ACADEMIC INPUTS FROM URBAN FLOODING: ANALYTICAL PERSPECTIVE 2024

National Institute of Disaster Management

National Disaster Management Authority

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EXECUTIVE SUMMARY

Rapid expansion of cities, driven by both population growth and rural-to-urban migration, is leading to the deterioration of living conditions, particularly in peri-urban areas. In Pakistan, the high rate of urban growth has become a significant issue, exacerbating water shortages and putting increased pressure on urban infrastructure. The post-monsoon urban flooding in Pakistan during 2024 highlighted significant challenges across major cities and regions. Intense monsoon rains effect the capacity of drainage systems leading to flooding and infrastructural damage.

Current study examines the causes, regional impacts, and responses along with comparative insights from global urban flooding events in developed countries based on best practices. The monsoon season in 2024 experienced heavier than average rainfall, putting enormous pressure on fragile drainage systems in major urban centers. Urban flooding has far-reaching impacts beyond just infrastructure damage, including disruption in business activities, social displacement, public health issues, and environmental impacts. To mitigate future urban flooding, it is essential to implement targeted regional policy interventions, enforce land use regulations, and implement some structural interventions like upgrading drainage infrastructure, investment in green infrastructure (green spaces), to enhance water absorption and reduce flood risks. Cities need to prioritize climate-resilient urban planning and enforce building codes that prevent construction in high-risk flood zones. The National Disaster Management Authority (NDMA) in Pakistan has taken steps toward improving flood preparedness, including the establishment of early warning systems and community-based disaster risk reduction programs. However, the scale of predictability of urban flooding requires comprehensive planning and investment in disaster management capabilities, particularly at the local government level. In order to manage disaster more efficiently with less or no impacts, we have to adopt the latest findings, case studies and successful practices followed by other countries. National Institute of Disaster Management (NIDM) – A Think-Tank on disaster management in Pakistan is in collaboration with National/International academia, focusing on Pro-Active measurements to deal with disasters. Based on research received from international academia and experiences, NIDM launched a comprehensive book “Global Best Practices on Disaster Management” that provides valuable insights to deal with multi hazard including urban flooding.

POST MONSOON URBAN FLOODING ANALYSIS, 2024

1. Overview

The Asian Development Bank highlight Pakistan's cities facing a steady decline in livability, becoming increasingly inefficient and scoring poorly on global competitiveness indices. Problems like congestion, pollution, water shortages, and unattractiveness are intensifying as urban populations surge. This rapid growth triggers an increased demand for housing, unsustainable use of natural resources, and widespread encroachments. Together, these factors not only degrade the urban environment but also significantly heighten the risk of urban flooding, compounding the challenges of managing resilient and sustainable cities.

Urban flooding is caused when inflow of rainwater in urban areas exceeds the capacity of drainage system to infiltrate into soil or carry it away. Federal Emergency Management Agency (FEMA) USA defines urban flooding as “the inundation of property in a built environment, particularly in more densely populated areas, caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems. It excludes flooding in undeveloped or agricultural areas. It includes situations in which rainwater enters buildings through

a) windows, doors, or other openings

b) water backup through pipes and drains

c) seepage through walls and floors.”

Urban flooding has become one of the most common and widely-distributed disasters in urban areas around the world because of the rise in impermeable areas due to haphazard urbanization and the increasing frequency and intensity of extreme events due to a changing climate. Urban flooding occurs due to excessive rainfall and inadequate drainage, which can be exacerbated by unsustainable urban expansion, changes in catchment topography, and increase of impervious surface. The risk of exposure to urban flooding is more in developing countries because of various anthropogenic and socioeconomic factors. Urban flood, being a natural disaster, cannot be avoided; however, the losses occurring due to flooding can be prevented by flood mitigation planning.

The complexity of urban flooding is driven by various risk factors and their associated challenges. For instance, population growth leads to multiple issues, including increased population density, changing demographic profiles, expanded infrastructure needs, and the development of assets to accommodate this growth. Additionally, land use changes in river basins, land subsidence caused by excessive groundwater extraction, low public awareness, informal settlements, and waste accumulation reduce the capacity of rivers and drainage systems. Physical and natural factors, such as tidal surges, extreme rainfall, river physiography, erosion, sedimentation, and inadequate flood control structures, also play a significant role in exacerbating urban flooding.

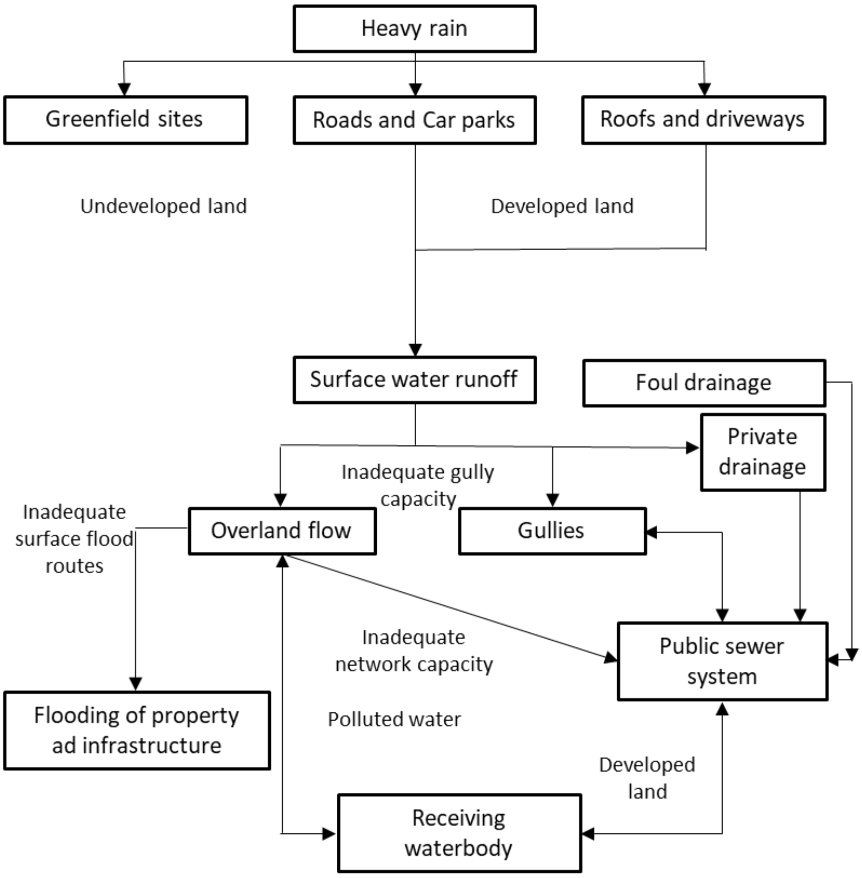

Figure 1.1. Systematic diagram of urban flooding

2. Causes of Urban Flooding

Due to **rapid urbanization**, agricultural land is being converted into residential and commercial areas destroying natural water absorption surfaces, such as wetlands and open spaces, leading to increased surface runoff during heavy rains. Many cities in Pakistan have outdated drainage systems and unable to cope with heavy rainfall ultimately resulting in flooding.

Encroachments and illegal construction on rivers, nullahs, natural drainage system, low lying areas and floodplains hinder the natural flow of water making the situation worst. Construction of substandard structures due to weak enforcement of building codes is another major cause of destruction caused due to flooding.

Vegetation plays a crucial role in absorbing rainwater leading to reduced soil erosion. **Deforestation** due to rapid infrastructure development has exacerbated the frequency and impacts of flood. Pakistan being a negligible contributor to greenhouse gas emissions, ranked among top ten countries vulnerable to **climate change**. Changing weather patterns has exacerbated the frequency of rainfall, resulting in heavy downpours that overcome existing drainage system causing urban flooding. Another major cause is **improper disposal** of solid waste that is leading to localized flooding. Significant **gap in awareness and preparedness** concerning the risks of urban flooding and the strategies needed for effective management and response.

