion of agricultural land and natural green spaces into "grey" infrastructure roads, buildings, and pavements radically alters the local hydrological cycle by reducing soil infiltration and accelerating surface runoff (Raza et al., 2012). This process is quantified through various indices, such as the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-Up Index (NDBI), which track the replacement of biomass with heat-retaining, non-porous materials (Mahboob et al., 2015).

Figure 1: Conceptual Framework of Urban Flood Vulnerability and System Interactions



2.1 Hydrological Conditioning Factors in Geospatial Modeling

Geospatial modeling of flood susceptibility relies on the identification and weighting of multiple criteria that govern the movement and accumulation of water. Elevation and slope remain the most fundamental predictors; lower-elevation areas within flat alluvial plains act as natural sinks for storm surges and runoff, while steep slopes in northern regions and surrounding valley cities like Quetta and Islamabad facilitate rapid flash floods (Ye et al., 2024).

Another critical parameter is the Topographic Wetness Index (TWI), which models the spatial distribution of soil moisture potential. In the flat terrains characteristic of many Pakistani urban centers, the standard TWI calculation is often modified to prevent mathematical errors in areas with zero slope, as expressed in the following simplified formula (Nikolaus et al., 2025).

TWI = ln(alpha / (tan beta + 0.5) In this calculation, "alpha" represents the cumulative upslope area draining through a point per unit contour length and "beta" denotes the local slope angle. Higher TWI values signify zones where water naturally gravitates and accumulates, often corresponding to the high-density urban cores where natural percolation has been eliminated (Bazai & Panezai, 2020).

Table 1: Key conditioning factors and their influence on flood susceptibility in urban geospatial models.

Factor Category	Variable	Influence on Flood Susceptibility
Topographical	Elevation	Higher influence in low-lying plains where water ponding occurs (Mukhtar et al., 2024; Nikolaus et al., 2025)
Topographical	Slope	Steepness dictates flow velocity; critical for mountain-adjacent cities (Nikolaus et al., 2025; Ye et al., 2024)
Hydrological	Drainage Density	Low density in urban areas prevents the efficient removal of peak runoff (Mukhtar et al., 2024)
Hydrological	Distance to Rivers	Proximity increases vulnerability to riverine overtopping and backflow (Nikolaus et al., 2025; Nikolaus et al., 2025)
Environmental	LULC (Impervious)	High built-up density directly correlates with increased runoff coefficients (Mukhtar et al., 2024; Sattar et al., 2023)
Environmental	NDVI	High vegetation density reduces runoff velocity and enhances infiltration (Sohail et al., 2023; Nikolaus et al., 2025)
Meteorological	Rainfall Intensity	Primary driver of pluvial flooding, especially during monsoonal peaks (Mukhtar et al., 2024)

2.2 The Mechanism of Rapid Urban Sprawl and Land Use Change

Urbanization in Pakistan is characterized by the emergence of "agro-polis" developments and mushrooming housing schemes that often bypass formal zoning regulations (Chakor Ventures, 2026). This unregulated expansion often targets peril-urban areas where essential ecosystem services, such as aquifer recharge zones and protective wetlands, are located (Akhtar & Dhanani, 2013). For example, the expansion of the built-up area in Karachi from 486 km2 in 1991 to over 1,582 km2 by 2013 represents an out-of-order development that has consumed marginal lands and historical waterways (Morales-Ruano et al., 2022).

The consequence of this transformation is twofold. First, it increases the physical hazard by creating higher volumes of surface water that the existing, often dilapidated, drainage systems cannot accommodate (Chakor Ventures, 2026). Second, it increases human exposure and vulnerability, as low-income communities and informal settlements are frequently established in high-risk zones, such as the banks of storm drains (nullahs) or coastal floodplains (Centre for Disaster Preparedness and Response, 202).

