NATIONAL DISASTER MANAGEMENT AUTHORITY

Comprehensive Review of Monsoon 2024

National Institute of Disaster Management

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1. Background

Pakistan is situated in the tropical to subtropical climatic zone, with over 60% of its area classified as arid. The country's annual temperature range varies from 15°C to 35°C for maximum temperatures and from 0°C to 14°C for minimum temperatures. The climate across Pakistan is as diverse as its topography: it is generally dry and hot near the coast and the Indus River plains, becoming progressively cooler in the northern uplands and the Himalayas. The country experiences four distinct seasons:

1. A cool, dry winter from December to February
2. A hot, dry spring from March to May
3. A summer rainy season, known as the southwest monsoon period, from June to September
4. Retreating monsoons from October to November

Most of Pakistan receives minimal rainfall, except for the northern regions, which can experience up to 200 mm of rain per month from July to September due to monsoons. Rainfall can vary greatly from year to year, leading to patterns of floods and droughts. El Niño significantly affects climate variability in Pakistan, influencing both temperature anomalies and the frequency and impact of floods in relation to its cycle.

Pakistan, like many other parts of the world, is experiencing the severe impacts of climate change and is among the top 10 countries most vulnerable to its effects. The nation faces significant risks from natural disasters such as floods, droughts, and heatwaves. These events lead to numerous problems, including casualties, injuries, property and infrastructure damage, displacement and migration, losses in agriculture and livestock, the spread of waterborne diseases, and challenges in recovery and rebuilding.

Flooding, in particular, has hindered both social development and economic progress in recent years. Since gaining independence, Pakistan has experienced 29 significant floods. The first recorded flood occurred in 1950, with subsequent major floods in 1955, 1956, 1957, 1959, 1973, 1975, 1976, 1977, 1978, 1981, 1983, 1984, 1988, 1992, 1994, 1995, and then annually from 2010 onwards. In 1995, floods resulted in 2,190 fatalities, affected 10,000 villages, and inundated 17,920 square kilometers of land. Earlier, in 1992, floods caused 1,008 deaths, damaged 13,208 villages, and covered 38,758 square kilometers. The 2010 floods, triggered by an exceptional monsoon, were among the most devastating in the country's history. They affected 160,000 square kilometers, resulted in 1,985 deaths, and inundated 17,553 villages, according to the Federal Flood Commission (FFC) Annual Report, 2020.

Between 1951 and 2020, Pakistan suffered significant losses due to natural disasters, with 13,262 lives lost, 197,273 villages damaged, and 616,558 square kilometers affected. These events have resulted in nearly Rs39 billion in economic losses.

In 2022, catastrophic floods inundated one-third of the country, particularly impacting the provinces of Sindh and Balochistan. The floods affected around 33 million people, causing 1,739 deaths and inflicting $14.9 billion in damage and $15.2 billion in economic losses, according to the government's damage assessment report.

Despite repeated disasters, the lessons from past floods, have not been fully applied. The state should focus on enhancing technical support for local disaster management, educating climate researchers to use weather and climate data for policy-making, and studying past flood experiences to improve future responses. Increasing glacial melting and rising monsoon rainfall, Pakistan is likely to face more frequent and severe floods in the future due to climate change. The government must develop more effective strategies for responding to early warnings and mitigating potential hazards.

2. Monsoon Projections 2024

The 2024 monsoon season in South Asia (June-September) was expected to bring above-normal rainfall to most regions, excluding northern, eastern, and northeastern areas. The Indian Ocean Dipole (IOD) would likely remain positive, allowing most of Pakistan to experience normal rainfall. However, southern Punjab, Balochistan, Sindh, and northern regions, including Khyber Pakhtunkhwa, could see significantly above-normal rainfall, particularly in July and August. This, combined with higher temperatures and snowmelt in the Upper Indus Basin, raises the risk of flash floods and glacier lake outburst floods (GLOFs).

2.1 Azad Jammu Kashmir and Gilgit Baltistan

Projections indicated that northern and northeastern Gilgit-Baltistan would experience above-normal temperatures of 1.5-2 degrees Celsius in June and August, decreasing to 1-1.5 degrees and shifting to the northwestern regions later. These rising temperatures are causing glaciers to retreat rapidly, increasing glacial melt and the risk of glacial lake outburst floods (GLOFs), suggesting a higher likelihood of flash floods and GLOFs in summer 2024. In Azad Jammu and Kashmir (AJK), temperatures would remain normal throughout the monsoon, with slightly above-normal temperatures in June as shown in Figure 1.

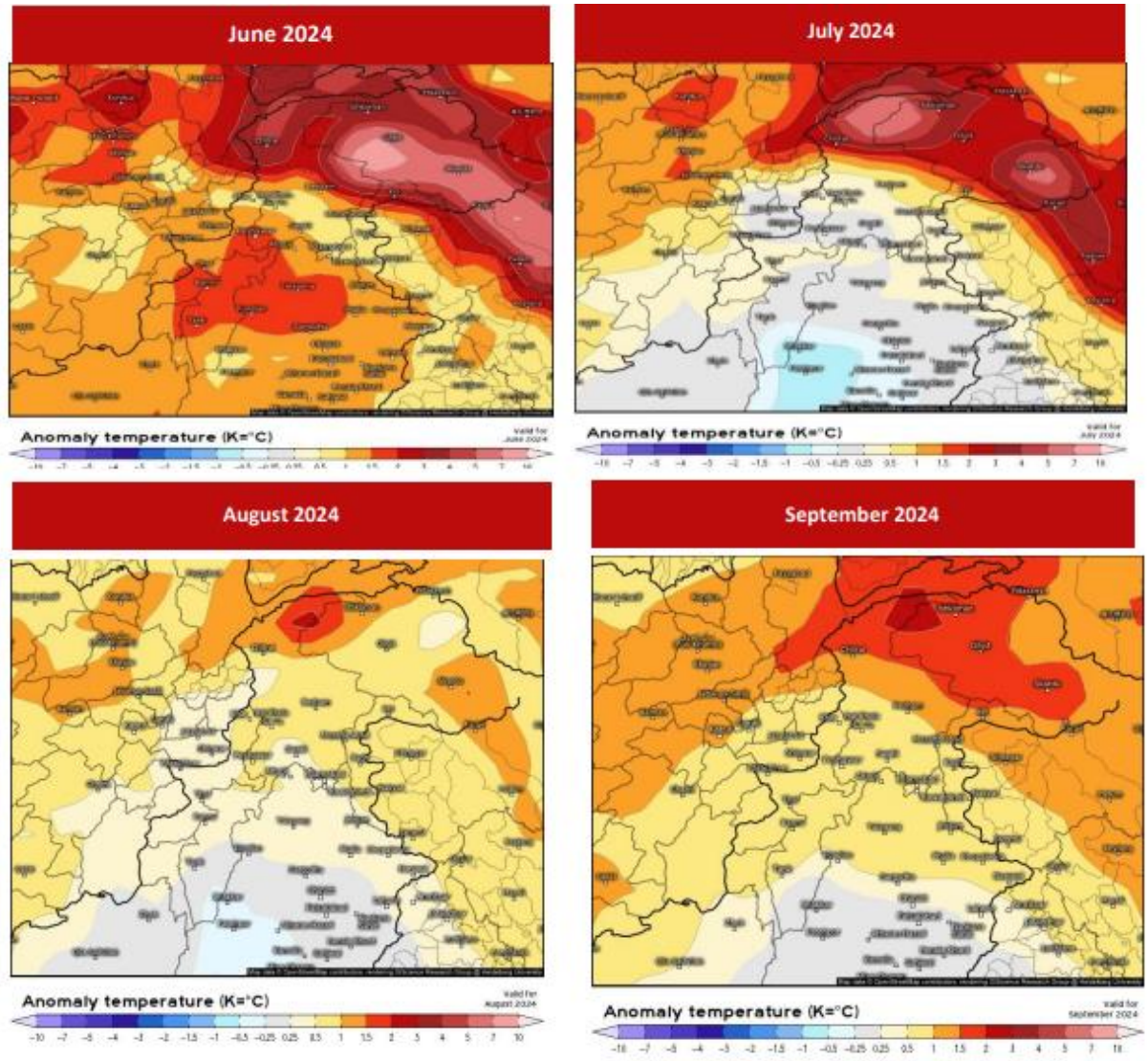


Figure 1: Projected Temperature Anomaly for the months of June-September

From June to September, Gilgit-Baltistan (GB) and Azad Jammu and Kashmir (AJK) were expected to experience precipitation levels ranging from below normal to normal, indicating generally mild rainfall with fewer extreme events as shown in Figure 2. However, July was forecasted to see slightly above-normal rainfall, leading to temporary increases in river and stream levels, particularly in high-altitude areas where snowmelt and runoff combine. While the overall monsoon season poses low flood risks, the increased rainfall in July might result in localized flooding, especially in areas with poor drainage.

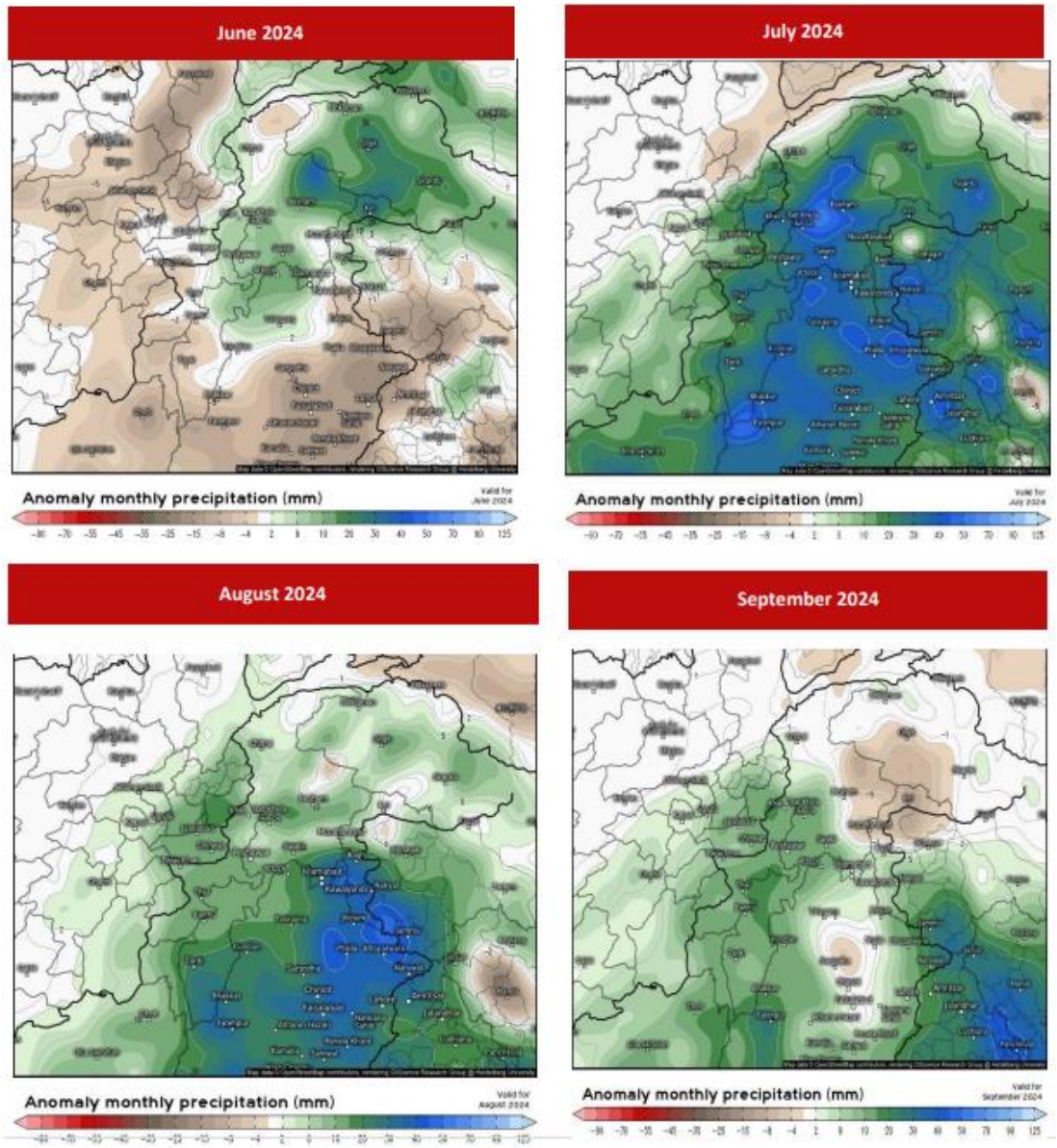


Figure 2: Projected Precipitation Anomaly for the months of June-September

As highlighted in Figure 3 the projected discharge for June to September 2024 showed a significant increase in water flow, starting at about 100,000 cubic feet per second (cusecs) on June 1. After a stable first week, discharge began to rise around mid-July, surpassing 250,000 cusecs by mid-month and peaking near 300,000 cusecs by mid-August. This trend indicated a high-medium level flood risk from mid-July to mid-August, driven by melting snow, glacier runoff, and increased rainfall in Gilgit-Baltistan and Azad Jammu and Kashmir.