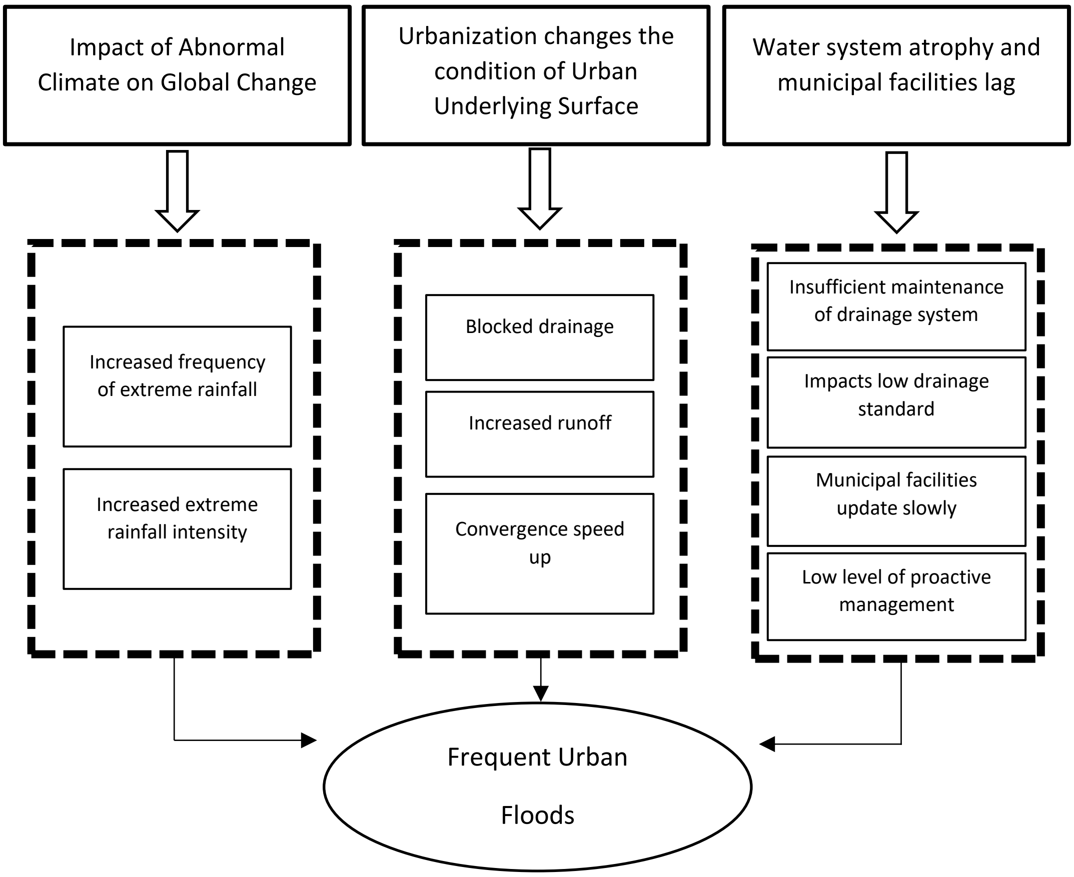

Figure 2.1. Factors Affecting Urban Flood Disaster

3. Analysis of Urban flooding in Pakistan (2024)

Pakistan's two largest cities Lahore and Karachi suffered massive loss of lives, economy and damage to infrastructure/property. Heavy rainfall from July to September 2024 in numerous cities of Pakistan experienced severe urban flooding due to unprecedented monsoon rains.

The national area-weighted rainfall for July 2024 was 57.5 mm, which was close to the average (-9%). The heaviest rainfall recorded at Sialkot Airport (Punjab) on 23rd July was 113.8 mm. Sialkot also recorded the highest total monthly rainfall of 468.2 mm. July is considered the wettest month of the year, contributing 21.3% to the annual rainfall and 44.9% to the monsoon season (July-September). Pakistan experienced three light to moderate rain spells during July. Rainfall varied regionally, with four provinces/regions receiving below average rainfall and two provinces recording above normal rainfall. Azad Jammu & Kashmir (AJ&K) recorded 94.7 mm (-46%), making it the third driest July in the past 64 years. Gilgit-Baltistan received only 4.6 mm (-65%), and Sindh recorded 33.8 mm (-44%), both significantly below average. Khyber Pakhtunkhwa had 84.0 mm (-21%), also below average. In contrast, Punjab recorded 112.4 mm (+8%) and Balochistan 34.3 mm (+16%), both slightly above average. Below is the average rainfall recorded for month of July in all provinces of Pakistan (Table.1).

Table 1.1. July 2024 Area-Weighted Rainfall

Region	Normal (mm)	Average (mm)	Comment
Pakistan	63.3	57.5	--
AJK	173.9	94.7	3rd driest (record 78.8 mm in 2020)
Balochistan	29.7	34.3	--
KPK	106.7	84.0	11th driest (record 0.7 mm in 1969)
Punjab	104.1	112.4	
Sindh	60.1	33.8	--
GB	13.3	4.6	--

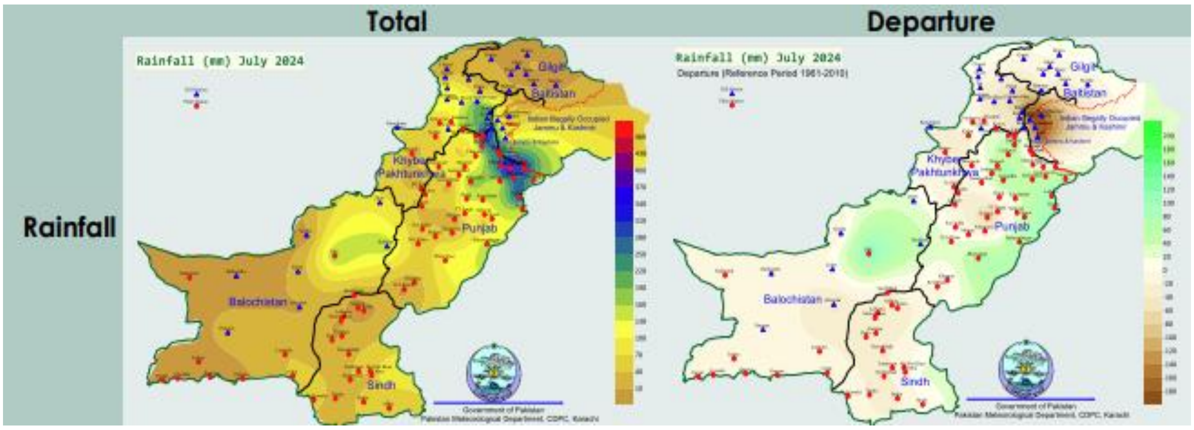

Figure 3.1. Spatial rainfall distribution and departure from normal (July-2024)

The rainfall for August 2024 was 138.9 mm, which was significantly above average (+147%) and rank as the second-wettest August in the past 64 years (PMD). While the highest rainfall on record is 193.2 mm, observed in 2022. The situation varied across regions, with four areas experiencing significantly higher than average rainfall, while two provinces faced slightly above-average rainfall. In particular, Sindh recorded 234.0 mm (+337%) and Balochistan 82.2 mm (+266%), marking both regions' third-wettest August in the past 64 years (previous records: 443.6 mm and 154.9 mm in August 2022, respectively). Punjab received 200.7 mm (+115%), making it the fourth-wettest August on record (the highest being 282.6 mm in 1973), while Gilgit-Baltistan recorded 30.9 mm (+85%), the sixth-wettest August (record: 89.1 mm in 1997). Khyber Pakhtunkhwa had 133.6 mm (+29%), and Azad Jammu & Kashmir saw 170.5 mm (+13%), both experiencing above-average rainfall. The wettest day of the month was August 1st, when 337.0 mm of rainfall was recorded at Lahore Airport (Punjab). Below is a province wise breakdown of the situation of rainfall, for month of August (Table.2).