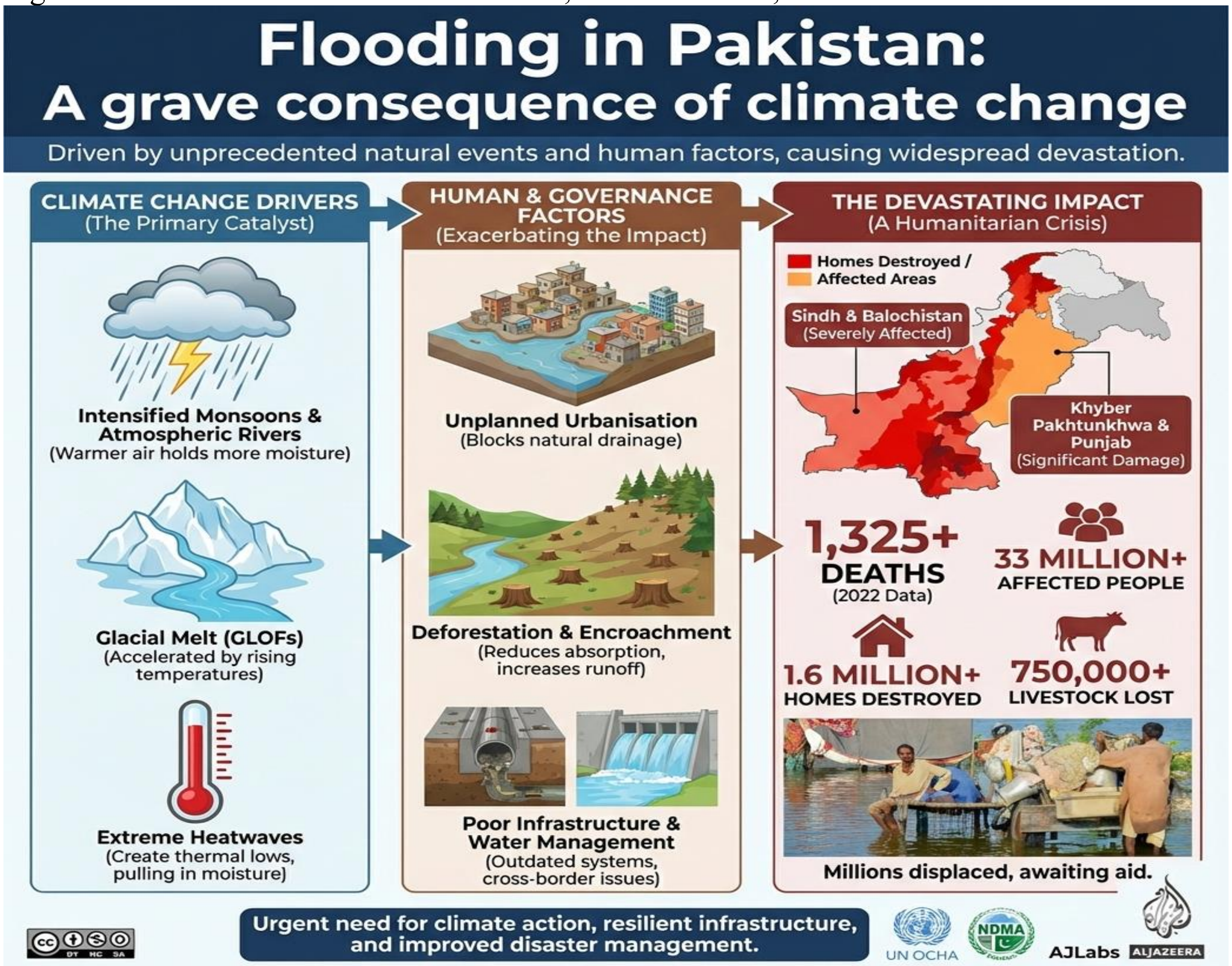
3. Historical Trajectory of Flood Events and Record-Breaking Extremes

The last two decades have served as a stark reminder of Pakistan’s high susceptibility to climate-induced catastrophes. Major events in 2010, 2022, 2024, and 2025 have demonstrated that urban flooding is no longer an anomaly but an annual feature of the monsoon season (Hassan et al., 2025).

