UiT The Arctic University of Norway

Department of Arctic and Marine Biology

Flood Resilience in Pakistan

Citizen Engagement, Government Initiatives, and Sustainable Development

Haseeb Ahmad

Master's thesis in Biology BIO-3950, November 2024

Table of Contents

List of Figures

Acknowledgements

I extend my heartfelt gratitude to my supervisor Tamer Abu Alam, who has been assisting me and encouraging me throughout this research. A special acknowledgment to my brother Awais Qurni and my friend Mohsin Naqvi, who spent two days with me and arranged medical camps for free treatment of the people from flood-affected areas in Balochistan. I am also grateful to Malik Ashir Murtaza, who assisted me in the collection of the climate data from Punjab, Pakistan.

My sincere appreciation goes to my friend Mariken whose support has been a crucial aspect during the time of writing my thesis.

I want to express my profound gratitude to my parents who always supported me and encouraged me throughout this journey.

I acknowledge the use of Al tools (i.e., ChatUiT and Grammarly) to assist in refining the language and improving the clarity of this thesis. All ideas, analyses, and interpretations presented are solely my own.

Abstract

This thesis analyses the impact of climate change, coupled with inadequate disaster management, on the rising frequency and severity of floods in Pakistan. The thesis focuses on the causes, socioeconomic impact, and government responses to floods by examining the interaction of natural and human elements. Due to the complexity of the research question, we have applied a multidisciplinary approach. The research draws on empirical climate data, community interviews, and policy analysis to propose a comprehensive strategy for effective flood mitigation in Pakistan.

The climate data analysis from Punjab province shows that rainfall is not the only cause of the floods; rather, it is accompanied by other factors like poor infrastructure, glacial melting, and upstream flow of water in the rivers. Citizen interviews highlight the severe social and economic repercussions of floods, including displacement, health risks, educational disruption, and agricultural loss. Women and children, in particular, face additional challenges, aggravated by cultural and economic constraints. The government's response, though well-intentioned, is often criticised for inadequate infrastructure, weak policy enforcement, and lack of public awareness campaigns.

The thesis findings highlight the need for a comprehensive flood management strategy. Stricter land-use regulations, the development of early warning systems, raising public awareness, and the improvement of infrastructure like dams and drainage systems are among the recommendations. Additionally, community-led initiatives and international collaborations are fundamental for building resilience. This study concludes that a multi-layered approach combining structural, policy-based, and community-centred strategies is vital for mitigating flood risks and adopting sustainable development in Pakistan.

Introduction:

1.1 Background and Rationale

As weather patterns are changing all over the world, climate change has led to greater environmental unpredictability, with floods becoming increasingly frequent and intense (Krisberg, 2018). These floods are symptoms of this climate crisis, driven by rising temperatures, increased glacial melting, shifting precipitation patterns, and coastal erosion. The impacts of such floods are extensive, undermining socio-economic stability (Thomas et al., 2013) and environmental situation worldwide. Pakistan, in particular, has been at the forefront of experiencing the severe effects of these climatic disruptions (Manzoor et al., 2022). Pakistan's unique geographical (Fig. 1.1) and meteorological characteristics make it particularly vulnerable to flooding, making it an important case study for understanding the larger ramifications of climate-induced natural disasters.

Pakistan's geographical layout, characterised by enormous river systems (Fig. 1.1), as well as its geological placement between South and Central Asia, have a considerable impact on its flood susceptibility (Kazemi, 2022). The country’s topography, which ranges from the snow-capped peaks of the north to the lush plains of the Indus River basin, has a significant impact on hydrological dynamics. The yearly monsoon rains, while necessary for agriculture, frequently cause catastrophic floods that affect millions (Manzoor et al., 2022). Socioeconomic factors, including population density and land use patterns, combined with geographical and climatic tendencies, exacerbate the risks and consequences of flooding disasters.

The flooding in Pakistan has extensive consequences that extend beyond water resource management (Irfan et al., 2019), impacting the national economy, infrastructure, and the livelihoods of the communities. Pakistan's geographic and climatic circumstances, combined with the large Indus River system, render it especially susceptible to catastrophic and recurring flooding (Khan & Adams, 2019), which has significant social and economic consequences (Manzoor et al., 2022), interrupting livelihoods, causing infrastructure damage, and putting a burden on public resources. To fully understand the scope of these impacts, a multidisciplinary approach is required, which includes climate analysis to assess changing flood patterns and causes, interviews with affected communities to capture the human and economic toll, and a critical review of government flood mitigation policies and initiatives. This thesis aims to give a thorough assessment of flood impacts in Pakistan by investigating climate dynamics, social

vulnerabilities, economic consequences, and the efficacy of government solutions to these issues.

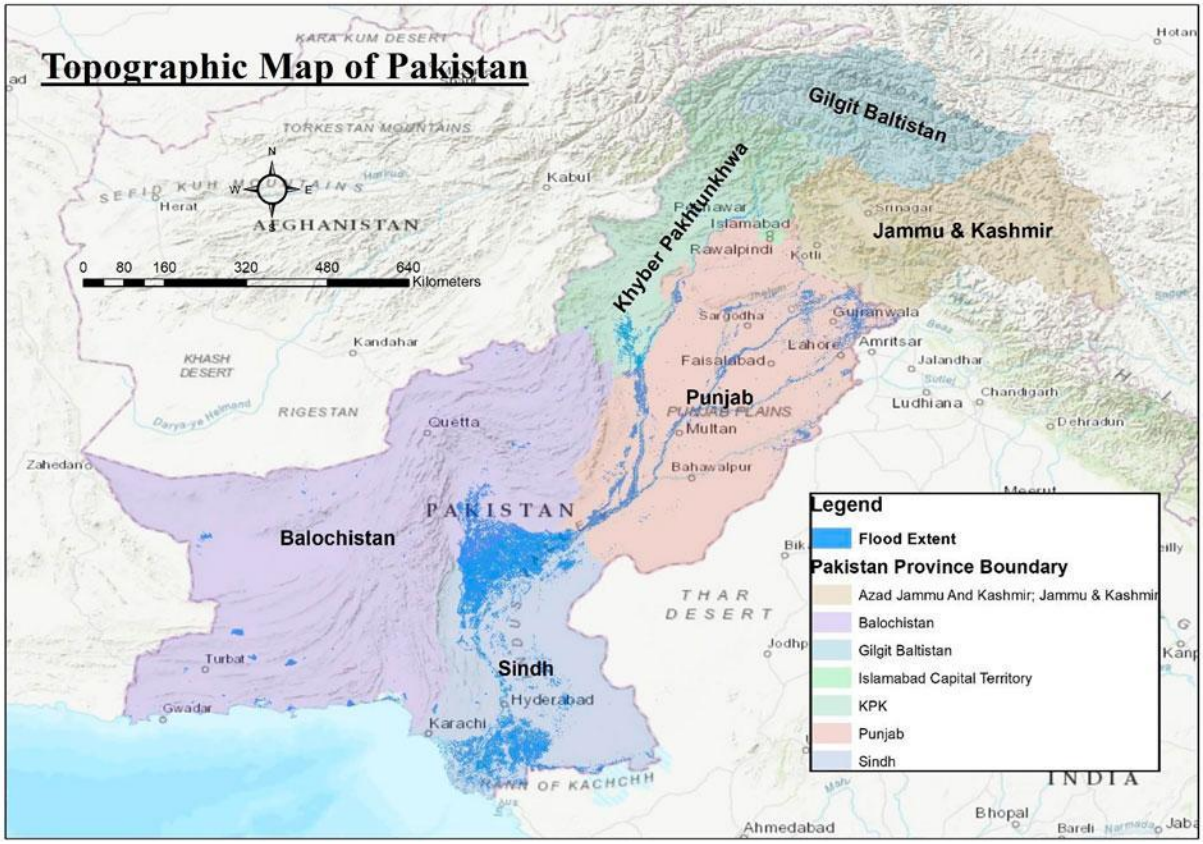

Fig. 1.1: Topographic map of Pakistan with recent flood events. Modified after Manzoor et al., 2022.

1.1.1 Historical Context and Recent Catastrophes

Pakistan has experienced several significant flooding disasters over the years, each impacting the country's environment (Aslam et al., 2020). The catastrophic floods of 1976, 2010, and 2022 were among the worst disasters the country had until now, highlighting the country's vulnerability to climate disasters. The 2010 flood, one of the worst floods in Pakistan's history, destroyed major portions of the country and underlined the human and economic costs of natural disasters (Mughal, 2021). The 2022 floods shook the whole country and posed many challenges for the communities and government. These recent floods show that the country is getting more vulnerable to the climate crisis.

Fig. 1.2: Aerial View of an affected area of Punjab during 2010 country-wide floods. Photo credits: https://www.theaustralian.com.au/

The comparison of floods in 2010 and 2022 reveals crucial information on the changing character of flood-related disasters in Pakistan. The tragedies caused significant destruction, reflecting changes in the magnitude of such disasters and the nation's ability to manage them (Deen, 2015). These comparisons reveal progress in disaster preparedness and response, while underscoring the increasing challenges posed by climate change, thereby requiring a reassessment of current policies and practices.

1.1.2 Climate Change: Future Impacts and Socio-economic Ramifications

Climate change has had a dramatic and severe impact on Pakistan's environmental and socioeconomic landscapes. Rising temperatures, changed precipitation patterns, and sea-level rise pose a number of difficulties to the country, ranging from higher energy consumption and decreasing agricultural output to increasing risks of flooding and coastal erosion (Sheer et al., 2023). These changes not only endanger the physical infrastructure but also have widespread consequences for public health, water security, and livelihood. Future estimates show a dismal picture, with considerable rises in temperature and sea level projected, emphasising the need for immediate action to reduce these effects and adapt to the changing climate.

Floods in Pakistan have far-reaching socio-economic and environmental consequences, affecting all aspects of life and livelihood. Floods have serious immediate and long-term

implications, ranging from housing and infrastructure destruction to agriculture and livestock loss (Sheer et al., 2023). Beyond the obvious consequences, floods increase existing social inequities, disrupt education and healthcare systems, and add to environmental degradation (Sayed, 2014). Addressing and comprehending these challenges necessitates a multidisciplinary approach that incorporates insights from climate science, urban planning, economics, and social sciences to develop comprehensive strategies that not only address the immediate effects of flooding but also build resilience against future events.

1.2 Research Objectives

The rising frequency and intensity of floods in Pakistan, intensified by climate change, present a complex challenge with extensive social, economic, and environmental ramifications. Recognising the complexity of these difficulties and the need for an integrated strategy, this thesis aims to dissect the topic from several perspectives using a multidisciplinary methodology. The study's objectives are to give a full understanding of the causes and consequences of the floods, as well as to contribute to the development of effective mitigation and adaptation solutions. The thesis focuses on the following objectives:

1. 1. Investigate the Causes of Floods: Determine the key natural and anthropogenic factors contributing to the increased frequency and severity of flooding in Pakistan. This will involve an inspection of climate changes, such as how global warming has impacted precipitation patterns, as well as land-use changes that increase flood risk.

2. Evaluate Social, Economic, and Environmental Implications: Investigate the widespread effects of floods on Pakistani society, the economy, and the environment. This includes assessing the direct and indirect effects on local communities, the agricultural industry, infrastructure, and natural ecosystems, as well as understanding the long-term implications for the region's sustainable development.

3. Analyse governmental roles in the causation and resolution of flood risks: Assess the impact of governmental policies, legislation, and initiatives on the escalation of flood risk and the management of flood-related issues. This will entail an examination of current disaster management frameworks, urban planning methodologies, and environmental legislation, alongside an assessment of the efficacy of governmental response and recovery initiatives.

4. Propose Solutions: Drawing from the outcomes of the previously specified objectives, present pragmatic and sustainable solutions to alleviate the effects of flooding and support the resilience of vulnerable communities. This will encompass suggestions for judicial reforms, improvements to infrastructure, community-driven adaptation strategies, and innovative technologies for more effective flood risk management.

1.3 Scope and Significance

It is very important to study the floods in Pakistan and the reasons behind these catastrophic floods to increase the flood resilience in the country. This study examines the causes and consequences of floods and explores potential solutions for these climate crises. The multidisciplinary approach employed here aligns with the intricacy of the topic and connects various fields of study, including environmental science, social sciences, economics, and policy analysis.

This study's significance extends beyond academics, with practical and policy ramifications. As floods continue to destroy significant areas of Pakistan, claiming millions of lives and creating massive economic losses, the need for educated and proactive answers has never been greater. This study aims to enhance the understanding of floods among policymakers, emergency management officials, and community leaders. The thesis aims to create the framework for improved resilience and preparedness methods that can lessen the effects of future flooding occurrences by mapping risk areas, reviewing governmental roles, and proposing comprehensive remedies.

The environmental analysis is crucial to understanding the impacts of these disasters on the atmosphere, air quality, biodiversity, and some other aspects related to the environment. Environmental analysis is critical for understanding the linkage among human lives, climate change, and floods.

This study promotes a collaborative effort to address one of our time's most serious concerns by emphasising the necessity for a multidisciplinary approach and suggesting solutions that take into account social, economic, and environmental elements. As a result, it not only contributes to the scholarly discourse on flood management and climate adaptation but also serves as a call to action for all those dedicated to building a more resilient and sustainable future in the face of growing climate hazards.

1.4 Research Methodology and thesis´ Structure

In this master's thesis, we take a holistic, interdisciplinary approach to addressing the serious issue of flooding in Pakistan, which has been exacerbated by the consequences of climate change locally and globally. The study's goal is to investigate the various causes of increased flood frequency and severity, assess their broad social, economic, and environmental consequences, and create effective mitigation and adaptation solutions. This goal is pursued by a thorough assessment of both natural and human-caused elements that contribute to flood susceptibility, as well as a complete analysis of the effects of such disasters on the Pakistani people and landscape.

The research methodology combines empirical climate data analysis with citizen interviews. An in-depth study of government policies, disaster management frameworks, and urban planning initiatives is carried out to assess the responsibilities and effectiveness of government activities in exacerbating and alleviating flood hazards.

The thesis is divided into seven chapters, as follows: The first chapter provides background, reasons, and objectives, establishing the context for the inquiry. The second chapter discusses the research strategy and methodology, including the data collection methods and analytical methodologies used.

The next chapters go into the core of the research findings. Chapter three presents climatic data and analyses it to determine the causes. Chapter four emphasises the importance of citizen engagement in improving flood resilience, backed up with case studies of community-based initiatives. Structured interviews with individuals are conducted to examine the socioeconomic and environmental effects of flooding. The fifth chapter examines national disaster management frameworks and flood control infrastructure development, as well as a critical assessment of government actions.