Table 2.1. August 2024 Area-Weighted Rainfall

Region	Normal (mm)	Average (mm)	Comment
Pakistan	56.2	138.9	2nd wettest (record 193.2 mm in 2022)
AJK	150.7	170.5	--
Balochistan	22.5	82.2	3rd wettest (record 154.9 mm in 2022)
KPK	103.6	133.6	--
Punjab	93.5	200.7	4th wettest (record 282.6 mm in 1973)
Sindh	53.6	234.9	3rd wettest (record 443.6 mm in 2022)
GB	16.7	30.9	6th wettest (record 89.1 mm in 1997)

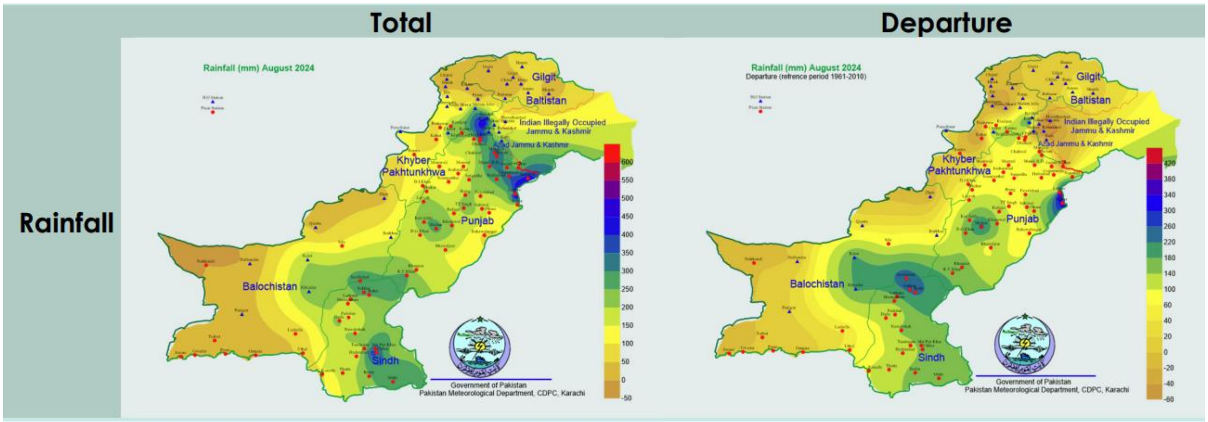

Figure 3.2. Spatial rainfall distribution and departure from normal (Aug-2024)

Climatologically, September is considered an average rainy month, contributing 7.2% to the annual national rainfall and 15.2% to the monsoon (July-September). During September 2024, Pakistan experienced four to five moderate to heavy rain spells. On a regional scale, Gilgit-Baltistan recorded 4.2 mm (-56%), significantly below average rainfall. Sindh received 10.6 mm (-47%), and Khyber Pakhtunkhwa (KP) received 26.3 mm (-43%), marking the eighth driest September on record (the lowest being 6.7 mm in 1968). Azad Jammu & Kashmir (AJ&K) recorded 41.4 mm (-36%), Balochistan 4.4 mm (-29%), and Punjab 30.9 mm (-11%), all with below-average rainfall. The wettest day of the month was September 27th, with 110.0 mm recorded at Chaklala Airbase (Punjab), while Islamabad (Zero Point) was the wettest location overall, with a monthly total of 191.0 mm. Below is the average rainfall recorded for month of September in all provinces of Pakistan (Table.3).

Table 3.1. Sept 2024 Area-Weighted Rainfall

Region	Normal (mm)	Average (mm)	Comment
Pakistan	21.4	15.0	--
AJK	64.9	41.4	--
Balochistan	6.2	4.4	--
KPK	46.0	4.2	8th driest (record 6.7 mm in 1968)
Punjab	34.7	26.3	--
Sindh	19.9	30.9	--
GB	9.7	10.6	--

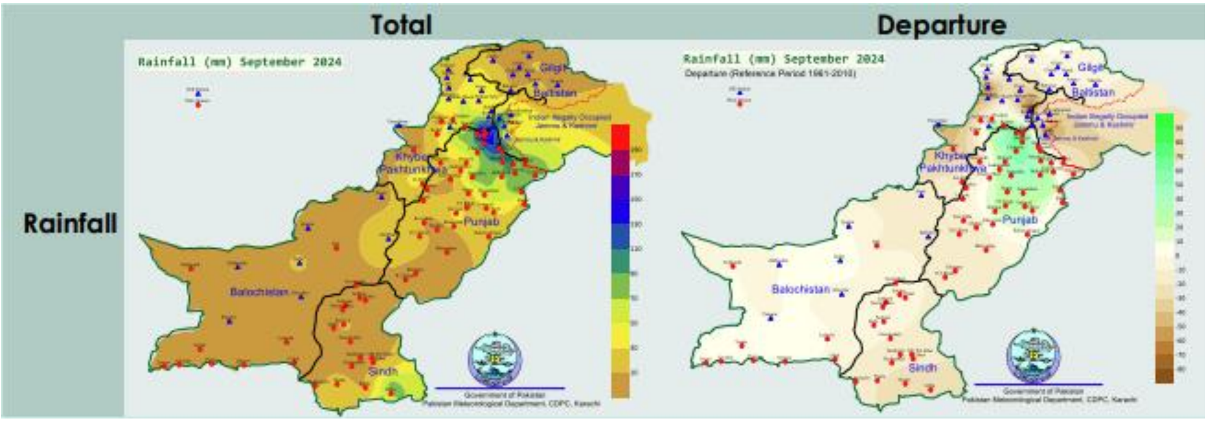

Figure 3.3. Spatial rainfall distribution and departure from normal (Sept-2024)

3.1. KP and AJ&K

Urban flooding in KP and Kashmir caused substantial damage to infrastructure (bridges, roads) leading to road blockage. Affected districts include Mansehra, Bannu, Lower and upper Chitral, Karak, Swat, and DI Khan. In Chitral, local NGOs and District Disaster Management Authorities (DDMAs) are actively involved in relief and restoration efforts following last week's flash floods. It also caused urban flooding in Peshawar significantly impacting low-lying neighbourhoods. Heavy rains on 16th August 2024 caused significant flooding on University

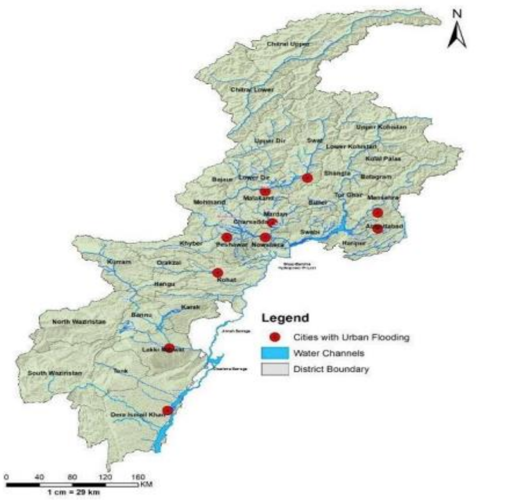

Figure 3.4. Map showing urban flooding in KP

Road in Peshawar, along with several other areas in the city including the cantonment. Blocked drains exacerbated the situation, leading to water accumulation near key locations such as Suray Pull, Bacha Khan Chowk, and the entrance to the Malak Saad Shaheed Flyover near Lady Reading Hospital and Balahisar Gate. The flooding led to widespread disruption, with power outages reported in various areas due to strong winds and rain. Several localities, particularly along Kohat and Charsadda roads, were without electricity for hours. Additionally, on 18th August 2024, DHA Peshawar experienced urban flooding, further complicating the city's recovery from the ongoing monsoon rains.

