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**GLOBAL CLIMATE ANOMALIES  
AND RECENT FLOODS IN PAKISTAN**

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**ABSTRACT**

*Climate scientists preferably use the term climate anomaly to explain any significant abnormal change of surface air temperature or precipitation in the weather pattern of any region. As a result, abnormal heat waves and extremely hot weather, severe winter snowfall and blizzards, long droughts, heavy rainfall, and extraordinary floods occur. Such anomalies were more often observed in different regions of the world during the last three decades. The term climate change, led by global warming due to the rising amount of carbon dioxide from burning fossil fuels, is generally considered the main cause. The ENSO phenomenon is also linked to the climate anomalies of the last three decades. In 2022 Europe, the USA, China, and Pakistan were affected by such climate anomalies. The Yangtze River region of China, the main rivers of European land, and the lakes and rivers of the dry land region of the USA experienced the worst long drought, creating an extreme shortage of water and electricity generation. On the other hand, Germany and southern China experienced the worst floods. Abnormally hot weather in the summer and extreme winter snowfall and blizzards severely affected people in Europe and the USA. In 2022, Pakistan was also severely affected by floods caused by abnormally heavy monsoon rainfall. Out of 170 districts, 38 were worst affected, causing the deaths of 1739 people, while houses and croplands of 33 million people were badly affected. Sindh was the most affected province, where heavy rainfall and poor drainage created catastrophic damage. Balochistan, southern Punjab, and districts of the Malakand region were severely affected by flash floods. The present study is based on the hypotheses that climatic anomalies (abnormal excessive rainfall and melting of snow) were the main causes of the flood disaster of 2022 in Pakistan. Failure of the National Disaster Management Authority is the secondary factor causing economic and human loss.*

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**Keywords:** Climate Change, Climate Anomalies, Drought, Flood, Monsoon

## **INTRODUCTION**

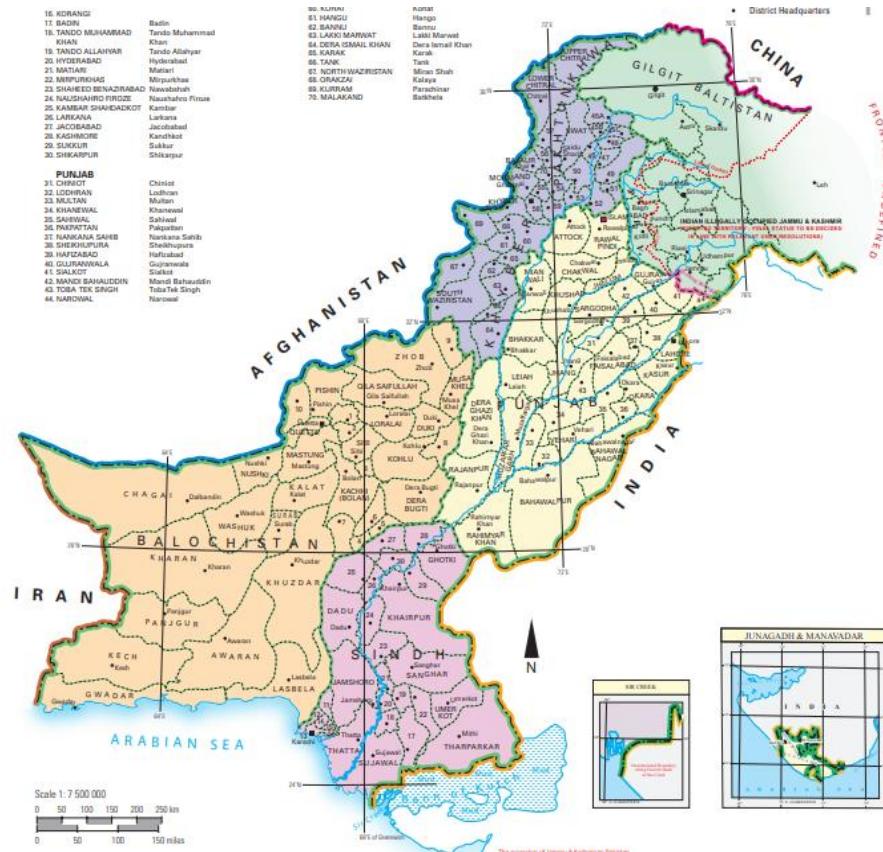
The Paleoclimate study of the Holocene geological epoch (last 12 thousand years ago) reveals that climate change was the most potent element on earth that brought changes to the earth's physical and cultural landscape. The Sahara Desert was once a fertile grassland, the fossilized trees and the fluvial land features of the extinct course of the Yellow Nile River and dry lakes reveal that Saharan and Sub-Saharan Africa had experienced a humid climate. Archaeologists presented one hypothesis about the disappearance of the Indus Civilization: the past humid climate and super floods in the Indus River. In the modern period, environmentalists present horrible pictures of present and future climate change phenomena, with human-caused emissions of carbon dioxide resulting in global warming, melting glaciers, sea level rise, excessive rain, and floods. Climate scientists generally accept recent phenomena such as rising global temperatures, abnormally hot weather in temperate regions, long spells of drought in humid regions, and heavy rain and floods in arid and semi-arid climatic regions of the world. However, climate scientists doubt that such climate change events are due to human causes of global warming. They also link them with natural causes like orbital changes of the earth and other astronomical and geological factors, which would also be caused by a pre-industrial era of climate change events (Barlim, C., 2022).