3.1 The 2010 and 2022 Mega-Floods

The 2010 floods were primarily riverine, impacting approximately 20 million people and causing immense damage to the rural economy, yet they also highlighted the vulnerability of urban centers along the Indus River system (World Weather Attribution, 2022). However, the 2022 monsoon season redefined the scale of the threat. Driven by record-breaking rainfall with Sindh and Balochistan receiving 726% and 590% of their usual August totals the disaster caused widespread urban flash floods, landslides, and the destruction of over 1.7 million homes (Sattar et al., 2023). The economic damage from these floods was estimated at over 14.9 billion dollars, with a significant portion of this loss concentrated in urban infrastructure and displaced city populations (Buriro & Jatoi, 2025).

Figure 2: The Climate-Flood Nexus: Drivers, Human Factors, and the 2022 Humanitarian Crisis



3.2 Emerging Threats: Cloudbursts and Northern GLOFs

In more recent years, particularly in 2024 and 2025, the nature of flooding has shifted towards more localized and unpredictable extremes. Cloudbursts have become increasingly destructive in high-altitude regions and valley-based cities like Islamabad and Muzaffarabad (Centre for Disaster Preparedness and Response, 2024). In July and August 2025, severe floods struck the Swat Valley and Gilgit-Baltistan, triggered by relentless monsoon rains combined with Glacial Lake Outburst Floods (GLOFs) (Hussain, 2025). These events highlight a critical need for geospatial models that can account for "non-stationarity" the reality that historical rainfall patterns are no longer a reliable predictor of future events due to the doubling of glacier melt rates in the Himalayas (Nie et al., 2021).

Table 2: Historical trajectory of major urban and regional flood events in Pakistan (2001–2025).

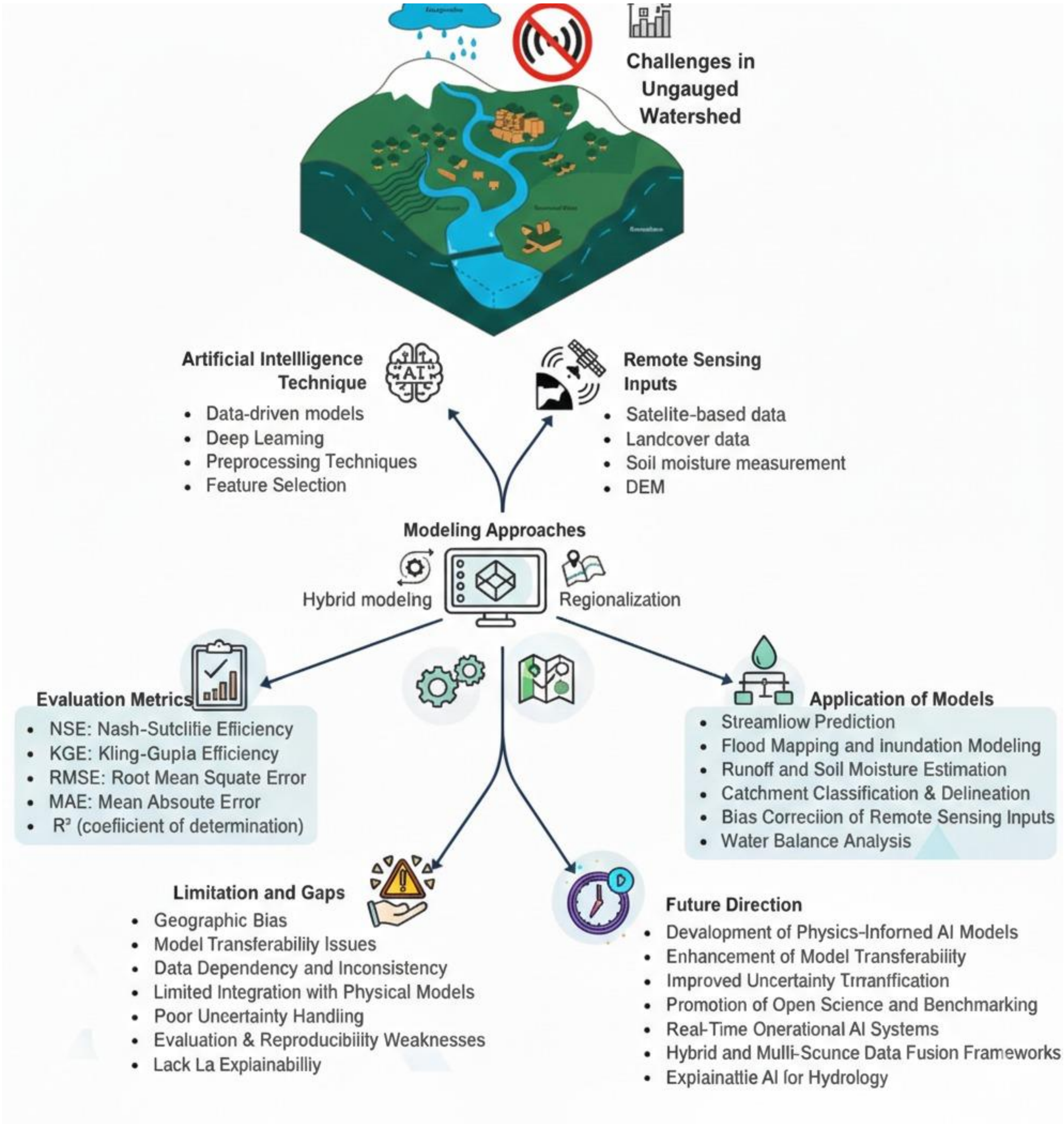
Year	Event Type	Primary Location/Impact	Notable Statistic
2001	Cloudburst	Islamabad	Extreme flash flooding in urban sectors (List of Floods, 2025)