The synthesis and discussion in Chapter 6 bring together significant study findings, linking flood resilience methods with sustainable development goals, and providing clear policy recommendations. The final chapter of the thesis summarises the research findings, discusses their implications for future research and practice, and makes final remarks.

This structure provides a comprehensive examination of flood resilience in Pakistan, with the goal of providing practical solutions for decreasing flood impacts and increasing country’s resistance to these climate disasters.

Chapter 2: Methodology

2.1 Research Design

As described in Chapter 1, this study uses a multidisciplinary research approach to thoroughly investigate the effects of floods in Punjab, Pakistan. Given the varied character of flood events, their causes, and consequences, this study combines factual climate data with citizen science involvement and a review of government records. This integrated approach is essential for capturing the environmental, social, and policy aspects of flood impacts, resulting in a more understanding of flood resilience in Pakistan.

To explore the origins, impacts, and reactions to flooding, the research technique was designed around three major components.

1. **Empirical Climate Data Analysis**: To assess the environmental factors and the weather patterns linked with flooding.
2. **Citizen Science and Community Engagement**: Documenting the experiences of flood victims and their socio-economic challenges because of floods.
3. **Government Initiatives Analysis**: To assess policy frameworks, disaster management policies, and the effectiveness of government flood response efforts.

By combining these methods, the study aims to provide a detailed understanding of flood dynamics in Pakistan and contribute valuable insights into flood-resilience strategies.

2.2 Data Collection Methods

2.2.1 Empirical Climate Data Analysis

To better understand the environmental causes and patterns of floods in Punjab, we evaluate climatic data from 12 regional districts. This data contains characteristics such as humidity, average rainfall, temperature, and wind speed. These metrics are critical for identifying climate trends and determining how precipitation patterns and temperature variability influence the frequency and severity of floods.

Climate data give a foundation for understanding the environmental components that influence floods, as well as the ability to examine past trends and potential future threats. By examining this data, we want to identify the links between climate change and increased flood events in Pakistan, thereby contributing to a better understanding of the region's flood risk.

2.2.2 Citizen Science and Community Engagement

Citizen science is essential for understanding and contextualizing the impacts of floods by integrating global scientific concepts with local expertise. It allows communities to convey their significant insights regarding the economic and social challenges arising from climate crises (De Sherbinin et al., 2021).

This research encompassed interviews with inhabitants of Marrian, a flood-prone riverine settlement situated near Tehsilpur city in southern Punjab and Jaffarabad in Balochistan. The qualitative research design employed (Creswell & Poth, 2016) utilized semi-structured interviews to investigate intricate social phenomena, including livelihood disruption, health consequences, and coping strategies following floods.

Participant Selection and Sampling: Purposive sampling (Tongco, 2007) was employed to select participants from diverse community sectors, including farmers, healthcare professionals, community leaders, and local politicians. This technique ensured a wide understanding of flood impacts among different demographic groups.

Categories of Interview Questions: The interview questions were centred around several themes.

- *Causes of the Problem*: Views on both natural and human-induced causes of floods, such as deforestation and inadequate river management.
- *Social Damage Due to Floods*: Examination of educational disruptions, health issues, and impacts on vulnerable groups, including women and children.
- *Economic Loss and Damage:* An examination of the financial impact on people and businesses, notably in agriculture and local sectors.
- *Government Actions and Initiatives:* Attitudes about government responsiveness, infrastructural assistance, and disaster relief adequacy.

- *Local Knowledge and Suggestions:* Community-driven flood mitigation and resilience techniques, with an emphasis on local adaptation activities.
- *Future Plans and Security:* Community expectations for long-term rehabilitation, safety measures, and access to critical services such as water, food, and education.

The interviews offer a comprehensive examination of the social and economic issues and challenges encountered by individuals in flood-prone regions.

Ethical Considerations: Ethical protocols were rigorously adhered to throughout the research and interview processes. We informed the interviewees about the research objectives and obtained their consent to use those interviews for this purpose. We ensured privacy by anonymizing personal information in the results reporting, adhering to European GDPR rules.

2.2.3 Government Initiative Analysis

It is very important to analyze the government initiatives to have complete insights of different aspects related to disaster management in the country and to suggest solutions to mitigate the effects of disasters in the country.

Scope of Initiatives Analysis: The investigation includes reviewing national and regional disaster management plans, environmental policies, and flood reports from previous catastrophes. This gives a critical review of these initiatives:

- *Effectiveness of Existing Policies*: The efficacy of existing policies and laws in limiting flood risks and other climate crises.
- *Government Response Strategies*: Assessment of government responses like emergency preparedness and infrastructure development.
- *Gaps and Recommendations*: Identifying flaws in the current framework and places where different upgrades can increase flood resilience.

The findings of this analysis help in understanding the role of government and authorities in flood resilience and other emergency relief efforts.

2.3 Multidisciplinary Approach

The integration of empirical climate data, citizen research, and policy analysis offers a thorough comprehension of the causes, effects, and responses to flooding in Pakistan. This methodology helps to gather more insights about the social, political, and economic scenario of the country by combining both qualitative and quantitative data. This strategy assures that the study can provide valuable insights into the complexity of flood resilience, thereby helping to design successful and long-term flood risk management policies in Pakistan.

Chapter 3: Climate Dynamics and Their Impact on Flood Events in Pakistan: A Data-Driven Analysis

3.1 Introduction and methodology

Climate data, including wind speed, precipitation, temperature, and humidity, are essential for comprehending the factors that contribute to flooding. These parameters not only influence the frequency and intensity of floods, but they also provide important insights into the larger climate dynamics that may be causing these severe events. Analysing long-term climatic data from various stations throughout Pakistan enables the identification of patterns, correlations, and trends associated with significant flood events.

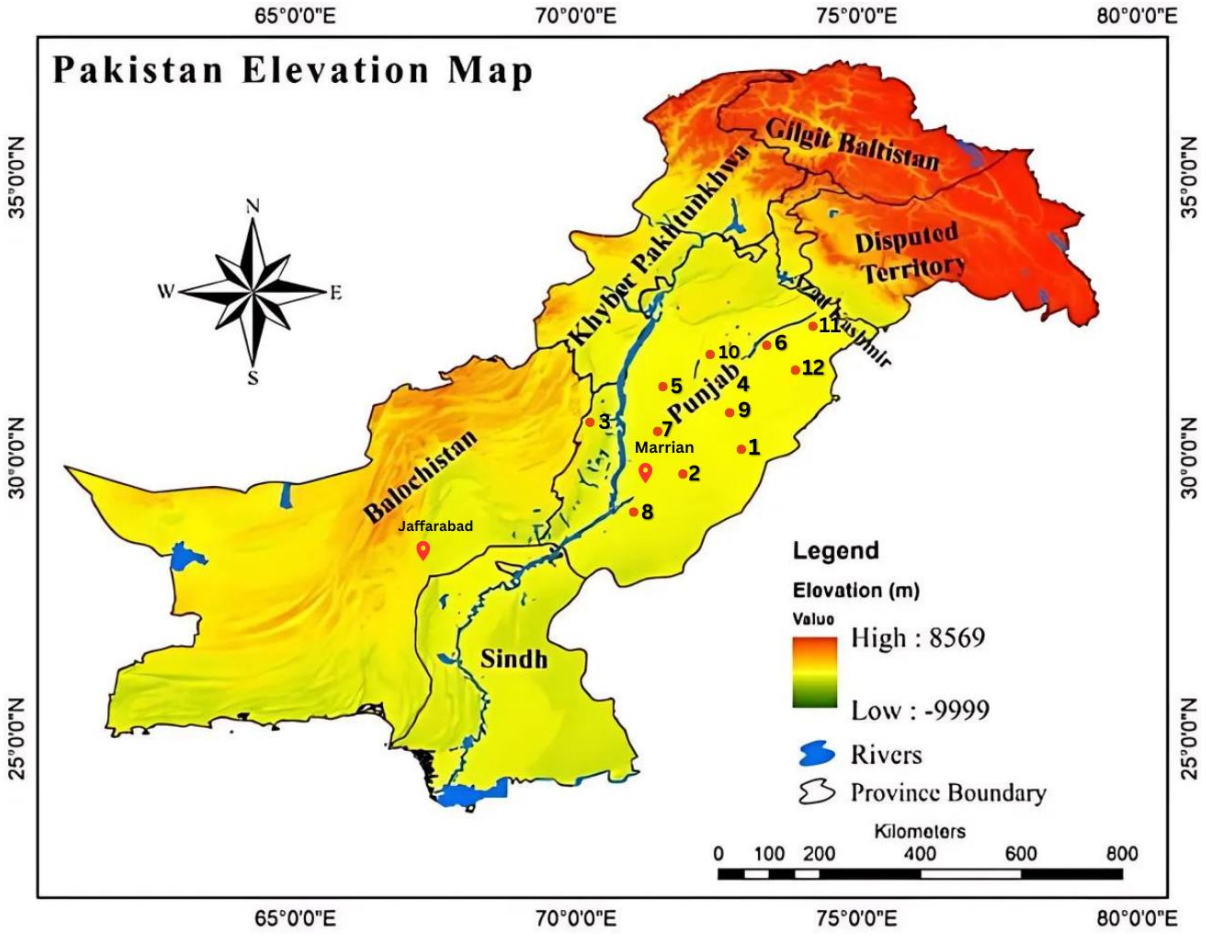

Fig. 3.1 depicts a digital elevation model of Pakistan, including the 12 weather stations used to obtain climate data. The station numbers correspond to those listed in Table 3.1.

We obtained data on seven climate parameters (average rainfall, lowest temperature, maximum temperature, humidity at 08:00 AM, humidity at 05:00 PM, wind speed at 08:00 AM, and wind

speed at 05:00 PM) from 12 weather stations (Fig. 3.1 & Table 3.1). and Appendix 1 shows the climate data collected from these sites. Furthermore, carbon dioxide emission statistics (Ritchie, H., 2022) for Pakistan are used to investigate the impact of CO2 and its relationship to flood episodes.

Table 3.1 shows the 12 weather stations used for climate data gathering. The station numbers match to those shown in Figure 3.1.

Station number	Station	Station number	Station
1	BAHAWALNAGAR	7	MULTAN
2	BAHAWALPUR	8	RAHIM YAR KHAN
3	DERA GHAZI KHAN	9	SAHIWAL
4	FAISALABAD	10	SARGODHA
5	JHANG	11	SIALKOT
6	JHELUM	12	LAHORE

To better understand the link between climate variables and flood events in Pakistan, a multifaceted method combining descriptive statistics and time-series analysis was used. The method began with cleaning and organising the climatic data, ensuring that all records were complete and precisely organised by year and month for each station. Monthly and annual averages of each climate parameter—wind speed, rainfall, temperature, and humidity—were then calculated to detect long-term trends or patterns that could be linked to flood episodes. To further investigate these links, time-series plots for each parameter were produced and overlayed with known flood episodes in Pakistan to determine correlations between climate change and flood incidence (Fig. 3.2-4 and Appendix 1).

3.2 Data presentation

Bahawalnagar station:

The wind speed at 8:00 a.m. in the Bahawalnagar area has changed over the years with a mean of 0.98 m/s, with relatively moderate variability and occasional maxima in particular months, such as July and August. The wind speed at 5:00 PM was higher than in the morning, with a mean of 2.16 m/s, indicating more substantial changes, especially during the summer months. Monthly total rainfall data exhibited considerable variability (Fig. 3.2), with certain months experiencing substantial precipitation (e.g., July and August) while others received minimal to no rainfall. The monthly average minimum temperature fluctuated between 5.6°C in the coldest months and 29.9°C in peak summer, whereas the maximum temperature ranged from 17.8°C to 43.6°C, demonstrating significant annual temperature variation. Humidity at 8:00 a.m. averaged around 75%, with lower values in the warmer months and higher values during the winter and monsoon seasons. In contrast, humidity at 5:00 PM averaged roughly 43%, with a noticeable drop during the hotter months and higher values during the monsoon season.

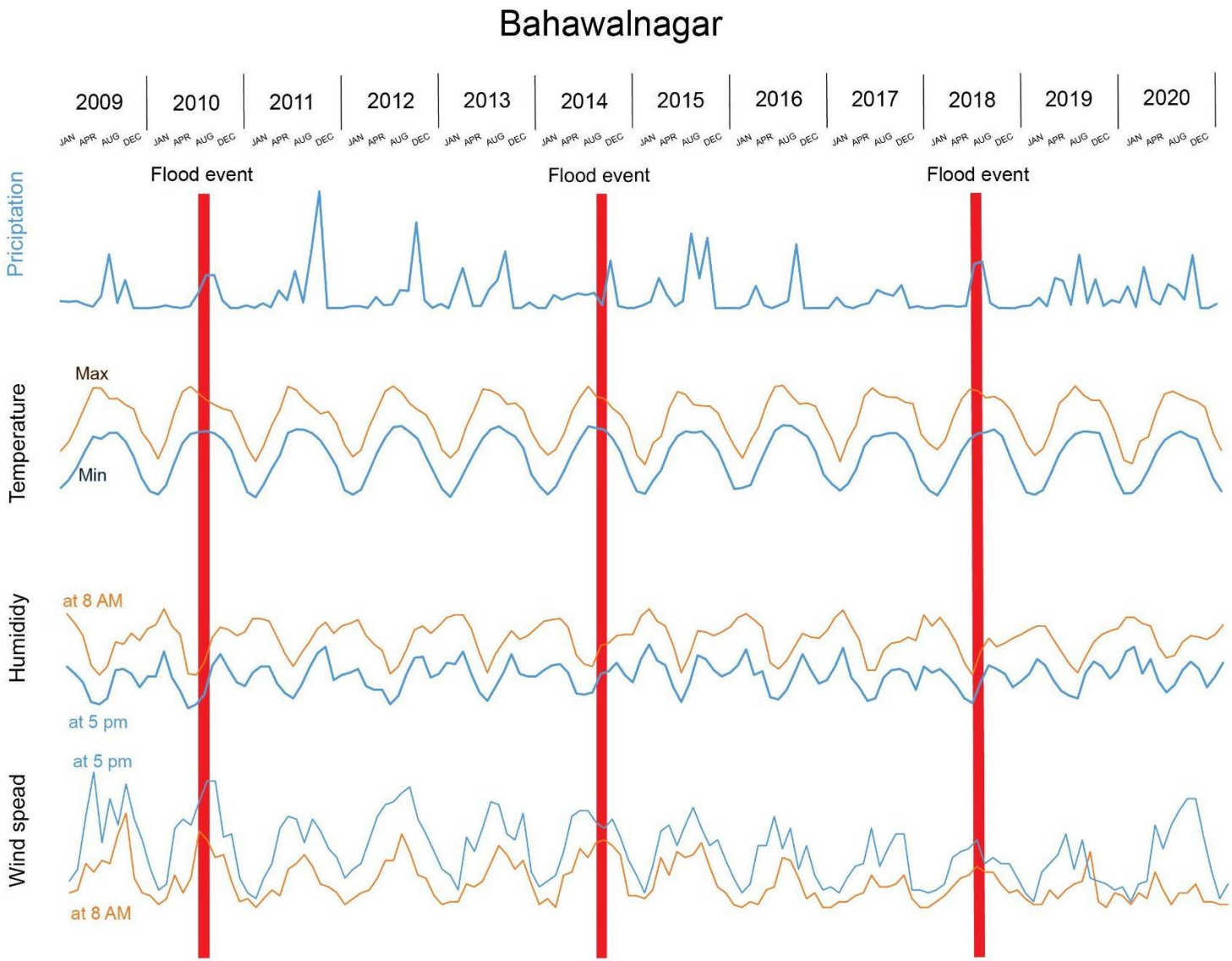

Fig. 3.2: Time-series representation of climate data from the Bahawalnagar station (2009–2020). This figure displays annual patterns in precipitation, maximum and minimum temperature, humidity (measured at 8 AM and 5 PM), and wind speed (measured at 8 AM and 5 PM). The red bars indicate significant flood events in 2010, 2014, and 2018. Note that some years had heavy rainfall but no floods

