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MANAGING HILL TORRENTS IN PAKISTAN

Challenges, Opportunities, and Regional Perspectives

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Zainab Naeem is a Ph.D scholar in environmental sciences, holding both a master's and bachelor's degree in the same discipline. Her research interests include climate resilience, circular economy, climate risk insurance, and environmental diplomacy.

At the Sustainable Development Policy Institute (SDPI), Zainab conducts research and policy advocacy on climate diplomacy, urban climate-resilient development, and circular economy. Her research project themes include urban climate-resilient development, used-textiles trade circularity, plastics circularity, plastic waste scoping analysis, water governance and stewardship, climate finance and risk insurance strategies. In addition to this, she has contributed in developing sustainability and environmental, social, and governance (ESG) reports for various organizations, highlighting ecological sustainability and socio-economic practices. She has facilitated training sessions on carbon markets, urban resilience, and climate communications for corporate entities, journalists, youth activists, and public sector organizations. She has also played an instrumental role in developing and implementing research communication and advocacy strategies for different research programs. She also has provided technical assistance to public and private schools on environmental education curriculum development.

In addition to her research and project leadership, Zainab is actively involved in fostering public-private partnerships for climate resilience, aiming to mobilize private sector actions to enhance community climate resilience. To materialize these efforts, she introduced the Sustainability Investment Expo and Sustainability Awards initiatives in SDPI and has been leading these initiatives since 2023.

She also serves as SDPI's focal person for both the Collect and Recycle Alliance and the UN Living Indus Initiative. Zainab has also received specialized trainings on the Sustainable Consumption and Production Hotspot Analysis Tool, greenhouse gas inventory emission reporting, geo-spatial modelling using remote sensing techniques, equipping her with advanced skills in sustainability analysis, emission reporting and environmental modelling.

As a dedicated climate activist, she regularly conducts capacity-building training sessions for different public/private organizations and academia. She represented SDPI as a delegate at COP28, further showcasing her commitment to global climate action.

Executive Summary

Pakistan encounters notable hurdles and prospects in managing hill torrents, which are crucial water sources for irrigation and local communities. This working paper provides a detailed analysis of the management and utilization of hill torrents in Pakistan, employing a mixed-methods approach for data collection and analysis.

The paper begins by examining Pakistan's vulnerability to climate change, highlighting the country's diverse geography and climatic patterns. With distinct agro-ecological zones and variable precipitation systems, Pakistan experiences frequent floods and droughts, aggravated by El Niño events and temperature anomalies. The devastating floods of 2022, triggered by intense monsoon rains and overflowing hill torrents, highlight the urgent need for effective management strategies. The floods affected millions of people, causing substantial economic losses and infrastructure damage across multiple provinces.

Hill torrents, characterized by rapid water movement and powerful currents, are essential for spate irrigation, accounting for a significant portion of Pakistan's irrigated land. However, the potential of hill torrents remains underutilized due to challenges in management and frequency issues. The paper explores regional perspectives on hill torrent management, detailing practices in Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan. Each province faces unique challenges and opportunities, requiring tailored approaches to water resource management.

In Punjab, hill torrents are vital for agriculture in districts such as D.G. Khan and Rajanpur, where spate irrigation systems operate. However, inadequate infrastructure and management practices contribute to water wastage and flooding.

Sindh relies on large hill torrents, known as '*nai*,' for water supply, but challenges persist in diverting excessive water and managing downstream impacts. Efforts to construct dams and reservoirs aim to mitigate flooding, but success has been limited, as seen in the 2022 floods.

In Khyber Pakhtunkhwa, terrace farming and spate irrigation are prevalent in the Panjkora Basin, yet vulnerability to flash floods poses significant risks. On the contrary, the province of Balochistan boasts the highest potential for spate irrigation, but the province faces challenges in managing diverse hill torrent systems effectively.

To address the critical issues in managing hill torrent areas in Pakistan, a comprehensive approach encompassing governance, infrastructure, nature-based solutions, and stakeholder engagement is essential. Policy recommendations were clustered around the following themes:

Governance and Infrastructure:
The recommendations focus on setting up a coordinated system for managing watershed areas, especially in regions such as Sindh and Balochistan that currently lack such integrated management. This involves better cooperation between provincial departments handling water resources and agriculture. The goal is to manage water more efficiently and reduce flood risks through comprehensive watershed management. Hence, to achieve this, it's crucial to improve collaboration between different departments, ensure policies are consistent across regions, and secure adequate funding from both private sources and development partners. Moreover, there is a need for involving local communities in decision-making processes and supporting local institutions with the necessary skills and resources.

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Climate Resilient Infrastructure
Building climate-resilient infrastructure, such as small dams and retention structures, is essential for managing water flows during hill torrents and reducing flood impacts. For this purpose, the departments responsible for infrastructure and water resources need to prioritize construction in areas most vulnerable to flooding. It's also important to design these structures to withstand climate challenges and to establish regular maintenance and monitoring systems to ensure their effectiveness over time. Additionally, it has been proposed to use nature-based solutions like terracing and traditional water management practices to enhance ecological resilience. This includes restoring natural habitats, integrating traditional knowledge with modern techniques, and promoting conservation efforts such as replanting forests and managing grazing lands.

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Technology and Innovation:
The recommendations highlight the role of modern technology in improving water management and disaster response capabilities. They suggest using technologies such as information and communication technology (ICT), remote sensing, and geographic information systems (GIS) for real-time data collection and analysis. For this purpose, the federal and provincial departments of technology and innovation, working alongside relevant agencies, are encouraged to lead these efforts. They should also focus on training disaster response teams and meteorological departments in using these technologies effectively. Moreover, developing early warning systems for hill torrents also needs to be prioritized, requiring collaboration between agencies such as the Federal Flood Commission, meteorological departments, and local communities. This includes creating advanced warning systems and educating communities on how to respond to alerts effectively.

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Community Engagement:
Strengthening community involvement and local cooperation is essential for successful water management efforts. Engaging local communities in planning and decision-making processes through forums, workshops, and educational initiatives is key to building sustainable practices. Additionally, supporting and strengthening local institutions, alongside continuous community engagement, are vital steps.

Incorporating the private sector into water management can also bring significant benefits. By highlighting the economic advantages of sustainable water projects, private investment can be attracted, encouraging partnerships between government agencies and businesses. These collaborations aim to create an inclusive environment where all stakeholders contribute to better water governance and resilience against natural disasters.

This working paper provides important insights into the complexities of managing hill torrents in Pakistan, forming a foundation for policymakers, practitioners, and researchers to craft informed strategies and solutions for the country's water management challenges.

Introduction

The impacts of climate change in Pakistan are severe and multifaceted, placing the country among the top 10 globally in terms of vulnerability. Pakistan's climate vulnerability is deeply intertwined with its diverse geography and climatic patterns. The country experiences a wide range of climates, from the hot and dry coastal regions and lowland plains of the Indus River to the cooler northern uplands and the Himalayas[1]. Recognized for its four distinct seasons—cool, dry winters from December to February; hot, dry springs from March to May; the summer monsoon season from June to September; and the retreating monsoons from October to November—Pakistan's weather is marked by significant variability. The country is geographically divided into three main regions: the northern highlands, the central and eastern Indus River plain, and the Balochistan Plateau to the south and west. Additionally, the country is segmented into 10 agro-ecological zones, each categorized based on factors such as physiography, climate, land use, and water availability (Table 1)[2] [3].

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The northern regions receive substantial monsoon rainfall, with up to 200 millimeters per month from July to September, while the rest of the country remains predominantly dry. This variability often results in cycles of floods and droughts, exacerbated by El Niño events, which significantly influence temperature anomalies and flood patterns.

Over the 20th century, Pakistan has warmed by approximately 0.57°C, with an accelerated warming of 0.47°C recorded since 1961[4] (Figure 1). This warming trend is more pronounced during the winter and post-monsoon months, particularly affecting the southern regions such as Punjab, Sindh, and Balochistan.