The phenomenon of climate change has been a burning topic in the last three decades to explain abnormal rain and floods, extremely hot and cold weather, long spells of drought, and extremely low water flow in rivers. The most recent climate anomalies were recorded in the years 2021 and 2022 in Europe, China, the USA, Australia and other parts of the World. The climate reports of European countries in 2022 stated that Europe experienced extremely hot weather and a dry summer in 2022. As a result, many countries in Europe, like France, Italy, Spain, Germany, Hungary, Portugal, Ukraine, etc., suffered drought conditions and water scarcity in rivers like the Rhine and Po. During the summer, much of Europe was affected by exceptional heat waves. The temperature was recorded at 1.4 degrees Celsius above the average summer temperature and 0.3 to 0.4 degrees Celsius warmer than the previous warmest summer in 2021. Precipitation was 10 percent less than average. European rivers were affected, with 63

percent below the average flow. This was the worst drought in the last 500 years. The hot and dry weather is fueling wildfires, reducing crop yields, and reducing hydroelectricity generation. The second region affected by climate anomalies in 2022 was China. The country was hit by its most severe heat wave and severe drought in six decades. The three Gorges dams of the Yangtze River reduced its water level to a dead level, and the southwestern provinces (Shanghai to Sichuan) were worst affected due to a shortage of electricity. The third region affected by extremely hot summers and droughts was the United States. The 17 western states were affected by hot and dry summer weather. Arizona, Colorado, New Mexico, Utah, Nevada Oregon, Texas, Nebraska, California and Arizona were the worst drought-affected states. The drought resulted in water depletion at the lowest level in major water reservoirs and lakes (Ross, 2023). During the last five years, Europe, Canada, and the United States experienced excessively cold winters, heavy snowfall, and blizzards. This abnormally cold weather disturbed daily life through road blockages, suspension of air traffic, crop failure, and excessive energy consumption. Canada, the Northern and central states of the United States, Europe, and Russia had been the worst affected regions of the world. In the year 2021, Germany recorded excessive rainfall in July. The Ahr and Erft rivers of Germany overflowed, flooding residential areas. Water mixed with mud caused mass destruction and fatalities in the states of North Rhine, Saxony, etc. In the year 2022, southeast Australia received heavy rainfall, which led to widespread flooding across southeast Australia and was declared the most expensive disaster. Sydney recorded 404 mm of rain in July 2022, 4 to 8 times the July average rainfall. In March, Sydney recorded 554 mm of rain, while the average rainfall in March is 131.6mm. Meteorologists linked the excessive rainfall in Australia and climate anomalies with the ENSO phenomenon called LaNina (Rohde K., 2023).