Figure 3.5. Urban flooding in university road Peshawar – Aug 2024

3.1.1. Response

The Rescue team reached the site immediately, rescued the people and started dewatering streets and roads from low lying areas. They removed the debris and trees from pathways and the traffic resumed after almost a two-hour break. The district administration of Upper Chitral coordinated with authorities to support the rehabilitation of schools, water supply schemes, and other critical infrastructure. Higher Authorities focused on clearing drainage systems and conducting public awareness campaigns. They also utilized real-time monitoring to assess water levels and respond swiftly.

Figure 3.6. Dewatering activity in affected areas

3.2 Punjab

Urban flooding affected multiple regions in Punjab in August 2024. Heavy rains in Lahore and Gujranwala resulted in urban flooding in different districts including

Sheikhupura, Gujranwala, Gujrat, Layyah, Vehari and Faisalabad. It was notably severe, particularly during the July rains. The city's outdated drainage infrastructure and rapid urban expansion worsened the flooding, with high water levels affecting areas near the River Ravi. This ultimately resulted in submerged streets, disrupted traffic, and power outages.

Lahore experienced record-breaking rainfall (1st - 4th August 2024), with the Pakistan Meteorological Department (PMD) reporting almost 360 millimetres (14 inches) of rain within a span of three hours. This extreme weather event resulted in widespread urban flooding across the city, severely affecting areas such as Model Town, Johar Town, DHA Phase 6, Shahdara, Tajpura Bazar, Canal Road, and the vicinity of Services Hospital. The intense rainfall led to significant disruptions in daily life and infrastructure across these regions.


Figure 3.7. Urban flooding in DHA & Tajpura Bazar Canal Road Lahore -- Aug 2024

Figure 3.8. Urban flooding in Services hospital Lahore -- Aug 2024

Rawalpindi experienced urban flooding, particularly in low-lying areas near Nullah Leh, which has become polluted due to poor sanitation systems. The waterway's width is shrinking as a result of construction activities along its banks and the dumping of construction materials and waste. This year it experienced severe flooding and waterlogging issues. It experienced peak rainfall exceeding 250mm during the monsoon season, leading to multiple overflows of the Nullah Leh.

Urban flooding severely impacted Liaquat Bagh Chowk and Committee Chowk due to heavy rainfall from 7th to 10th August 2024. These areas experienced significant water accumulation leading to road blockages and disruption of daily activities. The drainage systems in the affected regions were overwhelmed, contributing to the flooding and causing difficulties for residents and commuters.

Figure 3.9. Urban flooding in Nullah Leh, Rawalpindi - Aug 2024

Figure 3.10. Dewatering at Liaquat Bagh and Committee Chowk, Rawalpindi

In July, Faisalabad experienced urban flooding due to heavy rainfall, which disrupted transportation, affected industrial areas and densely populated residential neighbourhoods and daily activities. The city recorded rainfall of up to 180 mm, leading to localized flooding. Similarly, the city of Dera Ghazi (DG) Khan (19th August) also experienced urban flooding, further exacerbating the challenges posed by heavy rainfall in the region. Multan experienced urban flooding, particularly in its older neighbourhoods and areas near the Chenab River, causing disruptions in transportation and daily life activities. The city received approximately 120mm of rainfall, and the overflow of nearby rivers contributed to the flooding. These incidents demonstrate the widespread nature of urban flooding across Punjab during this period.

3.2.1 Response

Lahore city administration enhanced its response by deploying additional pumps and clearing blocked drainage systems. The Lahore Electric Supply Company (LESCO) acted swiftly to restore power in affected areas by promptly repairing tripped feeders. Real-time flood forecasting by PDMA was implemented to anticipate and manage flooding. Enhanced public warnings were issued to help mitigate damage and improve response. The local administration implemented an early warning system to notify residents in flood-prone areas, facilitating timely evacuations. Continuous dredging and widening efforts of the Nullah Leh prior to the monsoon season helped reduce potential damage. The National Disaster Management Authority (NDMA) utilized real-time flood monitoring to reduce the effects of the flooding. Additionally, local authorities raised public awareness through the "Pak NDMA Disaster Alert" app, providing residents with guidance on evacuation and flood preparedness. During the situation a 24/7 flood monitoring cell was established by the city administration to respond swiftly to flooding incidents. The industrial sector was advised to temporarily suspend operations during peak rainfall to ease the burden on the city drainage systems. The use of flood forecasting technology enabled authorities to anticipate and manage the situation more effectively. Drainage systems were cleared in coordination with local administrations, helping to mitigate the impact of the flooding.

3.3 Sindh

Karachi stormwater drains connect to two seasonal rivers, the Lyari and the Malir, both originating from the Kirthar range foothills and running parallel to each other, 14-20 km apart. Fifty-eight stormwater drains (nalas) channel water from catchment areas to these rivers, with over 600 smaller drains feeding into the larger nalas. The city experienced recurring urban flooding during the monsoon season, especially in the old city areas and parts of DHA exacerbated by poor solid waste management, unplanned urban expansion and blocked drainage systems. The city recorded around 150 mm of rainfall in a single day, resulting in significant flooding across several neighbourhoods. In August 2024, several regions in Sindh were severely impacted by urban flooding. Roads in Karachi were flooded and damaged, followed by continuous urban flooding in the city. The situation escalated on 18th August, when District Kamber Shahdadkot experienced significant urban flooding. Subsequently, urban flooding affected the district of Sanghar, further exacerbating the challenges in the region.

Figure 3.11. Urban flooding in Karachi -- Aug 2024

3.3.1 Response

Sindh government launched clean-up campaigns and more permanent solutions such as the development of landfill sites. A successful best practice was the community-led mapping and widening of drains in Manzoor Colony, which helped increase drainage capacity. The Karachi Metropolitan Corporation (KMC) launched a city-wide drain-cleaning initiative ahead of the monsoon season, helping to reduce the worst impacts of the flooding. The local government and PDMA sindh collaborated with the NDMA and other agencies to ensure timely evacuations of residents from the most affected areas. Local authorities prioritized reinforcing embankments and upgrading the city's drainage systems to manage excess water. Public awareness campaigns were launched to educate residents on flood safety measures.

4. Analysis of Urban flooding in developing countries (2023-2024)

4.1 Urban flooding– 2023

India (Mumbai and Chennai)

Mumbai

Severe flooding in July 2023 caused by monsoon rains that brought the city to a standstill. This recurring issue is due to poor drainage systems, unplanned urban growth, and coastal location. Mumbai received over 400 mm of rain in a 24-hour period in July 2023, overwhelming its outdated drainage systems (India Today, 2023).

Chennai

Chennai faced devastating floods in November 2021, after receiving over 300 mm of rainfall in a single day, exacerbated by blocked waterways and poorly maintained urban infrastructure.

Both cities suffer from unplanned expansion, poor drainage, and encroachment on natural water bodies, which limit the capacity of the urban environment to absorb or channel floodwaters. The Brihanmumbai Municipal Corporation (BMC) initiated the *Storm Water Drain Project* (BRIMSTOWAD), a long-term strategy to upgrade drainage networks. The project aimed to create a more climate-resilient city. In response to the 2021 floods, the city-initiated efforts to restore natural water channels and lakes, such as the *Kosasthalaiyar River Restoration Project*. Additionally, green infrastructure like rainwater harvesting had been promoted.

Figure.4.1. Urban flooding in Mumbai – July 2023

Bangladesh (Dhaka)

Dhaka

Dhaka experienced significant urban flooding in July 2023 due to heavy monsoon rains. Many areas were submerged, causing widespread displacement and economic disruption. Dhaka experienced a 40% increase in seasonal rainfall during the 2023 monsoon season, and poor drainage systems, exacerbated by unplanned urban growth, contributed to the flooding. Dhaka's low-lying geography makes it particularly vulnerable to both riverine and urban flooding, which worsens during heavy monsoon periods.

