The 2022 flooding on the Indus River was an interplay of hydrology, urbanization, and haphazard population growth

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Abstract

Pakistan ranks among the top ten countries most at risk from climate change according to the 2021 Global Climate Risk Index. Unfortunately, the country has yet to take significant measures to mitigate the effects of natural disasters. Indeed, Pakistan is faced with a myriad of natural disasters and geologic hazards such as landslides, riverine and flash flooding, heatwaves, cyclones, earthquakes, glacial melting, and saltwater intrusion. Tragically, despite the devastating floods along the Indus River System in 2010 that claimed thousands of lives and caused the displacement of millions, the government has taken little action to prepare for future events. Major flooding events have occurred in the Indus Basin in recent years due to channel alterations caused by haphazard population growth, temporal and spatial floodplain infrastructure and intensive deforestation and sediment yield. The 2022 floods broke all records of flood intensity and damages incurred in the Indus Basin. Future projections predict that natural disasters will be getting worse as a result of Anthropocene climate change. Unless the hydrology and morphology of the Indus River System is made more widely available to the decision-makers and policy-makers, the recurring problem of riverine flooding will hit Pakistan every year causing major damages.

Keywords: Indus Basin, Floods, Loss and Damage, Climate Change, Public Policy, Population growth, extending infrastructure, marginalization and increasing vulnerability of population and infrastructure

1. Introduction

Climate change is a significant global issue caused by a variety of factors, including variations in Jet streams, hot winds from Africa, and the heating of the Atlantic Ocean (Rousi, 2022). These changes result in higher sea surface temperatures and rising temperatures in the Arctic region, which can lead to depleted water resources, wildfires, ocean storms, and heat waves. We must remain vigilant and take action to address these challenges. For example, Europe is

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currently experiencing its worst drought in 500 years (Le Page, 2022), while China is grappling with an unprecedented heatwave that has caused rivers and lakes to dry up. In Jackson, Mississippi, the mayor has urged residents to evacuate the city as it prepares for further flooding. Indeed, the year 2022 was the warmest on record for the United Kingdom and the worst snow blizzard hit the United States in more than a century. The year 2023 broke the record of 2022, and heat index values in the first quarter of the year 2024 indicate that it may very well break the record of 2023. Subsequently, South Asian countries have been experiencing major environmental hazards in recent years.

Pakistan faces a multitude of environmental hazards closely attributable to climate change. Human alterations of river basins and watersheds have a long history and human-induced climate change affects every watershed on the globe (Wohl, 2019). The 2022 flood on the Indus River System (Fig. 1) has submerged one-third of Sindh province while 36% of the cultivated area was severely damaged (Qamer et al., 2023). The official government figures show that more than 1700 people have been killed, 33 million adversely affected and 8 million displaced by the recent megafloods in the country (OCHA, 2022) which is already going through a political storm of its own. World Bank estimates that this summer's record-breaking rain and flooding have caused more than $40 billion in financial losses (Ahmad, 2022). This was a perfect storm in the making. The underlying factors for this disaster were a combination of higher-than-normal monthly temperatures and torrential rain. The dry winds in April, May, and June created a vacuum that was filled by moisture-laden air from the Indian Ocean, leading to a cascade of rain (Dhame et al., 2020). The impact of climate change is felt worldwide, and this catastrophe is a direct result of torrential rains, compounded by melting glaciers.

Pakistan is ranked among the top ten countries most vulnerable to the impacts of climate change, according to the Global Climate Risk Index (Hamidi et al., 2020; CRI, 2021). The 2022 floods, which were described by the then Minister of Climate Change, Sherry Rehman, as "Biblical and unprecedented" (Lodewick, 2022), were undeniably massive in scale, but they were neither Biblical nor unprecedented. However, the recent devastating floods and the inadequate relief response from both the government and civil society have exposed the country's susceptibility to managing disasters. Climate change and environmental degradation have resulted in an annual loss of $24 billion for Pakistan. Table 1 shows flood damages in the Indus Basin from 1950 to 2022. The data was compiled from EM-DAT International Disaster Database and various press reports. Investing a fraction of this cost in devising local strategies to combat climate change could yield significant dividends for a developing country like Pakistan.