Bahawalpur station:

At 8:00 a.m. in the Bahawalpur region, the wind speed averages 2.14 m/s, demonstrating considerable seasonal variation, with an escalation during the summer months (June to August) and a reduction in winter. The wind speed at approximately 5:00 PM exhibits a comparable pattern, frequently exceeding an average of 3.12 m/s, with sustained peaks during the warmer months. Monthly total precipitation exhibits considerable variability, with certain months, notably July and August, experiencing substantial rainfall, while others receive minimal to no precipitation, indicative of a monsoonal pattern. The monthly mean minimum temperature ranges from 4.3°C in the winter to 30°C in the summer, indicating that the region's temperature varies significantly by season. The monthly average maximum temperature ranges from 18.8°C to 43.4°C, with the highest values in May and June. Humidity levels at 8:00 a.m. typically exceed 74%, with the lowest levels observed in May and June, coinciding with peak temperatures. The humidity at approximately 5:00 PM is reduced, averaging around 44%, and exhibits a comparable seasonal trend, decreasing in the warmer months and increasing during the monsoon season.

DG Khan station:

At 8:00 a.m., the wind speed in Dera Ghazi Khan varies moderately, ranging from 1.2 m/s to 6.5 m/s. Higher speeds are usually seen throughout the summer months, especially from June to August. The wind speed at 5:00 PM is typically greater, ranging from 1.5 m/s to 7.1 m/s, with peak values occurring during the summer months. Monthly total rainfall varies significantly, with some months seeing considerable rainfall (particularly in July and August) and others receiving little or no precipitation, indicating a strong monsoonal effect. The monthly average minimum temperature ranges from 5°C in winter to 29.9°C in summer, reflecting a significant temperature variation. The monthly average maximum temperature varies from 17.4°C to 43.7°C, peaking in May and June. At 8:00 a.m., humidity fluctuates between 46% and 91%, exhibiting lower levels in the warmer months and elevated levels during the monsoon season. Humidity at 5:00 PM exhibits a similar pattern, with a range of 23% to 66%, reflecting drier conditions in the afternoon, especially during the warmer months. The 2010 flood event is the only flood that correlates with a high rate of precipitation.

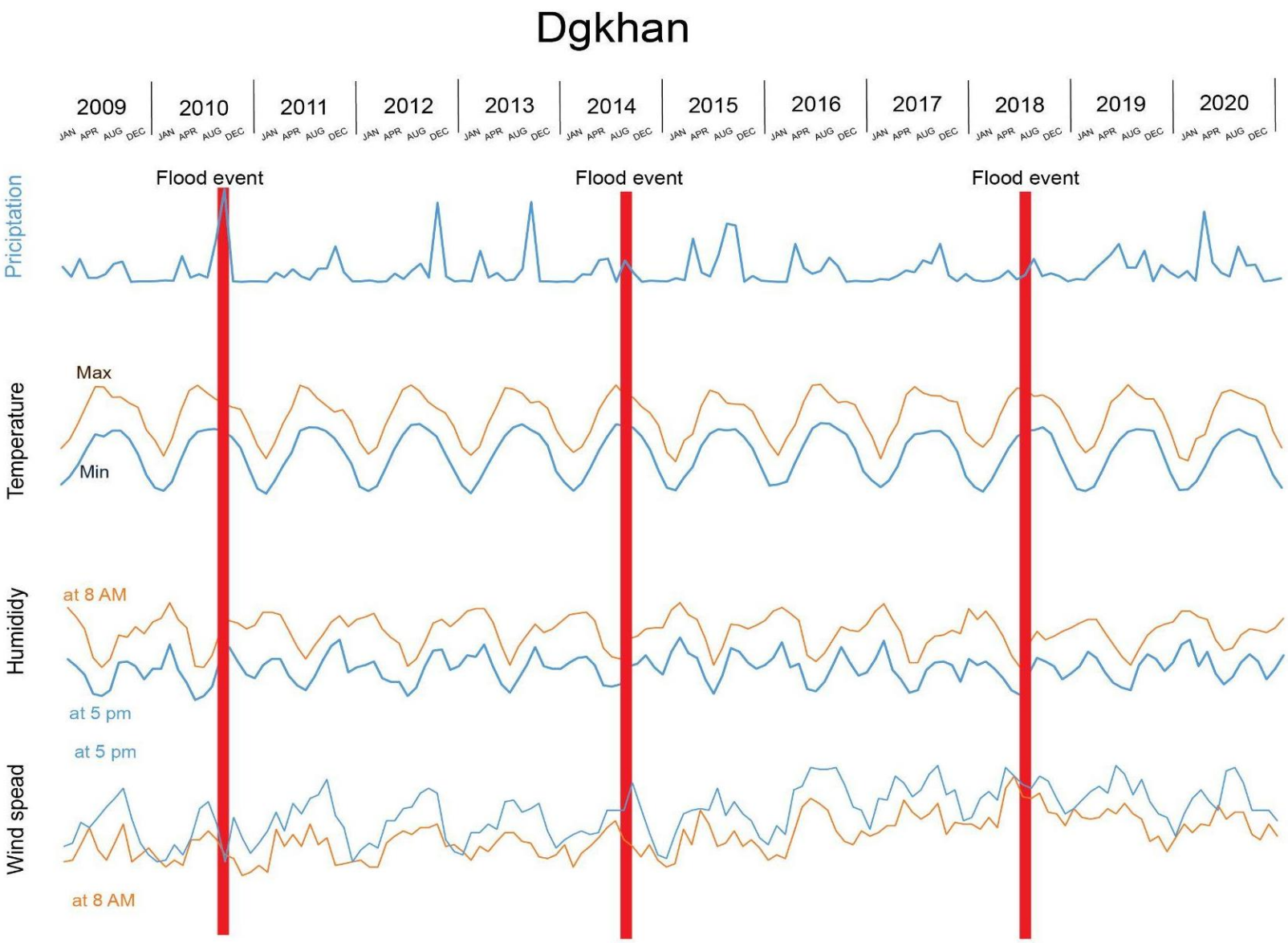

Fig. 3.3: Time-series representation of climate data from the Dera Ghazi Khan station (2009–2020). This figure displays the same parameters as Fig. 3.2. Red bars indicate major flood events in 2010, 2014, and 2018. Note: Some years have high precipitation but no flood events. The flood event of 2010 was associated with a high precipitation rate

Faisalabad station:

The wind speed at 8:00 AM in the Faisalabad area varies significantly throughout the year, ranging from as low as 0.1 m/s to peaks of roughly 6.5 m/s, with greater winds often occurring between April and August. Wind speeds at 5:00 PM are normally greater, ranging from 0.4 m/s to 7.6 m/s, and they peak during the warmer months. Monthly precipitation exhibits considerable variability, with certain months, notably July and August, experiencing substantial rainfall, while others receive minimal to no precipitation. The minimum monthly mean temperature ranges from 3.5°C in winter to 28.6°C in summer, reflecting significant seasonal temperature variation. The maximum monthly mean temperature ranges from 16.3°C to 41.9°C, with the highest values recorded in May and June. At 8:00 a.m., humidity ranges from 36% to 97%, with greater levels during the monsoon season and lower levels throughout the summer. Humidity at 5:00 PM ranges from 19% to 70%, with lower afternoon humidity, especially during hotter months.

Jhang station and Jhelum Station:

The both stations have similar parameters. At 8:00 a.m., the wind speed is ranging from 0 to 2.8 meters per second. The strongest winds are frequently observed between June and August. The wind speed around 5:00 PM varies somewhat, ranging from 0 to 3.7 m/s, with the maximum winds occurring during the summer months. Monthly rainfall varies greatly, with heavy rainfall occurring largely during the monsoon months of July and August, while many other months receive little to no precipitation. The monthly average minimum temperature ranges from approximately 3.4°C in winter to 28.3°C in summer, indicating a standard seasonal temperature pattern. The monthly average maximum temperature ranges from 16.7°C to 42.1°C, reaching its peak in May and June. At 8:00 a.m., humidity levels range from 46% to 95%, with maximum values often recorded during the monsoon season. Similarly, humidity around 5:00 PM ranged from 21% to 70%, with lower values being observed in the afternoon, especially during hotter months.

Multan station:

At 8:00 a.m. in Multan, wind speeds generally range from 0.1 to 10.3 m/s, with maximum values recorded between June and August. At approximately 5:00 PM, the wind speed exhibits a comparable trend, fluctuating between 0 and 10.1 m/s, with a maximum during the summer months. Monthly rainfall varies significantly, with peak values reported during the monsoon months of July and August, while other months frequently get little or no rain. The monthly average minimum temperature varies from approximately 4.6°C in winter to about 30.8°C in summer, adhering to a typical seasonal pattern. The monthly average maximum temperature ranges from 18.0°C to 42.3°C, reaching its peak in May and June. At 8:00 a.m., humidity levels fluctuate between 42% and 94%, with peak values typically observed during the monsoon season. Similarly, humidity around 5:00 PM ranged from 19% to 62%, with lower levels being observed in the afternoon, especially during hotter months.

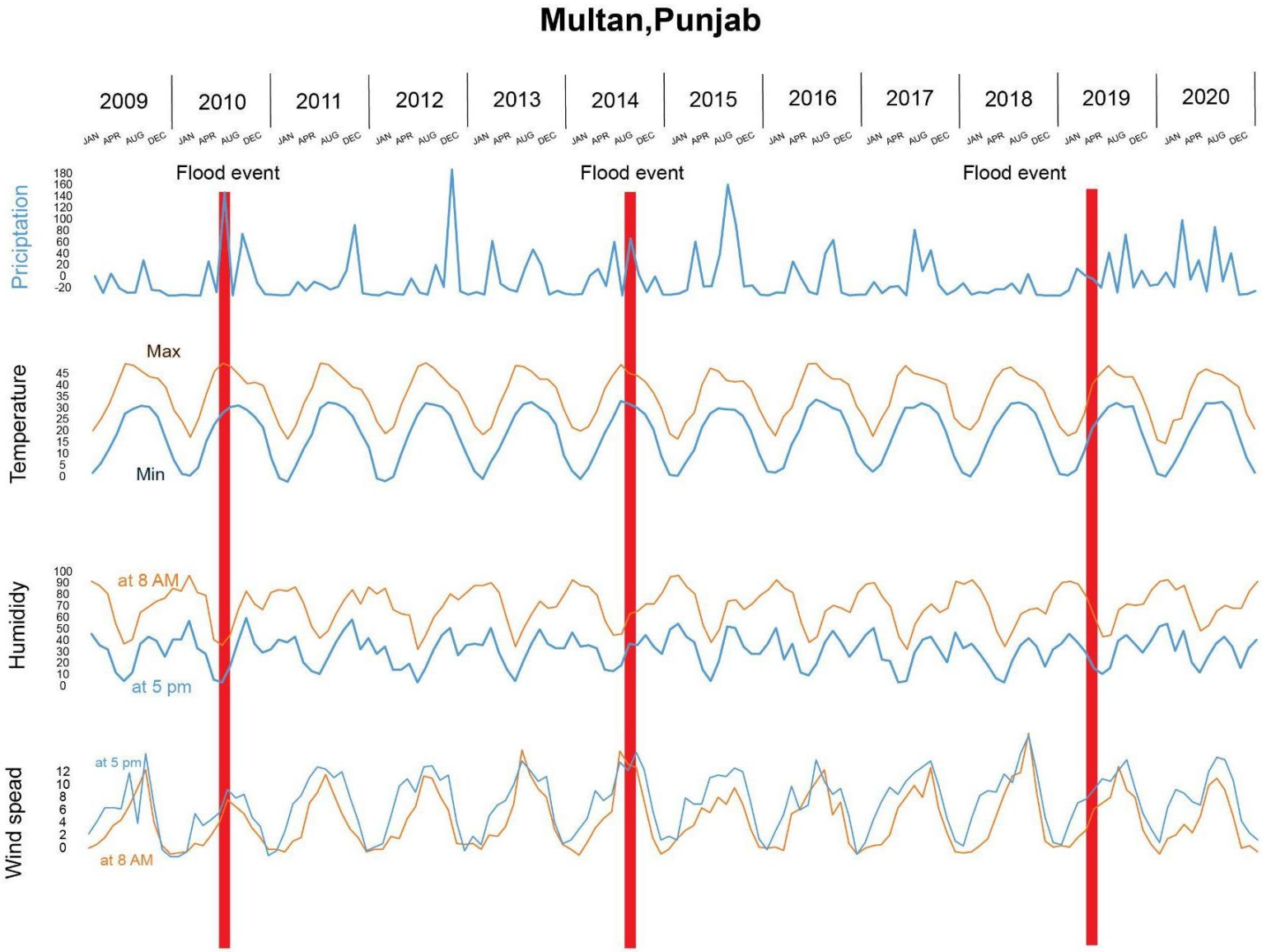

Fig. 3.4: Time-series representation of climate data from the Multan station (2009–2020). This figure displays the same parameters as Fig. 3.2. Red bars indicate major flood events in 2010, 2014, and 2018. Note: Some years have high precipitation but no flood events.