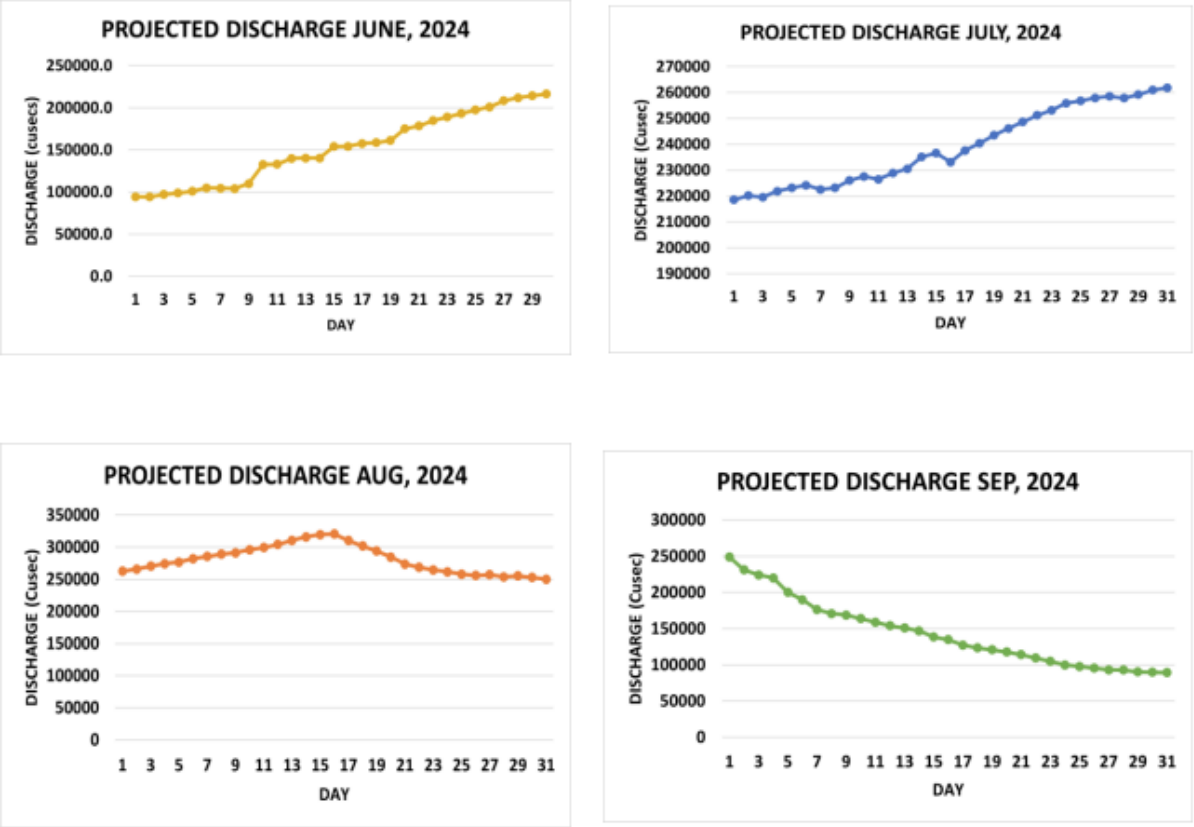


Figure 3: Predicted Discharge at Bisham for the months of June-September

2.2 Khyber Pakhtunkhwa

The 2024 monsoon forecast for Khyber Pakhtunkhwa (KP) indicated nearly normal to slightly above-normal rainfall. According to the Pakistan Meteorological Department (PMD) and the NEOC's multi-model ensemble, the region was expected to be wetter in the second half of the season.

In June, average temperatures in KP would be around 30.6°C (87.1°F), with highs up to 36.9°C (98.4°F) and lows around 23.1°C (73.6°F). Rainfall was projected at about 47 mm (1.9 inches) over 10 days, which was important for agriculture but could pose flood risks if heavy.

In July, average temperatures were expected to drop to about 28.4°C, with maximums reaching 42°C. Rainfall was forecasted at around 160 mm over 15-20 days, with frequent thunderstorms, increasing flood risk.

In August, average temperatures would be around 27.8°C, with highs up to 39°C. Rainfall was projected at about 140 mm over 12-18 days, continuing the trend of thunderstorms and local showers.

In September, average temperatures would be around 27.3°C, with maximums up to 34°C. Rainfall was expected at about 100 mm over 10-15 days, with occasional thunderstorms mainly in the first half of the month.

2.3 Punjab

June was expected to see slightly above-normal mean temperatures across the country, particularly in western Balochistan and northern regions (northern KP, GB, and AJK), with temperature anomalies of 1.5°C to 2.5°C above normal in most of Punjab. Rainfall in June was projected to be near normal for upper and lower parts of the country, with potential for above-normal rainfall in the core monsoon region, including northeastern Punjab and adjacent areas of KP and AJK as shown in Figure 4.

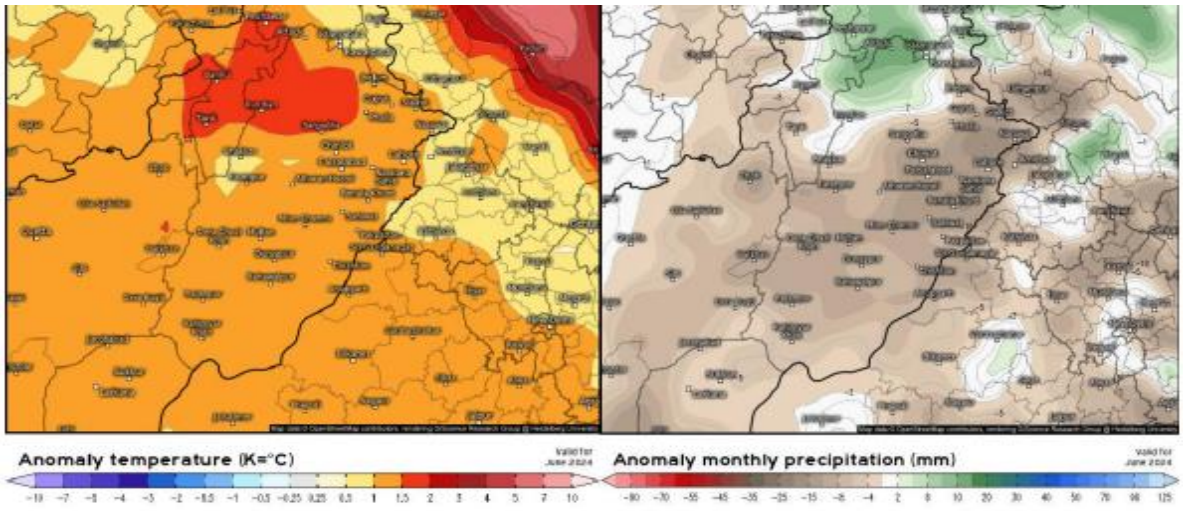


Figure 4: June 2024 Temperature and Precipitation Outlook

In July, most parts of the country were expected to have normal temperatures, but Punjab may see temperatures 0.25 to 0.5°C above normal. Rainfall was projected to be slightly above normal in the western regions and above normal in the east, particularly in northeastern Punjab, southeastern Sindh, and southern AJK, while northern areas like KP and GB would likely experience normal rainfall as highlighted in Figure 5.

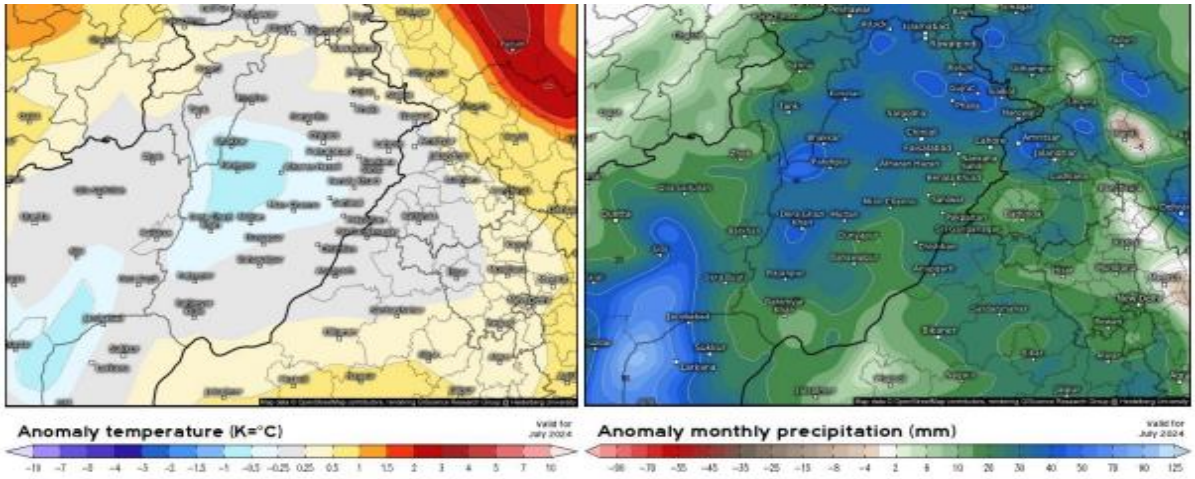


Figure 5: July 2024 Temperature and Precipitation Outlook

In August, as shown in Figure 6 mean temperatures were expected to remain normal, with a slight decrease in northeastern Punjab and slightly above-normal temperatures in northern Punjab. There was a probability of above-normal precipitation during that month.

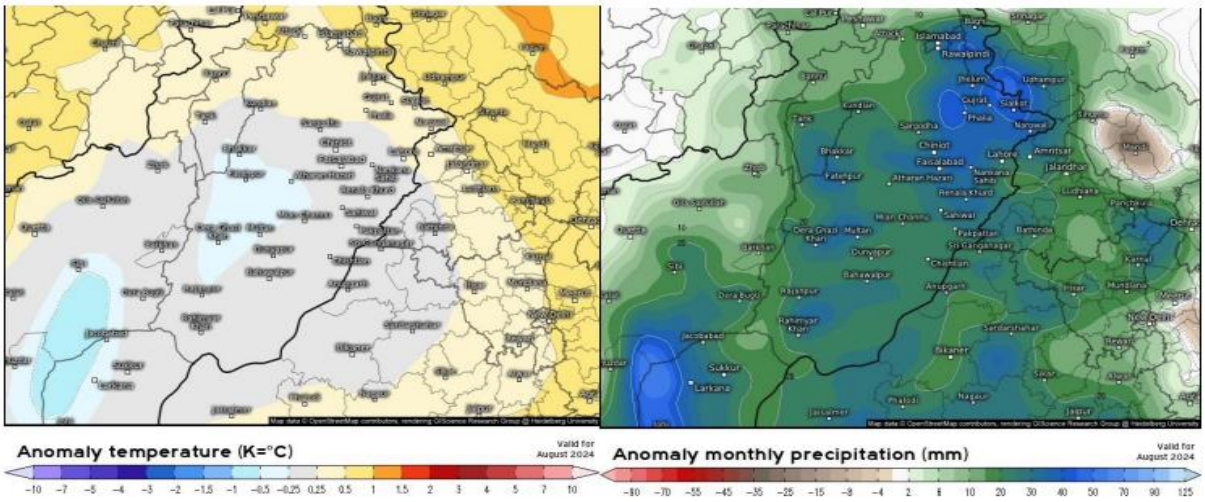


Figure 6: August 2024 Temperature and Precipitation Outlook

Figure 7, 8 & 9 clearly shows about the contributing factors, the type of flooding (Riverine Flooding) and what will be the projected situation of flood at Indus, Chenab, Ravi, Jhelum and Sutlej rivers during the months of June, July and August.