2010	Mega-Flood	Nationwide (Indus Basin)	2,000 deaths; 20 million people affected (List of Floods, 2025; World Weather Attribution, 2022)
2020	Monsoonal Rain	Karachi	231 mm rain in 12 hours; infrastructure collapse (Chakor Ventures, 2026; List of Floods, 2025)
2022	Record Monsoon	Sindh, Balochistan, KP	Wettest August on record since 1961 (Ye et al., 2024; World Weather Attribution, 2022)
2025	GLOF/Flash Flood	Swat Valley, Gilgit-Baltistan	111 deaths; infrastructure including KKH destroyed (Chakor Ventures, 2026; List of Floods, 2025)

4. Geospatial Modeling Methodologies: From AHP to Machine Learning

To manage the complexities of urban flood susceptibility, researchers in Pakistan have deployed a variety of geospatial technologies, moving from knowledge-driven models to advanced data-driven predictive analytics (Nikolaus et al., 2025).

Figure 3: Integrated Geospatial and AI Modeling Workflow for Ungauged Watersheds



4.1 Multi-Criteria Decision Analysis and AHP

The Analytical Hierarchy Process (AHP) combined with Geographic Information Systems (GIS) remains a popular tool for flood mapping, particularly in data-scarce environments like Balochistan and parts of Punjab (Ahmad et al., 2025). AHP allows experts to assign relative importance (weights) to various factors. For instance, in a comprehensive study of Punjab, "distance to rivers" was given a dominant weight of 21%, followed by "elevation" at 14% and "TWI" at 13% (Zhang et al., 2025). While AHP is valuable for providing a baseline for policy-making, its subjectivity is a known limitation, often requiring validation through Area under the Curve (AUC) methods to ensure reliability (Alshayeb et al., 2024).

4.2 Machine Learning and High-Resolution Predictive Models

The integration of Machine Learning (ML) has revolutionized susceptibility mapping by identifying non-linear patterns between flood occurrences and conditioning factors (Abdo et al., 2025). Models such as Random Forest (RF), eXtreme Gradient Boosting (XGBoost), and Convolutional Neural Networks (CNN) have been applied with high success (Kavzoglu et al., 2022). In studies across the Kabul River Basin and the Indus Kohistan, XGBoost and RF models have achieved AUC values ranging from 0.92 to 0.99, indicating exceptional predictive accuracy (Bibi et al., 2025).

These models highlight that the most influential predictors are often topographical (elevation and slope) and architectural (urban density and drainage capacity. A critical insight from these data-driven approaches is that even minor variations in urban density can have a disproportionate impact on flood likelihood, as high-density zones often lack the requisite drainage networks to handle peak flows (Mukhtar et al., 2024).