The elephant in the room remains the country's military expenditure (Dawn, 2019; Kalim and Hassan, 2014).

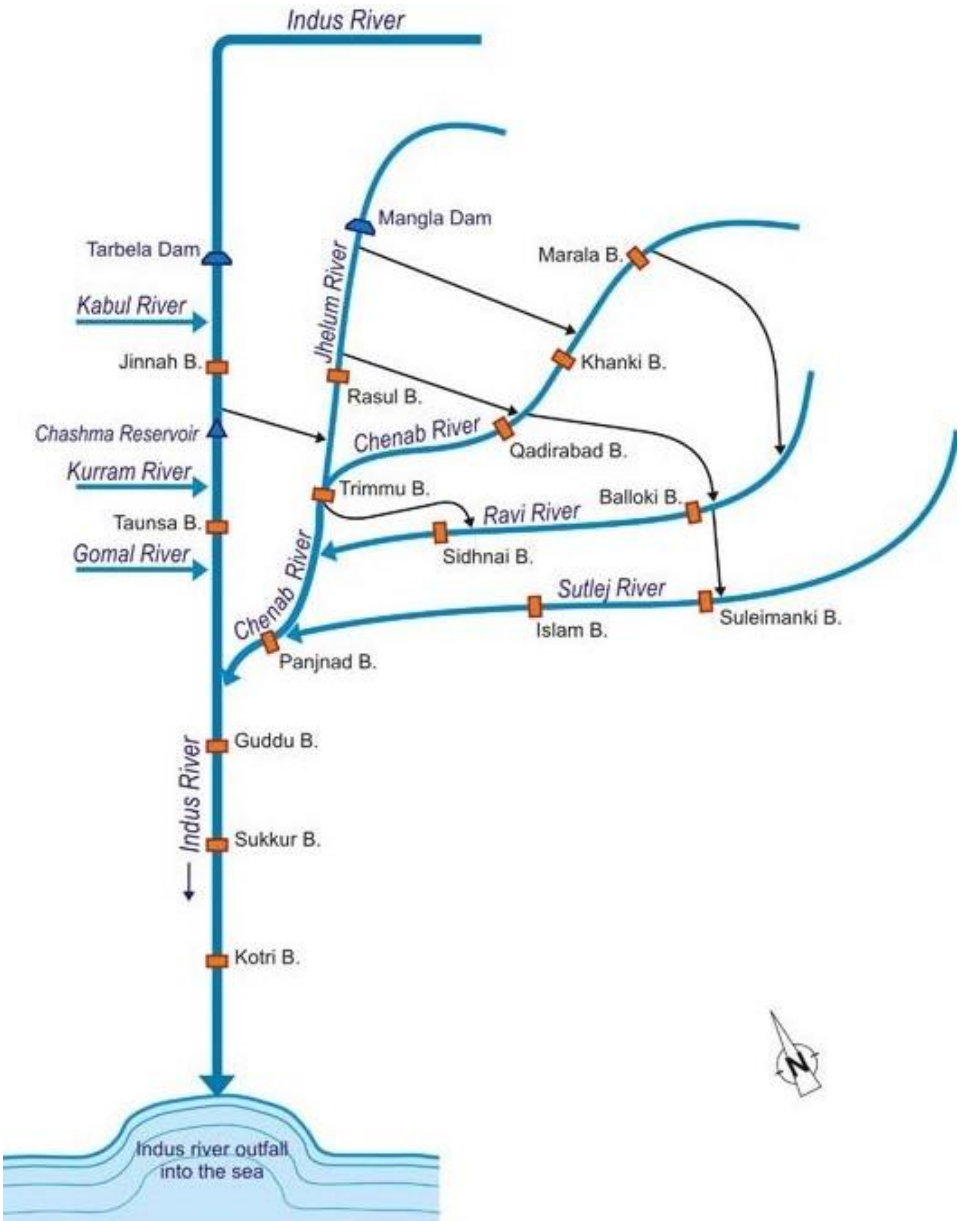

Figure 1. The Indus River System (Reproduced from: Ali, 2013).