Bangladesh has enhanced its flood forecasting capabilities, issuing early warnings for urban and riverine flooding. The city had been working on projects to improve drainage and has initiated the *Dhaka Integrated Flood Protection Program*, which includes building flood barriers and improving sewerage capacity. Efforts to create green spaces for water absorption and rehabilitate canals are underway to reduce future flood risks.

Figure 4.2. Urban flooding in Dhaka – July 2023

Nigeria (Lagos)

Lagos

Lagos was heavily flooded after intense rainstorms in June 2023, with many roads and homes inundated. The city's vulnerability is tied to its coastal location and inadequate drainage infrastructure. Lagos experienced a peak rainfall of over 200 mm in June 2023, a significant increase from previous years. The city’s infrastructure had struggled to keep up with its rapid population growth. Poor waste management, particularly the clogging of drainage systems with plastic waste, exacerbated the flooding.

Lagos has implemented better emergency response systems, including coordinated evacuation plans and flood early warning systems. The government is exploring floating housing concepts and improving drainage systems to accommodate increased rainfall. The Lagos State Government has focused on implementing climate-adaptive strategies, including rehabilitating coastal areas, wetlands, and mangroves to act as natural buffers against floods.

Figure 4.3. Urban flooding in Lagos – June 2023

Philippines

Manila

Manila experienced heavy rainfall due to Typhoon Jenny in October 2023 leading to widespread urban flooding, particularly in low-lying areas. Manila recorded over 300 mm of rainfall during Typhoon Jenny, causing rivers to overflow and devastating the city's drainage systems. Being located in a typhoon-prone region, Manila is highly susceptible to both storm surges and heavy rainfall flooding.

Manila has developed large-scale infrastructure projects, including the *Pasig-Marikina River Improvement Project* to mitigate flood risks. The city is promoting rainwater collection systems in both public and private buildings to reduce urban runoff. The Philippines' *National Disaster Risk Reduction and Management Council* (NDRRMC) has improved early warning systems, evacuation plans, and community-level preparedness.

Figure 4.4. Urban flooding in Manilla – Oct 2023

4.2 Urban flooding – 2024

India

Mumbai

Mumbai, Maharashtra. In the peak monsoon month, Mumbai recorded over 300mm of rain in just 12 hours in august 2024. Massive waterlogging led to transport paralysis, school closures, and over 20,000 homes being affected. Low-lying areas like Sion, Dadar**,** and Kurla were among the hardest hit.

Authorities activated BRIMSTOWAD, an upgraded drainage project designed to handle monsoon rains, and initiated a large-scale clean-up of drains clogged with waste. Mumbai also invested in the construction of rainwater harvesting systems and flood resilience parks to store excess water.

Figure 4.5. Urban flooding in Mumbai – Aug 2024

Bangladesh

Dhaka

Continuous monsoon rain in Dhaka exceeded 200mm in two days in July 2024. Dhaka's already fragile infrastructure led to severe waterlogging, impacting low-lying neighbourhoods like Kalyanpur and Mirpur. Major roads were submerged, cutting off access to critical facilities.

The Bangladesh Water Development Board (BWDB) deployed pumps to clear water from the streets, while community-based early warning systems were used to alert residents. There was also a concerted effort to restore natural canals, improve drainage systems, and manage solid waste disposal better to reduce future risks

Figure 4.6. Urban flooding in Dhaka -- July-2024

Nigeria

Kenya (Mombasa)

Heavy rains from Cyclone Hidaya led to over 100mm of rain in a single day. Widespread flooding disrupted transport, damaged homes, and caused landslides, displacing 200,000+ people in low-income urban areas.

The Kenyan Red Cross and local government authorities launched emergency response operations, including mobile clinics, food distribution, and water, sanitation, and hygiene (WASH) programs to reduce waterborne disease risks. The Mombasa County government began efforts to improve drainage by clearing stormwater channels and replanting mangroves to reduce coastal flooding.

Figure 4.7. Urban flooding in Mombasa -- July-2023

4.3 Comparative Analysis: 2023 Vs 2024

i. Shared Challenges

Many cities in developing countries are growing rapidly, but their infrastructure has not kept pace. This has resulted in inadequate drainage systems and encroachment on natural waterways. Poor waste disposal practices, particularly plastic waste, have clogged drainage systems, making urban areas more vulnerable to flooding. Unplanned urban sprawl has reduced the effectiveness of natural water retention systems, such as wetlands and rivers, in cities like Karachi, Lagos, and Dhaka.

ii. Effective Responses

Cities like Dhaka and Manila are adopting green infrastructure solutions, such as the restoration of waterways and the promotion of rainwater harvesting, to mitigate urban flooding risks. In countries like the Philippines and Bangladesh, early warning systems have been crucial in reducing fatalities and economic losses during floods. Public awareness campaigns in cities like Lagos and Karachi are essential for reducing risks, particularly in waste management and flood preparedness.

iii. Areas for Improvement

Many cities still rely on short-term responses to flood events. Sustainable urban planning and infrastructure upgrades, especially to drainage systems, remain critical. Greater collaboration between city planners, environmentalists, and local communities is needed to implement adaptive strategies for climate resilience.

Developing countries are increasingly focusing on adaptive measures to address the growing challenges of urban flooding, with a mix of infrastructure development, green initiatives, and community engagement playing a vital role in their responses.

5. Analysis of Urban flooding in developed countries (2023-2024)

5.1 Urban flooding - 2023

It was widespread, particularly affecting regions with both dense urbanization and vulnerable river networks. Here's a country-wise overview, including rainfall data, specific locations, and best practices employed to manage urban flooding.

Germany

Major river basins like the Rhine and Elbe were heavily affected. Hamburg, at the mouth of the Elbe experienced significant flooding due to record-high river flows. Storms in the latter part of the year led to river flow exceeding the 'high' and 'severe' flood thresholds. Heavy rainfall increased river levels across central Europe, affecting several urban areas. Germany relies on comprehensive flood protection systems, including early-warning systems, urban green infrastructure, and river basin management plans that include flood storage areas to buffer against peak water flows.

Figure 5.1. Urban flooding in Germany - 2024

Italy

Northern Italy, especially areas around the Po River basin, was prone to severe flooding. Florence and Venice were also impacted. Intense storms in the summer and fall of 2023 raised river levels significantly, with Venice seeing high water levels ("acqua alta") exacerbated by climate conditions. Italy employed a combination of engineering solutions such as the MOSE project in Venice (movable barriers to prevent flooding) and green infrastructure initiatives to enhance urban drainage and reduce runoff impacts.

Figure.5.2. Urban flooding in Italy – 2023

France

Paris, particularly around the Seine and Marne rivers, experienced severe urban flooding, with river flows exceeding historical highs. A series of storms led to river flooding in the summer and fall, with the Loire and Seine basins experiencing record or near-record rainfall, surpassing 'high' flood thresholds. Paris has developed multi-layered flood defences, including riverbank reinforcements and improved urban drainage systems. The French government also focuses on early-warning systems and floodplain zoning to minimize damages.