4.3 Remote Sensing and Synthetic Aperture Radar (SAR)

A major challenge in monitoring urban floods in Pakistan is cloud cover during the monsoon, which obscures optical satellite sensors. To circumvent this, researchers utilize Sentinel-1 SAR imagery. SAR is an active sensor that can penetrate clouds and detect water surfaces based on backscatter variations (Pech-May et al., 2023). This technology has been essential for delineating actual flood extents in cities like Lahore and Dera Ghazi Khan, providing "ground truth" data to validate susceptibility models (Ali et al., 2026).

5. Regional Case Studies: The Urban Expansion-Flood Nexus

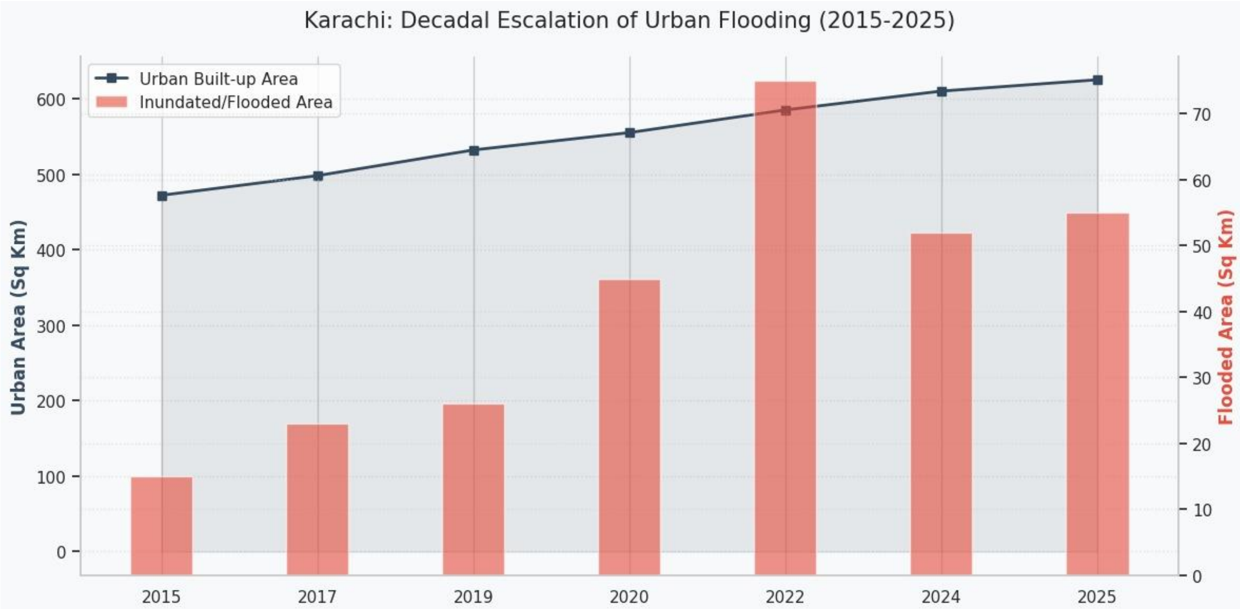
The specific dynamics of urban growth and its impact on drainage vary across Pakistan’s major metropolitan regions, each presenting unique geomorphological challenges.

5.1 Karachi: The Crisis of the Mega-Coastal City

Karachi represents the most severe case of structural drainage failure. With a population exceeding 20 million, the city's drainage system remains fundamentally unchanged since it was designed for a population of 3 million (Baig et al., 2024). Rapid, often unregulated urban sprawl has led to the systematic blockage of natural streams (nullahs). Out of approximately 3,600 km of natural waterways, nearly 870 km have been either removed or built over, with core urban areas seeing a 100% loss of these natural conduits (Shah et al., 2023).

Furthermore, the destruction of mangrove forests along the coast losing nearly 200 hectares in just 12 years has removed the city's natural buffer against storm surges and rising sea levels (Chakor Ventures, 2026). This combination of inland drainage blockage and coastal barrier loss makes Karachi exceptionally vulnerable to chronic waterlogging and catastrophic urban flooding during monsoonal events (Nizamani, 2022).