Rahim Yar Khan station:

At 8:00 a.m., wind speeds in the Rahim Yar Khan region range from 0.1 to 6.3 m/s, peaking between May and July. The wind speed at approximately 5:00 PM exhibits a comparable pattern, fluctuating between 0 and 5.6 m/s, with a maximum during the summer months. Monthly rainfall varies greatly, with the largest amounts falling in July and August, while other months frequently get little or no precipitation. The monthly mean lowest temperature fluctuates from roughly 4.4°C in the winter to around 29.3°C in the summer, indicating a distinct seasonal variation. The monthly average maximum temperature varies from 20.4°C to 44.9°C, peaking in May and June. At 8:00 a.m., humidity ranges from 45% to 90%, peaking during the monsoon season. Humidity at approximately 5:00 PM varies between 18% and 63%, with low levels noted during the peak heat of the day, particularly in the summer months.

Sahiwal station:

At 8:00 a.m. in the Sahiwal region, wind speeds generally range from 0 to 4.2 m/s, with elevated values noted from April to August. At around 5:00 PM, the wind speed demonstrates a consistent pattern, varying between 0 and 5.2 m/s, with a maximum during the summer months. Monthly precipitation exhibits significant variability, with the most considerable rainfall occurring from July to September, whereas the winter months typically receive minimal or no precipitation. The average monthly minimum temperature varies from approximately 3.2°C in winter to around 28.1°C in summer. The monthly average maximum temperature varies from 16.2°C to 42°C, with peak temperatures recorded in May and June. At 8:00 a.m., humidity varies from 46% to 96%, reaching its peak during the monsoon season. At approximately 5:00 PM, humidity fluctuates between 20% and 71%, with diminished levels observed in the afternoon, particularly during warmer months.

Sargodha station:

At 8:00 a.m., wind speeds in the Sargodha region typically vary from 0 to 3.2 m/s, with peak values observed from April to July. The wind speed at approximately 5:00 PM exhibits a comparable trend, fluctuating between 0 and 3.9 m/s, with a peak during the summer months.

Monthly rainfall varies significantly, with the monsoon season, particularly from July to September, producing the most precipitation, while the winter months frequently see little or no precipitation. The monthly mean lowest temperature fluctuates from roughly 4.7°C in winter to about 28.6°C in summer, indicating a seasonal pattern. The monthly average maximum temperature ranges from 16.8°C to 43.1°C, with the highest temperatures recorded in May and June. The humidity at 8:00 AM varies from 36% to 97%, reaching its peak during the monsoon season. Humidity around 5:00 PM ranges from 28% to 75%, with reduced levels observed during the warmer months.

Sialkot station:

In the Sialkot region, the wind speed at 8:00 a.m. varies from 0 to 2.3 m/s, with maximum values observed between July and September. The wind speed at approximately 5:00 PM exhibits a comparable pattern, fluctuating between 0 and 3.8 m/s, with summer peaks observed from April to August. Monthly rainfall varies greatly, with the highest values occurring during the monsoon season, particularly in July and August, while the winter months frequently see little or no precipitation. The monthly mean minimum temperature ranges from about 5°C in the winter to around 26.4°C in the summer, indicating a strong seasonal pattern. The monthly average maximum temperature ranges from 15.7°C to 42.1°C, with the highest temperatures generally recorded in May and June. Humidity at 8:00 a.m. varies from 40% to 99%, peaking during the monsoon season. At around 5:00 PM, humidity levels ranged from 18% to 77%, with lower values observed in the afternoon, especially during the warmer months.

Lahore station:

At 8:00 a.m., wind speeds in the Lahore region vary from 0 to 3.7 m/s, with higher values observed from April to September. At 5:00 PM, the wind speed exhibits a comparable pattern, fluctuating between 0 and 5.2 m/s, with maximum values occurring in April, May, and July. Monthly rainfall varies greatly, with substantial rains during the monsoon season, particularly in July and August, and little rain in the winter months. The average monthly minimum temperature ranges from 6.9°C in winter to 28.7°C in summer, reflecting a standard seasonal trend. The monthly average maximum temperature ranges from 16.2°C to 41.8°C, reaching its

peak in May and June. Humidity at 8:00 a.m. fluctuates between 38% and 91%, peaking during the monsoon season. At around 5:00 PM, humidity levels fluctuated between 20% and 72%, with reduced humidity observed in the afternoon, especially during the warmer months.

3.3 Discussion and Interpretation - Climate Dynamics

Wind speed exhibits a seasonal pattern across all stations, with elevated values recorded during the summer months, specifically from June to August. The increase in wind speed coincides with the monsoon season, during which atmospheric activity increases, leading to more powerful winds. Southern stations, including Multan and Rahim Yar Khan, experience heightened wind speeds, particularly in summer, owing to their susceptibility to monsoon currents and absence of substantial natural barriers (Latif & Syed, 2016; Ullah et al., 2021). Northern sites, such as Sialkot and Lahore, on the other hand, typically report lower wind speeds. particularly during the winter months, because of the Himalayas' protecting influence (Ashraf et al., 2012).

Rainfall varies notably across all stations, with the maximum rainfall occurring during the monsoon months of July and August. Pre-monsoon months such as May and June also get some rainfall, owing primarily to localised thunderstorms; however, the post-monsoon period (September to October) sees a significant decrease in precipitation. The winter months (December to February) are usually dry, with rare rainfall induced by western disturbances (Snead, 1968). Northern and northeastern stations, including Sialkot and Lahore, exhibit significantly elevated precipitation levels relative to southern stations such as Multan and Rahim Yar Khan. This discrepancy primarily results from the orographic effect and the northern stations' proximity to the monsoon trough (Ashraf et al., 2012), which enhances rainfall, especially in Sialkot. The southern regions, conversely, are situated in a rain shadow area (Salma et al., 2012), resulting in reduced overall precipitation.

Temperature patterns among stations show a definite seasonal cycle. The monthly mean minimum temperature peaks in the summer months (May to July), with values between 25°C and 30°C, whereas the lowest minimum temperatures occur in the winter months (December to February), frequently dropping to single digits in northern locations.

The monthly average maximum temperature exhibits a comparable trend, with May and June identified as the warmest months, consistently surpassing 40 degrees Celsius. A considerable temperature gradient exists from north to south. Northern stations like Sialkot and Lahore endure cooler winters and moderately milder summers, in contrast to southern stations such as Multan and Rahim Yar Khan, where temperatures are more extreme due to desert regions and lower elevation.

Humidity levels at all locations reach their peak during the monsoon season (July to September), coinciding with the peak rainfall periods. The pre-monsoon (March to May) and post-monsoon (October to November) months demonstrate the lowest humidity levels, reflecting high temperatures and low atmospheric humidity during these intervals. Northern and northeastern locations, such as Sialkot and Lahore, generally report higher humidity levels due to increased rainfall and cloud cover. Southern stations, including Multan and Rahim Yar Khan, exhibit lower humidity levels and have a dryer season.

The northern and southern locations exhibit considerable disparities in wind speed, precipitation, and temperature. Northern locations that benefit from orographic lifting and are closer to monsoon currents receive more rainfall and humidity, as well as warmer temperatures. Southern stations, on the other hand, have more arid circumstances, such as higher temperatures and less rainfall.

All stations experience a strong monsoon season characterized by substantial rainfall and humidity, followed by a dry winter marked by reduced temperatures. The transitional seasons of spring and fall deliver pleasant weather with gradually varying temperatures and humidity levels. The results illustrate the varied climatic conditions in the region, shaped by regional and seasonal fluctuations, underscoring the significance of localized climate data for efficient resource management and planning.

While the climate study reveals unique seasonal trends and spatial variances among locations, the data does not show a direct relationship between annual climate parameters and the frequency of flood events.

The significant floods in 2010, 2014, and 2018 were not consistently related to extremely high precipitation levels in all impacted places, nor with abnormal temperatures, humidity, or wind speeds. This implies that local meteorological factors alone may not be enough to cause flooding disasters.

Chapter 4: Citizen Engagement and Flood Resilience

4.1 The Value of Citizen Participation in Disaster Management

Citizen science plays an important part in disaster management (Tidball et al., 2012; Ottinger, 2022). Communities can become more resilient to disasters by including their residents in disaster management. Following floods, citizens' active participation in emergency relief response, assessing the damage, recording losses, and contributing to the restoration process ensures that recovery efforts address the community's true needs. Furthermore, constant monitoring of environmental and societal consequences might help to improve planning and resilience strategies for future catastrophes (Kocaman et al., 2018).

4.2 Methodology

4.2.1 Study Area and Context

Our research focuses on the impacts and repercussions of floods on populations in Pakistan's flood-prone areas. We focused our fieldwork on Marrian, a riverine village near Tehsilpur city in southern Punjab, and Usta Muhammad in Jaffarabad, Balochistan (Fig. 3.1). Because of its proximity to the River Chenab, the community is particularly vulnerable during periods of high water, making it an ideal case study for investigating the various effects of floods on rural communities.

4.2.2 Research Design and Methodology

The study used a qualitative method, with fieldwork and semi-structured interviews to acquire in-depth information from the impacted community. This approach enables us to record community members' real experiences, views, and coping mechanisms. Qualitative methods are ideal for studying complicated social phenomena because they provide rich, comprehensive data that quantitative methods may overlook (Creswell and Poth, 2016).

4.2.3 Participant Selection

A purposive sample strategy (e.g., Tongco, 2007) was used to recruit participants from a diverse range of the population. We conducted 20 interviews with people from varied backgrounds, including:

- **Farmers (6 Participants)**: Because agriculture is the primary source of income in the area, farmers gave crucial insights into the economic and environmental consequences of flooding.
- **Community Leader (2 participants)**: The leader provided insights into government, community mobilisation, and social dynamics during crises.
- **Students (4 participants)**: Student insights focused on the educational interruption caused by flooding.
- **Women (4 participants):** Because women bear the dual burden of domestic and agricultural work, their viewpoints are critical to understanding gender-specific issues. One of the women is a student, and the other is a farmer.
- **Community doctor/health officer (2 participants):** The doctor discussed the health implications and availability of medical resources during floods.
- **Irrigation Officer (1 participant):** The officer presented professional knowledge about flood management and infrastructure issues.
- **Shopkeeper and businessman (2 participants):** The shopkeeper emphasised the economic effects on small companies and the larger society.
- **The local politician (1 participant)** emphasised the link between local communities and the central government.

4.2.4 Data Collection: Interviews and Fieldwork

To account for the poor internet connectivity in Pakistan's small areas, the interviews were done in person from November 25 to December 10, 2023. Face-to-face interviews allowed for direct involvement with participants, promoting a more open discourse and recording nonverbal clues that improved the data (Silverman, 2014).

Each interview lasted 30 to 60 minutes and was conducted in the participants' native language to guarantee comfort and authenticity in their responses. The interview methodology includes both structured and open-ended questions, providing for flexibility in exploring emerging themes.

4.2.5 Categories of Questions

The interview questions were developed to address essential aspects of the study:

1. **Causes of the Problem:** We polled participants on their thoughts on the causes of floods, focussing on both natural and man-made reasons such as poor infrastructure, deforestation, and river management issues.
2. **Social harm Caused by Floods:** This category focused on understanding the social consequences, particularly the harm to the school system, the health implications, and the overall disturbance of daily life. Special emphasis was placed on how floods affected vulnerable groups, such as women and children.
3. **Economic Loss and Damage:** This category's questions focused on the financial implications, such as crop destruction, property loss, and the impact on local companies. Participants were invited to consider how these economic losses have impacted their long-term livelihoods.
4. **Government Actions and Initiatives:** We looked into local opinions of government responses to flood emergencies, such as the adequacy of relief, infrastructure development, and any preventive measures implemented.
5. **Local knowledge and suggestions:** To capture community-driven solutions, we asked participants to contribute proposals for flood mitigation based on their personal experiences and local knowledge.
6. **Future Plans and Security:** This category focused on understanding the community's expectations for future safety measures and their needs for long-term rehabilitation, including fundamental necessities like clean water, food, education, and health services.

4.2.6 Data Interpretation and Analysis

Thematic analysis, which is generally known for its usefulness in detecting, interpreting, and reporting patterns within qualitative data, was used to transcribe, translate, and code data from the interviews (Braun & Clarke, 2006). Themes were created based on reoccurring subjects and key insights revealed during the interviews.

- **Coding and Thematic Development:** The data were manually coded, with an emphasis on major topics relevant to the study's aims, such as flood causes, social and economic repercussions, government reaction, and community resilience. This technique allowed us to classify the answers systematically and make linkages between individual experiences and bigger sociopolitical factors.

- **Ethical Considerations:** We followed ethical rules throughout the research process. Before conducting interviews, participants were informed about the goal of the study and given their consent. Privacy and confidentiality were preserved, and personal information was anonymised in the reporting of results.

4.3 Case Studies of Community-Based Resilience Initiatives: data presentation

The interviews provided us with useful insights into the communities' individual needs, their perceptions of the efficacy of flood protection measures, and the responsibilities performed by residents and government organisations. Below is a summary of the important findings from these interviews, emphasising the different experiences, challenges, and opinions offered by those directly affected by the floods.

Interview 1 (Farmer):

A middle-class farmer in a village relies on agriculture to support his family. We asked him seven separate questions (section 4.2.5). He could not respond to all of them, but the points he expressed during his interview are as follows:

- We saw three significant floods in the recent decade: in 2013, 2014, and 2022. Throughout the floods, the government provided no relief or precautions, leaving the people powerless.
- Almost all of the area's population relies on agriculture, and soil erosion has ruined all harvests and caused individuals to lose their farms.
- Floods in this area are not caused by excessive rainfall, as we receive much less rainfall than in Northern Punjab. Rather, the floods were caused by an overflow of water from the adjacent Chenab River.

Interview 2 (Community Leader):

In Pakistan, it is usual for a village or small town to have a leader who makes decisions and handles major community matters. We asked the community leader various questions, with an emphasis on the issues of schooling in the hamlet. He stated that:

- Many students have dropped out of school due to limited resources and time spent coping with floods.
- Parents want their children to attend school, but there is only one school serving a community of about 8,000 people.

Fig. 4.1 shows the soil erosion on the bank of Chenab river after 2022 floods near Village Marrian, Punjab

Interview 3 (farmer who lost his entire land and home):

Many families lost their homes, as well as agricultural grounds. We interviewed one of the farmers who lost his home and land in the previous flood and was unable to rebuild even after a year. He stated the consequences he encountered as follows:

- We lost our homes and spent the nights under the stars for 4-5 weeks, with no assistance from any official institutions or structures.
- We spent all of our savings during the floods because the government did not provide us with funds or supplies.
- The floods in this area were caused by a lack of assistance and infrastructure across the river delta to keep water from entering the villages and agricultural lands.