The increased variability of precipitation systems, influenced by monsoon rains from the east and westerly disturbances from the Mediterranean, further complicates the climate landscape. This heightened variability leads to more frequent and intense extreme weather events, including heatwaves, floods, and droughts[5]. Floods frequently occur in Pakistan, primarily due to heavy downpour during the summer monsoon season and sometimes because of tropical cyclones. The northern provinces often suffer the most from these floods, especially when intense monsoon rains and melting glaciers cause the upper tributaries of the Indus River to overflow. Notable years when the northern regions were heavily impacted include 1992, 1995, 2012, and 2021. Conversely, the southern provinces faced severe flooding in 2003, 2009, 2007, and 2020[6].

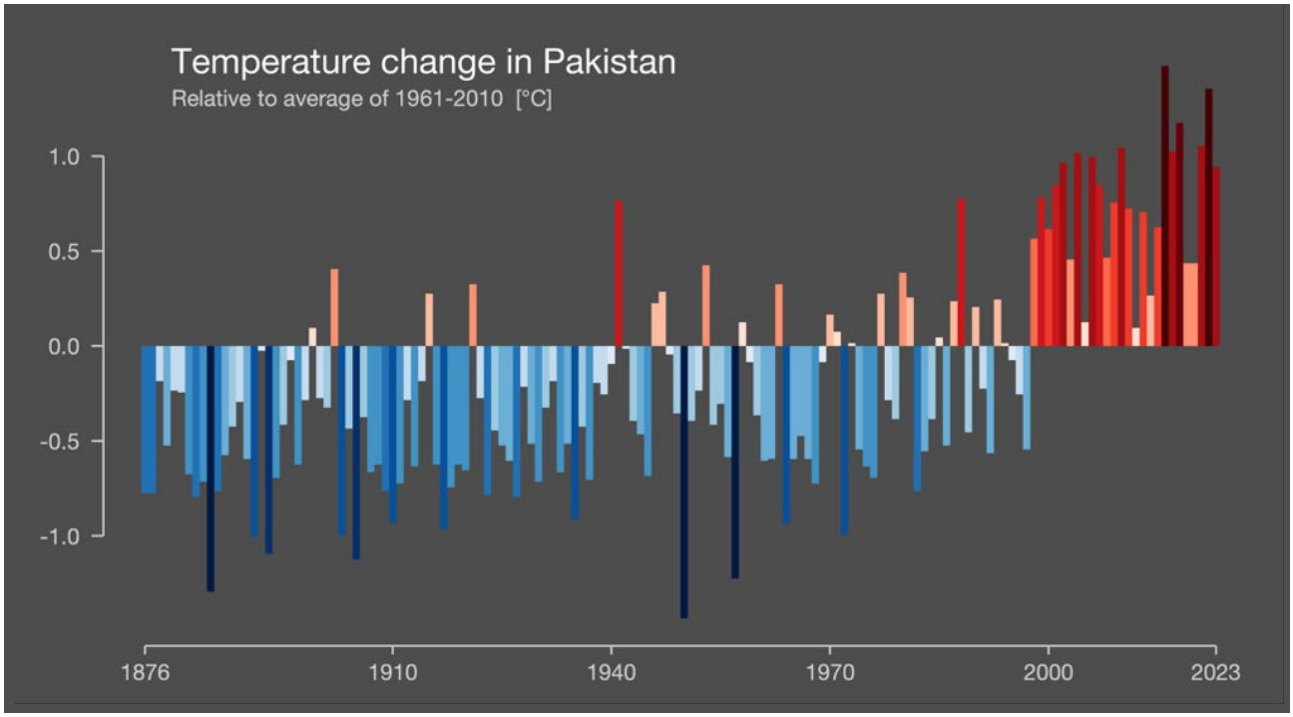
On average, Pakistan experienced one flood every three years between 1950 and 2011, totaling around 21 extreme floods. These floods resulted in the loss of 8,887 lives and caused an indirect economic impact of $19 billion. However, the floods in 2010 and 2022 were particularly devastating, affecting large areas across the entire country[7]. Large segments of the population live in extreme poverty, which amplifies their susceptibility to the adverse effects of climate variability. Pakistan's economy and livelihoods are

TABLE 1:
AGRO-ECOLOGICAL ZONES OF PAKISTAN

ZONE I- Indus Delta	The climate is arid with tropical marine influences. In the summer, the average monthly rainfall is around 75 mm, while in the winter it drops to less than 5 mm. Daily temperatures range from 34°C to 40°C in the summer and from 19°C to 20°C in the winter. The soils in the region are clayey and saline.
ZONE II- Southern Irrigated Plain	In the Lower Indus Plain, the climate is arid and subtropical. During the summer, the average monthly rainfall is about 18 mm in the northern areas and between 45 to 55 mm in the southern regions. The soils here are predominantly silty and sandy loam, while the upper areas of the floodplain have calcareous loamy and clayey soils.
ZONE III (a)- Sandy Desert	The maximum rainfall reaches up to 300 mm. The soils in the area are predominantly sandy and fine loamy sand.
ZONE III (b)- Sandy Desert	In areas with sand ridges and dunes, rainfall ranges between 300 and 350 mm. The soils are mainly sandy and fine loamy sand.
ZONE IV (a) – Northern Irrigated Plain	Floodplains and bar uplands. The climate ranges from semi-arid to arid. The annual rainfall averages 300 to 500 mm in the east and 200 to 300 mm in the southwest. The soil types include sandy, loam-clay, and loam.
ZONE IV (b) – Northern Irrigated Plain	Alluvial valleys in Peshawar and Mardan. The climate is semiarid. The average monthly rainfall is 20 to 30 mm. The soil types include silty clays and clay loams.
ZONE V- Barani (rain-fed) lands	This includes the Salt Range and Potohar Plateau. In the north, the average monthly rainfall is 200 mm in summer and 35 to 50 mm in winter. The climate in the southern region is semi-arid and hot. The average monthly rainfall is 85 millimetres in the summer and 30 to 45 mm in the winter.
ZONE VI – Wet Mountains – High Mountains	The average monthly rainfall is 235 mm in the summer and 116 mm in the winter. The soils range from silt loams to silty clays. Only a small part is used for rain-fed agriculture, while the majority is covered under forest.
ZONE VII- Northern Dry Mountains	The average monthly rainfall is 25 to 75 mm in the winter and 10 to 20 mm in the summer. The valley's soils are deep and clayey.
ZONE VIII- Western Dry Mountains	They consist of barren hills with steep slopes. The average monthly rainfall is 95 mm in summer and 63 to 95 mm in winter. The valleys' soils are deep and loamy. The majority of the area is utilised for grazing.
ZONE IX- Dry Western Plateau	Mountainous landscapes. Summertime rainfall averages 37 mm per month. A sea breeze blows across the coastal belt. This land is largely utilised for grazing.
ZONE X- Suleiman Piedmont	It stretches from D.I Khan in KP to Dera Ghazi Khan in Punjab and Dera Bugti, Kachhi, and Nasirabad in Balochistan. The average monthly rainfall is less than 15 mm. The highland torrents' flows are used for irrigation. Arid and subtropical climates are distinguished by scorching summers, mild winters, and low humidity.

FIGURE 1:
TEMPERATURE CHANGE IN PAKISTAN UNTIL 2023

The stripes above the bar indicate rising temperature.



heavily dependent on the annual water influx from the Indus River system, which is fed by Himalayan snowmelt. However, about 80 percent of the land is classified as arid or semi-arid, making it prone to desertification, with only 12 percent being dry sub-humid and a mere 8 percent categorized as humid[8]. Despite these challenges, Pakistan's low-middle-income status limits its readiness to address and adapt to climate change. The Notre Dame Global Adaptation Index ranks Pakistan as the 32nd least-ready country out of 181, underscoring the urgent need for comprehensive adaptation and mitigation strategies to safeguard its vulnerable population and economy[9].

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[5] Nadeem, F., Jacobs, B. and Cordell, D., 2022. Mapping agricultural vulnerability to impacts of climate events of Punjab, Pakistan. *Regional Environmental Change*, 22(2), p. 66.