Figure 4: Decadal Correlation between Built-up Area Expansion and Flood Inundation in Karachi (2015–2025)



5.2 Lahore: Imperviousness and Pluvial Risk

Lahore's transition is characterized by a massive increase in the Urban Impervious Surface Area (UISA), which grew by approximately 23.5% between 1992 and 2022. This increase in concrete and asphalt has halved the city's drainage capacity in certain zones. Research indicates that flooded areas in Lahore typically possess a drainage density of only 2.24 km/km2, compared to 4.26 km/km2 in non-flooded regions (Shao et al., 2023). The central high-density districts, where population levels reach 12,613 persons/km2, are at the highest risk, as the existing infrastructure cannot handle the rainfall intensity, which can peak at over 88 mm/hr during the monsoon (Abdullah, 2023).

5.3 Islamabad: Sectoral Stress and Hill Runoff

As a planned city, Islamabad initially possessed ecological buffers, yet rapid expansion has seen a 73% increase in population over 15 years, leading to the encroachment of green pastures (Gilani et al., 2020). The city's vulnerability is primarily dictated by its relationship with the Margalla Hills. Runoff from these hills flows through a network of nullahs, many of which have been obstructed by illegal construction in sectors like E-11 (Mir et al., 2025). This has not only led to frequent urban flash floods but has also caused a severe groundwater deficit. Over-pumping to meet the needs of a growing population has caused the water table to drop by an average of 1.7 meters annually, particularly affecting highly populated sectors such as F, G, H, and I (Sarwar et al., 2025).

5.4 Quetta: Sinking in a Bowl-Shaped Valley

Quetta's geomorphology creates a natural hydraulic trap. As a bowl-shaped valley surrounded by mountain ranges, it is inherently prone to flash floods. Unchecked urbanization with built-up areas increasing by over 52% from 1999 to 2019 has moved into the waterways that once carried mountain runoff away from the city center (Bazai & Panezai, 2020). Compounding this risk is the phenomenon of land subsidence; excessive groundwater extraction is causing the city to sink by approximately 10 cm annually (Asfandyar et al., 2025). Subsided land is more likely to experience prolonged inundation, as the natural gravity-based drainage becomes less effective (Akhtar et al., 2025).

Table 3: Comparative analysis of urban sprawl trends and core hydrological vulnerabilities in major Pakistani cities.

City	Population Growth / Sprawl Trend	Core Hydrological Issue	Land Cover Transformation
Karachi	Doubled (1991–2013) to 1,582 km2 (Mahboob et al., 2015)	Blockage of 870 km of natural streams (Urban development study, 2024)	Mangrove loss of 200 ha in 12 years (Chakor Ventures, 2026)
Lahore	Built-up grew from 34.9 to 37.4 km2 recently (Mukhtar et al., 2024)	Drainage density halved in high-risk zones (Mukhtar et al., 2024)	UISA grew 23.5% over 30 years (Sattar et al., 2023)
Islamabad	73% increase in 15 years (Sohail et al., 2023)	Illegal construction on storm drains (nullahs) (Centre for Disaster Preparedness and Response, 2024)	12% decline in tree cover (2020–2022) (Centre for Disaster Preparedness and Response, 2024)
Quetta	252k (1972) to 2.27m (2017) (Bazai & Panezai, 2020)	10 cm/year land subsidence (Land subsidence study, 2021)	95% built-up area increase (1999–2019) (Bazai & Panezai, 2020)

6. Socio-Economic Vulnerability and the Infrastructure Deficit

Urban flood susceptibility is intrinsically linked to the socio-economic status of the population. Vulnerability assessments using the Flood Vulnerability Index (FVI) in cities like Rawalpindi reveal that low-income communities suffer the most due to a lack of resilient housing and limited access to emergency services (Ahmad et al., 2025).

6.1 The Disaster Risk-Poverty Nexus

In major cities, the cyclical impact of flooding on low-income populations creates a poverty trap. These communities often reside in peri-urban slums or informal settlements located in low-lying areas or natural floodplains (Alam et al., 2025). When floods occur, they lose not only their homes but also their livelihoods, as physical access to the city is cut off and businesses are disrupted (Mukhtar et al., 2024). This vulnerability is aggravated by the fact that Pakistan spends less than 0.2% of its GDP on water services, significantly below the 0.3% recommended by the Human Development Index (Zia et al., 2023).