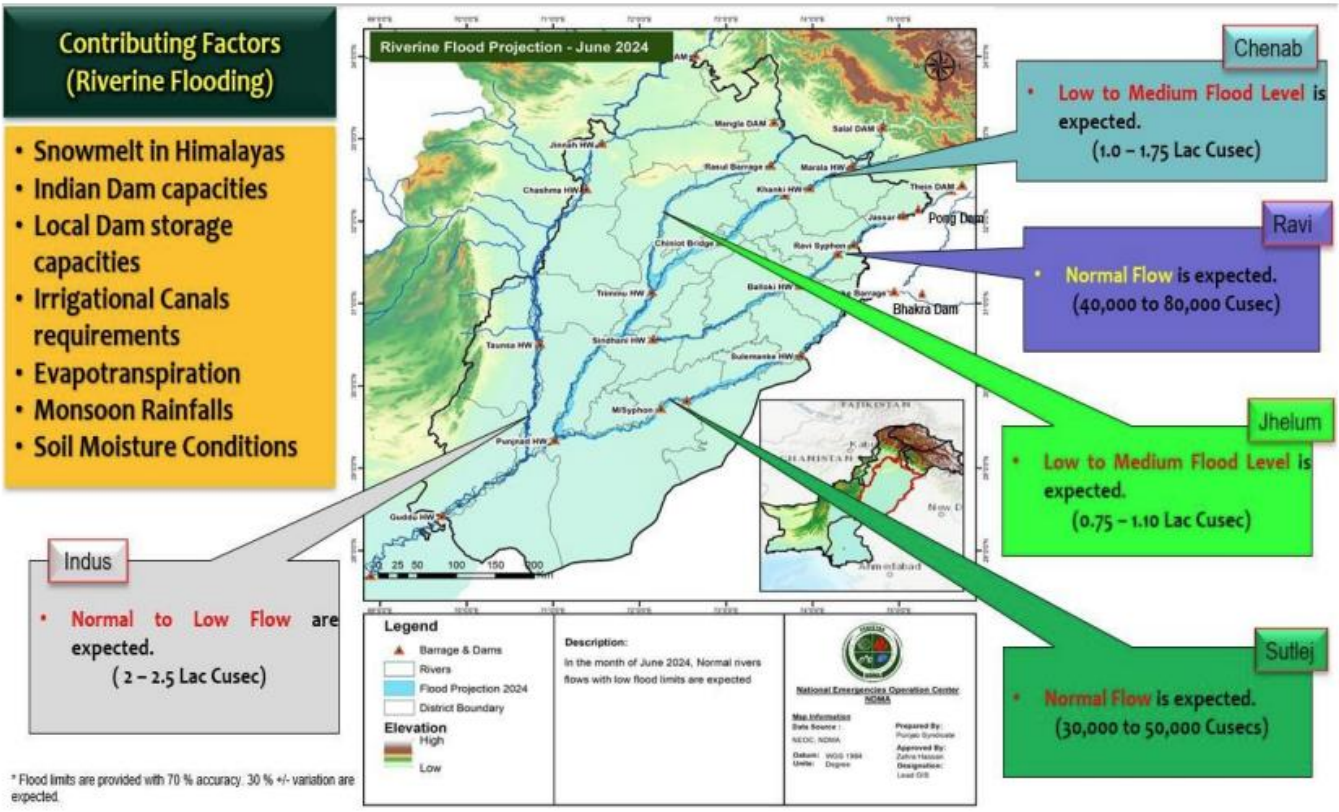


Figure 7: Punjab Flood Projection for the month of June 2024

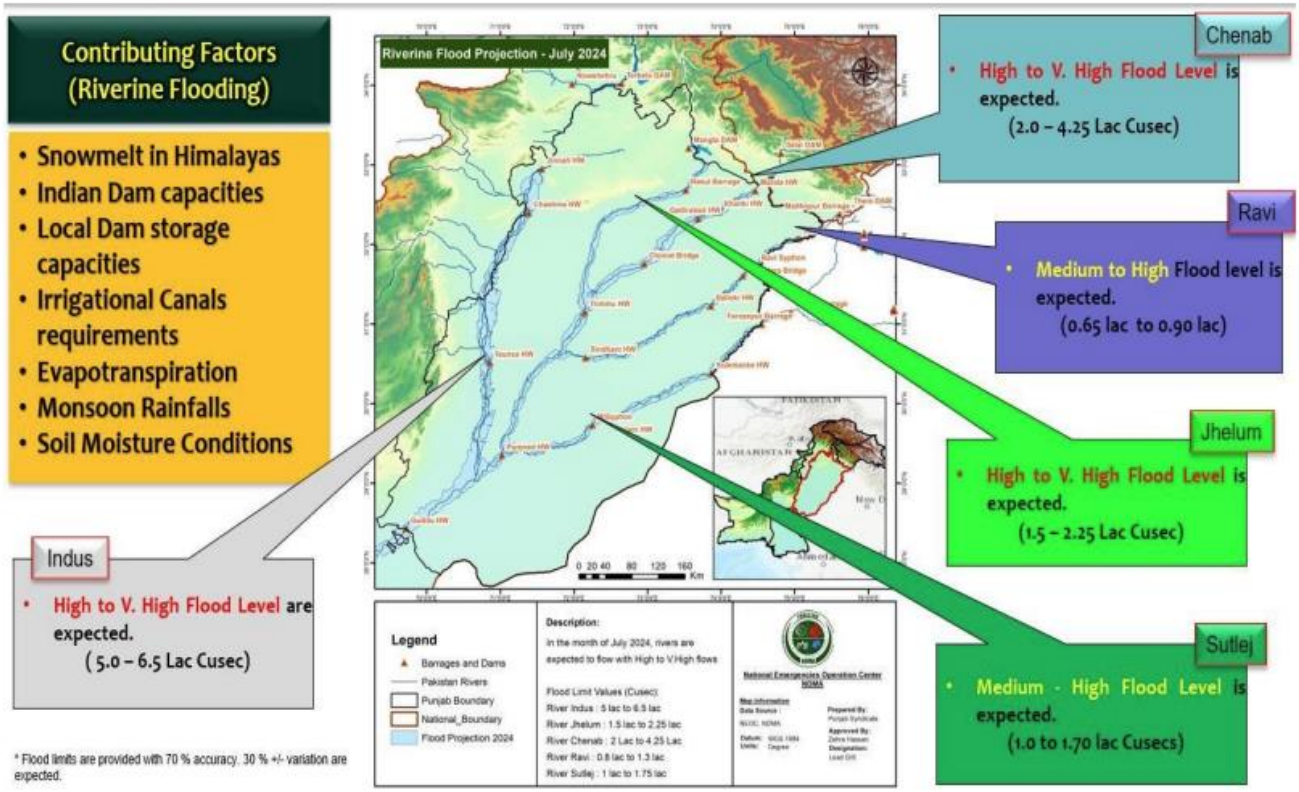


Figure 8: Punjab Flood Projection for the month of July 2024

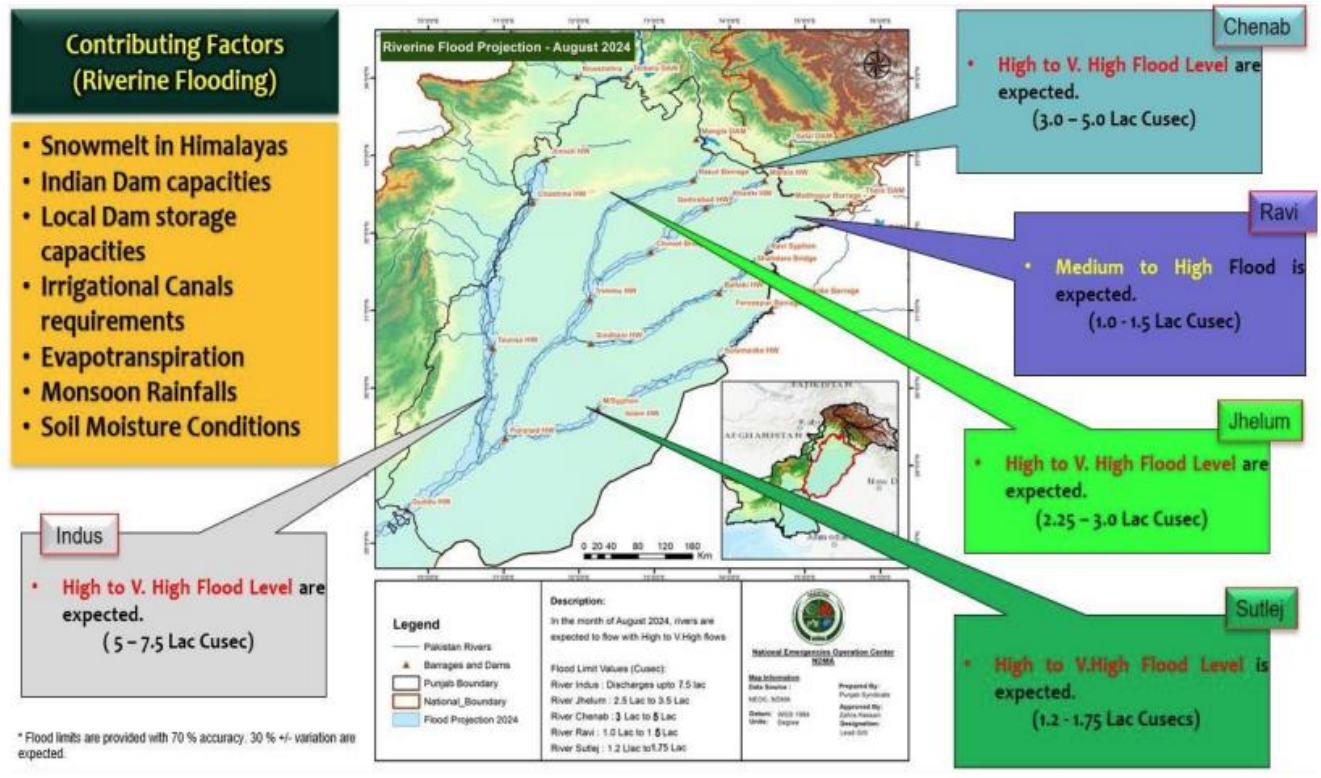


Figure 9: Punjab Flood Projection for the month of August 2024

2.4 Balochistan

In Balochistan in the month of June the projected precipitation in Figure 10 highlighted high vulnerability in districts such as Gwadar, Awaran, Lasbela, Barkhan, Loralai, Musa Khel, Killa Saifullah, Zhob, Sheerani, Pishin, Killa Abdullah, and Quetta.

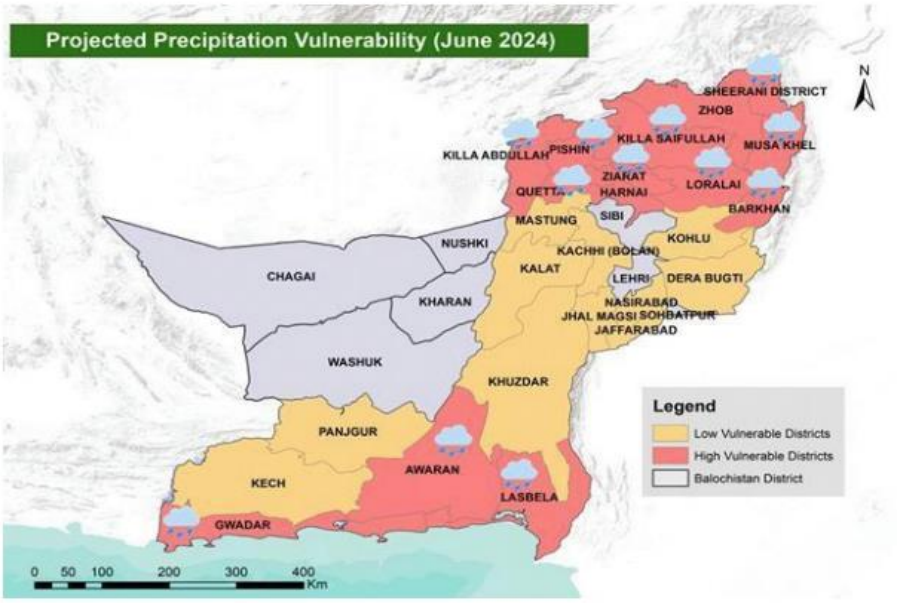


Figure 10: Projected Precipitation Vulnerability in June 2024 (Districts exposed to Precipitation in Balochistan) (NDMA, 2024)

July's projected precipitation indicated high vulnerability in districts such as Gwadar, Awaran, Lasbela, Barkhan, Khuzdar, Jhal Magsi, Jaffarabad, Sohbatpur, Nasirabad, Lehri, Kachhi, and Kalat as shown in Figure 11.

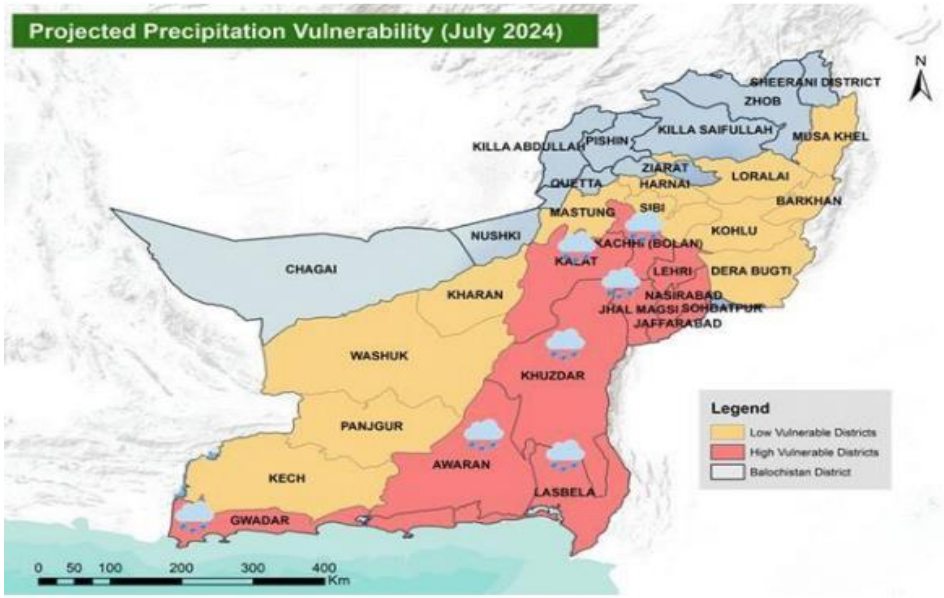


Figure 11: Projected Precipitation Vulnerability in July 2024 (Districts exposed to Precipitation in Balochistan)

However August's projected precipitation for Balochistan in Figure 12 highlighted high vulnerability in districts such as Awaran, Lasbela, Khuzdar, Jhal Magsi, Jaffarabad, Sohbatpur, Nasirabad, Lehri, Dera Bugti, and Kohlu.

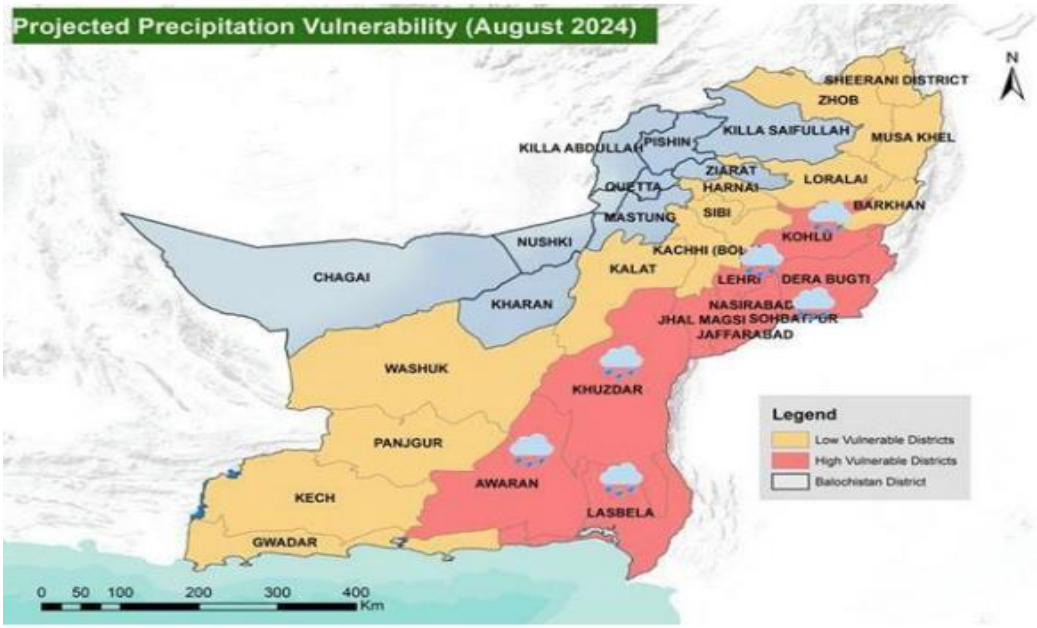


Figure 12: Projected Precipitation Vulnerability for the month of August 2024 (Districts exposed to precipitation in Balochistan) (NDMA, 2024)

September's projected precipitation for Balochistan highlighted high vulnerability in districts such as Gwadar, Awaran, Lasbela, Khuzdar, Jhal Magsi, Jaffarabad, Sohbatpur, Nasirabad, Lehri, Dera Bugti, Kohlu, Barkhan, Musa Khel, and Sheerani as depicted in Figure 13.