[6]Akhtar, A., Indus Basin Floods: Mechanisms. *Impacts, and Management*, p. 67.

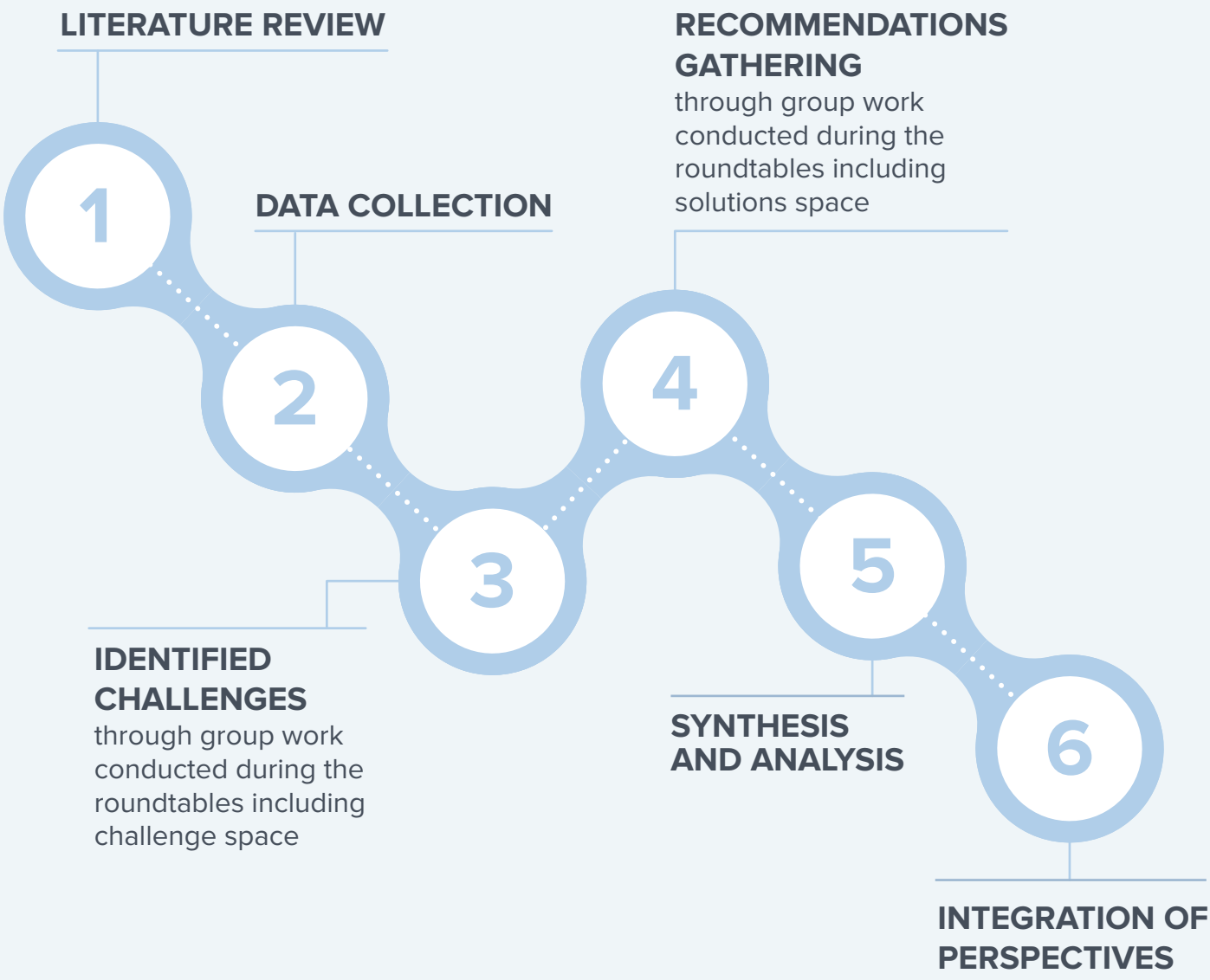
[7]Nanditha, J.S., Kushwaha, A.P., Singh, R., Malik, I., Solanki, H., Chuphal, D.S., Dangar, S., Mahto, S.S., Vegad, U. and Mishra, V., 2023. The Pakistan flood of August 2022: causes and implications. *Earth's Future*, 11(3), p.e2022EF003230.

[8]Rashid, A., Ryan, J. and Chaudhry, M.A., 2004. Challenges and strategies for dryland agriculture in Pakistan. *Challenges and strategies of dryland agriculture*, 32, pp. 359-371.

[9]Batool, S. and Saeed, F., 2018. Towards a climate resilient cotton value chain in Pakistan: Understanding key risks, vulnerabilities and adaptive capacities. *Pathways to Resilience in Semi-Arid Economies (PRISE) Working Paper. Overseas Development Institute*.