Interview 4 (woman):

Women in rural Pakistan have a higher workload than men due to their dual roles in agriculture and domestic responsibilities. So, it's critical to ask women about the difficulties they suffer as a result of floods. We interviewed a local woman who suffered greatly after the floods, losing all of her valuables and her home. Here are the points she raised:

- Women suffer the most from the floods since they have children and other responsibilities.
- A lot of children face malnutrition as the women can't feed their kids enough because of a lack of food during the flood period.
- Sending girls to school is often hindered by socioeconomic constraints, as families prioritise having their daughters contribute to household chores and work in agricultural fields to support the family's livelihood.

Interview 5 (student):

We interviewed a student who attended high school before the floods. He discontinued his studies following the flood for a variety of reasons, including:

- I dropped out of school to assist my father with various tasks and operate the shop, which was our sole source of income after losing much of our land in the floods.
- Because we spend the majority of our time dealing with floods throughout the year, I am unable to leave home to further my education in other cities.

Interview 6 (student):

This student was more interested in discussing and understanding the causes of floods. He was attending a school distance from his home because all of the schools in his village had been permanently closed following the floods. He stated that:

- Students were unable to attend school for over a year due to life-threatening floods in 2010.
- Many women who used to labour in the fields lost their employment and felt bleak.
- No one discusses the devastation caused by climate change or climate action.

Interview 7 (Farmer Woman):

This woman supported her family by working in the fields during harvest season and running a small dairy farm. She lost the majority of her animals in the floods. We asked her various questions, and she underlined the following points:

- We are mostly dependent on wheat and cotton crops throughout the year.
- We lost productivity for three to four years due to floods because soil erosion prevented us from growing anything on that site.
- The government assistance was insufficient to compensate for our losses.

Interview 8 (Community Doctor):

In rural areas, tiny medical centres provide basic medical services such as first aid and treatment for common illnesses. During an interview with a doctor at one of the medical centres, he stated that:

- The floods caused a significant epidemic of infections in the nearby communities.
- Patients did not have enough medicines or medical facilities.
- More floods are forecast in the next few years, but the government isn't serious about establishing new hospitals in vulnerable areas.

Interview 9 (Farmer):

An elderly farmer reported experiencing over 5 significant floods in his lifetime. These are the insights he shared during his interview:

- Until today, I hadn't recovered from the losses caused by the catastrophic 2010 floods.
- Every deluge causes more destruction than the previous one, yet no one strives to solve the root cause.
- The government have not constructed any support structures across the riverine villages, therefore those towns remain vulnerable to flooding.

Interview 10 (Shopkeeper):

We interviewed with a shopkeeper in a community who had to close his business for nearly a year due to flooding. He brought up the following issues:

- Every shopkeeper and small company owner suffered significant losses as a result of the floods, and we relied on government assistance.
- Our children were unable to attend school for a full year.

Interview 11 (Irrigation Officer):

We interviewed a sub-divisional officer from the flood-affected area's irrigation department. He worked there for the past six years and observed three severe floods. We asked him some questions on the involvement of authorities and their responsibilities, and he provided the following answers:

- Despite confronting floods practically every year, no feasible mitigation measures have been implemented by higher authorities in the impacted communities.
- We did our best to inform the government of the risks and implications that we may face if we do not take action, but the administration appears to be unconcerned about this matter.

Interview 12 (medical student):

We interviewed a medical student from Balochistan who witnessed the devastating floods in 2022. He shared with us some significant facts and occurrences from the time:

- It was a highly unexpected flood because there was not much rainfall in our region to generate floods, but runoff from the hills of Koh e Sulaiman became the cause of flooding in our region.

- As a student, it is beyond words to explain the difficulties that students encountered during the floods. Our institute arranged for us to take online lessons, but internet services were also disrupted throughout the region, causing us a number of issues.

Interview 13 (farmer):

We asked a farmer about the impact of floods on agriculture in Balochistan. The conclusion of this interview:

- Despite the community's best efforts, we were unable to salvage the crops, resulting in a significant loss for all farmers in the area.
- The government's backing was little. Floods will have a long-term negative impact on crop productivity.

Interview 14 (woman):

We asked a woman about her living conditions after floods.

- We were confined to a small plot of ground for 2-3 weeks, with little food and clean drinking water. I lost my livestock and practically all of my stuff in the flood.
- As a woman, I find it difficult to move around due to cultural constraints on women in Balochistan, which became even more difficult during the floods.

Interview 15 (community leader):

As we moved from region to region in the flood-affected areas, we attempted to obtain interviews with local or tribal leaders. In Balochistan, the tribal system is very strong, and each tribe has its own identity and cultural differences. So it was vital to delve at their perspectives on the flooding because they represent the entire tribe or community. We asked the tribe head some questions, and he clarified a few points:

- All of the help supplied to residents in afflicted areas was largely the result of community-led initiatives. Support and assistance were extended across tribal lines, with people of one tribe assisting those from another, exhibiting significant intercommunal cooperation during times of need.
- Sadly, we did not get any initial relief from the authorities.

Interview 16 (businessman):

We interviewed a pesticide business owner. He suffered a significant financial loss as a result of the floods, as his store was submerged. We asked if he wanted to convey anything, and he said:

- I had no clue we'd be in this circumstance, therefore I wasn't prepared.
- It will take me years to make up for this loss, and I have little hope that the authorities will assist me cover some of it.

Interview 17 (Farmer):

After conducting interviews and fieldwork, we organised a free medical camp in a flood-affected area of Balochistan to assist residents. Two young doctors from Punjab participated. There were a lot of individuals there for treatment and medications, so it was an opportunity to conduct interviews with various folks. During various interviews conducted during this medical camp, a farmer told us:

- We had been helpless for weeks, and the night the waters hit was pure chaos. We hurried around trying to preserve our belongings but were unable to accomplish much.
- The floodwaters overflowed my agricultural fields.

Interview 18 (female student):

When it comes to education in Balochistan, girls encounter numerous barriers to obtaining an education due to cultural limitations and a lack of quality education. Floods have exacerbated the educational situation in the impacted communities. We questioned a female student who observed the floodwaters, and she said:

- Following the flood, all of our schools were entirely closed. There is minimal probability that officials will try to rebuild the area's educational institutes.
- This was a highly stressful experience for all of the young students, since they encountered several issues and hardships at this time.

Interview 19 (regional health officer):

During a visit to a town, we addressed the regional health officer about their role during the floods and potential outcomes. He underlined the following points:

- There was a noticeable outbreak of infections throughout the town, with the possibility of an increase in the transmission of various diseases such as typhoid, malaria, fever, and others.
- We should be grateful for the community-driven measures taken by residents of the afflicted communities.

Fig. 4.2 shows one of medical camps that were set up by the team of this study in one of the flood-affected areas of Balochistan helping

Interview 20 (politician):

We interviewed a well-known politician from a municipality who assisted us in establishing medical camps and entertained us for two days. He clarified a few points about the flooding, including:

- I am attempting to persuade the authorities and bureaucracy to take concrete steps towards erecting a robust barrier or dams around residential areas to prevent flood water from invading the town and villages.
- Solid efforts must be done to safeguard the safety of people in the area and throughout Pakistan. People should be better educated on the impact of climate change on their life.

Fig. 4.3 Homes are surrounded and submerged in flood water in Jaffarabad, Balochistan on September 1, 2022 (Zahid Hussain / AP)

4.4 Evaluation of interview insights and methodological considerations

4.4.1 Overview and Quality of Interviews

The interviews with 20 persons from various flood-stricken areas of Pakistan provide valuable insights into the lived experiences, issues, and viewpoints of those affected by flooding.

Farmers, community leaders, students, women, healthcare experts, and local politicians made up the broad participant pool, providing for a thorough grasp of flooding's socio-economic and environmental consequences. The interviews were performed in the participants' native languages to ensure comfort and openness in expressing their perspectives. However, limitations were identified, including some interviewees' incapacity to answer all questions, variable degrees of information regarding flood causes, and cultural barriers to full engagement, particularly among women.

4.4.2 Gender Dynamics and Equality

The interviews reveal considerable gender differences in the effects of floods, with women facing a greater cost due to their combined roles in household and agricultural activities. Cultural norms frequently hinder women's movement, reducing their access to resources and opportunity for recovery. These characteristics make women and girls more vulnerable, particularly in terms of access to education and healthcare during and after floods.

4.4.3 Limitations of the Interviews

While the interviews produced a rich qualitative dataset, numerous issues arose. Some interviewees were unable to respond to all questions, which could be due to emotional hardship, a lack of comprehension of larger environmental issues, or distrust in authority. Furthermore, the interviews focus mostly on individual perceptions, which may not completely capture the structural and systemic variables that contribute to flood vulnerability.

4.5 Interviews discussion

4.5.1 Socioeconomic Impact of Floods

The interviews constantly emphasise the terrible socio-economic effects of flooding on communities, notably on farmers, shopkeepers, and small business owners. Many participants reported considerable financial losses as a result of crop destruction, animal losses, and company damage. This economic disturbance frequently prompted families to deplete their resources, relocate, or abandon their properties, resulting in long-term instability.

Agriculture and Livelihoods:

Farmers, who make up a substantial portion of the impacted population, have suffered significant losses owing to periodic floods. Soil erosion and crop damage have diminished agricultural output, with long-term implications for food security and income. For example, farmers in interviews 1 and 3 discussed the loss of crops and lands due to floods caused by river overflows, which were not caused by local rainfall but rather by poor riverine infrastructure management.

Small Businesses:

Small business owners, like the shopkeeper in interview 10 and the businessman in interview 16, had significant losses and were unable to continue operations for several months. Lack of preparedness and little government help have slowed rebuilding timeframes, exacerbating economic hardship in many communities.

Women's Workload and Vulnerability:

Due to their domestic and agricultural roles, women are especially sensitive to floods. The interviews revealed that women are not only directly affected by floods, but they also endure the added strain of caring for children, managing inadequate food supplies, and coping with cultural norms that limit their movement and access to relief (Hakim & Aziz, 1998). Interview 4 focused on the additional issues that women confront, such as child hunger and the requirement that females work in the home rather than attend school.

4.5.2 Educational Disruptions and Barriers

Flooding's influence on education was a constant subject (Ahmed et al., 2022), with many interviews emphasising how flood-related disruptions have significantly impacted learning. Floods have caused school closures, infrastructural damage, and prompted students to abandon their studies to assist their families. This educational interruption is especially significant for females, who are frequently kept at home to assist with household chores (Ali et al., 2010), as indicated in interviews 4 and 18.

School Closures and Limited Access:

Interviews with students and community leaders revealed that many flood-affected schools had been permanently or temporarily closed, leaving children with limited educational options. As mentioned in interview 2, a lack of schools exacerbates the educational divide, particularly in rural areas where access to excellent education is already limited.

Cultural and Economic Barriers for Girls:

Cultural and economic constraints can hinder girls' access to school. As discussed in Interview 4, families often prioritise urgent survival and income generation over females' education. This maintains the cycle of low educational attainment and economic dependency, limiting future chances for females in these regions (Ali et al., 2010).

4.5.3 Health Impacts and Healthcare Access

Floods have serious health consequences, such as the development of waterborne infections, a lack of access to safe drinking water, and insufficient medical care. Health professionals interviewed, including the village doctor in Interview 8 and the regional health officer in interview 19, stressed the vital need for improved healthcare infrastructure and disease prevention measures in flood-prone areas.

Disease Outbreaks:

Floods have been associated to illness epidemics, including typhoid, malaria, and waterborne infections (Noureen et al., 2022; Alied et al., 2024; Shaikh et al., 2023). The absence of adequate medical supplies and healthcare infrastructure has exacerbated these problems, leaving people vulnerable and underserved during disasters.

Healthcare Infrastructure Deficiencies:

Participants reported inadequate healthcare infrastructure in flood-affected areas. The interviews highlighted the critical need for stronger health systems, emergency response capabilities, and preventive strategies to address the health risks linked with reoccurring floods.

4.5.4 Governmental Roles and Community Resilience

The involvement of the government in flood control and recovery was a prominent source of worry during interviews. Participants regularly cited a lack of government support, both for emergency response and long-term infrastructure development. Interviews with community leaders, farmers, and municipal officials revealed a pattern of neglect and inadequate response by authorities.

Lack of Government Support and Accountability:

Interviewees voiced anger with the government's lack of support and accountability during and after floods. Despite numerous flood disasters, critical infrastructure improvements such as river embankments and flood barriers have yet to be constructed, leaving communities exposed (Paracha et al., 2024).

Community-Driven Initiatives:

Communities have relied on self-organization and mutual aid to address flood damage, as government support is limited. Interviews 15 and 19 showed considerable inter-communal solidarity, with tribes and local groups stepping in to provide aid and support when government efforts were absent.

4.5.5 Perceptions about Flood Causes and Climate Change

Understanding local opinions of flood causes is critical for effective flood risk management (Tran et al., 2024). Interviewees cited a variety of causes that contribute to flooding, including poor infrastructure management, climate change, and a lack of government intervention. However, there remained a large gap in understanding and discussion about climate change and its role in worsening flood hazards.

Lack of Climate Awareness:

Interviewees, particularly students and younger responders, reported a lack of public discussion on climate change and its implications. This lack of information impedes community-level support for climate action and adaptation strategies, as discussed in interview 6. Some

interviewees stated that their districts receive little rain, hence floods are most likely caused by upstream water flow and poor river system management.

These floods are frequently caused by the overflow of adjacent rivers, such as the Chenab, or by water flowing from faraway locations experiencing excessive rainfall, which accumulates and overwhelms the local infrastructure. This is exacerbated by the lack of proper water management measures, such as poorly maintained dams, inadequate drainage networks, and insufficient flood barriers (Paracha et al., 2024).

Infrastructure and Mismanagement:

Respondents often blamed floods on inadequate infrastructure, including deteriorated embankments and inadequate flood control measures along rivers. This impression was shared throughout respondents, emphasising the importance of targeted investments in flood management infrastructure.

4.6 Path Forward: Insights and Conclusion

The interviews provide a thorough picture of how floods affect rural populations in Pakistan. They demonstrate severe socioeconomic vulnerabilities, worsened by weak government responsiveness, cultural obstacles, and limited infrastructure. Women and children are especially vulnerable, with disrupted education, higher health risks, and disproportionate economic costs. Local initiatives play an important role in giving relief and support in the absence of formal government intervention, demonstrating community resilience.