Figure 5.3. Urban flooding in France – 2024

Denmark

Roskilde and Copenhagen are vulnerable to urban flooding, with increased sewer overflow during heavy rainfall. A 40% increase in rainfall intensities dramatically raised the damage from sewer overflows. Denmark is leading in the use of sustainable urban drainage systems (SUDS), including retention basins and green roofs that help absorb excess rainfall. It is integrating nature-based solutions like stormwater management parks to both handle excess water and improve urban spaces. Many cities across Europe are adopting green solutions such as bio infiltration areas, green roofs, and pervious pavements to absorb rainfall and reduce the load on drainage systems. Countries are increasingly focusing on managing entire river basins rather than just city-level drainage to control river flooding. Structural defenses, including flood barriers, are widely used in low-lying areas. In the Netherlands, advanced dike systems protect against floods, with the highest protection levels along coastal areas. Countries are emphasizing community preparedness, early-warning systems, and emergency response plans to reduce the impacts of floods

Figure 5.4. Urban flooding in Roskilde -- 2023

5.2 Urban flooding– 2024

Central Europe (Czechia, Austria, Romania, Hungary, Germany, Slovakia)

These countries experienced an unprecedented urban flooding event due to extremely heavy rainfall over four days. The most affected urban areas included regions along the Polish-Czech border and Austria. Record-breaking rainfall over four days, with estimates of the intensity and severity reaching levels seen only once every 100 to 300 years due to a rare Vb depression. Civil protection systems, enhanced over recent decades, mitigated the worst outcomes. Despite the scale of the flooding, fatalities (24 as of late September) were much lower than in similar past events. Emergency management systems worked well, involving evacuation efforts, closing critical infrastructure (schools, hospitals), and pre-emptive flood protection measures (Copenhagen Center for Disaster Research, 2024).

Figure.5.5. Urban flooding in Central Europe -- 2024

Denmark (Roskilde)

Denmark experienced urban flooding in august 2024. Adaptation strategies in Denmark focused on redesigning urban drainage systems to accommodate both droughts and heavy rainfall. Stormwater retention and vegetation-based solutions have been implemented, including bio infiltration areas and pervious paving to manage runoff. These green infrastructure solutions purify stormwater, recharge groundwater, and prevent sewer overflow.

United Kingdom

In 2024, UK faced critical urban flooding during summers events driven by heavy rains, particularly impacting critical infrastructure in major cities like London and Birmingham. The summer of 2024 saw rainfall surges, though not as severe as the 2021 floods, which had caused damage worth €38 billion. A key focus has been on strengthening urban resilience through policies aligned with the EU's Critical Entities Resilience (CER) directive, which emphasizes protecting national and local critical infrastructure. Cities have been adopting measures such as enhancing drainage systems, building flood defenses and integrating climate adaptation plans to prepare for future rainfall increases projected to grow by 25% by 2050.

Figure 5.6. Urban flooding in UK – 2024

5.3 Comparative Analysis: 2023 Vs 2024

I. Escalating Impact of Climate Change

Both 2023 and 2024 experienced heavy rainfall and urban flooding, but 2024 experienced more intense and frequent floods, especially in Central Europe. This is consistent with scientific predictions about the rising impact of climate change on European weather patterns. The urban infrastructure in many cities, particularly those with older drainage systems, remains ill-equipped to handle these climate challenges, despite gradual improvements.

II. Increasing Reliance on Green Infrastructure

The success of nature-based solutions, especially in Denmark and parts of Germany, underscored their importance. The adoption of green roofs, stormwater management parks, and bio infiltration systems not only reduced flooding risks but also improved urban environments. In contrast, areas relying heavily on traditional grey infrastructure (e.g., dikes and barriers) struggled when faced with unprecedented rainfall levels, such as in parts of the UK and Central Europe.

III. Technological and Policy Innovations

Both years highlighted the importance of data-driven solutions like real-time monitoring and early warning systems. The Copernicus Emergency Management Service in 2023 and the EU's Critical Entities Resilience directive in 2024 were crucial for anticipating and mitigating flood impacts. The growing use of flood risk mapping and cross-border cooperation reflected an increasing awareness of shared vulnerabilities, especially in river basins that span multiple countries.

6. Impacts of Urban Flooding

Urban flooding in Pakistan has severe, far-reaching impacts on various sectors, exacerbated by climate change, poor urban planning, and inadequate drainage systems.

Economic Losses

Urban flooding causes widespread damage to infrastructure, including roads, bridges, and buildings. Major cities like Karachi and Lahore are particularly vulnerable due to poor drainage systems and unregulated urban sprawl. Floodwaters disrupt industrial activities, delay projects, and cause extensive damage to key sectors such as agriculture and manufacturing. For example, the 2022 floods caused an estimated loss of $30 billion, severely affecting the agricultural sector and industries reliant on it.

Figure 6.1. Economic loss due to urban flooding

Housing and Infrastructure Damage

Figure 6.2. Structural damages due to urban flooding

Flooding often damages homes, especially in low-income and informal settlements where construction quality is poor. In urban centers, buildings are often constructed on natural waterways, which worsens the flooding situation by blocking water flow. This results in prolonged inundation of residential areas, with people displaced for extended periods.

Health Impacts

Urban flooding increases the spread of waterborne diseases like cholera, malaria, and dengue, exacerbating public health crises. The contamination of water supplies and the collapse of basic sanitation systems expose urban populations to severe health risks, which further strain already limited healthcare services. The dead bodies of affected people can trigger diseasee outbreaks such as cholera floods are linked with an earache, psychological distress, and gastroenteritis.

Figure.6.3. Health issues due to urban flooding

Social Displacement & Poverty Elevation

Urban flooding frequently displaces thousands of people, particularly those living in informal settlements. Displacement leads to long-term challenges, including loss of livelihoods, increase in poverty, access to education, and psychological trauma, especially in cities like Karachi, where flooding is recurrent.

Figure 6.4. Urban flooding leading to displacement

Environmental Degradation

Urban flooding contributes to soil erosion, deforestation, and the degradation of wetlands. The obstruction of natural watercourses by unplanned urban development worsens the environmental impact. Floodwaters also carry pollutants, further contaminating water bodies and the urban environment.

Figure 6.5. Environmental degradation

Disruption to Essential Services

Flooding severely disrupts essential services such as electricity, water supply, transportation, and communication. Power outages and damage to water supply systems are common during floods, making it difficult for residents to access clean water and critical services.

Figure 6.6. Urban flooding disrupting healthcare, transport, and utilities

7.Preparedness and Preventive measures by NDMA

NDMA took proactive approach during the monsoon season of 2024. Utilizing advanced forecasting tools, NDMA accurately predicted the weather and potential flooding scenarios three months in advance across various provinces. In response, it issued timely advisories to all the Provincial Disaster Management Authorities (PDMA's), enabling them to prepare effectively and mitigate risks. Additionally, NDMA coordinated with relevant government departments to ensure pre-positioning of resources, facilitated collaboration, and provided continuous monitoring throughout the monsoon period. This proactive approach significantly enhanced provincial preparedness and response efforts, minimizing the impact of flooding on vulnerable communities.

The National Institute of Disaster Management (NIDM) conducted a series of comprehensive trainings, workshops, district SIMEX and seminars on flood preparedness and response across all provinces of Pakistan. These programs were designed to enhance the capacity of local authorities, community leaders, and relevant stakeholders in managing flood risks effectively. Pre-monsoon meetings and simulation exercises (SIMEX) are held to prepare for urban flooding scenarios. Disaster Risk Reduction (DRR) societies, in partnership with interface universities, are established and actively mobilized across universities. Additionally, community resilience campaigns are regularly conducted to enhance preparedness and awareness. Through these initiatives, NIDM provided critical knowledge on early warning systems, emergency response protocols, and community-based disaster risk reduction strategies. By promoting collaboration and improving the skills of those involved, NIDM played a vital role in strengthening Pakistan's overall resilience to flood-related disasters. Some of the preventive measures are as follows;

a) Flood hazard map of mega cities needs to be prepared with respect to the drainage system and different nullah on the basis of degree of hazards.
b) Early warning system needs to be provided on the different mullahs keeping in view the degree of danger so that necessary evacuation may be carried out in case of emergency situation.
c) Cleaning of different nullahs/storm drains may be carried out well before the onset of monsoon season so that blockage in these nullahs/storm drains can be avoided.
d) Provincial governments may carry out necessary legislation to stop further dumping of garbage into these nullahs by the local inhabitants
e) Removal of encroachments in Nullahs needs to be carried out on top priority.
f) Carryout mass campaign among the public to raise the awareness of the flood hazards and its consequences.
g) Government needs to invest in the rehabilitation of storm drains and carry out proper maintenance of the system.
h) Identification of low-lying areas prone to pondage and inundation in congested areas of the metropolis.
i) Strengthening the understanding of flood risk management, floodplain regulations and effective urban planning through capacity building efforts for Municipal Corporations and line departments.
j) Implementation of necessary measures such as widening, dredging and de-silting of storm water and sewerage drains to maintain their functionality and reduce the risk of urban flooding.
k) Removal of encroachments along floodplains and drains to reclaim the original extents of water flow, facilitating unobstructed drainage and preventing waterlogging in urban areas during heavy rainfall events.