Methodology

FIGURE 2:
MIXED METHODS APPROACH

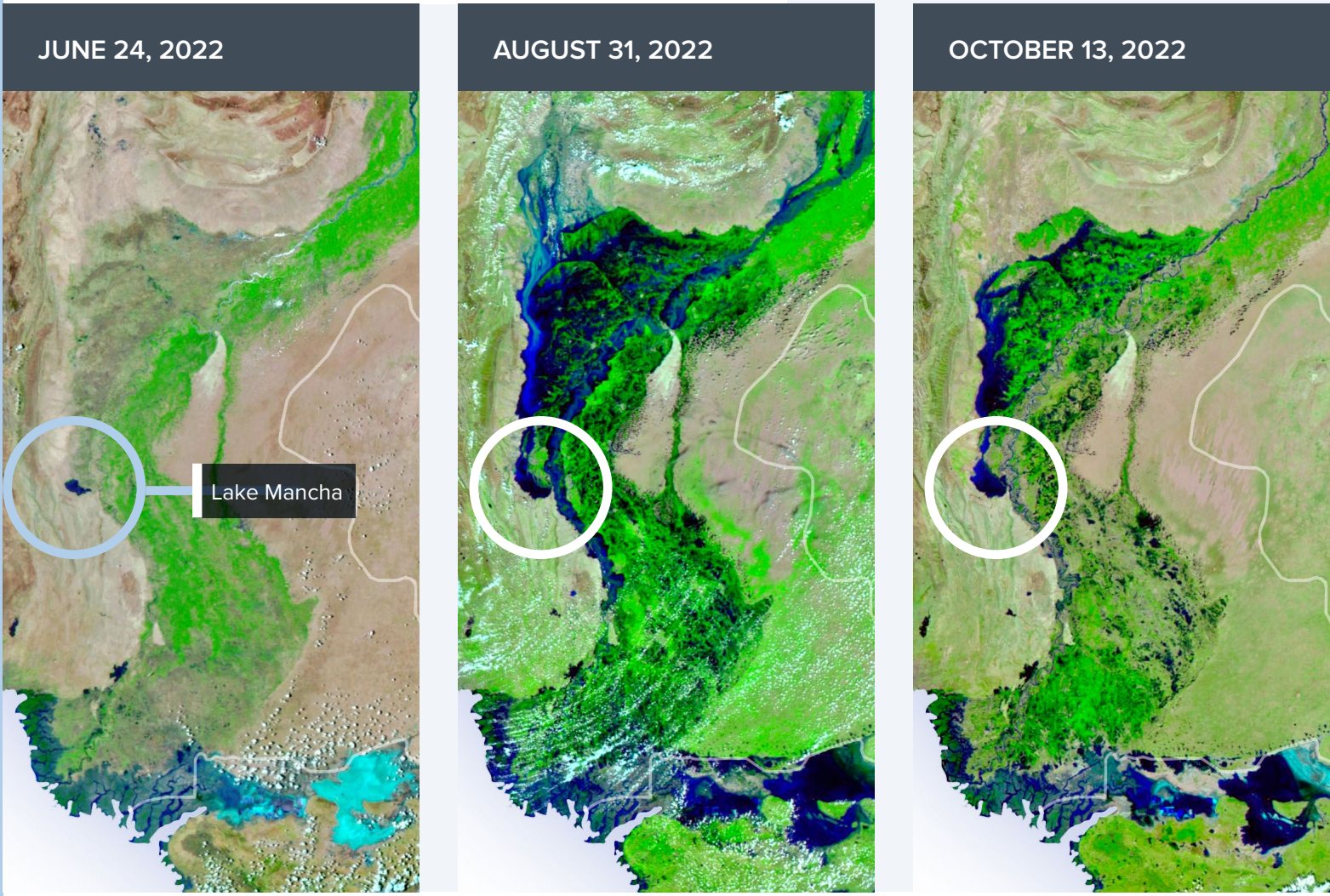


The methodology employed in this working paper encompassed a mixed-methods approach, combining both qualitative and quantitative techniques to gather data and insights on the management and utilization of hill torrents in Pakistan. Initially, a thorough review of existing literature, policy documents, and research reports was conducted to establish a foundational understanding of the subject matter. This qualitative data collection method ensured the incorporation of existing knowledge and insights into subsequent phases of the study. Following this, primary data collection was undertaken through national roundtable discussions and focused group sessions involving key stakeholders from various sectors. These qualitative sessions engaged communities, governmental bodies such as the Federal Flood Commission and the National Disaster Management Fund, as well as non-governmental organizations such a the Rural Support Programme Network and local development partners with expertise in hill torrents. Moreover, specific virtual dialogues were organized for Balochistan and Sindh to address regional nuances and concerns. Stakeholders such as water governance institutions and irrigation departments participated in these dialogues, providing valuable perspectives on challenges and opportunities related to hill torrent management. Throughout these interactions, key challenges were identified, and a wide array of recommendations was gathered, capturing the diverse perspectives and insights of all involved parties. The inputs received from these discussions were meticulously recorded and analyzed to inform the findings and recommendations presented in this working paper. Overall, this mixed-methods approach facilitated a holistic understanding of the issues surrounding hill torrents in Pakistan and ensured the incorporation of diverse stakeholder perspectives in the research process. The methodology has been indicated in steps in the (Figure 2).

Floods 2022

In the summer of 2022, Pakistan faced an unprecedented climate-fuelled disaster. Unusually hot weather in the spring and summer of 2022 enhanced an intense depression from the Arabian Sea, bringing heavy rainfall to the southern regions. In March and April, an unusual time for severe heat, temperatures soared above 50°C in some areas, causing various types of damage such as reduced wheat yields, livestock losses, forest fires, infrastructure damage, and health issues[10].

FIGURE 3:
The satellite images indicates the southern part of Pakistan submerged under flood water in 2022 . Source: NASA[12]



Overall, Pakistan received 243 percent more rainfall than usual, significantly impacting the densely populated and impoverished nation. The flooding affected more than 33 million people, destroying 1.7 million homes and resulting in nearly 1,500 deaths.

The hot summer also accelerated the melting of Pakistan's glaciers in the north, which feed the Indus River. A La Niña event, combined with other factors, extended and intensified the monsoon over Pakistan, leading to severe flooding[11]. From mid-June to late August, the country was hit by record-breaking monsoon rainfall in several intense pulses, leading to widespread flooding by the end of August. The Indus River overflowed across thousands of square kilometres, causing urban flash floods, landslides, and Glacial Lake Outburst Floods. The southern province of Sindh was particularly hard-hit, forming a 100-kilometer wide lake, and along with Balochistan, faced the worst of the disaster. The rainfall in these regions reached 726 percent and 590 percent of the usual August totals, respectively, marking the wettest August since records began in 1961 (Figure 3).

On August 25, the government declared a national emergency. Preliminary damage estimates suggest losses around $30 billion, with further economic disruption expected. The disaster destroyed approximately 6,700 kilometers of roads, 269 bridges, and 1,460 health facilities. Additionally, 18,590 schools were damaged, 750,000 livestock were killed, and about 18,000 square kilometers of cropland were ruined, including nearly 45 percent of cotton crops, a key national export.

In addition to the devastating effects of the monsoon rains and river overflow, hill torrents wreaked havoc in several provinces of Pakistan, particularly Balochistan, Sindh and South Punjab, exacerbating the already dire situation. The flood embankments or dykes were not sufficient enough to hold back the torrents and eventually hundreds of villages were submerged under water. In particular, the hill torrents originating from the Suleiman Range caused colossal damage to mud houses, livestock, infrastructure and also the loss of human lives as reported by different news agencies in 2022. The cities of Dera Ghazi Khan and Rajanpur, positioned between the Suleiman Range hill torrents from the west and the Indus River in the east, bore substantial damage. This resulted in downstream repercussions in Balochistan and Sindh. More than 100,000 individuals were affected, approximately 4,000 households were damaged, and more than 200,000 acres of crop area were impacted in Dera Ghazi Khan and Rajanpur (Figure 4). More than 0.30 million people were affected by the hill torrents flood in southwestern Punjab.

During the 2022 floods, 16 areas were affected throughout the country due to the flooding caused by hill torrents (Table 2).

FIGURE 4
FLOODS OF 2022

TABLE 2
AREAS AFFECTED IN PROVINCES DUE TO HILL TORRENTS DURING FLOODS 2022

FEDERAL AREAS & AZAD KASHMIR HILL TORRENTS	■ Gilgit Baltistan ■ Federally Administrated Tribal areas (FATA) ■ Azad Jammu & Kashmir
KHYBER PAKHTUNKWA HILL TORRENTS	■ D.I.Khan ■ Bannu ■ Kohat ■ Hazara Area ■ Kabul River
PUNJAB HILL TORRENTS	■ D.G.Khan ■ Pothowar Area ■ Rachna & Ghaj Doabs
BALOCHISTAN HILL TORRENTS	■ Zhob-Loralai ■ Kachhi Basin ■ Kharan Closed Desert Basin ■ Makran Coastal Area
SINDH HILL TORRENTS:	■ Kirther Range ■ Karachi Area ■ Sehwan ■ Petaro area

[10] Fu, Z.H., Zhou, W., Xie, S.P., Zhang, R. and Wang, X., 2024. Dynamic pathway linking Pakistan flooding to East Asian heatwaves. *Science Advances*, 10(17), p.eadk9250.

[11] Tang, S., Qiao, S., Wang, B., Liu, F., Feng, T., Yang, J., He, M., Chen, D., Cheng, J., Feng, G. and Dong, W., 2023. Linkages of unprecedented 2022 Yangtze River Valley heatwaves to Pakistan flood and triple-dip La Niña. npj *Climate and Atmospheric Science*, 6(1), p. 44.

[12] NASA Earth Observatory. 2022.

Hill Torrents in Pakistan

Hill torrents are commonly found in rough landscapes, especially in mountainous areas around the globe. They are characterized by steep gradients, which lead to swift water movement, and their streams can be turbulent and forceful, often displaying powerful currents. The term "torrent" refers to channels that carry rapid flows of flash water, typically found in steep mountainous regions. These channels are known by various names locally, and in some areas where hill torrents originate, spate irrigation is practiced.

REGIONAL TERMINOLOGIES FOR HILL TORRENTS

In Punjab they are called *rod kohi*, with r*od* meaning water channels and k*ohi* referring to hills or mountains. While in KP Province, they are known as *zam*. In Balochistan, they are termed as *sailaaba* or *khushkhaba* while in Sindh, they are known as *nai*.

© Destroyed home during flood in sawat pakistan By PNG River Gfx / Adobe Stock

SIGNIFICANCE OF HILL TORRENTS

Approximately 55 percent of Pakistan's land area is drained by hill torrents, which include around 14 major torrents. This network forms the country's second-largest irrigation system—known as spate irrigation—following the Indus Basin Irrigation System. Of the roughly 13.25 million hectares of land with irrigation potential, 6.35 million hectares lie in hilly regions, and 6.9 million hectares are in foothills and plains. Effective water management could make a substantial portion of this land cultivable through hill torrent irrigation. Currently, however, due to challenges related to the frequency and management of these torrents, only between 0.72 and 2.0 million hectares are irrigated annually using spate irrigation, representing roughly 9 percent of Pakistan's total irrigated area each year.