Addressing these difficulties necessitates a multifaceted approach that includes improving flood management infrastructure, expanding healthcare and educational access, promoting gender equality, and raising public understanding of the effects of climate change. Only such integrated efforts may break the cycle of flood risk and enable communities to construct a more resilient future (Goh et al., 2024).

Chapter 5 : Government policies and initiatives

Since its independence in 1947, Pakistan has faced many major floods until now, which shows the vulnerability of the country towards natural disasters like floods. Meanwhile, its important to analyse the role and involvement of the government in the mitigation of the floods in Pakistan, especially in the areas that are more vulnerable to the floods and are affected almost every time. Although the strategies and measurements for the mitigation of floods have not improved much with time in Pakistan, the government of Pakistan has played a critical role in flood prevention in Pakistan. The government of Pakistan established the NDMA (National Disaster Management Authority), different infrastructure projects, collaborates with different international organisations, and other policy initiatives (Vakili, 2022). The following are the key steps that the government of Pakistan took for the prevention of floods until now:

5.1.1 Establishment of NDMA:

The National Disaster Management Authority (NDMA) was established in 2006 and is an autonomous federal authority that deals with all types of catastrophes and their management in the country. Its primary role of NDMA includes:

- Reparing early warning systems before any disaster in collaboration with PMD the Pakistan Meteorological Department (National Disaster Management Authority (NDMA), n.d.). PMD uses satellite data and predictive models to examine the severity of the disasters, either floods or any other disasters like heavy rainfall, storms, etc.
- Organising different workshops and programs in collaboration with PMD to educate the public on how to deal with or respond to the early warnings during a disaster. NDMA uses different media sources, like electronic media and newspapers, for these educational campaigns.
- Ensuring the establishment of emergency operational centres at district and provincial levels in the affected areas. These operational centres work in collaboration with each other to elevate the relief response on a bigger level.
- Ensuring the coordination among the different departments that are working for relief in the hazard-prone areas (Akhtar, 2023).

5.1.2 Flood protection infrastructure development:

Dams and water reservoirs play a very important role in controlling floodwaters during heavy rainfalls. Dams are sources of clean energy in the form of hydropower, reducing the CO^2 emissions. The government of Pakistan has financed some big projects over time for the construction of several dams and water reservoirs like Tarbela Dam and Mangla Dam. There are other projects for water storage and floodwater control as well, like Warsak Dam, Hub Dam, Chashma Barrage, Rawal Dam, Dargai Dam, Gomal Dam, Mirani Dam, Satpara Dam, Manchar Lake, Tanda Dam, and some small dams in Balochistan.

Some big projects like the Diamer-Basha Dam and Mohmand Dam are under construction on the Indus River and Swat River, respectively, which are considered to be milestones in this regard (Sabir et al., 2017).

Tarbela Dam:

Tarbela Dam is one of the world's biggest water reservoirs. It is located on the Indus River in Khyber Pakhtunkhwa province. The purpose of building Tarbela Dam was the generation of hydropower, flood control, and irrigation. Overflow of water in the Indus River is one of the biggest reasons for flooding in different areas of Pakistan, so Tarbela Dam plays a key role in controlling the waterflow in the Indus River (Khan & Tingsanchali, 2008).

Fig. 5.1 shows Tarbela dam located in Tarbela, Haripur District , after spillways have been opened (Hamid Waleed) August 20, 2024

Mangla Dam:

Mangla Dam is Pakistan's second largest dam, and it is built on the Jehlum River and located in Azad Jammu and Kahmir. Mangla Dam is one of the crucial projects for floodwater management and irrigation (Kayani, 2012).

5.1.3 Flood Forecasting and Early Warning Systems:

Pakistan Meteorological Department (PMD): The PMD plays an important role in the mitigation of floods by collaborating with different departments of government and providing warnings, weather, and flood forecasts on the basis of meteorological data. In response to the devastating floods in 2010 and 2022, PMD has improved their warning systems significantly, especially in the technology field, where upgraded meteorological tools like doppler radars, automated weather stations, and satellite-based observation systems have been introduced to deal with the current and upcoming disasters in the country.

PMD works in coordination with other government bodies linked to the disaster management .This collaboration with other government departments helps enhance the country's flood forecasting efforts (Vakili, 2022).

5.1.4 International Aids:

Pakistan has received International aid and support during major floods in the country in all major floods like in 2010 and 2022. This aid and support is in the form of humanitarian aid, financial support, and technical expertise from different countries, international organisations, and non-governmental organisations (NGOs).

2010 Floods were among country's worst natural disasters, which affected more than 20 million people across the country. The recovery and impact time of the event were measured as 6 months (Kirsch et al., 2012). During these floods, the UN (United Nations) started a relief program and raised $2 billion for support efforts. Other UN agencies like UNICEF, the World Health Organisation (WHO), and the World Food Programme (WFP) also contributed to these relief efforts.

2022 Floods were also among the country's worst natural disasters, as one-third of the country is considered to be submerged in the flood waters (Higgs, 2024). These floods affected approximately 33 million people across the country. During that time, the response from different international organisations and other countries was significant. The World Bank contributed $2 billion for relief efforts during 2022 floods (Rehmat et al., 2023). Some other organizations and governments of other countries contributed to these relief efforts as well.

5.2 Discussion and Key Challenges:

The country faces some challenges when it comes to dealing with the floods, as:

5.2.1 Urbanisation and poor planning:

Weak drainage systems in large cities like Karachi and Lahore cause a lot of problems in handling heavy rainfall. These cities are expanding exponentially with time as the population increases and the trend of netizens moving to larger cities increases as well. However the drainage system and other infrastructure did not upgrade with this urban growth. The average rainfall in Lahore is 628.8mm. In every monsoon season, the Lahore city is experiencing heavier rainfall due to climate change (Siddiqui & Siddiqui, 2018). Meanwhile, the upgrade of the drainage system and other infrastructure is not at a good shape that allows the system to mitigate the risk.

5.2.2 Weak policy implementations:

The government has defined some policies to deal with the disasters, but the implementation of those policies is not efficient. The reasons can be limited resources, the negligence of the relevant government bodies, ineffective planning by bureaucracy, and lack of political will (Deen, 2015). Lack of coordination among the departments dealing with disaster management, like NDMA (National Disaster Management Authority), PDMAs (Provincial Disaster Management Authorities), and other relevant departments, causes delayed responses at the time of disasters or floods. These government bodies make plans for disaster management, pre-flood emergency, embankment of the rivers, evacuation plans, and improvements in the drainage systems, and these plans often face delays, which is another key challenge in dealing with the floods in the country (Batool et al., 2024).

5.2.3 Insufficient funding for disaster relief:

The country has been facing economic instability for the past few decades, which comes in relation to some political crises and inflation at the global level. Because of these financial problems, the government cannot issue large funds for flood relief or pre-flood preparedness. Most of the funds and aid from international organisations and other countries go to emergency relief during disasters, leaving very few funds for other projects like dam maintenance and drainage system upgrades (Aslam, 2018).

5.2.4 Lack of public awareness:

The literacy rate in urban areas of Pakistan is 77.3%, and that in rural areas is 52%, which is comparatively lower than the urban areas (Jamil, 2023). So communities, especially those living in rural areas, face a lot of challenges in dealing with the disaster due to the lack of knowledge about how to deal with and perceive the initial warnings.

Education programs and awareness campaigns are limited as compared to the large population of the country, and these programs are very important for all the citizens to protect their livelihoods during the time of disasters (Shah et al., 2020).

5.2.5 Ageing infrastructure:

Various drainage systems and infrastructure for flood control are out of date. For example, Pakistan's two largest dams, Tarbela and Mangla, were built decades ago and serve an important role in flood control. Tarbela Dam was erected in 1976, whereas Mangla Dam was built in 1967. Since then, there have been no major repairs to these dams in accordance with modern requirements. The government did not efficiently alter these facilities to meet modern norms, limiting disaster resistance (Akhtar, 2023).

Chapter 6 : Synthesis and Discussion

In this chapter, we state and critically analyse the findings presented in Chapter 3 (Climate Data), Chapter 4 (Citizen Engagement and Flood Resilience), and Chapter 5 (Government Policies and Initiatives) to address the multifaceted objectives of this study comprehensively. The discussion will explore the principal causes of flooding in Pakistan, analyzing both natural and anthropogenic factors that exacerbate the frequency and severity of flood occurrences. The aim here is to uncover how climate change and anthropogenic actions exacerbate the nation's vulnerability to floods.

This chapter also discuss about the many social, economic, and environmental effects of these floods, including how they directly and indirectly affect people, natural ecosystems, and important infrastructure. Through comprehensive analysis of citizen interviews, we evaluate the impact of floods on livelihoods, intensification of inequality, depletion of economic resources, and the long-term challenges they present to sustainable development in Pakistan. Finally, informed by the findings from these diverse perspectives, we propose a set of practical and sustainable recommendations to address flood risks more effectively. These recommendations include policy reforms, infrastructure enhancements, community-based adaptation strategies, and technological innovations designed to mitigate flood vulnerability and promote resilience in impacted communities.

6.1: Causes of the Floods

This study examined climate data from various stations in Punjab province and revealed that during significant flood events, certain environmental factors were not extreme at the time of the floods. If we focus on the fact that the rainfall or precipitation should be high in the flood-affected areas, then its not quite evident after looking at the climate data of those areas. In Figure 3.3, for example, we can see that there is a major flood event in 2014 from August to September in DG Khan, but the precipitation is not very high as compared to the other months of the year. Likewise, in 2018, there is a major flood event from April to August, but precipitation during that time in DG Khan is very low. In 2019, Multan faced a flood event from April to June, but according to Figure 3.4 , the precipitation is low as compared to the other months during that year. The Bahawalnagar region experienced the 2010 historical floods, but its rainfall was not as high as that of other flood-affected regions (Figure 3.2).

On the other side, very high precipitation was observed in these regions but no flood events during that time. Like in DG Khan during December 2012, December 2013, and April 2020 (Figure 3.3). Multan experienced very high rainfall in December 2012 and August 2015, but again there was no flood event in the region (Figure 3.4). In Figure 3.2, there is a peak in precipitation in December 2011, which is the highest precipitation in that region from 2010 to 2020, but there was no flood event in the Bahawalnagar region during that time period.

The precipitation data from the regions that are mostly affected by the floods in Punjab, indicates that precipitation is not directly linked to the floods. However, more rainfall during the time of floods elevates the effects of disaster in the region, and the water level rises in the rivers. It indicates that there are other factors that contribute to the flooding in Pakistan, either environmental or human-driven.

Citizen knowledge is in the line with the discussion above. Some interviewees indicated that their regions experience little rainfall, and they believe that floods are likely due to upstream water flow. Often, these floods result from overflow in nearby rivers, such as the Chenab, or from water traveling from distant areas with heavy rainfall (Ali et al., 2021).

In addition to climate and physical factors, interviewees highlighted human-related factors that exacerbate the nation’s vulnerability to floods. Many interviewees explained the inefficiency of the authorities during the time of the disaster. Interviewees highlighted that the absence of regular maintenance and proactive management renders the region increasingly vulnerable to severe flooding (Interview 9 & Interview 11).

Interviewees, especially students and younger respondents, observed a lack of public dialogue about climate change and its impacts. This lack of awareness limits the community's understanding of risks and hinders advocacy for proactive climate action and adaptation strategies. For example, as emphasized in interview 6, in the absence of widespread awareness, community members are less inclined to advocate for infrastructure enhancements or support policies aimed at flood prevention and resilience-building. This lack of awareness, therefore, not only reduces individual preparedness but also contributes to the systemic vulnerabilities that increase the region’s flood risk (e.g., Stofer et al., 2019; Murunga et al., 2022; McNally, 2018).

6.2: Floods in Pakistan - a global context

Over the past several decades, Pakistan's CO_2 emissions have increased, but a sudden hike in this trend after the 2000s can be observed (Fig. 6.1). This increase can be attributed to the country's growing reliance on fossil fuels, industrial expansion, and urbanization (Rehman et al., 2019). Still, Pakistan only contributes 1% to the global emissions (Ritchie et al., 2020).

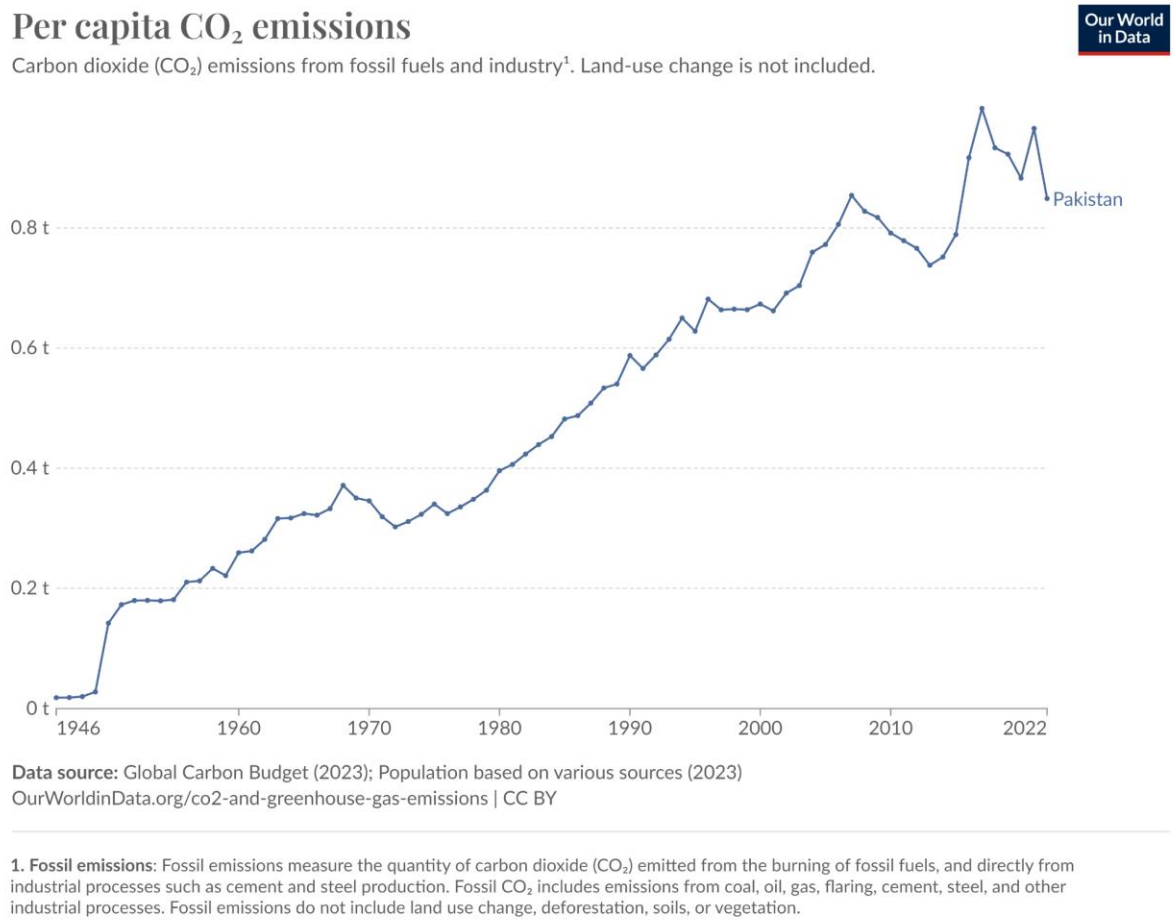

Figure 6.1: Per capita CO_2 emissions in Pakistan from 1946 to 2022. The data, sourced from the Global Carbon Budget (2023), shows a gradual increase in emissions, with a notable rise in recent decades due to increased fossil fuel consumption and industrial activities. Pakistan's CO_2 emissions per capita remain significantly lower than those of neighbouring countries like China and India.