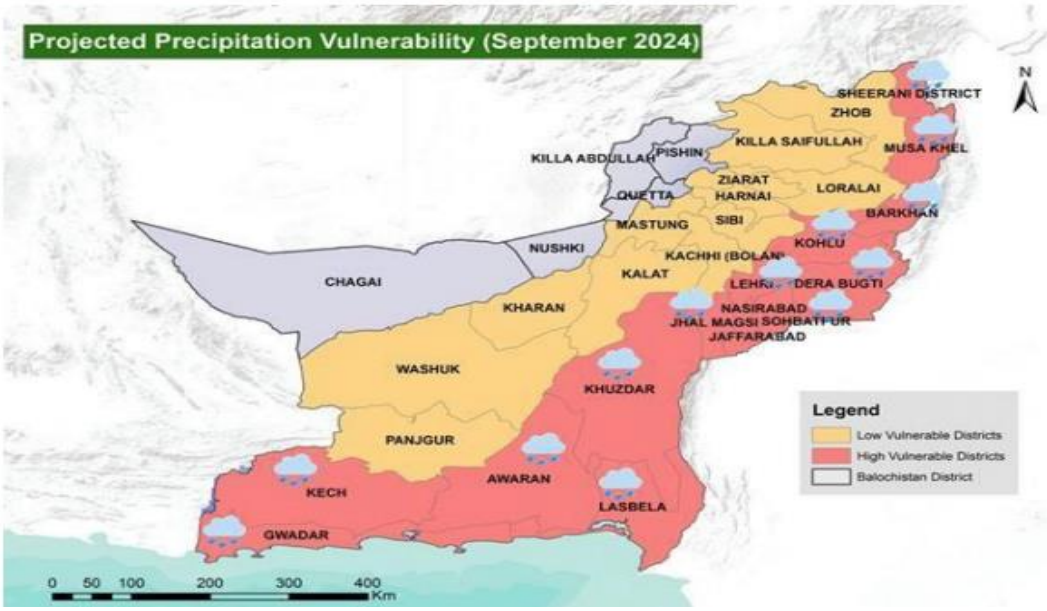


Figure 13: Projected Precipitation Vulnerability for the month of September 2024 (Districts exposed to precipitation in Balochistan)

2.5 Sindh

In June 2024, Sindh was expected to have normal temperatures, with anomalies likely ranging from 0.5°C to 1.5°C above normal. There was a probability of normal to slightly above-normal precipitation, with over a 40% chance of precipitation anomalies as highlighted in Figure 14.

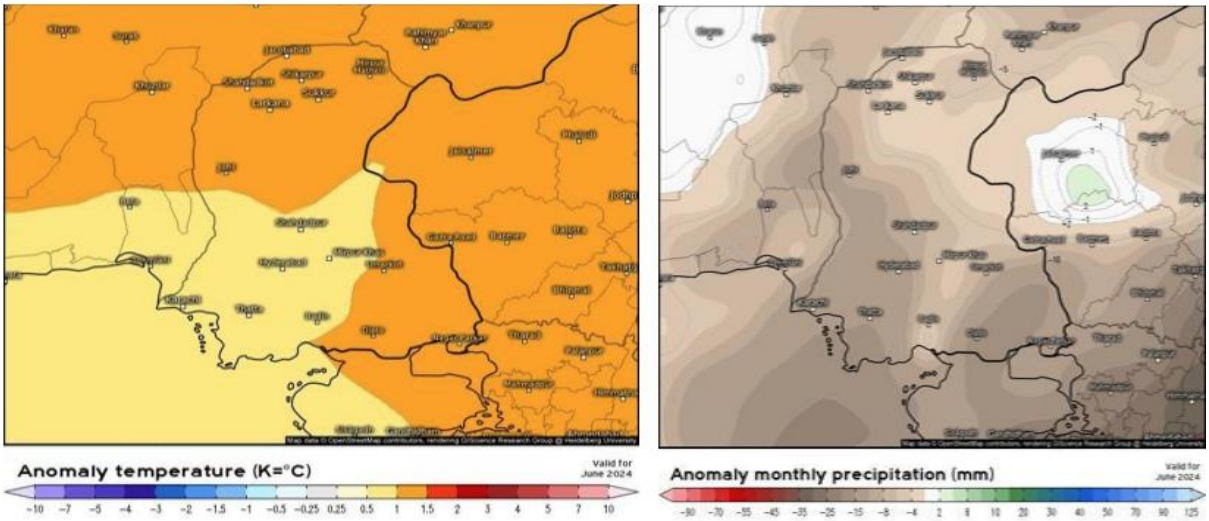


Figure 14: Projected Temperature and Precipitation Anomaly in Sindh for the month of June 2024

In the month of July 2024, Sindh was expected to have above-normal temperatures, with anomalies likely between 0.25°C and 1°C. There was also a high probability of above-normal precipitation, with over a 50% chance of precipitation anomalies as shown in Figure 15.

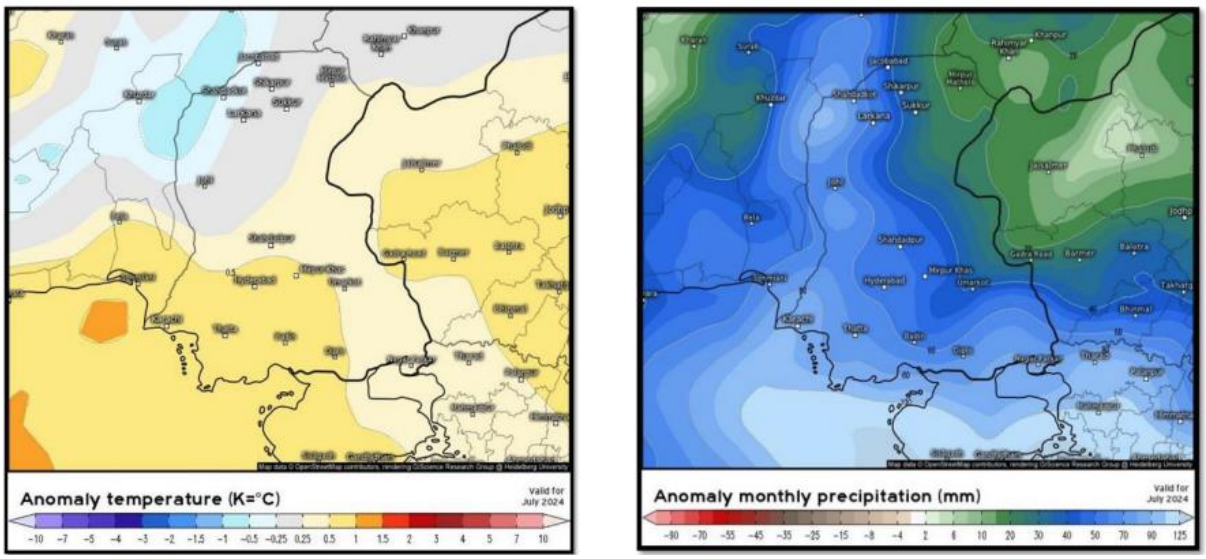


Figure 15: Projected Temperature and Precipitation Anomaly in Sindh for the month of July 2024

In August 2024, Sindh was expected to experience above-normal temperatures, with anomalies likely between 0.1°C and 1°C. There is also a high probability of above-normal precipitation, with over a 60% chance of precipitation anomalies as highlighted in Figure 16.

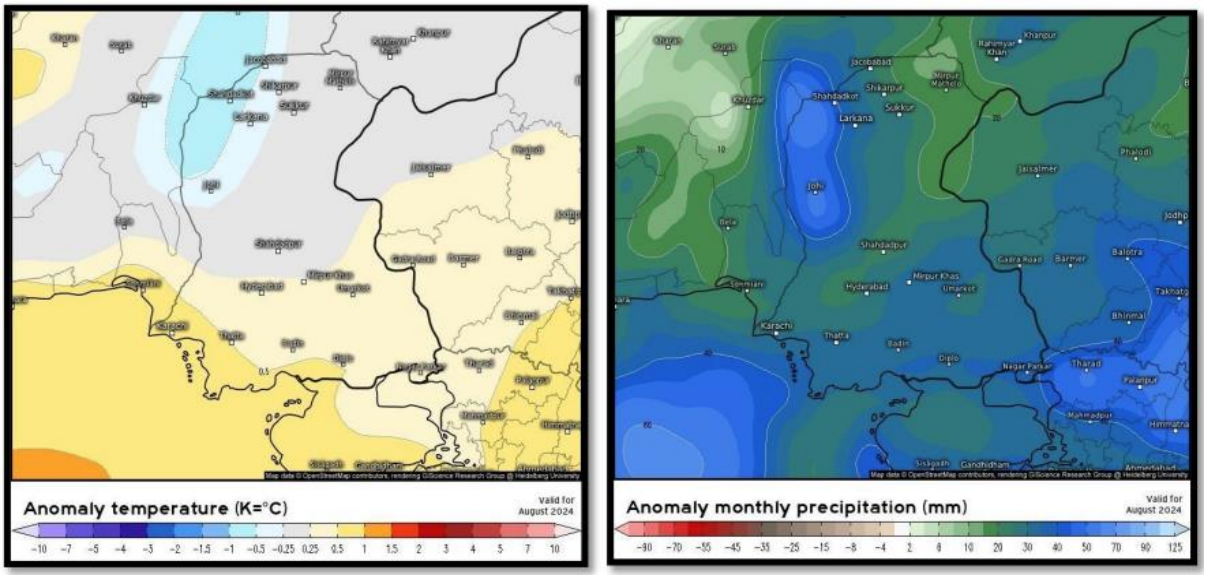


Figure 16: Projected Temperature and Precipitation Anomaly in Sindh for the month of August 2024

As shown in Figure 17 in September 2024, Sindh was expected to have normal temperatures, with anomalies likely between -0.25°C and 1°C. There was a probability of above-normal precipitation, with precipitation anomalies expected to be above normal.

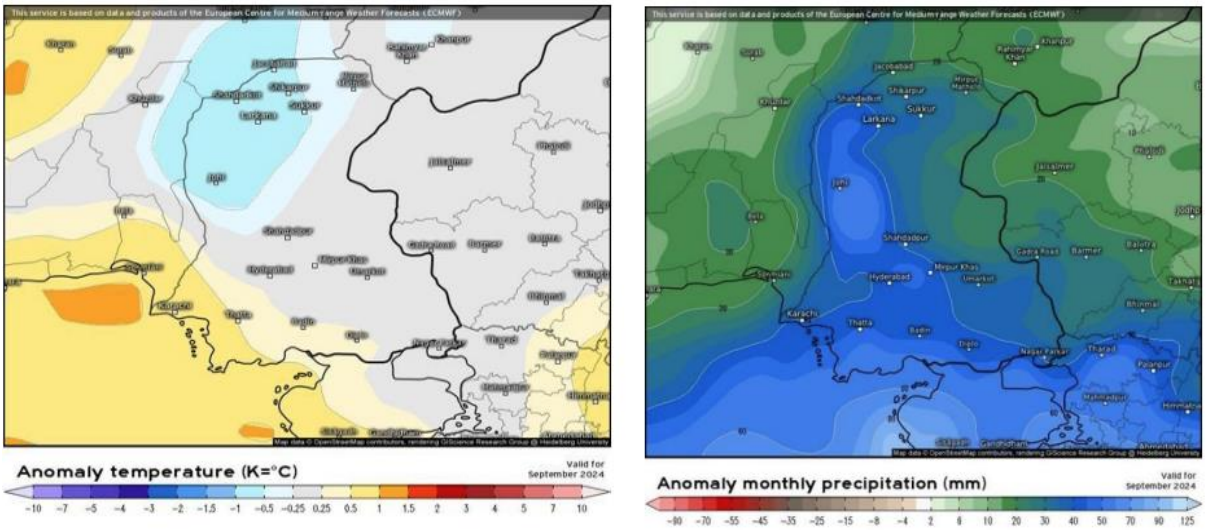


Figure 17: Projected Temperature and Precipitation Anomaly in Sindh for the month of September 2024

3. Projected Weather Impacts

In light of the projected weather conditions, following impacts are expected in aforesaid regions of Pakistan: -

- Moderate to very heavy rains may increase water flows in local streams and rivers, leading to riverine and flash flooding in vulnerable areas.
- Urban flooding is a concern in vulnerable urban areas across the country due to moderate to very heavy rains.
- Landslides may occur in vulnerable regions such as Murree, Galiyat, AJ&K, Gilgit-Baltistan and mountainous areas of Khyber Pakhtunkhwa and Balochistan.
- With rising temperatures and forecasted rainfall in Gilgit-Baltistan and Khyber Pakhtunkhwa, river and stream flows are expected to increase, raising the likelihood of glacial lake outburst floods (GLOFs) in at-risk valleys.
- Dust storms and wind-thunderstorms, along with heavy rainfall, may damage loose structures like electrical poles, solar panels, hoardings, tall trees, and construction sites.
- Expected normal to slightly above-normal rainfall in Northeast Punjab, AJK, and KP poses a risk of localized flooding (urban and flash), while also replenishing water reservoirs and groundwater resources.
- Recent weather conditions have resulted in considerable soil moisture, so farmers should irrigate according to crop needs.
- Daytime temperatures are expected to remain above normal early in the forecast period, but rains and cloudiness towards the season's end will help normalize temperatures.
- Flash and urban flooding are anticipated in hill torrent areas of Koh-e-Suleman and in major city plains of Sindh, Punjab, AJK, and KP due to heavy rainfall.