Across all four provinces, there are approximately 14 identifiable hill torrent areas, presenting a combined potential of about 23 billion cubic meters across roughly 1,200 locations[18].

SPATE IRRIGATION

Spate irrigation is a system in which run-off water from flash floods and mountain springs is diverted by constructing small dams (bunds), embankments and channel. It is used for irrigating fields located in the valley. Moreover, it provides water for local farming system, forestry, and rangelands as well as drinking water supplies-either directly or through recharge of shallow aquifers. Spate irrigation is a community-based system that's eco-friendly, relying on gravity for water flow and promoting organic farming. Spate irrigation is being practiced in the Piedmont plains of D.I. Khan (KPK), Dera Ghazi, Khan (Punjab), Jamshoro, Dadu (Sindh) and in Sulaiman ranges, Kachhi plain, and Kharan and Lasbela basins of Balochistan province. However, the major practice, as per the Pakistan Agriculture Research Council is in three agro-ecological regions: the Western dry mountains, the Suleiman piedmont range, and the Balochistan plateau. The sediment-rich flow from hill torrents is beneficial for agriculture.

The *rod kohi* irrigation system in Pakistan operates based on a water distribution method known as *warabandi*, established during the British colonial era and maintained since Pakistan's independence. Under this system, farmers' irrigation rights are recorded in handwritten registers specific to each *rod kohi* area, which serve as official documentation. However, despite these regulations, the *warabandi* system is not effectively implemented on the ground. The government has allowed farmers to manage water allocation independently, without interference. In practice, the upstream farmer irrigates their land first, reserving as much water as possible, often leading to overirrigation and water wastage. Once their needs are met, they pass water to downstream farmers[20].

REGIONAL PRACTICES OF SPATE IRRIGATION IN PAKISTAN

• Punjab

The torrential area of Dera Ghazi (D.G.) Khan and Rajanpur districts in Punjab is located between the Indus River and the Khirthar and Suleiman Mountain Ranges (KSMR), bordered by Sindh to the south, Balochistan to the west, and Khyber Pakhtunkhwa (KPK) to the north. About 45 percent of the total catchment area is within these two districts, with the remaining 55 percent in Balochistan[21]. The western part of the area, known locally as the "Pachad" area, lies on the right side of the Indus River. It is not irrigated by the local canal network but is fertile due to sediment deposits brought down by floodwaters from the mountains. The Pachad area stretches from the point where torrents enter the plains (darrah) to the right bank of the Indus River[22]. The region is characterized by 13 major hill torrents, originating from the Koh-e-Suleman Range and flowing through D.G. Khan and Rajanpur towards the Indus River. In total, there are around 200 hill torrents of various sizes, with a combined catchment area of 30,772 square kilometers. This area extends 360 kilometers in length from Ramak

TABLE 3
WATER POTENTIAL OF HILL TORRENTS ACROSS PAKISTAN BY PROVINCES[19].

PROVINCE	VOLUME (BCM)	RUNOFF (BCM)	W-USE (BCM)	BALANCE (BCM)
KPK	15.729	4.201	2.103	2.099
PUNJAB	5.484	1.410	0.46	0.948
SINDH	2.734	0.473	0.102	0.371
BALOCHISTAN	47.767	8.491	1.670	6.821
TOTAL	71.714	14.575	4.337	10.238

to Kashmore, with a width ranging from 25 to 40 kilometers. Within the D.G. Khan irrigation zone, 13 hill torrents are classified as major, each with a discharge exceeding 15,000 cusecs. Seven of these major torrents are in D.G. Khan district, and six are in Rajanpur district. Plans are underway to construct dams to capture floodwater from four of these major hill torrents: Vidore, Mithawan, Kaha, and Chachar. The 2022 monsoon brought unprecedented rainfall to three specific hill torrent areas—Kaura, Vehova, and Sanghar—significantly impacting the upstream of the Taunsa Barrage. This led to high floods in Taunsa, Guddu, Kotli, and Sakkhar for more than 45 days. The situation intensified on August 25 when heavy rainfall in the Swat and Kabul catchment areas added 600,000 to 700,000 cusecs of water, however, it was managed with support from the Dam Management Authority. According to a conservative estimate, these hill torrents generated an estimated 9 to 10 million acre-feet of water due to intense rainfall, surpassing the total water storage capacity of 3.43 million acre-feet, including Chashma, Mangla, and Tarbela Dams.

• Sindh

In the Southern Indus basin, in Sindh, spate irrigation is a common and wide practice in areas of Qambar Shahdadkot, Dadu, Jamshoro, Malir, Thatta, Khairpr Mirs, and Nagarparker. In Sindh, large hill torrents, locally referred to as *nai*, are not diverted to fields due to their heavy discharge, which is beyond the handling capabilities of local farmers. Most water passes downstream into major water bodies, i.e., Manchar, Hamal, Kenjhar Lakes, and the Indus, without contributing much directly to irrigation. Some *nai* with catchment areas ranging from 20 square kilometers to more than 7117 square kilometers could also flow perenially, especially in Kohistan region, near Jamshoro. The main *nais* in the region include Desoi, Dawoo, Darwat, Baran, Sari, Mole, and Kalu. There are also specific reservoirs and ponds built in the low-lying areas to capture floodwater from the upstream including the one coming from the Suleiman Range and Kirthar Hills. The watershed drainage slope of hill torrents is divided into two parts: one area directs excess floodwater towards Nai Baran, which is the primary channel, gathering overflow from torrents like Desoi, Dawoo, and Darwat during severe floods, diverting it into the Indus River. The second part of the drainage slope receives a large amount of runoff from torrents like Mole, Sari, and Rahuja,

ultimately channeling the torrential floodwater into the Kalu Nai and storing it in Lake Keenjhar, a significant natural lake situated at the foothills of Thatta district[24]. During the 2022 floods, the water coming from Balochistan through the Main Nara Valley Drain (MNVD) affected the area of Manchar Lake and Dadu District. The impact of the water from MNVD was far worse than the hill torrents coming through the Kirthar range. Additionally, to control the hill torrents, Nai Gaj and Darawat dams have being constructed in Sindh specifically to manage the hill torrents coming from Kirthar Lake, however, in 2022 both these structures failed to curtail the quantum of hill torrents.

• Khyber Pakhtunkhwa

In the north, in Khyber Pakhtunkhwa, Panjkora Basin is an area where terrace farming-spate irrigation is practiced as the area has huge vulnerability to hill torrents. The Panjkora Basin, situated in the Eastern Hindu Kush region of Northwest Pakistan, is a significant geographical area drained by the River Panjkora and its tributaries. It stretches 113 kilometers in length with a total catchment area of 5,905 square kilometers. The basin is flanked by two mountain ranges, the eastern and western, which separate it from neighboring basins. These mountains, reaching elevations exceeding 4,000 meters above sea level, are often snow-covered with glaciers nestled in their valleys. The basin itself varies in elevation from 437 meters above sea level in the south to approximately 5,963 meters above sea level in the north. Snowfall is a prominent feature during the winter months, with annual rainfall ranging from 823 to 2149 millimeters. Snowfall typically begins in November in the upper reaches and descends to lower elevations as temperatures drop in December. Snowmelt starts in March and continues depending on the elevation. Due to its unique combination of hydrological, meteorological, and geomorphological factors, the Panjkora Basin is particularly prone to flash floods. Apart from Panjkora Basin, the areas of Bannu and Hazara in Khyber Pakhtunkhwa Province also have hill torrents with potential for spate irrigation. In the southern region of KP, there are D.I Khan and Tank districts bounded by three different ranges including the Suleiman Range in the west, Bhittani range in the north and Marwat range in the east respectively. There are five major hill torrents (*zam*) are present in this belt. Here as well, through embankments, hill torrent water is being diverted for terrace farming.