l) Regular assessment and maintenance of serviceability and operability of pumping stations responsible for managing stormwater and sewage disposal, establishing robust maintenance protocols and contingency plans.
m) Training and refresher programs for technical manpower involved in flood management and drainage operations to enhance their skills and knowledge.
n) Provision of reliable backup electricity arrangements, such as generators for sewage disposal and pumping stations / de-watering pumps to guarantee uninterrupted operation during power outages, enabling efficient drainage and sewage management during flood events.
o) Establishment of dedicated committees at the municipal level, particularly in major cities, responsible for planning and implementing contingency plans, involving relevant stakeholders and experts / volunteers for a coordinated and proactive approach to flood preparedness / response in urban areas.

8. Best Practices for Urban flooding

The recent floods in Pakistan and other countries highlight the pressing need for effective flood management strategies. Drawing lessons from these incidents, several best practices have been identified that can help reduce the risks and damage caused by floods. These include strengthening early warning systems to provide timely alerts, upgrading infrastructure to better manage excess water with improved drainage systems and flood barriers, and promoting sustainable land-use planning to protect natural wetlands. Moreover, encouraging community involvement and educating the public about flood preparedness can empower individuals to take proactive steps. By adopting these measures, we can create more resilient communities that are better prepared for future flood events.

Cloudburst Management Plan

Cloudburst Management Plan includes constructing parks, streets, and urban spaces designed to channel excess water to underground reservoirs and lakes. Green roofs, permeable pavements, and large underground storage tunnels are part of this city-wide plan. These measures aim to reduce the risk of flooding while enhancing urban green spaces.

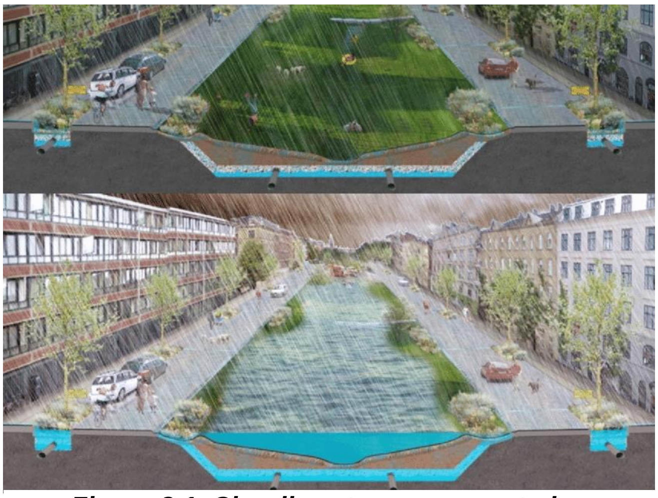

Figure 8.1. Cloudburst management plan

Natural and Engineered Drainage Systems

In planned cities, existing flood control measures and drainage systems, both natural and engineered, were originally designed based on past climate conditions. However, with the emergence of new climate patterns due to climate change, these systems have become less effective. To enhance urban resilience to flooding, upgrading flood management plans is necessary. While some progress has been made in this regard, many regions, especially in developing areas, are still lagging behind and will require significant adaptation efforts to improve flood resilience.

Urban drainage systems are critical to managing stormwater runoff. In many Pakistani cities, existing drainage networks are either outdated or poorly maintained, leading to frequent flooding. Improved drainage involves upgrading capacity, ensuring regular maintenance, and separating stormwater from sewage systems to prevent overflows during heavy rains. Modern drainage designs, like underground reservoirs and tunnels, can store excess water and release it gradually, preventing streets from flooding.

Figure 8.2 Drainage system

Permeable Roads

Permeable roads are constructed using porous materials such as permeable concrete, asphalt, or interlocking pavers that allow water to pass through the surface and soak into the underlying soil. This prevents excessive runoff, reduces the burden on drainage systems, and helps recharge groundwater. In urban areas like Karachi, where heavy rains can lead to waterlogging, permeable roads could significantly alleviate flooding by minimizing surface water accumulation. By promoting water infiltration, they reduce erosion and help manage stormwater more sustainably.

Figure 8.3. Permeable roads and alleys

Green Roofs

A green roof is a building's rooftop covered with vegetation, planted over a waterproofing membrane. Green roofs absorb rainwater, provide insulation, reduce energy costs, and combat the urban heat island effect. During heavy rains, they act as natural buffers by holding rainwater temporarily, which slows its release into the drainage system, reducing the risk of flooding. In densely built cities, where impermeable surfaces dominate, green roofs offer an ecological solution to improve stormwater management.

Figure 8.4. Green roofs

Monitoring Systems

Flood monitoring systems use technology like sensors, remote sensing, and Geographic Information System (GIS) mapping to monitor rainfall, water levels, and drainage systems in real time. These systems help authorities detect and predict flood risks, allowing for timely alerts and disaster management. Implementing such systems across Pakistan's urban areas would enhance preparedness, enabling the evacuation of at-risk populations and preventing major economic losses

Rainwater Harvesting

Rainwater harvesting involves collecting rainwater from roofs or other surfaces and storing it for later use, such as irrigation, washing, or even potable purposes if adequately treated. In urban areas, this technique reduces the volume of water flowing into drainage systems, easing the pressure during peak rainfall events. For water-scarce regions of Pakistan, rainwater harvesting also serves as a vital water conservation strategy, offering dual benefits of flood mitigation and enhanced water availability.

Figure 8.5. Rainwater harvesting

Bioswales

Bioswales are shallow, vegetated channels that manage stormwater by guiding, filtering, and slowing down water runoff. They capture rainwater and allow it to infiltrate the soil, filtering out pollutants in the process. By integrating bioswales in urban landscapes, especially in cities like Karachi or Lahore, they reduce the velocity of stormwater and help mitigate localized flooding while improving water quality.

Figure 8.6. Bioswales

Blue-Green Infrastructure

Blue-green infrastructure refers to the integration of water management (blue) with natural, vegetated areas (green). Examples include restoring wetlands, creating water-sensitive urban parks, and integrating waterways into urban planning. This concept allows cities to manage water sustainably while providing ecological benefits, such as improved air quality and biodiversity. It helps manage excess stormwater by slowing down runoff and allowing water to percolate through natural systems rather than overwhelming man-made infrastructure.

Figure 8.7. Blue-green infrastructure

Reusing Wastewater

Recycling and treating wastewater for purposes like irrigation, industrial use, or cooling systems reduces the demand on freshwater supplies and prevents untreated wastewater from contributing to urban flooding during rains. Reusing wastewater reduces the volume that needs to be managed during floods and provides an alternative water source for non-potable uses, enhancing the overall resilience of urban water systems

Geotagging of Water Bodies and Reservoirs

Geotagging involves mapping water bodies, reservoirs, and other key infrastructure using GPS and GIS technologies. This allows authorities to monitor water levels, identify areas at risk of overflow or flooding, and manage resources more effectively. By implementing geotagging, water bodies in urban Pakistan can be better managed, reducing the risk of floods and ensuring the protection of vital water resources.