4. Overview of the Monsoon Season in 2024

The 2024 monsoon season has led to considerable devastation in Pakistan, particularly in the provinces of Balochistan, Punjab, and Sindh. Intense rainfall has resulted in widespread flooding, landslides, and significant damage to infrastructure. The country has experienced rainfall levels above the seasonal average, and unusually high temperatures have further complicated the situation by accelerating snowmelt in areas such as upper Khyber Pakhtunkhwa, Azad Jammu and Kashmir, and Gilgit-Baltistan.

Figure 17 highlights the different districts affected by monsoon rains in 2024. Also showing deaths and injuries, deaths and damaged houses and infrastructure damaged in the affected districts.

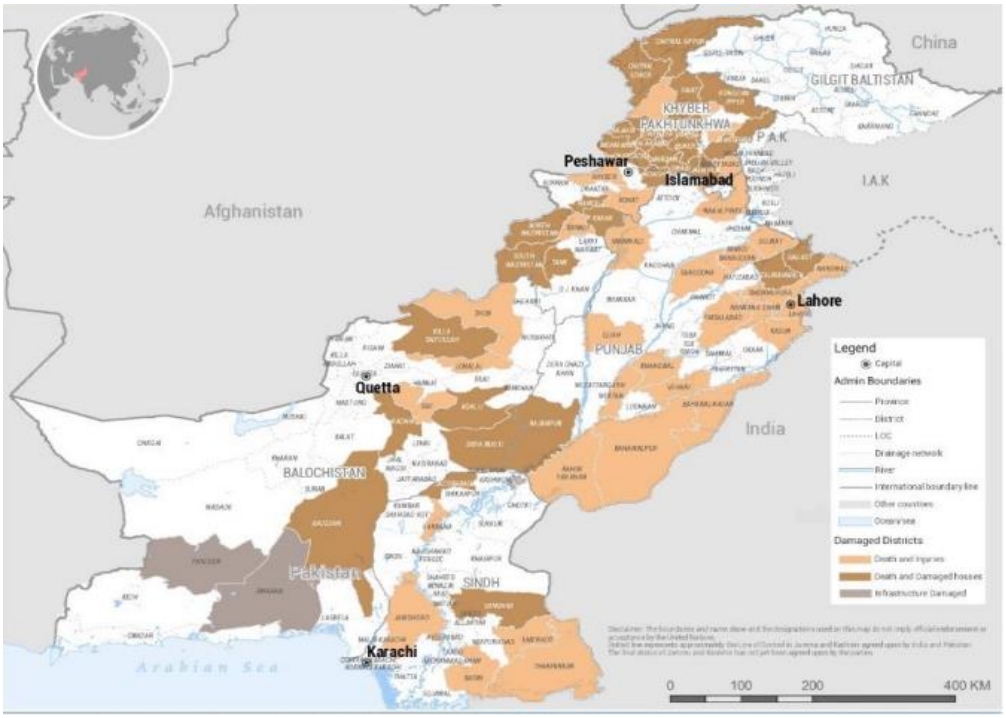


Figure 17 : Districts in Pakistan affected by Monsoon in 2024

Table 1 presents the total rainfall for July, August, and September across various provinces in Pakistan. It clearly highlights significant variations in rainfall during July and August, while September experiences considerably less rainfall.

Table 1: Significant Rainfall Totals for the months of July, August and September 2024.

Sr.no.	Province/District	July (mm)	August (mm)	Till 20 September (mm)
	PUNJAB			
1.	Bahawalnagar	151	85.02	21.02
2.	Bahawalpur City	120.2	155.93	0.2
3.	Bahawalpur Airport	87.11	150.42	0.01
4.	Bhakkar	90.44	186.5	3
5.	Chakwal	72.91	189.5	23
6.	D.G. Khan	54.01	183.52	21
7.	Faisalabad Airport	129.5	188.04	0.01
8.	Chaklala Airbase	385.06	359.07	66.01
9.	Islamabad Zeropoint	289.73	424.16	109.6
10.	Islamabad Airport	128.83	163.61	70.2
11.	Jhang	123.63	203.61	15.01
12.	Joharabad	88.71	121.71	11.2

13.	Jhelum	221.8	356.61	23.81
14.	Kasur	133.02	188.05	11.01
15.	Khanpur	23.6	188.8	0.01
16.	Kot Addu	40	245.02	5.2
17.	Kamra Airbase	155.82	226.55	46.02
18.	Lahore Airport	302.04	603.14	33.02
19.	Lahore City	282.04	290.74	79.8
20.	Layyah	32.62	206.5	25.11
21.	Mandibahauddin	304.53	321.33	54.51
22.	Mianwali Airbase	104.01	158.01	10.01
23.	Multan Airport	62.72	275.6	0
24.	Multan City	42.22	234	3
25.	Mangla	275.81	320.3	32
26.	Murree	271.52	264	71.01
27.	Noorpur Thal	23.62	100.41	5.01
28.	Okara	106.61	125.1	8.8
29.	Rahim Yar Khan	4.01	258.22	0
30.	Gujranwala	270.02	353.52	42.31
31.	Gujrat	306	251.01	29.01
32.	Sahiwal	48.22	191.03	0
33.	Shorkot Airbase	17.13	166.03	49.01
34.	Sheikhupura	157.51	189.51	5.5
35.	Sargodha Airbase	182.03	197.23	26.02
36.	Sargodha City	176.8	182.33	21
	Sialkot Cantt	326.34	244.92	64
37.	Sialkot Airport	468.21	284.02	92
38.	T.T. Singh	118.81	229.7	0.01
39.	Hafizabad	143.2	273.83	47
40.	Khanewal	38.01	211.07	12
41.	Narowal	183.63	436.72	80.73
42.	Attock	76.62	209.81	57.61
	GILGIT BALTISTAN/ AJK			
43.	Astore	6.1	92.2	12
44.	Bunji	4.06	30.26	1.82
45.	Babusar	0	0	0
46.	Bagrote	13.81	64.22	13.02
47.	Chilas	6.23	20.24	4
48.	G.Dopatta	71.8	192.9	91.8
49.	Gilgit	9.36	24.35	7.02
50.	Gupis	10	29	8

51.	Kotli	102	241.01	24
52.	Muzaffarabad Airport	138	258.51	19
53.	Muzaffarabad City	192	185.31	15
54.	Rawalakot	102.61	157.91	73
55.	Hunza	0	87.1	1
56.	Skardu	1.08	22.94	1.53
	KHYBER PAKHTUNKHWA			
57.	Balakot	228	351	25
58.	Bannu	30.02	103.01	0.02
59.	Cherat	129	249	48
60.	Chitral	20.1	3.4	5.2
61.	D.I.Khan (City)	52.45	123.61	16.81
62.	D.I. Khan (Airport)	22.01	138	54
63.	Dir	125.01	118.01	6
64.	Lower Dir	106.81	132.22	3.21
65.	Drosh	24.4	8.8	1
66.	Kakul	191.8	461	42
67.	Kalam	30.02	51.61	21.5
68.	Kohat Airbase	47.02	65.04	26
69.	Malamjabba	188	255	19
70.	Mirkhani	41.01	12.7	14.23
71.	Parachinar	82	138	2
72.	Peshawar Airbase	87.04	85.03	6.22
73.	Peshawar City	56.3	84.04	2.02
74.	Bacha Khan A/P	64.62	85.14	4.03
75.	Pattan	30	42	28
76.	Risalpur	100.03	222.05	44.01
77.	Saidu Sharif	114.7	79.6	25.5
78.	Takht Bai	90.2	148.71	40.3
	SINDH			
79.	Badin	49.22	242.61	9
80.	Chhor	101.61	228.31	14.4
81.	Hyderabad Airport	28.82	165.2	1
82.	Hyderabad City	31.4	194.2	0.01
83.	Jacobabad	15	281.04	3
84.	Karachi A/P	67.21	159.49	0.62
85.	Larkana	24.01	194.04	3
86.	Mithi	38	296.5	79
87.	SH.B.Abad	30.6	194.81	1
88.	Padidan	14.7	136.71	15.7

89.	Rohri	0.02	252.02	0
90.	Sukkur	0.01	255.02	0
91.	M.JO.Daro	7.03	181.62	0
92.	Thatta	22.4	169	22
93.	Dadu	10	212.03	0
94.	Mirpur Khas	28.8	384.9	2
95.	Tando Jam	60.91	208.6	0
96.	Sakrand	8.2	221.01	0.01
97.	Khairpur		303	0
	BALOCHISTAN			
99.	Barkhan	0.02	143	32
100.	Dalbandin	149.01	4.04	0.01
101.	Gawadar	0	10	3
102.	Jiwani	0	5	1
103.	Kalat	0	195	13
104.	Khuzdar	21	237.7	1
105.	Lasbela	7.65	70.2	8
106.	Nokkundi	39.52	0	0
107.	Panjgur	0	26	1
108.	Pasni	16.7	10	6
109.	Quetta (SH Manda)	0	24.85	0.01
110.	Quetta (Samungli)	0.01	46.06	1.01
111.	SIbbi	0.01	116.02	0
112.	Turbat	167.01	16.8	0
113.	Ormara	0.03	11.01	12
114.	Zhob	81.03	35	0

Table 2, 3 and 4 shows the situation of flood at major stations along River Indus, River Chenab and River Kabul. At most of the stations the flood classification was observed to be at medium level, however at few stations it was low and not a single station with high flood was observed.

Table 2. The flood situation at major stations along River Indus.

S.no.	Structure/ Control Point	Flood Classification	Flood Flow
1.	Tarbela	Low flood	329,200 cusecs
2.	Kalabagh	Medium flood	393,739 cusecs
3.	Chashma	Medium flood	412,568 cusecs
4.	Taunsa	Medium flood	440,296 cusecs
5.	Guddu	Medium flood	389,896 cusecs
6.	Sukkur	Medium flood	380,850 cusecs

7.	Kotri	Low flood	226,896 cusecs

Table 3. The flood situation at major stations along River Chenab.

S.no.	Structure/Control Point	Flood Classification	Flood Flow
1.	Marala	Medium flood	160,950 cusecs
2.	Khanki	Medium flood	163,215 cusecs
3.	Qadirabad	Low flood	145,219 cusecs

Table 4. The flood situation at major stations along River Kabul.

S.no.	Structure/Control Point	Flood Classification	Flood Flow
1.	Warsak	Medium flood	64,000 Cusecs
2.	Nowshera	Medium flood	114,200 cusecs

Table 5 and 6 highlights the situation of flood in Hill Torrents in District Rajanpur and DG Khan. Highlighting the maximum water discharged during 2024.

Table 5. Flood Situation in Hill Torrent District Rajanpur.

S.no.	Hill Torrents	Flood Flow	Historical Peak
1.	Kaha Hill Torrent	105,276 cusecs	108,941 cusecs (2022)
2.	Kala Bagga Khosra Hill Torrent	27,640 cusecs	-
3.	Chachar Hill Torrent	63,940 cusecs	75,900 cusecs (2022)
4.	Pitock Hill Torrent	14,600 cusecs	-
5.	Sori Shumali Hill Torrent	7250 cusecs	13,000 cusecs (2010)
6.	Zangi Hill Torrent	33,600 cusecs	-
7.	Sori Janubi Hill Torrent	16,560 cusecs	22,300 cusecs (2012)

Table 6. Flood Situation at Hill Torrent District DG. Khan.

Sr. No.	Hill Torrent Discharge	Maximum 2024
1	Kaura	39,337 cusecs
2	Vehova	28,638 cusecs
3	Sanghar	24,064 cusecs
4	Sori Lund	51,4460 cusecs
5	Vadore	-
6	Sakhi Sarwar	9370 cusecs
7	Mithawan	61,905 cusecs

River Ravi, Jhelum and Sutlej remained Normal.

5. Challenges Faced during the Monsoon Season 2024

The 2024 monsoon season presented several challenges across multiple sectors in Pakistan. The key challenges faced during the season include:

- **Unpredictable Rainfall Patterns:** The monsoon saw sporadic, heavy rainfall in some areas while others experienced lesser rainfall than expected making it difficult for authorities to predict and manage flood situations effectively.
- **Urban Flooding:** Major cities such as Lahore and Gujrat faced severe flooding due to inadequate drainage systems and unplanned urban expansion.
- **Breaches in Flood Protection Embankments:** Breaches occurred in flood protection embankments in both Sindh and Balochistan, exacerbating the flood situation and causing widespread damage to crops and settlements.

6. Comparison of 2022, 2023 & 2024 Flood Events

Flood Experience of Monsoon Season 2022

The 2022 floods in Pakistan were significantly impacted by a notable shift in the monsoon path, which moved further south and resulted in extreme rainfall across Sindh and Balochistan. This phenomenon was unusual, particularly in the Lower Indus region, where heavy rain affected the catchments of hill torrents originating from Balochistan. Most of the flooding in Sindh stemmed from a combination of lateral inflow from these torrents and direct local rainfall. The situation was devastating for the southern regions, leading to widespread flooding due to both direct precipitation and flash floods from the hill torrents. Warning times were severely limited, especially in areas primarily affected by direct rainfall. In contrast, the main Indus River did not experience extraordinary flood magnitudes, with discharges at barrages generally remaining below design levels, and in some cases, even below flood warning thresholds. A critical lesson from the 2022 floods highlighted the need to promote

sustainable land and water use practices, alongside implementing future flood protection measures based on a thorough understanding of the development-disaster nexus. Additionally, these floods underscored the necessity to expand the existing radar network and enhance rainfall, runoff, and river flow telemetry systems, particularly to improve coverage in vulnerable hill torrent regions.