Though Pakistan's share of global emissions is small, the country is very susceptible to the impacts of climate change. Pakistan is situated near major CO_2-emitting nations like China and India, where per capita emissions are considerably higher—8 tonnes per person for China and 2 tonnes per person for India, compared to Pakistan's 0.8 tonnes per person (Ritchie et al., 2022).

The link between global warming and intensified flooding is well documented (Bronstert, 2003. Although our analysis found no direct correlation between local climate factors and flood events (Figure 3.3), the broader influence of global warming cannot be ignored. Rising global temperatures may exacerbate monsoon patterns, snowmelt rates in the Himalayan region (Ashraf et al., 2012), and unpredictable rainfall, all of which increase Pakistan's vulnerability to severe floods (Otto et al., 2023).

Rapid industrialization exacerbates the increase in CO_2 emissions, hindering Pakistan's transition from a fossil-fuel-dependent economy (Rehman et al., 2022). The country shows the least interest in transitioning to renewable energy sources and diminishing its carbon footprint. Further research is essential to comprehend the potential detrimental effects of global carbon dioxide emissions on Pakistan.

6.3: Social, Economic, and Environmental Implications

The floods in Pakistan impose a wide range of social, economic and environmental implications, affecting the lives of millions of people in the country in several aspects. In this section we discuss these implications guided by the citizen knowledge collected in this study.

Social implications: Floods cause a lot of social impacts, like human displacements, loss of lives, health risks and impacts on education. In 2022 floods, 33 million people were affected, around 8 million people were displaced from their homes, 13,000 kilometres of roads and 2.2 million houses were affected (Paracha et al., 2024). During 2010 floods, approximately 20 million people were affected across all four provinces: KPK, Punjab, Sindh and Balochistan. Almost 1800 people died during two months of floods, July and August (Warraich et al., 2011). This event became one of the most drastic humanitarian crises in the history of Pakistan.

There are significant health problems linked with flooding in Pakistan. There are several cases of waterborne diseases like dengue, hepatitis, diarrhoea, scabies and cholera during the floods, as people were consuming water from the contaminated sources (Baqir et al., 2011). During 2022 floods, over 5 million children were at health risks due to the lack of access to clean drinking water (Abdullah et al., 2024).

There are many implications on the education sector, as well as thousands of schools were destroyed during these floods and the reconstruction process of the schools was not very effective, which affected the future learning and economic opportunities in the country. In 2010 floods, it is estimated that 10,000 schools were destroyed (Kirsch et al., 2012).

Economic implications:

Floods bring severe economic losses to Pakistan and mess up different sectors like industries, agriculture, government machinery, infrastructure projects, trade, technology, and much more. Agriculture is considered to be the backbone of Pakistan's GDP. About 25% of the land area of the country is used for agriculture (Mughal, 2018). The 2022 floods affected 1.7 million hectares of crops (Fao, 2023), which ultimately deepened food security and elevated food prices in the country. The damage to the industries and infrastructure like roads, and buildings contributed to the economic loss. Jobs were affected and many departments and industries were closed for a long time period. World Bank estimated around $30 billion loss during the 2022 floods (Rehmat et al., 2023).

Environmental Implications:

With floods come many environmental problems and challenges like soil erosion, biodiversity loss, water pollution, deforestation, and damage to riverbank areas. Floods cause land erosion, which then results in land degradation and affects the crops productivity (Lal & Moldenhauer, 1987). Different rivers of Pakistan experience sediment deposition, which challenges the agriculture sector (Shrestha, 2024).

Water pollution is another problem that has intensified with time because of floods. The contaminated floodwaters pose implications for human and animal health as they carry harmful materials like pesticides (Gautam, 2003), industrial wastes, and sewage. Consuming this water for drinking results in an outbreak of many waterborne diseases (Baqir et al., 2011). Floods also damage the natural habitats of wild animals in the affected regions, resulting in the displacement of wildlife. The deforestation caused by floods leads to biodiversity loss in the country (Anjum et al., 2010).

6.4: Governmental Roles in the Causes and Solutions

Weak governance plays a big role in Pakistan's vulnerability to the climate crisis. There is no connection between the policy and implementation, which magnifies the problem. Even though the leaders of the country have been well aware of the climate crisis for at least the past 20 years, the efforts to manage this crisis are still not efficient. NDMA (National Disaster Management Authority) and Provincial Disaster Management Authorities were established

after the historic floods of 2010, but their efficiency in issuing early emergency warnings has not improved all these years.

Pakistan lacks strong policies for water management. River management poses significant challenges; upstream projects such as dams are inadequately engineered to alleviate downstream flooding. Regional governments often focus on short-term solutions rather than sustainable, long-term flood resilience (Anees, 2022).

The country's flood defenses, which include dams and drainage systems, are not well maintained and are outdated (Akhtar, 2023). Tarbela and Mangla dams, the country's largest water reservoirs, were built decades ago (in 1976 and 1967, respectively), and the government is not paying much attention to modernizing them according to the new standards and needs. In urban areas, government is not doing much to improve the drainage systems, especially in big cities. In provinces like Balochistan and Sindh, the lack of upgrading of the drainage systems is escalating the problem, especially during the heavy rainfall season (Khan, 2022). The government needs to upgrade all these drainage systems and water reservoirs, which are related to the control of flood waters, in order to make them resistant to disasters like floods, which are expected every year in the country (Saad et al., 2024).

6.5: Recommended Actions for Sustainable Development and Enhanced Flood Resilience

After understanding the data presented in the thesis and other findings about causes of floods, we propose some measures and recommendations to rectify the impacts of floods in the country. These recommendations include infrastructure development, policy modifications, educational improvements, environmental management, and international cooperation. These recommendations can assist Pakistan in developing resilient systems to protect lives, livelihoods, and ecosystems from future flood hazards. These recommendations include:

1. Strengthen Flood Management Infrastructure

- **Construct and upgrade Dams and Water reservoirs:** Build more dams and reservoirs to control excess rainfall water in the summers. Finalize the ongoing projects like Diamer and Bhasha Dam. Upgrade the current dams like Tarbela and Mangla dam according to modern standards.

- **Strengthen river embankments and flood barriers:** Construct and enhance embankments along all major rivers, particularly the Indus and Chenab, which often experience flooding.
- **Improve Urban Drainage Systems:** Upgrade the drainage systems in the cities and especially big cities like Karachi and Lahore to manage the excess rainfall water during the heavy monsoon rain season.

2. Adopt and Implement Integrated Water Management Policies

- **Develop Comprehensive River Basin Management Plans:** Implement plans that include efficient water storage, redirection of excess monsoon water, and regular river dredging to prevent erosion. Interregional collaboration is vital for a combined strategy.
- **Improve Regulatory Standards for Construction in Flood-Prone Areas:** Implement more strict regulations to govern land utilization and construction within floodplains. Guarantee that all development initiatives in these areas integrate resilient infrastructure capable of withstanding floodwaters.

3. Enhance Early Warning Systems and Community Preparedness

- **Upgrade Meteorological and Data Collection Systems:** Invest in modern meteorological forecasting technologies, including Doppler radar systems and automated weather stations. It can help Pakistan Meteorological Department (PMD) predict the disaster more efficiently.
- **Implement Community-Based Early Warning Mechanisms:** Involving local communities to the flood relief efforts and early warning mechanisms can help with flood resilience.

4. Increase Public Awareness and Education on Flood Risks

- **Launch Public Awareness Campaigns:** Implement extensive initiatives focused on flood safety, the ramifications of climate change, and community-oriented resilience strategies, aimed at both urban and rural populations. Campaigns must exhibit cultural diversity and utilize diverse media channels.
- **Integrate Disaster Preparedness into Educational Curriculums:** Include disaster preparedness and environmental education within school curricula to equip young people with the knowledge needed to respond to climate-induced natural disasters.

5. Promote Community-Based Adaptation and Resilience Building

- **Encourage Community-Led Flood Mitigation Projects:** Stimulate and support different community-led initiatives and make sure positive outcomes from those initiatives.

6. Increase International Collaboration and Seek Financial Support

- **Leverage International Expertise in Climate-Resilient Infrastructure:** Collaborate with and seek help from experts from different countries to upgrade the country's disaster management system and modify the infrastructure according to modern standards.
- **Seek Climate Adaptation Funding:** Obtain financial support from international entities addressing climate change, such as the United Nations' Green Climate Fund, to enhance relief initiatives against the climate crisis.

7. Improve Government Accountability and Policy Implementation

- **Establish Transparent Monitoring and Reporting System:** Introduce a strict monitoring and reporting mechanism for all the relevant departments responsible for disaster management. More accountability and transparency can help improve many things in different departments regarding disaster management.
- **Enhance Coordination Between Disaster Management Authorities:** Ensure more coordination among all disaster management authorities. The national disaster management authority should cooperate more with the provincial disaster management authorities.

Chapter 7 : Conclusion

The thesis underscores the need for integrated strategies to mitigate the severe impacts of recurring floods in Pakistan, which are escalated by climate change, inadequate infrastructure, and limited public awareness. By examining climate data, conducting community interviews, and reviewing government policies, the current study identifies both natural and human-driven factors as contributors to Pakistan’s flood events. Climate-related factors, such as shifting rainfall patterns and river overflow from upstream sources, combine with infrastructure deficiencies, governance challenges, and low public awareness to heighten Pakistan’s vulnerability to floods.

These floods have socio-economic impacts, which are multifaceted. Communities experience health crises, agricultural losses, displacement, loss of lives, and educational disruption, with women and children disproportionately affected due to cultural and social norms. Interviews with citizens and local stakeholders reveal a substantial deficiency in governmental support, frequently compelling communities to depend on their own initiatives for recovery and relief.

This study emphasises the necessity of a thorough, multifaceted strategy to improve flood resilience. Enforcing land-use restrictions, improving early warning systems, and strengthening flood control infrastructure, such as drainage systems and dams are important measures. To enhance flood preparedness at local and national levels, it is imperative to foster international alliances and collaboration, promote community-led resilience programs, and elevate public understanding regarding climate change. Together, these actions can reduce flood risks and pave the way for a more secure future for Pakistan's most vulnerable regions.

This research advocates for a hybrid approach that integrates community empowerment, policy reforms, and structural enhancements. Concentrating on these domains can empower Pakistan to develop a resilient framework that protects ecosystems, livelihoods, and human lives from the increasing threats of climate-induced flooding. The study's conclusions and recommendations aim to advance sustainable flood management practices, fostering a more resilient and secure future for Pakistan's most vulnerable communities living in the flood-prone areas.

Appendix

Appendix 1: This contains the climate data from all 12 stations of Punjab, Pakistan, this data is collected from Pakistan Meteorological Department and the link to the excel sheet containing the data is below:

https://docs.google.com/spreadsheets/d/155yVlFbSU38JrC77uSxHXw7XmIPsjut8/edit?usp=sharing&ouid=114580493226316602054&rtpof=true&sd=true

References

Abdullah, M. A., Shaikh, B. T., Sikander, A., & Sarwar, B. (2024). Public Health and Health System's Responsiveness During the 2022 Floods in Pakistan: What Needs to Be Done? Disaster Medicine and Public Health Preparedness, 17, e567. doi:10.1017/dmp.2023.224

Ahmad, D., Shah, S. Z. A., & Afzal, M. (2022). Flood hazards vulnerability and risk of food security in Bait community flood-prone areas of Punjab Pakistan: In SDGs achievement threat. *Environmental Science and Pollution Research*, 29(59), 88663–88680. https://doi.org/10.1007/s11356-022-21683-z

Ahmed, R., Barkat, W., Ahmed, A., Tahir, M., & Nasir, AM (2022). The impact of flooding on education of children and adolescents: Evidence from Pakistan. *Water Economics and Policy* , *8* (03), 2240009.

Akhtar, N. (2023, September 29). A Path to Managing Pakistan's Flood Crisis. *Stratheia*. https://stratheia.com/a-path-to-managing-pakistans-flood-crisis/

Ali, S., Cheema, M., Waqas, M., Waseem, M., Leta, M., Qamar, M., ... & Rahman, M. (2021). Flood mitigation in the transboundary Chenab River Basin: A basin-wise approach from flood forecasting to management. *Remote Sensing*, 13(19), 3916. https://doi.org/10.3390/rs13193916

Ali, W., Fani, M. I., Afzal, S., & Yasin, G. (2010). Cultural barriers in women empowerment: A sociological analysis of Multan, Pakistan. *European Journal of Social Sciences*, 18(1), 147–155.

Alied, M., Salam, A., Sediqi, S. M., Kwaah, P. A., Tran, L., & Huy, N. T. (2024). Disaster after disaster: The outbreak of infectious diseases in Pakistan in the wake of 2022 floods. *Annals of Medicine and Surgery*, 86(2), 891–898.

Anees, M. S. (2022, October 21). The anatomy of Pakistan's 2022 floods. The Diplomat. https://thediplomat.com/2022/10/the-anatomy-of-pakistans-2022-floods/

Anjum, S. A., Wang, L. C., Xue, L. L., Saleem, M. F., Wang, G. X., & Zou, C. M. (2010). Desertification in Pakistan: Causes, impacts and management. *Journal of Food Agriculture and Environment, 8*(1), 1203-1208.