• Balochistan

The province of Balochistan has the highest potential for spate irrigation due to the geographic landscape and availability of hill torrents. There are highland and lowland based distinctions among the hill torrents and kind of spate irrigation being practiced in Balochistan. Highland systems, located in the Khurasan Range, the eastern slopes of the Sulaiman Range, and the Central Brahui Range in Balochistan, typically have smaller catchments. Consequently, the spates in these areas are short-lived and more challenging to control due to the steep slopes and the limited availability of suitable materials for building diversion structures. As a result, water distribution in highland systems tends to rely more on natural gravity flow rather than complex distribution rules. In contrast, lowland systems, such as those in the vast Kacchi Plains, Las Bela, and the Kharan basin of Balochistan, feature large catchments and very shallow gradients. These systems can experience semi-perennial flow that moves slowly. Water control is often managed through earthen barrages, although deflecting spurs and free intakes, like those in highland areas, are also used. The slow-moving, prolonged flow in lowland systems has led to the development of extensive rules for water allocation[28].

There are four different water supply systems in the Sailaba irrigation, namely nullah, manda, diffuse, and riverine-like[29]:

a. *Nullah* systems are based on a single *nullahs* (ephemeral stream), usually one with a mountainous catchment.
b. *Manda* systems depend on rivers or large *nullahs*, which collect water from many small ephemeral streams with quite hilly catchments.
c. Diffuse supply systems utilize large sloping areas as contributing catchments, where the runoff is collected into shallow *nullahs* by the time it reaches the diversion point.
d. Riverine systems are designed to divert water from perennial streams only when a sufficient flood stage is reached for the water to flow into diversion canals. In Balochistan, management of hill torrents involves a multi-faceted approach that combines infrastructure development,

community engagement, and environmental conservation efforts. The government, along with various non-governmental groups and local communities, has implemented initiatives such as building check dams, gabion structures, and retaining walls to control the flow of water during torrential rains. Additionally, afforestation programs have been undertaken to stabilize soil and prevent erosion however, still, the province suffers from hill torrent-based flooding.

POLICIES AND REGULATORY FRAMEWORKS FOR MANAGING HILL TORRENTS

In Pakistan, in different provinces, hill torrents are either being managed by communities or by local regulations. Also, as per the Constitution of Pakistan, water distribution and management is a devolved subject between the federal government and the provinces. Like in Khyber Pakhtunkhwa, the rules and regulations called *kulyat* and *riwajat-i-abpashi* (rules and regulations for irrigation) are being employed by the locals to manage the hill torrents. Additionally, within these regulations, the *warabandi* system is also integrated which governs water distribution amongst the communities. However, in KP, because it is upstream, most of the water which is not required is being diverted downstream which eventually results in flooding. Also, there are on-farm water management programs being developed by the communities to manage and harvest the hill torrent water. In the lowlands or downstream, if farmers are unable to resolve a problem, the district administration steps in to enforce regulations. In the uplands or upstream areas, water distribution issues are mediated by tribal elders forming the Jirga.

Apart from this, the Federal Flood Commission also introduced the flood protection plans in which hill torrent flood management has been mentioned. The 2018 National Water Policy, established through consultation with the Council of Common Interests, emphasizes the importance of watershed management and water harvesting to enhance spate irrigation. These measures aim to promote integrated water resource management and reduce water loss. However, the policy lacks specific directives or strategies dedicated to the management of hill torrents, leaving a gap in addressing the unique challenges posed by these water flows. At provincial level, Sindh has notified the Sindh Water Policy in 2023 that addresses managing hill torrents for spate irrigation. Under this policy, a Supervisory Control and Data Acquisition system will be established which will also address issues in the main Indus River system, where unauthorized bunds and bridge construction, as well as floodplain conversion to farmland, have significantly reduced the river's capacity to manage high flood situations. In Sindh, a Hydro-Agro Information system is set to be implemented to monitor hill torrents, assess risks and vulnerabilities, and provide timely updates to relevant departments for effective management. Although the policy is well-structured, its recent introduction means that progress has been gradual.

In contrast, Punjab has enacted the Punjab Irrigation, Drainage, and Rivers Act 2023, which prohibits infrastructure construction along floodplains and outlines necessary control measures. The act includes provisions for developing village irrigation plans and establishing a control unit to enhance coordination among departments, monitor vulnerabilities, and manage water distribution and harvesting. However, while the act addresses floodplain management and water resources broadly, it lacks specific guidelines for hill torrent management. Progress has been slow since its enactment last year, with ongoing efforts in South Punjab involving district administrations and water user associations working directly with farming communities on hill torrent management.

While Pakistan's provincial policies reflect a commitment to resource management and flood risk reduction, several areas need attention. Enhancing community involvement, improving inter-departmental coordination, addressing the unique challenges of hill torrents, and expediting implementation will be essential to building a more comprehensive water management strategy.

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Challenges

The challenges around hill torrents and spate irrigation have been examined in context with water governance, agriculture, and nature-based solutions.

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The focus on water governance challenges in *rod kohi* areas included issues such as landscape alterations, lack of water allocation mechanisms, absence of watershed management regulations, and the need for innovative ecosystem-based solutions over high-end engineering interventions. Additionally, the agriculture and livelihood vulnerabilities highlighted the social impacts in *rod kohi* regions, exploring how local practices, structural faults, and climate change-induced floods affect small farmers, often leading to water flow regulations that favour larger landowners at the expense of smaller ones. Furthermore, the challenges of instituting nature-based solutions and building community capacity for community-led water management were emphasized. These challenges have been discussed below in detail.

• **Landscape Alteration and Poor Infrastructure:** Significant changes in the landscape since the late 1960s, such as the conversion of wetlands to agricultural areas and poorly placed dams, have exacerbated flooding issues. Existing infrastructure, such as the Kachi Canal, has structural faults that worsen flood risks. Additionally, there is inadequate planning for land use, resulting in construction in flood-prone areas and deforestation caused by urbanization. Increased rainfall, poor irrigation infrastructure, frequent breaches, and silt accumulation from floods raise land levels and require de-siltation efforts, all contributing to extensive flood damage. Also the lack of proper groundwater recharge facilities results in inefficient water use and increased flood risks.

• **Lack of Historical Data and Early Warning Systems:** There is no established mechanism for water allocation, resulting in interventions not based on historical data. There are also no specific early warning systems for hill torrents, leaving communities unprepared. Additionally, there is a lack of sufficient gauges and monitoring systems to accurately predict and manage the flow of water from hill torrents. This data gap hinders timely and effective flood response.

• **Absence of Watershed Management Regulations:** There are no formal rules or regulations for watershed management, leading to uncoordinated and ineffective practices and significant water losses that could be used for agriculture. There is no dedicated policy framework or management authority for hill torrent management, leading to uncoordinated efforts and lack of sediment load analytics before dam construction.

• **Overemphasis on High-End Engineering Solutions:** Investments are heavily skewed towards high-end engineering solutions, often overlooking innovative ecosystem-based solutions and indigenous knowledge of local communities.

• **Small-Scale and Underutilized Interventions:** Existing interventions, such as the *rod kohi* system, are small-scale and insufficient. Valuable knowledge from historical documents like the Rod Kohi Act is not effectively utilized.

• **Conflicting Perspectives and Coordination Issues:** Different stakeholders have conflicting perspectives on water use, leading to uncoordinated interventions. There are challenges in coordinating efforts between the private sector, federal bodies, and local communities, resulting in issues in implementing early warning systems and water use management plans.

• **Destruction of Livelihoods and Economic Impact:** Hill torrent water frequently destroys homes, crops, and livestock, severely impacting local livelihoods and leading to economic losses and migration. Women are disproportionately affected, as they often have to leave their assets and resources behind.

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• **Lack of Community Preparedness and Capacity Building:** Communities, particularly in Balochistan, are not adequately prepared for disasters, with insufficient training in disaster risk reduction that does not align with indigenous practices. Local community-based initiatives are often overlooked in favour of state-led actions, resulting in gaps in effective flood management.

• **Land Disputes and Security Concerns:** Land disputes frequently impede the implementation of nature-based solutions. Although security concerns can be mitigated through collaboration with local bodies, they still pose a challenge.