Flood Experience of Monsoon Season 2023

This year saw exceptionally high flooding in the River Sutlej due to cumulative outflows from Indian dams. The peak discharge caused significant inundation in nearby villages, damaging crops and infrastructure. Lessons learned emphasized the importance of removing encroachments, enhancing infrastructure resilience, completing flood protection projects, and improving cross-border coordination with India regarding water management. The management of hill torrents was also highlighted as crucial for optimizing water use and minimizing flood risk.

Flood Experience of Monsoon Season 2024

There was not a single major flood event (High to Exceptionally High Flood) in any of the Indus River System's rivers. Medium Flood Levels were noted in River Indus at the Kalabagh-Chashma-Taunsa-Guddu-Sukkur-Kotri Reaches. At Mara-Khanki Reach, River Chenab recorded a Medium Flood Level, while at Nowshera-Warsak Reach, River Kabul recorded the same. River Jhelum remained at Low Flood Stage near Mangla while River Ravi flowed at Normal Flow Stage. Additionally, on August 8, 2024, Lai Nullah in Rawalpindi, Islamabad reached the Evacuation Stage at Kattarian (22.7 feet gauge level) and Gawalmandi (19.0 feet gauge level) as a result of heavy rainfall at its catchment. Some localized flood events were also observed in Sindh, Balochistan and Punjab which were managed by the concerned Provincial Irrigation departments and PDMAs/ DDMAs. Lessons learnt include improved future coordination among all stakeholder departments to better combat with the future floods, clear encroachments from flood waterways and carry out essential 2022 flood damages restoration works, yet not started.

Overall, while 2022 was marked by devastating floods, the subsequent years demonstrated a shift toward improved management practices and preparedness, contributing to a more resilient approach to future monsoon seasons.

7. Case Studies

A study reveals that global warming is causing the South Asian monsoon season to become more intense and unpredictable.

7.1 Philippines

Since July 9, the combined effects of the southwest monsoon and Tropical Cyclone Gaemi (locally named Carina) have brought severe and continuous rainfall to 7 regions, 17 provinces, and 53 cities/municipalities across the Philippines. Effecting more than 4.8 million individuals. The National Disaster Risk Reduction and

Management Council (NDRRMC) reports 39 fatalities (14 confirmed and 25 under validation), nine injuries, and six missing persons. Approximately 108,000 people were displaced and resided in 557 evacuation centers. The disaster has caused significant damage, with infrastructure losses estimated at USD 73.4 million (PHP 4.3 billion) and agricultural damage totalling USD 9.4 million (PHP 552 million), impacting around 23,500 farmers and fisherfolk.

In response, the Philippine government coordinated relief efforts, supporting families in evacuation centers, and initiating early recovery measures. Over 100 cities and municipalities had declared a state of calamity, which allows access to disaster funds. The Department of Social Welfare and Development, along with other national agencies, has distributed approximately USD 5.44 million (PHP 319 million) in aid to the affected regions. Non-governmental organizations and UN agencies were also providing essential supplies, including food, non-food items, and modular tents, to assist the displaced populations.

In 2023, the Philippines faced significant flooding, exacerbated by multiple weather systems, including tropical storms. Although the damage was severe, the response mechanisms and preparedness were less coordinated than in 2024. The flooding in 2023 resulted in higher fatalities and displacement, alongside critical infrastructure damage. In contrast, the lessons learned from the previous year significantly influenced the preparedness and response strategies for 2024. Enhanced forecasting and early warning systems, improved community engagement, and stronger inter-agency collaboration were key factors that contributed to a more effective response.

In 2024, several best practices were implemented to enhance disaster response. The government improved weather forecasting capabilities for timely alerts and better community preparedness. Community-based disaster risk management initiatives engaged local populations in training, boosting resilience and awareness of flooding risks. Rapid declarations of a state of calamity in over 100 municipalities allowed for quicker access to disaster response funds. Enhanced coordination among government agencies, NGOs, and international organizations ensured effective aid delivery. Investments in flood-resistant infrastructure and land-use planning, such as better drainage systems and flood barriers, mitigated flooding impacts. Additionally, early recovery initiatives focused on immediate relief and long-term recovery for affected communities.

7.2 Bangladesh

On August 20, 2024, heavy monsoon rains combined with a low-pressure system over the Bay of Bengal led to widespread flooding in eastern Bangladesh as shown in the flood inundation map of Bangladesh in figure 18. This resulted in rising water levels in the Dhalai, Feni, Gomti, Halda, Khoai, Manu, Muhuri, and Surma-Kushiara Rivers.

By August 27, the flooding, described as the worst Bangladesh has seen in three decades, had affected over 5.8 million people, leaving more than 1.2 million stranded without relief, according to the Ministry of Disaster Management and Relief (MoDMR). Figure 19 highlights the different districts of Bangladesh affected by flood, the Sylhet and Chattogram divisions were the hardest hit, with the floods impacting 545 municipalities across 74 upazilas (subdistricts) in 11 districts: Brahmanbaria, Chattogram, Cox's Bazar, Cumilla, Feni, Habiganj, Khagrachari, Lakshmipur, Moulvibazar, Noakhali, and Sylhet. Reports indicate that the floods have caused 52 deaths—17 in Feni, 14 in Cumilla, 8 in Noakhali, 6 in Chittagong, 3 in Cox's Bazar, and 1 each in Brahmanbaria, Khagrachhari, Moulvibazar, and Lakshmipur. The true death toll is likely higher due to ongoing challenges with access, rescue operations, and data collection. By August 30, nearly 296,900 hectares of farmland in the affected districts had been inundated. The situation was exacerbated by the release of water from the Dumbur dam in India, which Indian authorities attributed to high water levels in the dam. This release significantly increased river levels in Bangladesh. As of August 30, 2024 approximately 502,500 displaced individuals were taking refuge in 3,403 evacuation shelters across the affected districts, facing urgent needs for food, clean water, dry clothing, and water purification tablets.

In 2023, Bangladesh experienced significant flooding, particularly in the northern and northeastern regions, caused by similar monsoon conditions and river overflows. However, the scale of the disaster in 2024 was unprecedented, with a broader geographic impact and higher numbers of affected individuals. While the 2023 flooding

prompted responses, the 2024 situation highlighted deficiencies in preparedness and the need for enhanced measures.

In 2024, Bangladesh implemented key best practices to enhance flood response and resilience. The Bangladesh Meteorological Department (BMD) improved forecasting for timely alerts, while local governments and NGOs conducted community preparedness programs, including grassroots early warning systems. Quick establishment of evacuation shelters ensured displaced populations had access to essentials like food and clean water. Improved communication between Bangladeshi and Indian authorities facilitated better management of dam water releases. Investments in flood-resistant infrastructure, such as levees and drainage systems, mitigated urban flooding impacts. Nature-based solutions, like restoring wetlands and enhancing mangroves, were also adopted to reduce flood risks. Early post-flood recovery measures focused on restoring livelihoods and rebuilding infrastructure in affected areas.

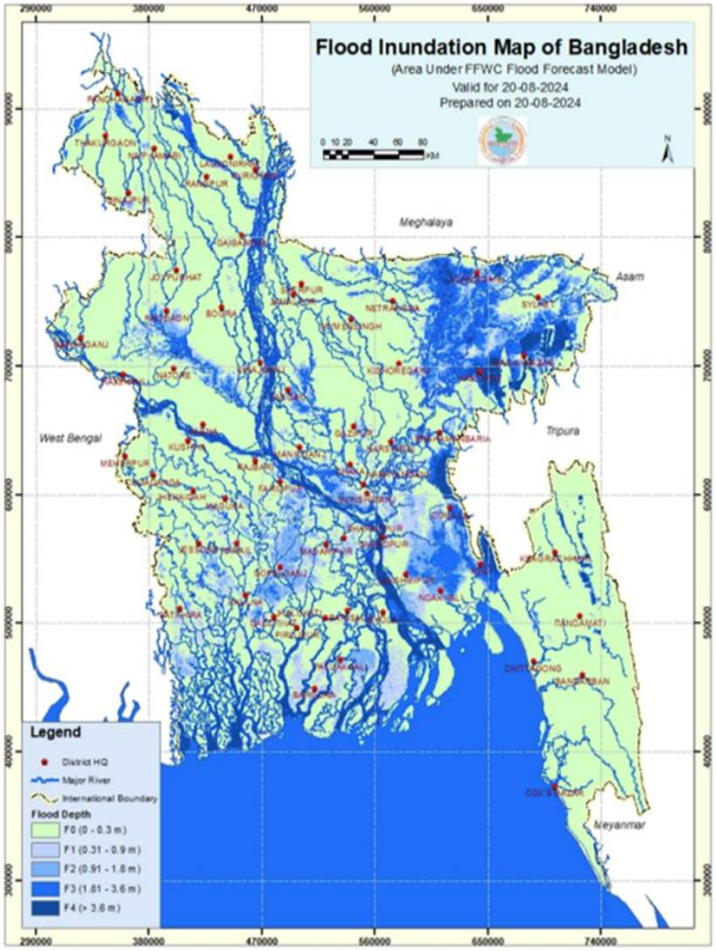
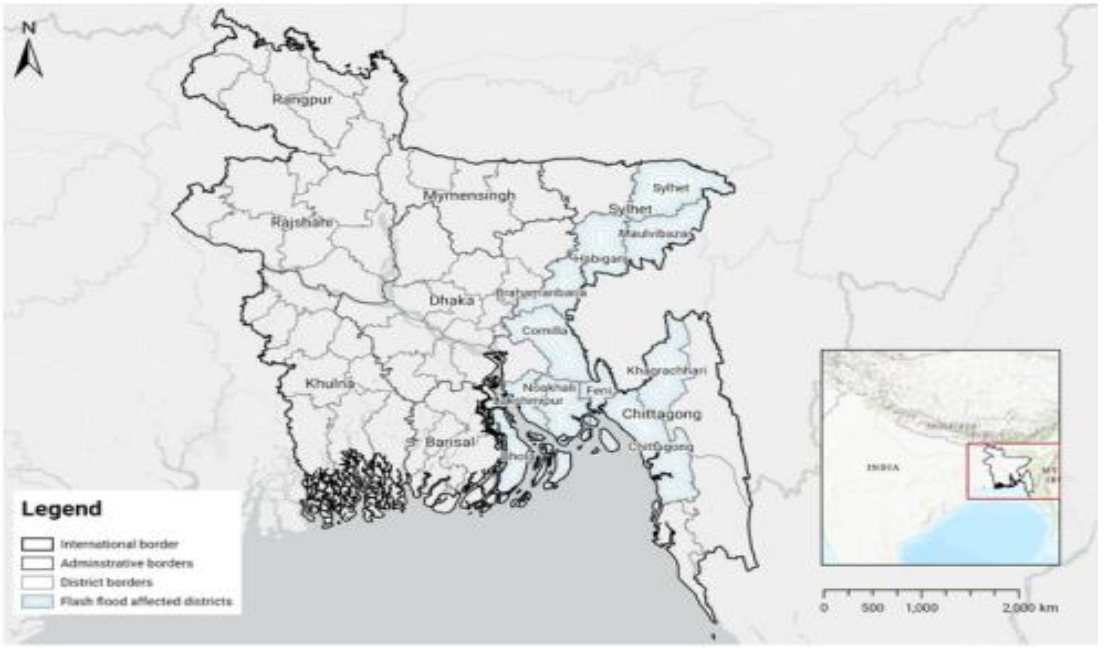


Figure 18. Flood Inundation map of Bangladesh



Source: ACAPS with data from OCHA

Figure 19. Flood Affected Districts of Bangladesh

7.3 India

The 2024 monsoon season led to severe flooding across India, notably affecting Assam, Delhi, Himachal Pradesh, Nagaland, and Maharashtra.

- **Assam**: Nearly 2.3 million people in 28 districts had been impacted by flooding, which had submerged homes, farmland, and infrastructure. The Brahmaputra River and its tributaries were at dangerously high levels, causing extensive damage to roads and bridges. Rescue and relief operations were ongoing, but the scale of displacement remained a significant challenge.
- **Delhi**: The Indian Meteorological Department had issued an orange alert for heavy rainfall, heightening concerns of worsening flooding. Political disputes

- over flood management and preparedness intensified, underscoring the need for better coordination and effective governance.
- **Himachal Pradesh**: A major landslide on the Shimla National Highway near Kingal village blocked traffic and communication. Authorities worked to clear debris and restore access, with no casualties reported so far. This incident highlights the region's vulnerability to monsoon-induced disasters.
- **Nagaland**: Heavy rains have caused severe flooding and landslides, with five people feared drowned. Rescue and relief efforts were ongoing, as authorities work to assist affected communities and manage the crisis.
- **Maharashtra**: In Raigad district, heavy rains created a flood-like situation, trapping tourists at a waterfall. Rescue operations were in progress, highlighting the region’s need for improved disaster preparedness.

In response to the severe flooding during the 2024 monsoon season, India implemented several strategic practices to enhance disaster resilience and management. Integrated watershed management was prioritized, focusing on restoring natural ecosystems like wetlands and forests to improve water retention and reduce runoff. Real-time data sharing among meteorological departments and local authorities improved coordination during crises, while the development of detailed flood risk maps helped identify vulnerable areas for targeted infrastructure improvements. Community-based disaster risk management (CBDRM) engaged local populations in assessing risks and planning, ensuring local knowledge was integrated into strategies. Automated flood monitoring systems were deployed in critical river basins to provide timely data, facilitating proactive responses. Additionally, long-term plans for relocating communities from high-risk zones were initiated, and policies related to land use and urban planning were updated to enhance flood resilience. Investments in climate-resilient agriculture promoted sustainable practices, including flood-resistant crop varieties. Regular emergency drills and simulations improved preparedness, while partnerships with academic institutions fostered innovative solutions for flood prediction and management. Nature-based solutions, such as restoring mangroves and other natural barriers, were also adopted to enhance coastal resilience and mitigate flooding impacts, emphasizing a holistic approach to flood management that balances human needs with ecological health.