Table 1. Flood damages from floods on the Indus River system, 1950-2022.

Year	Damages ($ million)	Deaths	Affected Villages	Flooded Area (km^2)
1950	227	2,910	10,000	17,920
1955	176	679	6,945	20,480
1956	148	160	11,609	74,406
1957	140	83	4,498	16,003
1959	109	88	3,902	10,424
1973	2,388	474	9,719	41,472
1975	318	126	8,628	34,931
1976	1,621	425	18,390	81,920
1977	157	848	2,185	4,657
1978	1,036	393	9,199	30,597
1981	139	82	2,071	4,191
1983	63	39	643	1,882
1984	35	42	251	1,093
1988	399	508	100	6,144
1992	1,400	1,008	13,208	38,758
1994	392	431	1,622	5,568
1995	175	591	6,852	21,686
1998	38	47	161	7,848
2001	490	201	8,267	33,862
2003	530	230	9,754	34,231
2005	580	640	11,009	34,054
2006	475	400	12,891	34,873
2007	550	526	13,264	36,592
2010	32,056	2,113	48,675	38,600
2011	66	516	38,700	9,098
2012	485	498	19,358	31,287
2013	330	268	11,402	22,491
2014	295	255	12,239	21,852
2015	180	119	9,357	18,074
2016	315	337	10,891	19,549
2017	205	167	8,741	17,502
2018	95	60	2,560	6,741
2019	180	206	14,567	19,540
2020	688	507	28,905	36,740
2021	10	220	13,908	24,930
2022	42,108	1739	55,000	75,000

Heatwaves are just one of the manifestations of the Holocene climate change which the earth is witnessing in the 21st century. It's worth noting that 14 out of the last 15 years have been the hottest on record (NASA, 2022a). Experts have observed that the Indian Ocean is experiencing a much faster rise in sea surface temperature compared to other oceans, leading to changes in monsoon patterns. Unfortunately, this change may result in saltwater intrusion, a coastal hazard that replaces freshwater aquifers with saline water from the ocean. This can have a significant impact on drinking water supplies and the habitats of mangroves along the Sindh and Balochistan coastlines. In fact, saltwater intrusion can occur as far as 65 km upstream in the Indus River estuary (Wang et al., 2019).

The depletion of groundwater tables across the country is becoming an increasingly concerning issue due to the lack of aquifer recharge and rainwater harvesting. The situation is only being compounded by the effects of climate change. While the Attabad Lake incident was caused by a rockfall, the threat of Glacial Lake Outburst Floods (GLOFs) is a growing concern in Pakistan, where over 7,000 glaciers are present, any one of which could pose a significant threat. A study of 179 GLOFs that occurred from 1533 to 2020 in five major valleys in northern Pakistan highlights the "Karakoram anomaly," where many glaciers experience irregular, frequent, and sudden advances (surges) that could potentially lead to ice dam lake formation and subsequent outburst flooding throughout the region (Bazai et al., 2021).

2. Discussion

According to scientists at the World Meteorological Organization in Geneva, the 2010 floods in the Indus River Basin were the most devastating natural disaster ever recorded. They attributed the disaster, in part, to higher sea surface temperatures in the Atlantic (Gronewold, 2010). Further research has indicated that future extreme precipitation events will result in significantly increased rainfall rates in the Bay of Bengal, Kashmir, north Pakistan, and the Arabian Sea. This could lead to even more severe socio-economic consequences than those experienced during the 2010 Pakistan flooding (Van der Schrier, 2018). Consequently, this prediction has been proven true by the recent flooding event in 2022, which caused the highest recorded losses. Images captured by the Visible Infrared Imaging Radiometer Suite (VIIRS) on the NOAA-20 satellite illustrate the progression of the floods from August to October 2022 (NASA, 2022b), with a comparison image from June of the same year provided for reference (Fig. 2).