Pakistan has been facing serious river flood and rain flood disasters for the last three decades. The super flood of 2010 was the worst flood in Pakistan in the last 50 years. In July-August 2022, the provinces of Balochistan and Sindh received a mean total of 350 mm of rainfall, which is five times more than the 20-year average of total July-August rainfall (70 mm), which was not recorded in the last 50 years. The heavy rainfall caused a flash flood disaster in Balochistan

province and a disastrous rainwater flood in Sindh, which completely washed-out houses, crops, roads, and bridges in major parts of the provinces. The hill torrents of the Sulaiman Mountain range washed out villages and crops in southern Punjab province (NDMA, 2022 and WMO, 2023).



**METHODOLOGY AND SOURCES OF DATA**

The study is based on data collected from two sources i.e. data of normal total mean rainfall (July and August) and data of total rainfall (July and August, 2022) are provided by the Pakistan Meteorological Department, while data of economic loss was obtained from government sources and field surveys. The performance of the National Disaster Management Authority (NDMA) is evaluated on the basis of an opinion survey of the flood-affected people in 38 severe affected districts of the four provinces of Sindh, Balochistan, Khyber

Pakhtunkhwa (KPK), and Punjab. The snowball and stratified random sampling techniques are used, which cover a total of 3800 respondents (100 respondents in each of the 38 flood-affected districts). If more than 50 percent of respondents are satisfied with the performance of the NDMA, the district is marked 1; otherwise, 0. The data on rainfall, economic loss, and performance of the NDMA are statistically analyzed with the help of the following methods:

1. The statistical techniques of product moment correlation and multiple correlation are used to examine how much economic loss in the flood-affected districts depends upon excessive abnormal rainfall and the performance of the NDMA. Product moment correlation and multiple correlation are mathematically expressed as follows:

(Product moment Correlation)

$$r_{xy} = \frac{n \sum xy - \sum x \sum y}{\sqrt{(n \sum x^2 - (\sum x)^2)(n \sum y^2 - (\sum y)^2)}}$$

$$\text{(Multiple Correlation)} R_{1.23} = \sqrt{\frac{r_{12}^2 + r_{13}^2 - 2r_{12}r_{13}r_{23}}{1 - r_{23}^2}}$$

2. Hypotheses that: (i) abnormal excessive rainfall was the main cause of the flood disaster of 2022 in Pakistan, and (ii) failure of the National Disaster Management Authority is the secondary factor causing economic and human loss. The statistical technique of hypothesis testing is applied.

**Hypothesis 1.**

Null hypothesis: abnormal heavy rainfall is the main cause of economic loss.

Alternative hypothesis: abnormal heavy rainfall is not the cause of economic loss.

**Hypothesis 2.**

Null hypothesis: The performance of NDMA is unsatisfactory.

Alternative Hypothesis: The performance of NDMA is unsatisfactory.

T-test is applied, and it is tested at a 95% confidence level.

$$t_{xy} = \frac{r_{xy} \sqrt{n-2}}{1 - r_{xy}^2}$$

3. The Flood Intensity Index of each affected region is computed on the basis of estimated economic loss (billion US\$) of a district and the total estimated economic loss (billion US\$) of a country.

*Flood Intensity Index (FII) =*

$$\frac{\text{Total economic loss of a District due to flood hazard}}{\text{Total economic loss of a country due to flood hazard}}$$

The three categories of flood Intensity Index are recognized: i.e. (i) High-intensity flood-affected regions; (ii) Moderate-intensity flood-affected regions; and (iii) Low intensity affected regions.