7.4 Nepal

In June and July of 2024, heavy monsoon rainfall in Nepal triggered a series of landslides, causing casualties and damage. In Chitwan District, a major landslide swept away two passenger buses, resulting in eight fatalities and 54 people missing, as reported by the Nepal Disaster Risk Reduction Portal (DRR). Since July 10, five landslides across Baglung, Chitwan, Kaski, and Myagdi districts had resulted in 25 deaths and 13 injuries.

As of July 30, the Ministry of Home Affairs reported 143 deaths and 47 missing persons due to various disasters, including floods and landslides. Fatalities included in Koshi province, 6 in Madhesh, 31 in Bagmati, 42 in Gandaki, 24 in Lumbini, 8 in Karnali, and 10 in Sudurpaschim. Over 3,779 households were displaced.On August 16, a glacial lake outburst in Koshi province caused flash floods and mudslides, displacing 135 people and damaging 20 houses, a school, and a health facility in Thame village, Solukhumbu district, as reported by media outlets by August 19. In contrast, the floods of 2023, were also impactful, primarily affected lower-lying areas with less severe landslides, resulting in fewer casualties but notable damage to infrastructure.

During the 2024 flooding in Nepal, several best practices were implemented to enhance disaster response and resilience. Localized early warning systems expanded the dissemination of real-time alerts through mobile apps and SMS. Rapid response teams, including trained volunteers, facilitated swift rescue operations, while temporary shelters provided safe housing for displaced individuals. Improved drainage infrastructure and the construction of retention basins helped mitigate urban flooding. Rehabilitation efforts focused on restoring livelihoods through cash-for-work programs, and local disaster management committees empowered communities to lead preparedness initiatives. Additionally, partnerships with NGOs enhanced resource mobilization, and the integration of traditional knowledge into flood management fostered community resilience.

7.5 Central European Floods 2024

The 2024 Central European floods, caused by Storm Boris, had been some of the most severe in decades, impacting countries across the region, including Austria, Poland, the Czech Republic, Romania, and Hungary. The storm brought torrential rainfall, leading to rivers overflowing their banks and devastating floods. Some areas saw up to 19 inches of rain in just a few days, with the highest levels recorded in the Czech Republic.

The floods caused significant damage to infrastructure, homes, and farmlands, displacing thousands of people. In Poland, more than 2,600 individuals were evacuated as water levels reached crisis levels in regions like Lower Silesia and Opole Voivodeship. Similarly, Austria and Romania experienced widespread destruction, with parts of Lower Austria and Romanian villages inundated.

The human toll had also been tragic, with at least 17 people confirmed dead across the region. The floods disrupted daily life, with power outages, closed roads, and transportation systems paralyzed in several areas. The Czech Republic, for instance, saw major interruptions to railway services, while in Slovakia and Hungary, flood warnings remained active along rivers like the Danube.Experts have linked these severe weather events to global warming, noting that Europe has been experiencing increasingly extreme weather patterns due to rising temperatures. The economic impact of these floods are expected to be substantial, with early estimates suggesting damages in the billions.

In response to the 2024 Central European floods, various strategic best practices were implemented across Europe to enhance flood resilience. Key initiatives included the restoration of floodplains and wetlands to improve water absorption, alongside the development of detailed flood risk maps that inform urban planning and emergency responses. Investment in green infrastructure, such as green roofs and permeable pavements, helped manage stormwater effectively. Existing infrastructure was retrofitted with modern flood defenses, and comprehensive public awareness campaigns were launched to encourage community preparedness. Climate-resilient urban planning guidelines were adopted, and rapid response protocols ensured quick action during flooding events. Financial mechanisms, like flood recovery funds, supported prompt rebuilding while promoting sustainability. Collaboration with local

stakeholders and regular emergency drills further strengthened the region's ability to mitigate future flood risks.

Properties are damaged as floodwaters rise following heavy rain on September 15, 2024 in Jesenik, Czech Republic.

A torrent of water flows along the river Bela during heavy rain on September 14, 2024 in Mikulovice, Czech Republic.

This aerial photograph taken on September 15, 2024 shows the flooded village of Rudawa, southern Poland.

Damaged buildings and vehicles are seen at town center after flooding caused by torrential rains in Jesenik, Czech Republic on September 16, 2024.

General view taken by drone of a flooded area by Nysa Klodzka river in Nysa, Poland September 16, 2024.

Local residents rescue an elderly person from the rising flood waters in the Romanian village of Slobozia Conachi on September 14 2024.

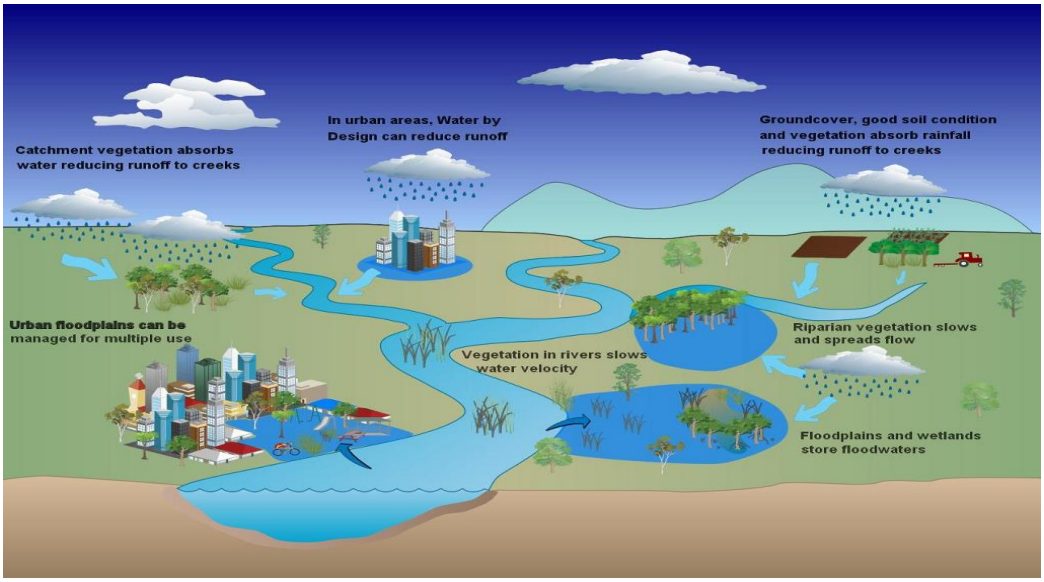
People clean the floor of a church after the flood water withdrew from the village of Pechea, Romania, on September 15, 2024.

This aerial photograph taken on September 15, 2024 shows a view of the flooded streets in Glucholazy, southern Poland.

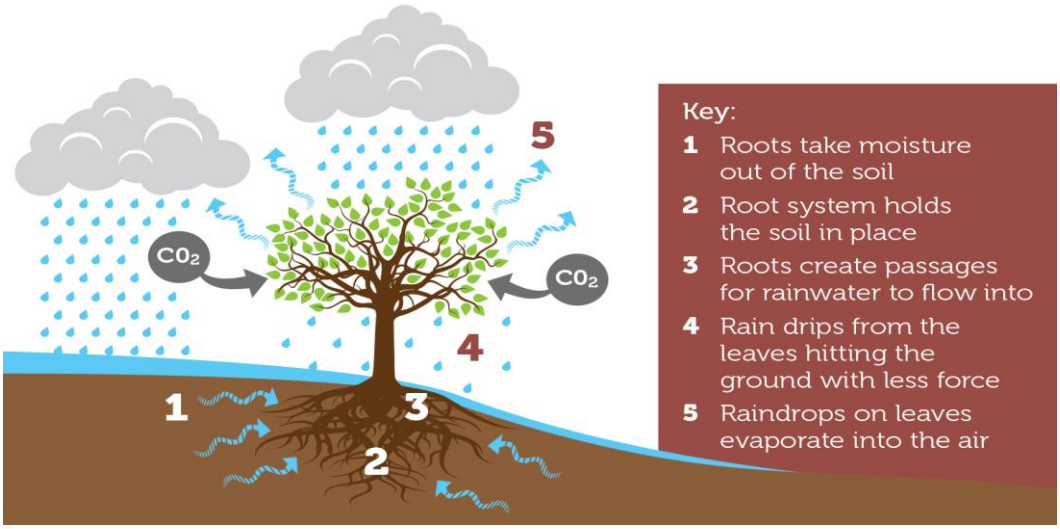
8. Best Practices for Floods

The recent floods in Pakistan and other countries have underscored the urgent need for effective flood management strategies. Learning from these events, we have identified several best practices that can significantly mitigate the risks and losses associated with flooding. These include enhancing early warning systems to ensure timely alerts, improving infrastructure to manage excess water through better drainage and flood barriers, and implementing sustainable land-use planning that preserves natural wetlands. Additionally, fostering community engagement and education around flood preparedness can empower residents to take proactive measures. By adopting these practices, we can build more resilient communities that are better equipped to handle future flood events. Some of the Best Practices used to avoid floods and its damages are as follows:

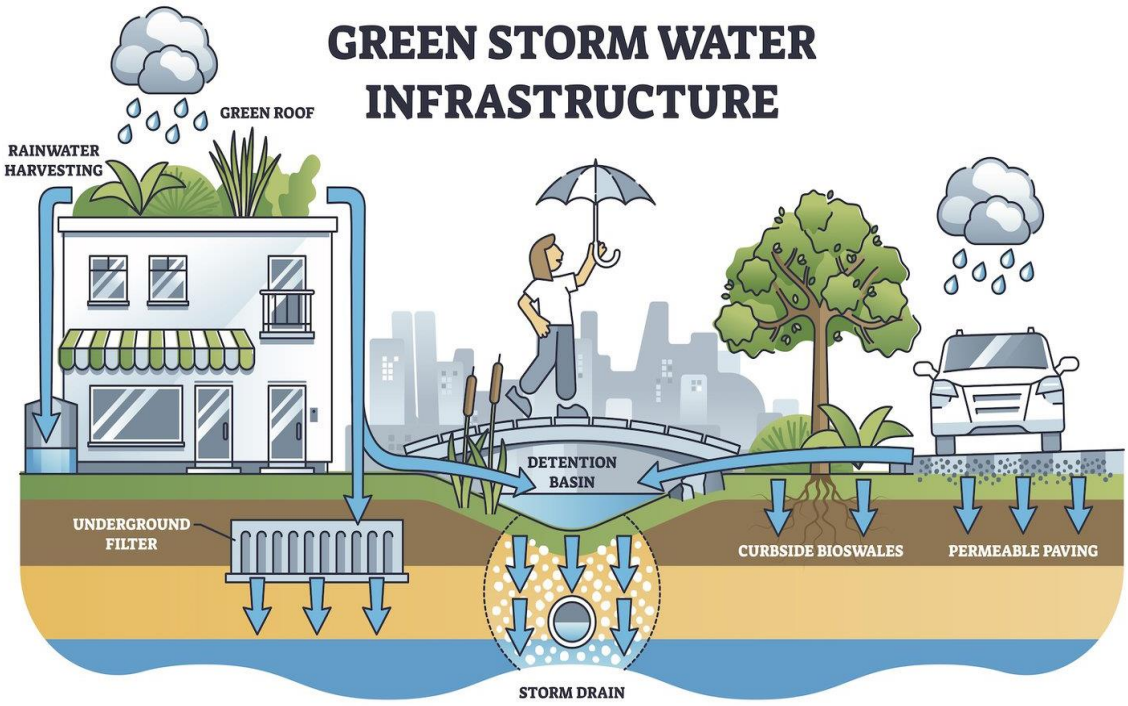
- **Nature-Based Solutions:** Leverage ecosystems like wetlands to manage water flow and absorb floodwater effectively.



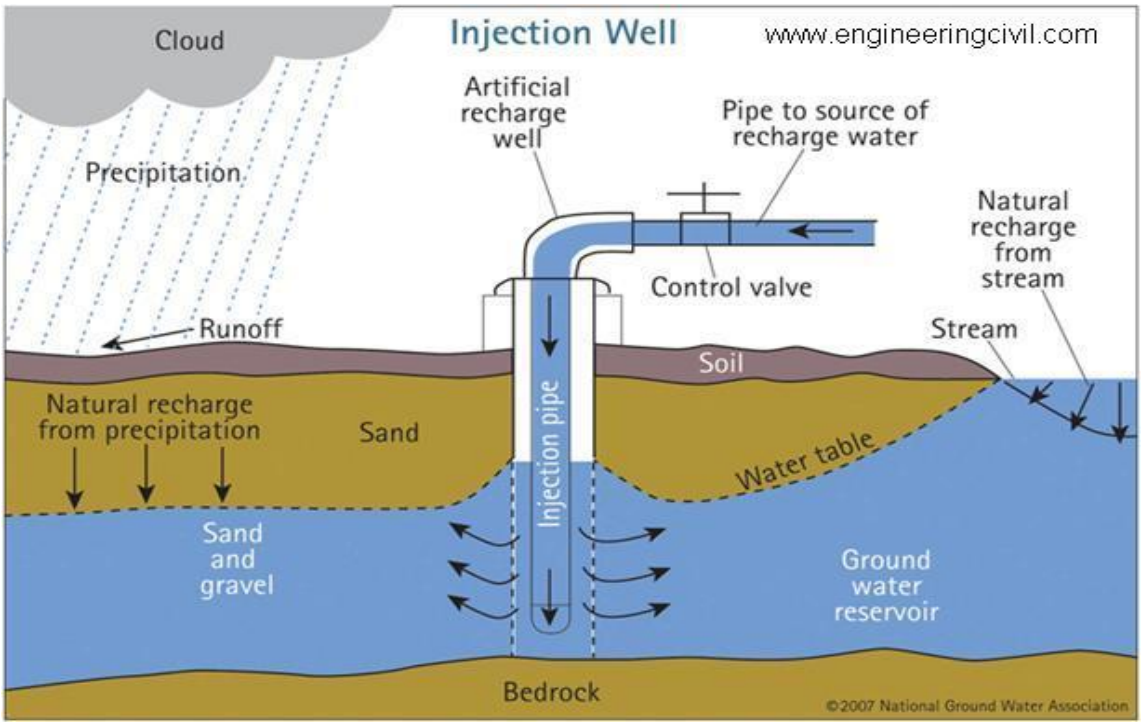
- **Reforestation:** Restore forests to enhance resilience, prevent soil erosion, and reduce flash flood risks.