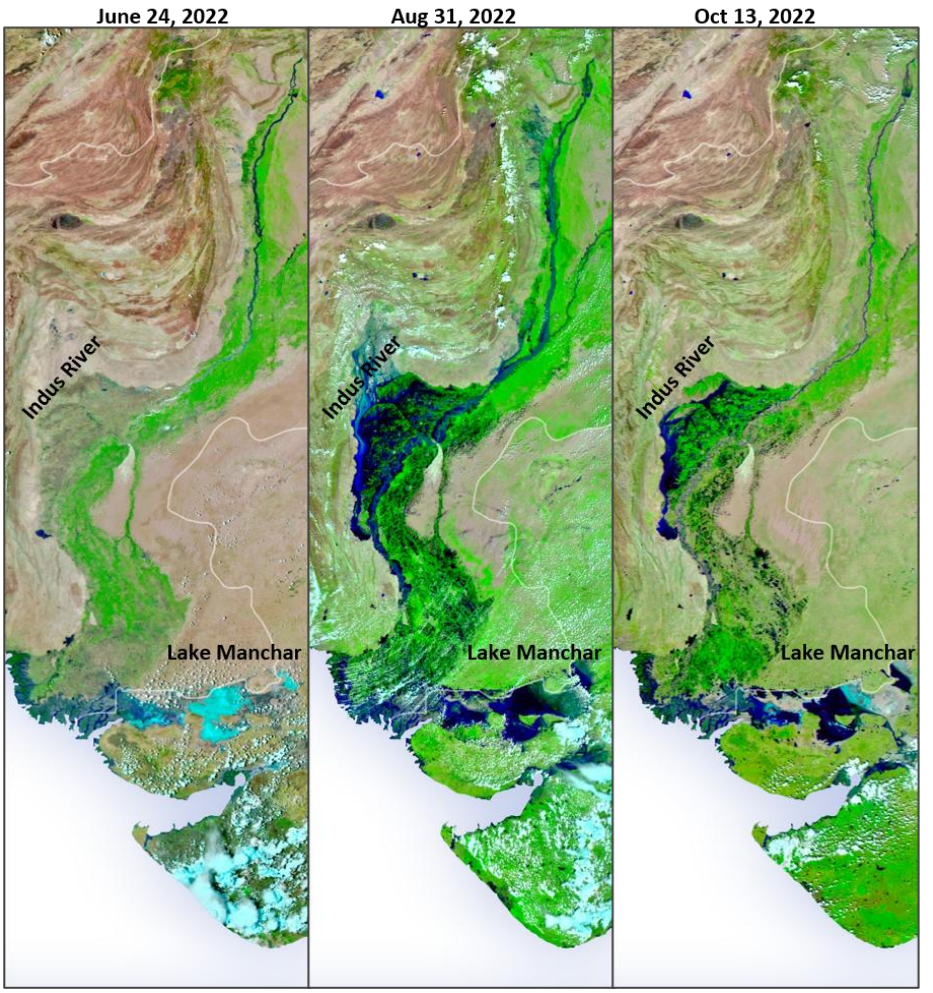

Figure 2. NOAA-20 VIIRS images showing flood progression on the Indus River system.

According to recent climate projections, it appears that both Gilgit-Baltistan and Kashmir are experiencing a notable increase in summer days - up by 24 days in Gilgit and by 18 days in Muzaffarabad. Unfortunately, this increase may also trigger a rise in GLOFs. The KP province, on the other hand, has seen a significant uptick in very heavy precipitation extremes, leading to more flood events. Peshawar has already experienced a 0.9°C increase in the past mean maximum temperature index, and projections indicate that the KP province could see an even more staggering increase of 1.3°C in the mean maximum temperature by the year 2045 (Ahmad and Mahmood, 2017).