6.2 Public Health and the WaSH Crisis

Flooding in urban Pakistan triggers immediate public health emergencies. The overflow of untreated urban sewage into residential areas a common occurrence in Sahiwal, Kamoke, and Lahore leads to the contamination of both surface and groundwater resources (Fida et al., 2023). Post-disaster assessments from the 2022 floods highlight a sharp increase in waterborne diseases, such as cholera and dysentery, as displaced populations lack access to clean water, sanitation, and hygiene (WaSH) services (Nizamani, 2020). The lack of separate stormwater and sewage systems means that even minor monsoonal flooding can spread bacterial contamination throughout high-density neighborhoods (Hashmi et al., 2025).

7. Environmental Consequences: Beyond Surface Flooding

The impact of rapid urban expansion on natural drainage networks has long-term environmental repercussions that compromise the future livability of Pakistani cities (Zehra et al., 2025).

7.1 Groundwater Depletion and Aquifer Stress

As urban sprawl replaces absorbent green spaces with non-porous surfaces, the natural recharge of underground aquifers is severely diminished. In Karachi and Islamabad, this has led to a critical groundwater deficit, with projections indicating a potential drop in the water table to 140 meters by 2025 if unsustainable extraction continues (Hafeez et al., 2024). The loss of watershed management areas, such as the Chichawatni and Depalpur forests, further jeopardizes the ecological balance and the land's ability to regulate water flow (Kumar et al., 2025).

7.2 The Urban Heat Island (UHI) Effect

A critical second-order insight is the correlation between urban expansion, vegetation loss, and rising temperatures. Studies in Karachi, Lahore, and Islamabad have documented a consistent increase in Land Surface Temperature (LST) as built-up land expands (Akhtar & Dhanani, 2013). The replacement of vegetation with heat-retaining surfaces like asphalt and concrete has created intense Urban Heat Islands (UHIs), which increase energy demands and exacerbate health risks during heatwaves, such as the 2015 event that caused over 1,200 deaths in Karachi (Arshad et al., 2020).

8. Resilience Building: Mitigation Strategies and Policy Frameworks

Addressing the multifaceted challenges of urban flooding requires a shift from emergency relief to a framework of proactive, climate-smart adaptation (National Disaster Risk Reduction Strategy, 2025).

8.1 The Sponge City Framework and Nature-Based Solutions

One of the most promising strategies for cities like Karachi is the implementation of the "Sponge City" (SC) model. By mimicking natural hydrological cycles, SC design focuses on absorbing, slowing down, and purifying stormwater through green infrastructure (Davis, 2022).

- **Permeable Pavements and Green Roofs:** Utilizing materials that allow water to percolate and installing vegetation on rooftops can significantly reduce peak runoff in dense urban cores ((Alshayeb et al., 2024).).
- **Rain Gardens and Urban Wetlands:** Landscaped depressions and constructed wetlands can act as temporary retention zones, releasing water slowly back into the drainage network or the ground (Palazzo et al., 2022).
- **Restoring Natural Waterways:** Reclaiming encroached waterways and restoring mangroves are essential for restoring the city's natural flood barriers (Bazai & Panezai, 2020).

8.2 Disaster Governance and National Strategies

The National Disaster Risk Reduction Strategy (NDRRS) 2025–2030 provides a comprehensive roadmap for enhancing resilience through multi-hazard risk understanding and decentralized governance. A key recommendation is the strengthening of District Disaster Management Authorities (DDMAs) through increased legislative and resource support (Waseem & Rana, 2023).

Table 4: Summary of policy goals, strategic interventions, and intended outcomes for flood resilience.