• **Inadequate Utilization of Existing Studies and Knowledge:** Existing studies on hill torrent management and the valuable experiences of various organizations and communities are not adequately incorporated into practical frameworks or capitalized upon. Communities do practice nature-based solutions in KP, Sindh and even Balochistan, however, their efforts are not recognized or taken into account by the authorities who manage disasters and also who plan for infrastructure development.

• **Coordination Deficits:** Poor coordination exists between federal and provincial departments and among various departments within provinces. This disjointed approach hampers effective flood management and disaster response.

• **Environmental Degradation:** Depletion of vegetation in hilly areas and encroachment on natural waterways lead to increased water velocity, higher sediment loads, and more severe flood impacts.

[31] Sindh Water Policy.2023.

[32] Punjab Irrigation, Drainage and Rivers Act.2023.

Policy Recommendations

The policy recommendations address critical issues in hill torrent and spate irrigation management, focusing on the need for integrated watershed management, bottom-up planning, early warning systems, community engagement, and private sector involvement. They emphasize the need for climate-resilient infrastructure, nature-based solutions, modern technologies, and enforcement against illegal structures. Enhanced community coordination and research implementation are crucial, along with establishing a centralized coordination body to streamline efforts and data sharing across provincial and federal levels. These recommendations have been clustered under different themes such as governance, climate resilient infrastructure, community engagement, and so on, discussed below in detail.

Governance

INTEGRATED WATERSHED MANAGEMENT SYSTEM

There is a need to establish an integrated watershed management system, particularly in regions lacking such systems like Sindh and Balochistan. This entails coordination among relevant provincial departments of water resources and agriculture to ensure efficient water resource management and flood risk mitigation through holistic watershed management approaches. The responsibility for implementing this recommendation falls on the provincial departments of water resources and agriculture. By adopting a holistic approach, it ensures that all aspects of watershed management are addressed, including water allocation, conservation, and flood control. The implementation can involve:

- **Inter-Departmental Coordination:** Fostering collaboration between provincial water resources and agriculture departments to streamline efforts.

- **Policy Alignment:** Ensuring that policies and strategies are consistent across departments and regions to prevent conflicting actions.

- **Resource Allocation:** Securing adequate funding and resources to support integrated watershed management activities by engaging private sector, provincial budgets and support from development partners.

ADOPT BOTTOM-UP PLANNING APPROACHES

Shift from a top-down to a bottom-up planning approach that involves local stakeholders in decision-making processes. Ensure that policies are responsive to the needs and knowledge of local communities. Strengthen institutional mechanisms by developing institutional capacity

within departments responsible for hill torrent management. Provide training and resources to ensure effective implementation and enforcement of policies. This can be made possible through the following steps:

- **Stakeholder Involvement:** Creating platforms for local communities to participate in planning and policy development and decision making.
- **Capacity Building:** Strengthening the capabilities of local departments and institutions through training and resources so they are able to handle the technicalities.
- **Responsive Policy Design:** Developing and promoting policies that are adaptable to local conditions and needs.

ESTABLISHMENT OF CENTRALIZED COORDINATION BODY

Establish a centralized body for coordination at provincial and federal levels to align efforts and facilitate data collection and circulation. This body will play a crucial role in coordinating water governance initiatives and promoting collaboration among stakeholders at the national level. The responsibility for establishing this body lies with relevant federal and provincial government departments involved in water governance including the Federal Flood Commission. Additionally, involving local community leadership in this body is also important. This can be established through following ways:

- **Institutional Framework:** Setting up the organizational structure and defining roles and responsibilities.
- **Data Management:** Creating systems for comprehensive data collection, sharing and coordination.
- **Stakeholder Engagement:** Engaging relevant government departments and agencies in coordinated efforts.

Climate-Resilient Infrastructure

Construct climate-resilient infrastructure, including small dams and retention structures, to handle water runoff during hill torrents and mitigate flood risks. Departments of infrastructure development and water resources are responsible for spearheading the construction of such infrastructure to enhance resilience against climate-induced disasters. The responsibility for implementing this recommendation lies with departments of infrastructure development and water resources. This can be implemented by keeping in view the following steps:

- **Infrastructure Planning:** Identifying and prioritizing critical areas for infrastructure development specially those where vulnerabilities are high.
- **Resilient Design:** Ensuring that infrastructure projects incorporate climate resilience principles and adaptive designs.
- **Maintenance and Monitoring:** Establishing systems for ongoing maintenance and performance monitoring.

IMPLEMENT NATURE-BASED SOLUTIONS

Adopt nature-based solutions such as the development of terracing walls, deep wells filled with stones for groundwater recharge, and the revival of traditional water management practices like the Karez system in Balochistan. Utilize native species and materials in rehabilitation efforts to enhance the effectiveness and sustainability of nature-based solutions. This recommendation emphasizes leveraging local ecological knowledge and resilient materials, with departments of forestry and environment responsible for implementation. Implement environmental conservation measures with a focus on reforestation and range management to reduce water velocity and sediment loads. Prevent encroachment on natural waterways and enforce environmental protection regulations. This can be implemented in following ways:

- **Ecological Restoration:** Using native species and natural materials in rehabilitation projects. Also, producing native crops through rotation methods can be helpful.
- **Traditional Practices:** Integrating traditional water management methods with modern techniques such as updating the Karez systems.
- **Conservation Efforts:** Promoting reforestation and range management to reduce water velocity and sediment loads.

ADDRESSING ILLEGAL STRUCTURES

Mitigating flood risks involves removing illegal structures that obstruct natural waterways. Effective enforcement mechanisms are necessary to prevent such encroachments and ensure the free flow of water. Key actions can include:

- **Regulatory Enforcement:** Strengthening regulations and enforcement to remove and prevent illegal structures.
- **Community Awareness:** Educating communities about the risks posed by illegal constructions.
- **Regular Inspections:** Conducting routine inspections to identify and address obstructions.

Technology and Innovation

LEVERAGING MODERN TECHNOLOGIES

Utilize modern technologies, including ICTs, remote sensing, and GIS, to support monitoring, evaluation, and decision-making in water governance and disaster management. Departments of technology and innovation, working alongside relevant agencies like meteorological departments and disaster management authorities, should be responsible for implementing these tools to improve efficiency and effectiveness. The strategy could include the following steps:

- **Technology Integration:** Implementing advanced technologies for real-time data collection and analysis such as using GIS/remote sensing techniques and maps.
- **Capacity Enhancement:** Training relevant agencies and departments in the use of these technologies such as disaster response units and meteorological departments.
- **Collaboration:** Working with technology providers and innovation agencies to keep systems updated.

EFFECTIVE EARLY WARNING SYSTEMS

Develop and implement effective early warning systems for hill torrents, with the Federal Flood Commission and meteorological departments identified as the implementing bodies. Timely alerts provided by these systems are crucial for enabling proactive measures to minimize the impact of floods on vulnerable communities and infrastructure. The Federal Flood Commission and meteorological departments are tasked with the implementation of this recommendation. Additionally, an effective early warning system should be developed by keeping in view the following:

- **System Development:** Designing and deploying advanced early warning technologies by engaging technical departments and also the local communities so they are aware.
- **Collaboration:** Engaging the Federal Flood Commission and meteorological departments in system operations and then connecting them with relevant provincial line departments for emergency response.
- **Community Outreach:** Educating communities on how to respond to early warnings effectively and also regarding the systems in place.

Community Engagement

ENHANCING COMMUNITY ENGAGEMENT AND COORDINATION

Enhance community engagement and coordination at the grassroots level to ensure the success of water governance initiatives. Closer collaboration between local communities and relevant government departments is essential for faster implementation and more effective solutions tailored to local needs. The responsibility for this recommendation primarily lies with local government bodies and relevant provincial departments. The focus should be on:

- **Inclusive Planning:** Developing participatory mechanisms for community involvement in decision-making through seminars, focus group discussions, and the like.
- **Capacity Building:** Empowering local communities through education and training.
- **Ongoing Support:** Providing continuous support and resources to maintain community engagement.