The livelihoods of impoverished farmers across Pakistan are being severely impacted by floods, droughts, and desertification. Overpopulation, deforestation, and unplanned urbanization have resulted in the country losing a significant portion of its vegetation canopy, with less than 5% of Pakistan being covered by forests and planted trees. In contrast, India has covered 24.01% of its geographical area with 789,164 km^2 of forest (Krishnayya, 2015). Despite reforestation efforts, Pakistan has yet to witness any substantial improvement, as campaigns have prioritized aesthetics over tangible results.

Chronic air- and water-borne victor diseases are on the rise and can quickly become endemic or even pandemic where healthcare facilities are meager, especially in rural parts of the country around the Indus River system. Reports of diarrhea, skin infections, and other waterborne ailments are widespread. Public health experts are witnessing a rise in mosquito-transmitted diseases, such as dengue and malaria, as well as severe gastrointestinal infections like cholera and typhoid. Pakistan is one of the last endemic strongholds of wild poliovirus, and experts fear a potential resurgence of the enteroviral disease poliomyelitis. In fact, after the major floods in 2010, Pakistan accounted for over 60% of all global poliomyelitis cases, with most new cases coming from flood-impacted areas (Taylor-Robinson, 2022). Malnutrition is one of the major causes of Pakistan's persistently high maternal mortality rate, and climate change could exacerbate this issue. Shockingly, an estimated 40% of children in Pakistan are malnourished, which sets off a vicious cycle when they become teenage mothers (Devi, 2022).

The Indus River Basin has been plagued by annual flooding due to factors such as fresh snowpacks, glacial melts, and unprecedented monsoon rains. Shockingly, the ice sheets in the Himalayas have been shrinking at a rate 10 times faster in the last 40 years compared to the previous several centuries, contributing significantly to the recent flooding incidents (PRI, 2022). Glacial melt accounts for a significant portion of streamflow in the Indus System, highlighting the need for an effective flood control system. Building small and medium dams on the Indus and Kabul Rivers could help mitigate chronic power shortages and solve the recurring flooding issue.

Although there is a general understanding among the public regarding the risks of climate change in their communities, the government's perspective requires significant reform. A prime example of this is when a category-4 tropical cyclone named Nilofar was developing in the Indian Ocean in October 2014 and was headed for the Karachi coastline. Despite a female lawmaker's warning, Sindh Assembly Speaker Agha Siraj Durrani dismissed the threat and suggested that the

tomb of Saint Abdullah Shah Ghazi would shield Karachi from the cyclone. He even advised those who were "afraid of the cyclone" to move to interior Sindh. Had Nilofar made landfall on the Karachi coast, the government's failure to issue warnings or mobilize any assets would have been catastrophic. Unfortunately, this is just one of many examples of how the government must act to safeguard its citizens from the consequences of climate change.

The lack of consistent policies for addressing climate change from one administration to the next has posed a significant challenge. Despite the launch of the ambitious National Climate Change Policy in March 2013, it was swiftly set aside. Furthermore, the Climate Ministry has not been granted any budget allocation and is still located in the same building as it was in 2012. Its primary responsibility is to coordinate climate change strategies and promote stakeholder engagement. The recent floods in Pakistan are a result of both infrastructure shortcomings and poor governance. After the devastating floods of 2010, no flood adaptation strategy was established, and the transboundary water institutions in the Indus River Basin are now in disarray. Nevertheless, the Colorado River Basin can provide valuable insights into the development of institutional frameworks in the Indus Basin (Sattar, 2018). It is worth noting that large infrastructure projects continue to be built on riverbeds, which can have unintended consequences. When natural topography is blocked, water will always find a way to flow under the influence of gravity and hydrolysis.