Sponge City

This iinitiative is one of the most innovative flood management strategies. The concept revolves around cities absorbing, storing, and purifying water naturally, much like a sponge. This is achieved through permeable pavements, green spaces, and wetlands that help capture rainwater and allow it to infiltrate the ground. Cities like Wuhan and Xiamen have successfully implemented this approach, reducing flood risks while also improving urban water quality and reducing the urban heat island effect.

Figure 8.8. Sponge city

Flood Defense System

Thames Barrier is an iconic flood defense system that protects the city from tidal surges. The movable flood barrier spans the River Thames and is capable of being raised during high tides or storm surges to prevent flooding in central London. The barrier has been effective in safeguarding millions of residents from catastrophic flooding events. As sea levels rise due to climate change, such large-scale flood defenses become increasingly vital for coastal cities.

Water Squares

In Rotterdam, the Water Square (Benthemplein) is a creative solution to urban flooding. During dry weather, it serves as a public space for recreation, but when heavy rains occur, the square collects excess stormwater, temporarily storing it to prevent floods in surrounding areas. The Netherlands is globally recognized for its expertise in flood management, and water squares combine aesthetic public spaces with practical flood control measures.

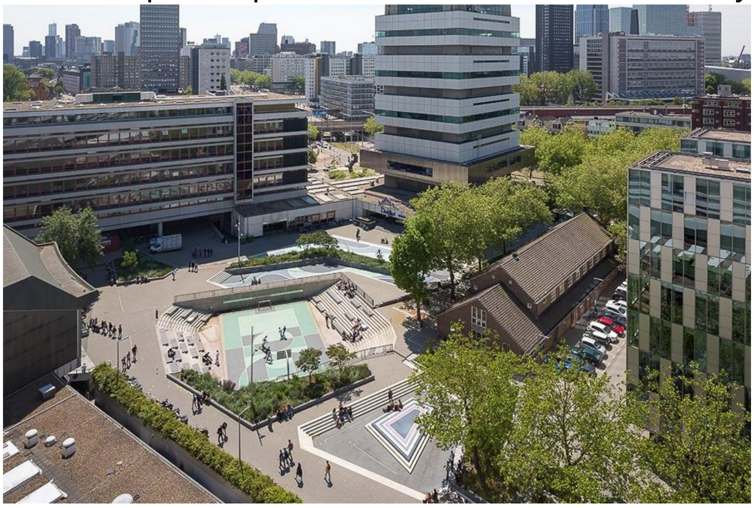

Figure 8.9. Water squares

Floating Homes

Floating homes are a revolutionary idea. These houses are built on platforms that can rise with floodwaters, allowing them to remain safe even during extreme flooding. This approach combines architectural innovation with flood resilience, providing a long term solution for cities with frequent water-level fluctuations.

Figure 8.10. Floating homes

Floodable Parks

Floodable parks can temporarily hold excess stormwater during heavy rains. They are designed to combat flooding with natural wetlands and marshes that helps to absorb and filter water before it's released back into the environment. These parks function as dual-purpose public spaces offering recreation during dry periods and acting as flood control systems during storms

Underground Floodwater Temple

Tokyo's Metropolitan Area Outer Underground Discharge Channel, also known as the "Underground Temple," is an engineering marvel. This massive underground reservoir system with enormous pillars is designed to store excess rainwater during typhoons and heavy storms. The stored water is then slowly released into the river system, preventing surface flooding in Tokyo's low-lying areas.

Figure 8.11. Underground Floodwater Temple in Tokyo

Green Alley Programs

Green Alley Programs which aim to transform impervious alleyways into permeable surfaces. These alleys are redesigned with permeable pavements, bioswales, and greenery that capture stormwater, reduce runoff, and recharge groundwater supplies. This approach helps urban areas reduce flood risks while also beautifying the city and mitigating heat.

Figure 8.12. Green Alley Programs

Flood-Resistant Buildings

Floating agricultural systems and flood-resistant buildings are becoming common in rural and urban areas prone to seasonal flooding. These buildings are designed to be elevated or built on platforms ensuring they remain above water even during major flood events. Such architectural solutions are crucial in adapting to changing climate patterns.

Figure 8.13. Flood resistant buildings

Figure 8.14. Flood resistant building near coastline in Bangladesh

9. Way forward

Urban Flooding in Pakistan is a recurring phenomenon. Raid urban sprawl and poor maintenance of natural and engineered drainage system make flooding further worse necessitating identification of flood prone urban areas during floods. To address urban flooding in Pakistan, strengthening institutional coordination is essential. A central body that brings together stakeholders like NDMA, Federal Flood Commission (FFC), PMD, PDMA's including provincial disaster management authorities, water management bodies, and City development authorities and urban planning agencies, should be established to streamline efforts and ensure cohesive planning during floods. Upgrading drainage infrastructure is crucial, given that rapid urbanization has outpaced the development and maintenance of drainage systems. Modernizing stormwater networks, rehabilitating natural waterways, and removing illegal encroachments on floodplains can help mitigate flood risks. Urban planning must integrate flood risk maps that are regularly updated through GIS and remote sensing data to identify flood-prone areas. These maps should guide proper zoning laws to prevent construction in vulnerable areas. Additionally, enhancing disaster preparedness and response capacity is vital. Government institutions both at federal and provincial level, local authorities, and communities should be trained, while regular simulation exercises should be conducted to ensure readiness and preparedness. Public awareness campaigns can also play a key role in educating citizens on flood risks and emergency responses. Implementing efficient early warning systems that leverage technology like mobile alerts and public address systems can provide real-time information to at-risk populations, allowing for timely preventive actions. Moreover, promoting climate-resilient infrastructure such as rainwater harvesting, permeable pavements, and green spaces will reduce surface runoff and help absorb excess rainwater. Water resources in Pakistan are managed by multiple agencies, leading to fragmented efforts. An interdisciplinary water management plan that aligns the objectives of various ministries, clearly defining roles and responsibilities, is necessary for effective resource management. Collaboration with international experts can offer insights into innovative flood management solutions, such as nature-based defenses and urban resilience planning. Pakistan can also benefit from partnerships with donor agencies and global institutions to implement best practices. Lastly, securing sustained funding for flood prevention and management is crucial. It is essential to ensure that industrial waste is disposed of separately to prevent the mixing of harmful pollutants with sewage water. Additionally, establishing solid waste recycling plants in every city should be prioritized to promote waste management and resource recovery. Furthermore, planning and developing more cities is crucial to reduce congestion and alleviate the pressure on a single urban center, promoting sustainable growth and infrastructure resilience. Adequate resources must be allocated to urban areas prone to flooding, with the possibility of involving the private sector to provide additional financial and technical support. By addressing these areas, Pakistan can reduce the impact of urban flooding, protect vulnerable populations, and build resilient cities.

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Data Contribution

National

1. Federal Flood Commission
2. National Disaster Management Authority
3. National Water Policy, Ministry of Water Resources, Government of Pakistan
4. Pakistan Meteorological Department
5. Provincial Disaster Management Authority – GB

6. Provincial Disaster Management Authority – KPK
7. Provincial Disaster Management Authority – Punjab
8. Provincial Disaster Management Authority – Sindh
9. State Disaster Management Authority – AJ&K
10. United Nations Office for the Coordination of Humanitarian Affair

International

1. African Development BankWorld Economic Forum).
2. Asian Development Bank (ADB)
3. Brihanmumbai Municipal Corporation (BMC)
4. Centre for Science & Environment (CSE)
5. East Asia Forum
6. European Union
7. Japan International Cooperation Agency (JICA)
8. National Emergency Management Association
9. Philippines' *National Disaster Risk Reduction and Management Council* (NDRRMC)
10. Resilient Cities Network
11. Centre for Disaster Philanthropy
12. UN-Habitat
13. World Bank
14. World Economic Forum