Ashraf, A., Naz, R., & Roohi, R. (2012). Glacial lake outburst flood hazards in Hindukush, Karakoram and Himalayan Ranges of Pakistan: implications and risk analysis. Geomatics Natural Hazards and Risk, 3(2), 113–132. https://doi.org/10.1080/19475705.2011.615344

Aslam, M. (2018). Flood management current state, challenges, and prospects in Pakistan: A review. *Mehran University Research Journal of Engineering & Technology*, 37(2), 297–314. https://search.informit.org/doi/10.3316/informit.443904665290819

Baqir, M., Sobani, Z. A., Bhamani, A., Bham, N. S., Abid, S., Farook, J., & Beg, M. A. (2011). Infectious diseases in the aftermath of monsoon flooding in Pakistan. *Asian Pacific Journal of Tropical Biomedicine*, 2(1), 76–79. https://doi.org/10.1016/s2221-1691(11)60194-9

Batool, S., Zaffer, A., & Batool, F. (2024). Role of new media in good governance: A study of disaster management authorities of Pakistan. *MUL*. https://doi.org/10.58932/MULA0029

Blair, H., & Joseph, K. (2024). Punjab's sustainable energy future: The energy endorsement label. *CLASP.ngo*. Retrieved February 20, 2024, from https://www.clasp.ngo/updates/punjabs-sustainable-energy-future-the-energy-endorsement-label/

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

Bronstert, A. (2003). Floods and climate change: Interactions and impacts. *Risk Analysis*, 23(3), 545–557. https://doi.org/10.1111/1539-6924.00335

Chaudhary, Q. U. Z. (2017). *Climate change profile of Pakistan*. Asian Development Bank. https://www.adb.org/publications/climate-change-profile-pakistan

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage Publications.

Deen, S. (2015). Pakistan 2010 floods: Policy gaps in disaster preparedness and response. *International Journal of Disaster Risk Reduction*, 12, 341–349. https://doi.org/10.1016/j.ijdrr.2015.03.007

De Sherbinin, A., Bowser, A., Chuang, T., Cooper, C. B., Danielsen, F., Edmunds, R., ... Sivakumar, K. (2021). The critical importance of citizen science data. *Frontiers in Climate, 3*. https://doi.org/10.3389/fclim.2021.650760

Fahad, S., & Wang, J. (2020). Climate change, vulnerability, and its impacts in rural Pakistan: a review. *Environmental Science and Pollution Research* , *27* , 1334-1338.

Fao. (2023). Pakistan: Floods response update, February 2023. https://openknowledge.fao.org/items/0add3bbd-589d-440a-aed3-ace465d84ef

Gautam, K. P., & Van Der Hoek, E. E. (2003). *Literature study on the environmental impact of floods*. Netherlands: Delft Cluster.

Goh, K. C., Kurniawan, T. A., Goh, H. H., Zhang, D., Jiang, M., Dai, W., ... Meidiana, C. (2024). Strengthening infrastructure resilience for climate change mitigation: Case studies from Southeast Asia. *ACS ES&T Water*. https://doi.org/10.1021/acsestwater.4c00591

Haider, A. (2021). Diurnal temperature range (DTR) assessment in major cities of Punjab, Pakistan. *Pakistan Journal of Science*, 73(2).

Hakim, A., & Aziz, A. (1998). Socio-cultural, religious, and political aspects of the status of women in Pakistan. *The Pakistan Development Review, 37*(4), 727–746. https://www.jstor.org/stable/41261079

Hashmi, H. N., Siddiqui, Q. T. M., Ghumman, A. R., Kamal, M. A., & Mughal, H. U. R. (2012). A critical analysis of the 2010 floods in Pakistan. African Journal of Agricultural Research, 7(7), 1054-1067.

Higgs, K. (2024). A Great Disaster: The Floods of 2022 in Pakistan. In *Climate Change and Global Health: Primary, Secondary and Tertiary Effects* (pp. 178-185). GB: CABI.

Irfan, M., Qadir, A., Ali, H., Jamil, N., & Ahmad, S. R. (2019). Vulnerability of environmental resources in Indus Basin after the development of irrigation system. In *IntechOpen eBooks.* https://doi.org/10.5772/intechopen.86722

Jamil, B. R. (2023). What does a literacy crisis mean for the citizens of Pakistan? *The News International*. Retrieved from https://www.thenews.com.pk/tns/detail/1108006-what-does-a-literacy-crisis-mean-for-the-citizens-of-pakistan

Kayani, S. (2012, June 25). Mangla Dam Raising Project (Pakistan): General Review and Socio-Spatial Impact Assessment. https://hal.science/hal-00719226/

Kazemi, A. (2022). Geographic, historic, political, riparian, and socio-economic factors that lead to Pakistan as a land of penta Mesopotamia. *Pakistan Journal of Social Research*, 4(1), 330–335. https://doi.org/10.52567/pjsr.v4i1.656

Khan, N. M., & Tingsanchali, T. (2008). Optimization and simulation of reservoir operation with sediment evacuation: a case study of the Tarbela Dam, Pakistan. Hydrological Processes, 23(5), 730–747. https://doi.org/10.1002/hyp.7173

Khan, SI, & Adams, TE (Eds.). (2019). *Indus River Basin: water security and sustainability* . Elsevier.

Kirsch, T. D., Wadhwani, C., Sauer, L., Doocy, S., & Catlett, C. (2012). Impact of the 2010 Pakistan floods on rural and urban populations at six months. *PLoS Currents*. https://doi.org/10.1371/4fdfb212d2432

Kocaman, S., Anbaroğlu, B., Gökçeoğlu, C., & Altan, O. (2018). A review on citizen science (CitSci) applications for disaster management. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-3/W4, 301–306. https://doi.org/10.5194/isprs-archives-xlii-3-w4-301-2018

Krisberg, K. (2016). Climate change linked to floods, warmer temperatures nationwide.

Lal, R., & Moldenhauer, W. C. (1987). Effects of soil erosion on crop productivity. *Critical Reviews in Plant Sciences*, *5*(4), 303–367. https://doi.org/10.1080/07352688709382244

Latif, M., & Syed, F. S. (2016). Determination of summer monsoon onset and its related large-scale circulation characteristics over Pakistan. Theoretical and Applied Climatology, 125, 509-520.

Maskey, S. (2018). Flood risk in the changing climate. *Journal of Flood Risk Management*, 11(2), 109–110. https://doi.org/10.1111/jfr3.12458

Manzoor, Z., Ehsan, M., Khan, MB, Manzoor, A., Akhter, MM, Sohail, MT, ... & Abioui, M. (2022). Floods and flood management and its socio-economic impact on Pakistan: A review of the empirical literature. *Frontiers in Environmental Science* , *10* , 1021862.

McNally, B. (2018). Building carbon literacy: how the Irish press normalise public discussion about climate mitigation actions. Climate Change Management, 271-284. https://doi.org/10.1007/978-3-319-70479-1_17

Mughal, H. (2021). A critical analysis of 2010 floods in Pakistan. *Academia.edu.* https://www.academia.edu/56877698/A_critical_analysis_of_2010_floods_in_Pakistan

Mughal, M. A. Z. (2018). Rural urbanization, land, and agriculture in Pakistan. Asian Geographer, 36(1), 81–91. https://doi.org/10.1080/10225706.2018.1476255

Murunga, M., Pecl, G., Ogier, E., Leith, P., MacLeod, C., Kelly, R., et al., (2022). More than just information: what does the public want to know about climate change?. Ecology and Society, 27(2). https://doi.org/10.5751/es-13147-270214

Noureen, A., Aziz, R., Ismail, A., & Trzcinski, A. P. (2022). The impact of climate change on waterborne diseases in Pakistan. *Sustainability and Climate Change, 15*(2), 138–152.

Onu, D. B. (2024). The impacts of flooding on the depletion and dispersal of plants. *Greener Journals*. https://www.gjournals.org/2024/05/12/050524055-onu/

Ottinger, G. (2022). Becoming infrastructure: Integrating citizen science into disaster response and prevention. *Citizen Science: Theory and Practice, 7*(1).

Otto, F. E. L., Zachariah, M., Saeed, F., Siddiqi, A., Kamil, S., Mushtaq, H., Arulalan, T., AchutaRao, K., Chaithra, S. T., Barnes, C., Philip, S., Kew, S., Vautard, R., Koren, G., Pinto, I., Wolski, P., Vahlberg, M., Singh, R., Arrighi, J., & Clarke, B. (2023). Climate change increased extreme monsoon rainfall, flooding highly vulnerable communities in Pakistan. *Environmental Research Climate, 2*(2), 025001. https://doi.org/10.1088/2752-5295/acbfd5

Paracha, M. B., Aftab, F. N., & Heyns, A. M. (2024). Pakistan: Devastating floods have widened spatial disparities. *World Bank Blogs*. https://blogs.worldbank.org/en/transport/pakistan-devastating-floods-have-widened-spatial-disparities

Priyanti, R. P., Hidayah, N., Rosmaharani, S., et al. (2019). Community preparedness in flood disaster: A qualitative study. *International Quarterly of Community Health Education, 40*(1), 67–68. https://doi.org/10.1177/0272684X19853169

Qureshi, A. S. (2011). Water management in the Indus Basin in Pakistan: Challenges and opportunities. *Mountain Research and Development*, (252). https://bioone.org/journals/mountain-research-and-development

Rehmat, A., Ahmad, S. M., Danish, S., Umar, A., Khaver, A., & Khan, R. M. (2023). Claiming repair for loss and damage due to floods 2022: The case of Pakistan.

Ritchie, H., Roser, M., & Rosado, P. (2020). CO_2 and Greenhouse Gas Emissions. *Our World in Data*. https://ourworldindata.org/co2/country/pakistan

Ritchie, H. (2022). CO_2 emissions dataset: our sources and methods. *Our World in Data*. Retrieved from https://ourworldindata.org/co2-dataset-sources

Saad, S., Mahsud, M. I., & Mian, G. (2024). Climate change impacts: exploring the rising climate-security nexus in Pakistan. Liberal Arts and Social Sciences International Journal (LASSIJ), 8(1), 177–190. https://doi.org/10.47264/idea.lassij/8.1.10

Sabir, M., Torre, A., & Magsi, H. (2017). Land-use conflict and socio-economic impacts of infrastructure projects: the case of Diamer Bhasha Dam in Pakistan. Area Development and Policy, 2(1), 40–54. https://doi.org/10.1080/23792949.2016.1271723

Salma, S., Rehman, S., & Shah, M. A. (2012). Rainfall trends in different climate zones of Pakistan. *Pakistan Journal of Meteorology*, *9*(17).

Sayed, S. A. (2014). Flood disaster profile of Pakistan: A review. *Science Journal of Public Health, 2*(3), 144. https://doi.org/10.11648/j.sjph.20140203.11

Semu-Banda, P. & Nawaz, M (2023). Addressing Persistent Challenges Faced by Flood-Affected Women and Girls in Pakistan – One Year On. UNFPA Pakistan. Retrieved from https://pakistan.unfpa.org/en/news/addressing-persistent-challenges-faced-flood-affected-women-and-girls-pakistan-%E2%80%93-one-year

Shaikh, O. A., Rahim, M., Essarani, M., Nadeem, S., Ochani, S., Al Hasibuzzaman, M., & Ullah, K. (2023). Dreadful infectious disease outbreaks threaten flood-ravaged Pakistan. *Annals of Medicine and Surgery, 85*(6), 3237–3238.

Shah, A. A., Gong, Z., Ali, M., Sun, R., Naqvi, S. A., & Arif, M. (2020). Looking through the Lens of schools: Children perception, knowledge, and preparedness of flood disaster risk management in Pakistan. *International Journal of Disaster Risk Reduction , 50* , 101907.

Sheer, A., Fatima, S., & Sharif, A. (2023). Impact of climate change on Pakistan and proposed solutions: Evidence from literature. *Migration Letters, 20*(6), 97–112. https://doi.org/10.59670/ml.v20i6.3464

Shrestha, M. (2024). *ICIMOD - International Centre for Integrated Mountain Development*. https://www.icimod.org/

Siddiqui, R., & Siddiqui, S. (2018). Assessing the rooftop rainwater harvesting potential in urban residential areas of Pakistan: A case study of Model Town, Lahore, Pakistan. *International Journal of Economic, Environment, and Geology, 9*, 11–19.

Silverman, D. (2014). *Interpreting Qualitative Data*. SAGE Publications - 100 p. ISBN: 9781529672602.

Snead, R. E. (1968). Weather patterns in Southern West Pakistan. *Archiv Für Meteorologie Geophysik Und Bioklimatologie Serie B, 16*(4), 316–346. https://doi.org/10.1007/bf02243179

Stofer, K. A., Lundgren, L., Dunckel, B. A., James, V., Lange, M., & Krieger, J. L. (2019). Public engagement on climate and health in museums and participatory dialogues may foster behavior change. The Journal of STEM Outreach, 2(1). https://doi.org/10.15695/jstem/v2i1.10

Thomas, V., Albert, J. R. G., & Pérez, R. T. (2013). Climate-related disasters in Asia and the Pacific. *Social Science Research Network*. https://doi.org/10.2139/ssrn.2295783

Tidball, K. G., Krasny, M. E., Louv, R., Fitzpatrick, J. W., Dickinson, J. L., & Bonney, R. (2012). A role for citizen science in disaster and conflict recovery and resilience. *Citizen Science*, 226–233.

Tongco, M. D. C. (2007). Purposive sampling as a tool for informant selection. *Ethnobotany Research & Applications, 5*, 147–158.

Tran, H. N., Rutten, M., Prajapati, R., Tran, H. T., Duwal, S., Nguyen, D. T., Davids, J. C., & Miegel, K. (2024). Citizen scientists' engagement in flood risk-related data collection: A case study in Bui River Basin, Vietnam. *Environmental Monitoring and Assessment, 196*(3). https://doi.org/10.1007/s10661-024-12419-2

Ullah, W., Wang, G., Lou, D., Ullah, S., Bhatti, A. S., Ullah, S., ... & Ali, G. (2021). Large-scale atmospheric circulation patterns associated with extreme monsoon precipitation in Pakistan during 1981–2018. Atmospheric Research, 253, 105489.

Vakili, Y. (2022). Flood prevention in Pakistan: What's changed since 2010? *International Relations Review*. https://www.irreview.org/articles/flood-prevention-in-pakistan-whats-changed-since-2010

Ware, T. (2021). A look at the Indus Basin irrigation system. Retrieved from https://www.twl-irrigation.com/indus-basin-irrigation-system/

Warraich, H., Zaidi, A. K., & Patel, K. (2011). Floods in Pakistan: A public health crisis. *Bulletin of the World Health Organization, 89*, 236–237.

Yaqub, M. (2015). Flood causes, consequences, and protection measures in Pakistan.