Pakistan has been experiencing significant challenges in generating hydropower from large reservoirs due to significant power line losses and silt accumulation. As a consequence, the country must explore alternative energy sources to meet its persistent energy shortages. Even so, exercising caution in utilizing these resources is important, as the depletion of freshwater aquifers could potentially lead to a critical water shortage in Pakistan within the next three years (Ahmad et al., 2022).

Over the years, significant progress has been made in researching the Indus River basin. However, there are still several gaps and areas that require further attention in the domains of climate change, glacial dynamics, water pollution and transboundary cooperation. Understanding the specific impacts of climate change on the Indus River Basin is crucial. More research is needed to assess how rising temperatures, changing precipitation patterns, and glacial melt will affect water availability, agriculture, and ecosystems in the region. The basin depends heavily on glacial meltwater. Investigating the dynamics of glaciers in the region, their response to climate change, and their long-term sustainability is essential for predicting future water availability.

Research on effective water management strategies and governance structures is needed to address the increasing water stress in the basin. This includes studying transboundary water disputes, water allocation mechanisms, and the role of various stakeholders in water management. Understanding the ecological health of the basin is important for sustaining biodiversity and supporting livelihoods. Research on the impact of water usage, pollution, and habitat degradation on the basin's ecosystems is needed. Research on water quality and non-point pollution sources in the Indus River and its tributaries is necessary to address issues of contamination and their impact on human health and ecosystems. Needless to say, there is a need for improved data collection, monitoring, and modeling of water resources in the basin. This includes streamflow measurements, groundwater monitoring, and satellite-based remote sensing to better understand the basin's dynamics. Addressing these research gaps is essential for the sustainable management of water resources in the Indus River Basin, particularly in the face of growing challenges such as population growth, urbanization, and climate change. Collaboration among researchers, policymakers, and local communities is crucial to fill these gaps and develop effective strategies for the future.

3. Recommendations

Pakistan needs a robust flood management policy that encompasses the larger issue of water management as a whole in the context of the changing climate in the Himalayan region. Preventing the loss of life and livelihoods should be the main focus of such an effective policy in the Indus Basin. There are too many organizations involved in managing floods and relief activities and there is a lack of coordination among federal, provincial and local entities. Water courses and floodplains are being encroached upon by powerful entities that make urban flooding even worse. Traditional ‘flood control’ mechanisms alone would not suffice to mitigate the negative effects of riverine and flash flooding.

Implementing sustainable solutions that involve both adaptation and mitigation is crucial in combating the daunting challenge of climate change. Recognizing the long, arduous journey ahead, it is wise for the government to integrate climate change into school and college curricula. While organizing seminars and conferences is a positive step, it only scratches the surface of this complex issue. Disaster management departments must continue to explore more comprehensive approaches to effectively combat this behemoth problem. Asking for a climate change 'Loss and Damage' fund will not bear much fruit as a growing number of studies show, however, that aid is eroding rather than strengthening cooperation among stakeholders (Bano, 2012). It is imperative to focus on climate change

adaptation and mitigation strategies and find local solutions rather than keep looking outwards.

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References

Ahmad, B., Mahmood, S., 2017. Observed, simulated, and projected extreme climate indices over Pakistan. Anchor Academic Publishing.

Ahmad, S., Zahra, J., Ali, M., Ali, S., Iqbal, S., Kamal, S., Tahir, M., Aborode, A.T., 2022. Impact of water insecurity amidst endemic and pandemic in Pakistan: Two tales unsolved. Annals of Medicine and Surgery, 81, 104350.

Ahmad, M., 2022. Pakistan: World Bank Estimates Floods Caused $40B in Damages. Associated Press DBA Press Association.

Ali, A., 2013. Indus basin floods: Mechanisms, impacts, and management. Mandaluyong City, Philippines. Asian Development Bank, 2013.

Bano, M., 2012. Breakdown in Pakistan: How Aid is Eroding Institutions for Collective Action. Stanford Economics and Finance.