ENGAGE THE PRIVATE SECTOR

Develop business cases that highlight the potential profitability of water management projects, supported by robust data, to attract private sector investment. Encourage public-private partnerships for sustainable water management solutions. This can be done through:

- **Investment Incentives:** Highlighting the economic benefits and profitability of water management projects.
- **Partnership Development:** Facilitating collaborations between government agencies and private entities.
- **Data-Driven Proposals:** Supporting investment proposals with robust data and analyses.

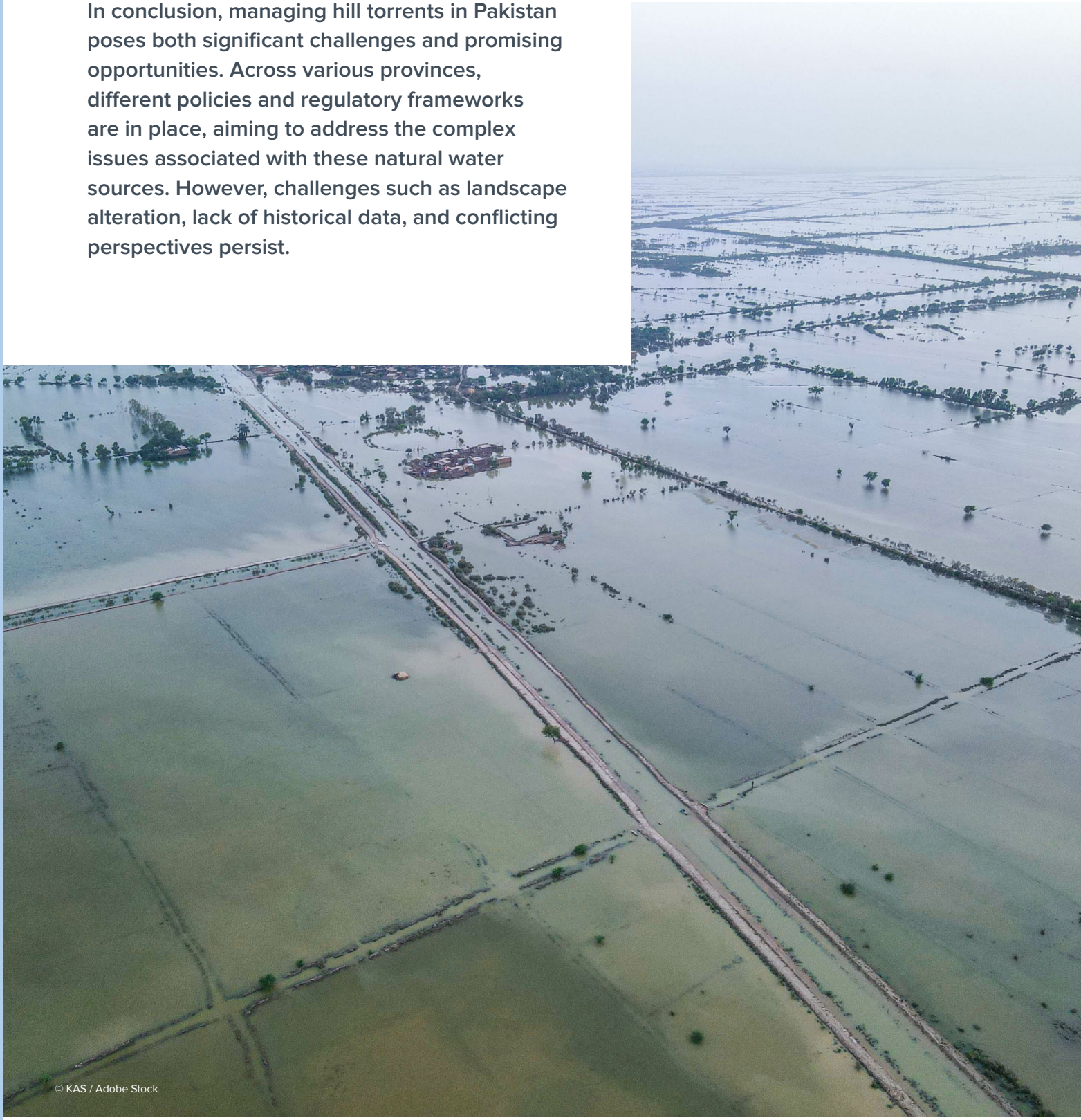
IMPLEMENTATION OF RESEARCH PLANS

Implement research plans on hill torrents to inform evidence-based decision-making and guide practitioners. The National Agricultural Research Center (NARC) and relevant research institutions should be tasked with implementing these plans to provide valuable insights and inform policy formulation. The NARC and other departments should lead this as per following:

- **Research Development:** Designing and executing research projects focused on hill torrent dynamics.
- **Knowledge Dissemination:** Sharing findings with policymakers, practitioners, and communities.
- **Policy Integration:** Using research outcomes to guide policy and practice in hill torrent management.

Conclusion

In conclusion, managing hill torrents in Pakistan poses both significant challenges and promising opportunities. Across various provinces, different policies and regulatory frameworks are in place, aiming to address the complex issues associated with these natural water sources. However, challenges such as landscape alteration, lack of historical data, and conflicting perspectives persist.



To address these challenges and fully realize the potential of hill torrent management, it is essential to adopt integrated watershed management approaches, emphasize bottom-up planning, and establish effective early warning systems. Key elements of a comprehensive strategy include community engagement, private sector involvement, and the promotion of climate-resilient infrastructure and nature-based solutions. Tackling issues such as illegal structures obstructing waterways and enhancing community coordination are vital for sustainable water management. Additionally, utilizing modern technologies and implementing research initiatives can provide critical insights for evidence-based decision-making. Establishing a centralized coordinating body to streamline efforts and foster collaboration among stakeholders is crucial for success. By overcoming these obstacles and implementing these recommendations, Pakistan can leverage hill torrent water management to safeguard communities and support sustainable spate irrigation development.

ORGANIZATIONS WORKING ON HILL TORRENTS/ SPATE IRRIGATION:

Some of the international development organizations and local civil society organizations are engaged through different projects which either directly or indirectly integrate hill torrents/spate irrigation management, including community engagements. Select water organizations and projects (fall 2024) are listed on the right.

- HELP Foundation Pakistan: Working at the community level with the farmers and small businesses to prevent the loss and damage from disasters. Developed farmer associations, community-based early warning, and more.
- Halcrow Pakistan Private (Ltd.) Designing of irrigation and drainage canals and associated structures, which varies from the design of small field channels carrying a few liters to large canals with a capacity of 30 cubic meters per second.
- NDC-National Development Consultants (Pvt.) Ltd. Engineering consulting firm, with major projects including the Duber Kehwar hydropower project, Kachhi canal, Gomal Zam, Sukkur Barrage, and more.
- Asian Development Bank Pakistan: Punjab Water Resources Management Projects. The project will contribute to the improvement of the irrigation infrastructure that will enhance water availability and increase the productivity of the agriculture sector in the Punjab.
- Asian Development Bank Pakistan: Khyber Pakhtunkhwa Water Resources Development Project. Agricultural production; irrigation; land-based natural resources management; and water-based natural resources management.
- The World Bank Pakistan-Balochistan Integrated Water Resources Management & Development Project.
- Pakistan Red Crescent Society (PCRS) Social mobilization and capacity building of communities affected due to hill torrents flooding in KP
- Water Sprint Providing technical assistance on the Khyber Pakhtunkhwa Water Resources Development Project of ADB.
- WWF Pakistan Recharge Pakistan: An initiative of the Ministry of Climate Change, Recharge Pakistan is a collaboration to reduce climate vulnerability through ecosystem-based adaptation and integrated flood risk management.
- World Bank Sindh Flood Emergency Rehabilitation Project (SFERP).
- NRSP Social mobilization, infrastructure and technology development, environment, and natural resource management
- Mott MacDonald Currently working with the ADB and World Bank to restore effective irrigation in Sindh through stakeholder engagement and technical engineering. Major projects include the Ghazi Barotha hydropower project.
- NESPAK Water resources planning, dams and barrages, irrigation systems, flood management, and forecasting systems.

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