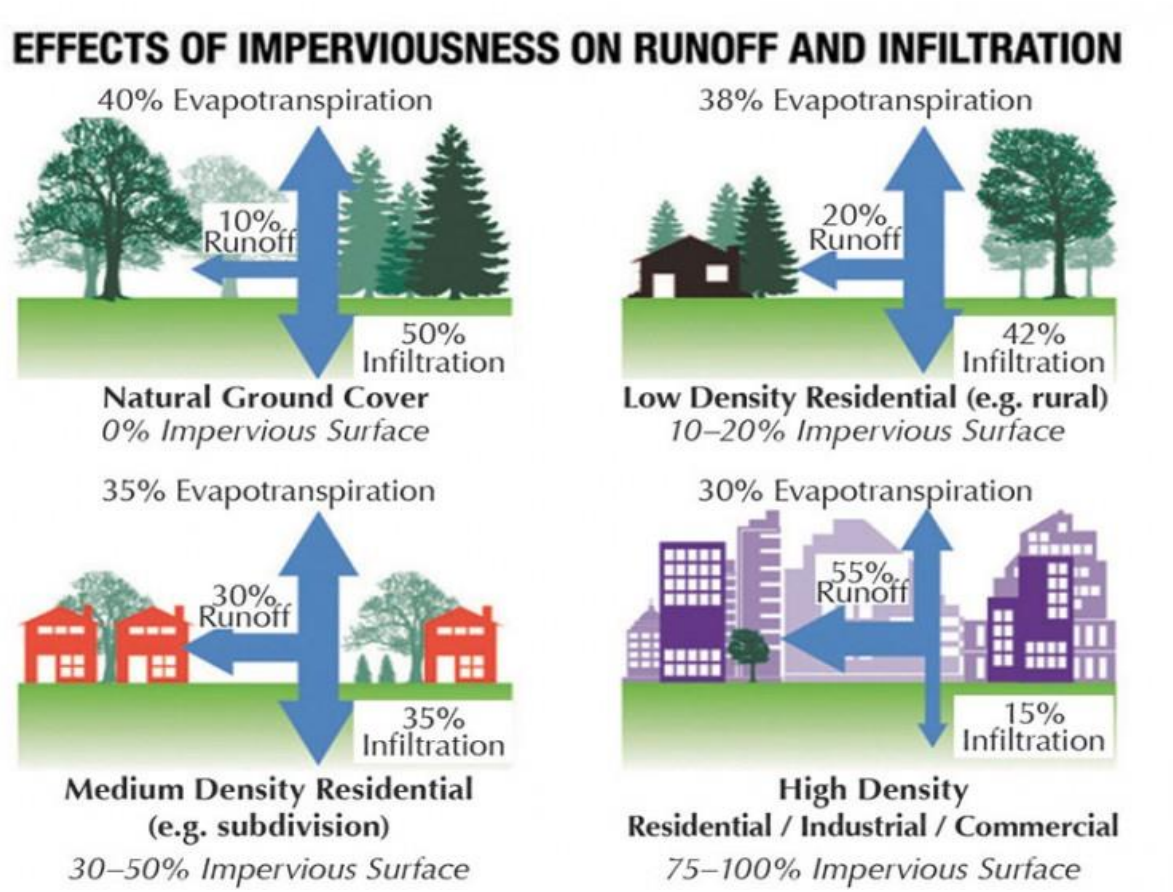
- **Invest in Flood Protection:** Upgrading flood defenses can save lives and create jobs. For example, shifting from a 9-year to a 25-year flood protection system in Pakistan could save $11.90 for every $1 spent and reduce flood likelihood from 11% to 4%.
- **Improve Water Governance:** Implement integrated water resource management to optimize resource allocation using better data.
- **Land Use Planning Controls:** Strategic planning can limit construction in flood-prone areas. Delineating flood-prone areas involves identifying and mapping regions at risk of flooding, which informs urban planning and risk management strategies. Enforcing building codes in these areas ensures that structures are designed to withstand flood conditions, minimizing damage and enhancing community resilience during flood events.
- **River Basin Flood Modelling:** Maintain updated flood models to assess the impact of new developments on existing residents.
- **Green Infrastructure:** In areas prone to localized flooding, green infrastructure can absorb rainfall, reducing water pooling and flooding while improving water quality by filtering pollutants. Techniques like ponds and retention systems help manage stormwater, preventing it from overwhelming drainage systems. Examples include permeable pavements, rain gardens, and bioswales.
  Communities facing flooding can use models to assess how green infrastructure can mitigate their flood risks. Hydrologic and hydraulic modeling helps identify effective green and gray infrastructure solutions for flood reduction and improved water quality.



- **Build aquifer storage and recovery infrastructure**: Enhance groundwater storage to promote recharge during excess surface water flows, improving climate resilience during droughts. This may involve percolation basins and injection wells for natural or artificial recharge.



- **Implement adaptive stormwater management:** Reduce impervious surfaces and upgrade undersized culverts to better manage stormwater.



- **Analyze extreme precipitation events:** Assessing the frequency and intensity of extreme rainfall can reveal risks to water utility systems not designed for such conditions. Modeling these events helps understand their potential impacts.
- **Flood Insurance:** Flood insurance is essential for protecting property owners from financial losses due to flood damage, especially in flood-prone areas where standard homeowners' policies may not provide coverage. It ensures quicker recovery and rebuilding after a flood event, making it a vital part of disaster preparedness and risk management.
- **River Training & Dredging:** River training and dredging involve modifying river channels to enhance flow capacity and reduce flood risk, improving navigation and water management. These practices help maintain clear waterways, prevent sediment buildup, and mitigate the impact of flooding in surrounding areas.

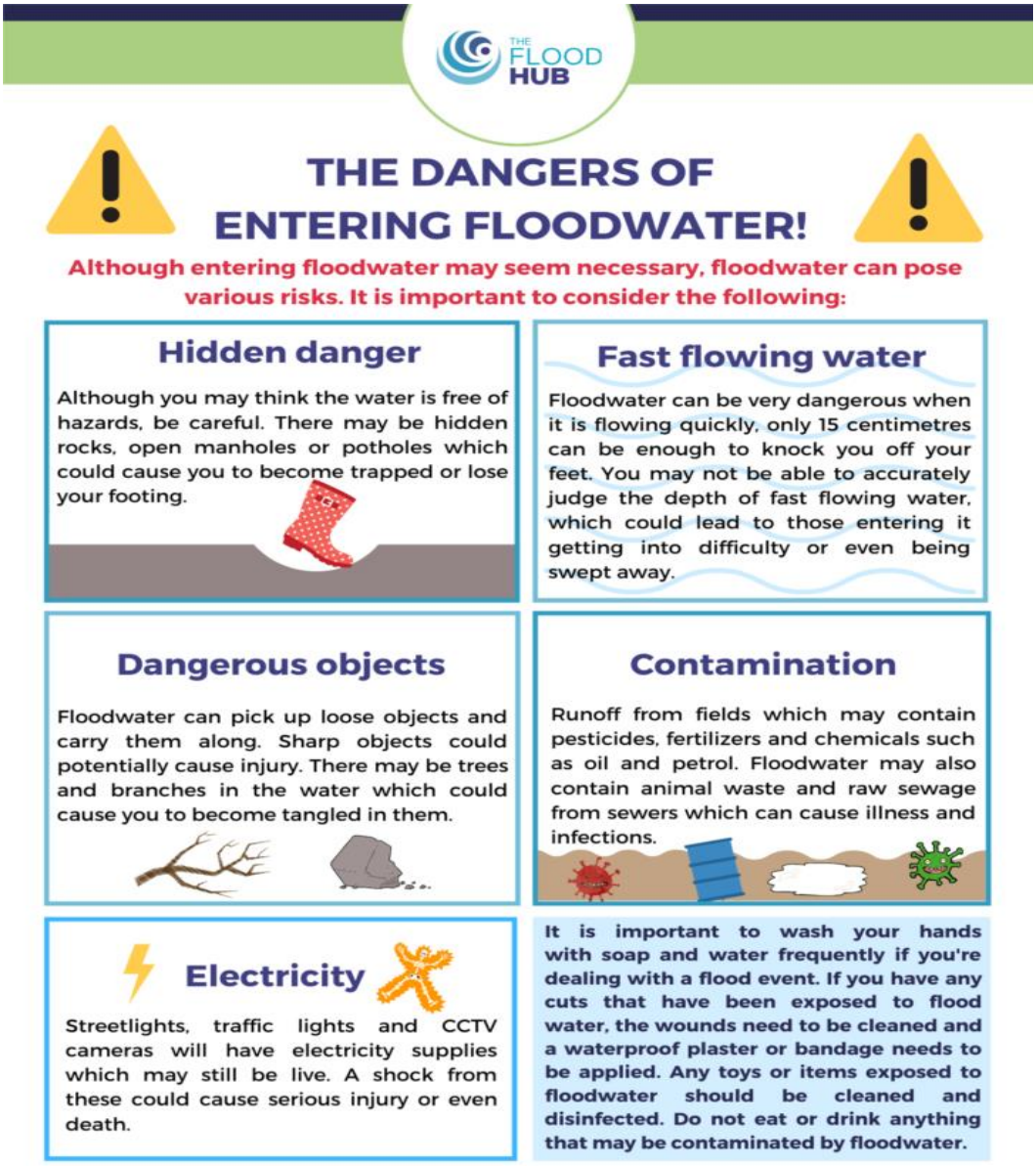
How to prepare yourself before, during and after the floods.

Before the Floods: Preparation Tips

- **Monitor Warnings:** Stay informed about weather alerts from authorities.
- **Prevent Blockages:** Keep drains clear of debris and report any hazards, like live wires or open drains, for quick repairs.
- **Prepare an Evacuation Kit:** Have essentials ready, including ID, important documents, clean water, non-perishable food, clothes, medications, and a flashlight.
- **Charge Devices:** Ensure your phone and power banks are fully charged.
- **Plan for Safety:** Be prepared to move to higher ground or shelters. Keep a list of shelters and emergency contacts handy.

During the Floods: How to Respond

- **Protect Valuables:** Store valuables and food in waterproof bags and elevate them.
- **Manage Stormwater:** Remove water from rooms using buckets and towels, and turn off gas and unplug appliances.
- **Avoid Floodwaters:** Stay away from floodwaters due to potential contamination. Don’t swim, walk, or drive through fast-moving or deep water.
- **Navigate Standing Water Safely:** If wading is necessary, use a pole to check depth and avoid ditches and debris.
- **Follow Instructions:** Listen to and cooperate with rescue personnel during evacuation.



After the Floods: How to Stay Safe

- **Prevent Disease:** After floods, the risk of vector-borne (e.g., dengue, malaria) and water-borne (e.g., typhoid) diseases rises. Maintain hand hygiene, drink boiled or purified water, cook food thoroughly, and eat safe foods.
- **Avoid Mosquitoes:** Use nets and repellents, and keep areas clean to reduce mosquito breeding.
- **Seek Medical Attention:** If you have persistent fever or diarrhea after flooding, seek medical care promptly.
- **Stay Informed:** Know evacuation routes, warning signals, and flood-prone areas in your community.
- **Ensure Water Safety:** Boil or chlorinate water for drinking and food prep to prevent disease

- **Practice Hygiene:** Avoid floodwater contact while washing dishes or preparing food, and wash hands after handling floodwater.
- **Avoid Hazardous Areas:** Steer clear of flooded areas to avoid hidden dangers like chemicals or electrical hazards.
- **Protect from Mosquitoes:** Use repellent, sleep under nets, and wear long clothing near stagnant water.

9. Way Forward

- **Enhanced Forecasting and Monitoring Systems:** Invest in upgrading meteorological tools and technology to improve the accuracy and timeliness of rainfall predictions.
- **Urban Flood Management Plans:** Develop and implement comprehensive urban flood management strategies, including the upgrading of drainage infrastructure in major cities such as Karachi & Lahore. Consider building rainwater harvesting systems to reduce the pressure on drainage systems during heavy rains

- **Riverine Flood Mitigation**: Strengthen riverine flood protection measures by reinforcing embankments, expanding river channel capacity, and maintaining floodplain zoning regulations.
- **Reinforcement of Flood Protection Embankments:** Prioritize the reinforcement and repair of embankments, particularly in flood-prone areas of Sindh and Balochistan. Conduct regular safety audits and maintenance to prevent breaches during future monsoon seasons.
- **Reforestation Initiatives:** Promote afforestation and reforestation in watershed areas to improve soil stability and reduce runoff, ultimately mitigating flood risks.

By addressing these recommendations, Pakistan can be better prepared for the challenges posed by the 2025 monsoon season, reducing the impact on lives, infrastructure, and the economy.

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20. United Nations Environment Programme
21. Climate Change Knowledge Portal
22. National Emergency Management Association