Bazai, N.A., Cui, P., Carling, P.A., Wang, H., Hassan, J., Liu, D., Zhang, G., Jin, W., 2021. Increasing glacial lake outburst flood hazard in response to surge glaciers in the Karakoram. Earth-Science Reviews, 212,103432

CRI, 2021. Global Climate Risk Index. https://www.germanwatch.org/en/19777

Dawn, 2014. Abdullah Shah Ghazi will save us from Cyclone Nilofar: Durrani. https://www.dawn.com/news/1140929

Dawn, 2019. Pakistan among Top 20 Military Spending Countries in 2018: Report. https://www.dawn.com/news/1479310

Dhame, S., Taschetto, A.S., Santoso, A., Meissner, K.J., 2020. Indian Ocean warming modulates global atmospheric circulation trends. Climate Dynamics, 55(7/8), 2053–2073.

Devi, S., 2022. Pakistan floods: impact on food security and health systems. Lancet (London, England). Sep 10. 400(10355): 799–800.

Gronewold, N., 2010. Is the Flooding in Pakistan a Climate Change Disaster? Scientific American. https://www.scientificamerican.com/article/is-the-flooding-in-pakist/

Hamidi, A.R., Zeng, Z., Khan, M.A., 2020. Household vulnerability to floods and cyclones in Khyber Pakhtunkhwa, Pakistan. International Journal of Disaster Risk Reduction, 46, 101496

Kalim, R., Hassan, M.S. 2014. Impact of Military Expenditures on Poverty in Pakistan. Social Sciences Bulletin / Socialo Zinatnu Vestnesis, 19, 27–43.

Krishnayya, N.S.R., Christian, B., Vyas, D., Saini, M., Joshi, N., Manjunath, K.R., Kumar, T., Padalia, H., George, R., Kushwaha, S.P.S., 2015. Monitoring of forest cover in India: imaging spectroscopy perspective. Current Science, 108(5), 869–878.

Le Page, M., 2022. Worst drought in 500 years? New Scientist. August 20, 2022. 255(3400), 8.

Lodewick, C., 2022. A 'climate disaster of biblical proportions' is hitting Pakistan, official says. https://fortune.com/2022/09/02/pakistan-flood-biblical-disaster-foreign-minister-zardari/

NASA., 2022a. Tied for 6th Warmest Year in Continued Trend, NASA Analysis Shows. https://www.nasa.gov/press-release/2021-tied-for-6th-warmest-year-in-continued-trend-nasa-analysis-shows

NASA, 2022b. Flood woes continue in Pakistan. https://earthobservatory.nasa.gov/images/150470/flood-woes-continue-in-pakistan

OCHA Relief Web, 2022. Pakistan: Floods - Jul 2022. https://reliefweb.int/disaster/fl-2022-000254-pak

PRI, 2022. Doomsday flooding in Pakistan linked to glacial melt, expert says. PRI's The World. September 2022.

Rousi, E., Kornhuber, K., Beobide-Arsuaga, G., Luo, F., Coumou, D., 2022. Accelerated western European heatwave trends linked to more-persistent double jets over Eurasia. Nature Communications, 13(1), 3851.

Sattar, E., Robison, J., McCool, D., 2018. Evolution of Water Institutions in the Indus River Basin: Reflections from the Law on the Colorado River. University of Michigan Journal of Law Reform, 51(4), 715–776.

Taylor-Robinson, A.W., 2022. Pakistan floods: Incidence of vector- and water-borne infectious diseases soars. Microbes and Infectious Diseases, 3(4), 776–779.

Van der Schrier, G., Rasmijn, L.M., Barkmeijer, J., Sterl, A., Hazeleger, W., 2018. The 2010 Pakistan floods in a future climate. Climatic Change, 148(1/2), 205–218.

Wang. J., Li, L., He, Z., Kalhoro, N.A., Xu, D., 2019. Numerical modelling study of seawater intrusion in Indus River Estuary, Pakistan. Ocean Engineering, 184, 74–84.