Policy Goal	Strategic Intervention	Intended Outcome
Risk-Sensitive Planning	Mandatory flood risk assessments for new housing (Chakor Ventures, 2026; National Disaster Risk Reduction Strategy, 2025)	Stop development in high-risk zones

Infrastructure Retrofitting	Separating sewage and stormwater networks (Office of the Auditor General of Pakistan, 2022; Chakor Ventures, 2026)	Prevent public health crises during floods
Integrated Data Systems	Using AI, RS, and GIS for real-time monitoring (Office of the Auditor General of Pakistan, 2022; National Disaster Risk Reduction Strategy, 2025)	Enhanced early warning and anticipatory action
Ecological Conservation	Scaling up "Billion Tree Tsunami" in urban zones (Chakor Ventures, 2026)	Improved water absorption and UHI reduction
Community Preparedness	Localized training and inclusive planning (National Disaster Risk Reduction Strategy, 2025; National Disaster Risk Reduction Strategy, 2025)	Enhanced resilience for vulnerable populations

9. Future Outlook: Challenges and Research Gaps

Despite the technological advancements in geospatial modeling, several foundational barriers remain in Pakistan's flood management landscape (Abdo et al., 2025).

9.1 Data Inconsistency and Scarcity

The accuracy of flood susceptibility models is fundamentally limited by the availability and resolution of input data. Traditional modeling often relies on historical records that fail to account for the dynamic changes of the last decade (Ullah, 2024). Furthermore, the lack of high-resolution Digital Elevation Models (DEMs) and localized rainfall data especially for capturing intense cloudbursts creates significant uncertainty in predicting extreme (Hussain, 2025).

9.2 Institutional and Political Barriers

The effective implementation of flood risk management policies at the district level is often hindered by weak institutional capacity and frequent political transformations (Sarwar et al., 2025). There is a critical need for a systems approach that integrates urban planning, poverty alleviation, and disaster risk reduction (Bibi et al., 2025). Without strong regulatory enforcement to prevent construction in high-risk zones and restore natural waterways, even the most advanced geospatial models will remain purely descriptive rather than preventative tools (Zafar & Zaidi, 2019).

The synthesis of geospatial modeling and urban dynamics in Pakistan underscores that the "unchecked and haphazard" growth of cities is the primary driver of the current flood crisis (Zafar & Zaidi, 2019). The transition from grey infrastructure towards nature-based "Sponge Cities," supported by advanced predictive modeling and robust disaster governance, offers the only sustainable path to protecting the country's burgeoning urban populations from the escalating threats of a changing climate (Mahboob et al., 2015).

Conclusion

Rapid, largely unregulated urban expansion across Pakistan has transformed once-manageable flood hazards into chronic, high-impact threats that now define the vulnerability of the country's major cities. Geospatial modeling combining traditional multi-criteria approaches (AHP) with advanced machine learning and remote sensing consistently demonstrates that the replacement of permeable land and natural drainage systems with impervious cover is the dominant driver of increased surface runoff, reduced infiltration, and amplified flood susceptibility, particularly in low-lying plains, coastal megacities like Karachi, and valley-bound urban centers. Historical mega-events (2010, 2022) and emerging localized extremes (cloudbursts, GLOFs in 2024–2025) reveal a clear trend: historical hydrological patterns no longer predict future risk under non-stationary climate conditions and ongoing sprawl. While predictive models achieve high accuracy, their practical utility is constrained by data scarcity, institutional fragmentation, and weak enforcement of land-use regulations. Sustainable flood resilience demands a paradigm shift from reactive disaster response to proactive, integrated risk management prioritizing risk-sensitive urban planning, mandatory flood assessments for new developments, restoration of natural waterways and wetlands, separation of stormwater and sewage infrastructure, expansion of urban green spaces, and deployment of real-time monitoring systems (AI, SAR, IoT). Nature-based “sponge city” strategies, combined with community-inclusive preparedness and robust governance, offer a viable path to reduce vulnerability, protect lives and livelihoods, and align urban growth with ecological limits. Without decisive policy action and cross-sectoral coordination, the compounding pressures of urbanization and climate change will continue to escalate economic losses, displace populations, and undermine Pakistan’s development trajectory. Future research should focus on high-resolution, dynamic modeling, incorporation of socio-economic vulnerability layers, and long-term evaluation of mitigation interventions to support evidence-based, adaptive urban flood governance.

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