## **RESULTS AND DISCUSSION**

### **Recent Climate Anomalies**

Climate scientists proposed two scientific reasons for recent excessive rain and flooding, as well as extreme hot and cold weather and drought.

### **The El Niño–Southern Oscillation (ENSO)**

The ENSO phenomenon is an irregularly periodic variation in winds and sea surface temperatures over the tropical Pacific Ocean that affects the climate of tropical and subtropical regions, particularly in the southern hemisphere. The warming phase of the sea temperature is known as El Nino, and the cooling phase is called La Nina. ENSO is an important climate phenomenon linked with changes in normal sea temperature due to changes in the circulation pattern of cool and warm oceanic currents that influence normal pressure, temperature, and precipitation patterns across the globe.

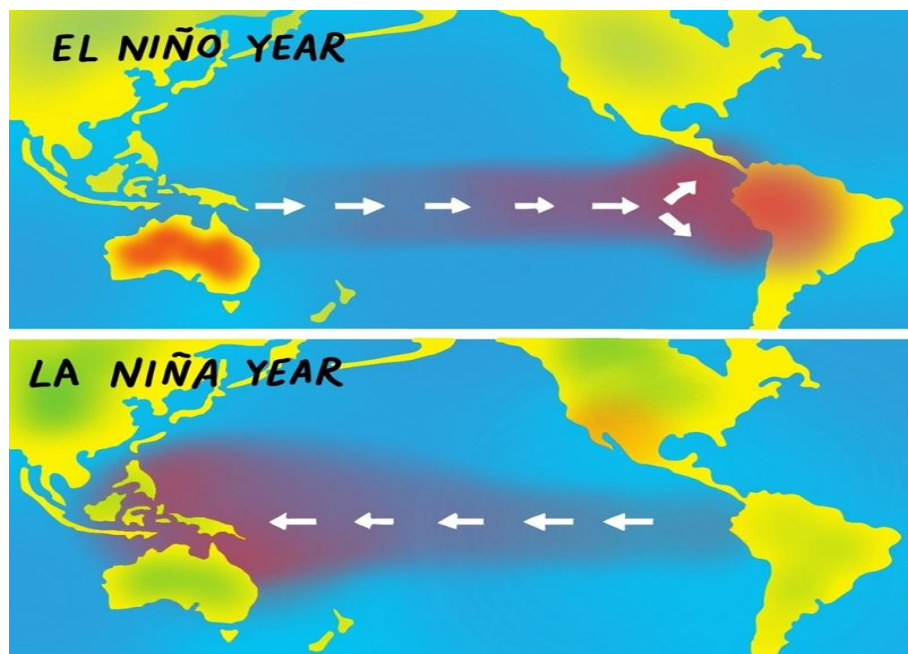


Fig 1: ENSO phenomena

In the El Niño phenomenon, rising sea temperatures increase excessive evaporation while rising air temperatures change normal pressure and wind circulation patterns. The normal easterly winds (blowing east to west) become weak and now winds move from west to east due to changing air pressure (Fig 1). As a result, when one region receives heavy rain, drought prevails in the opposite region. For example, as a result of El Niño, the ocean water in the central and eastern Pacific Oceans becomes warmer than normal, the moist winds move to the west, and eventually, Indonesia and Australia receive less rainfall than normal, while western Pacific countries like Ecuador and northern Peru receive heavy rainfall, resulting in coastal flooding and erosion like in 1952, 1965, 1994, 2001, 2014 and 2018. As El Niño brings rain to South America, it brings droughts to Indonesia and Australia. These droughts threaten the region's water supplies, as reservoirs dry and rivers carry less water. The reverse condition develops in the La Niña phenomenon: cooling of the ocean surface, or below-average Sea Surface Temperatures (SST), in the central and eastern tropical Pacific Ocean, while warming ocean water occurs in the western Pacific region of South America. Dry weather and less

precipitation prevail in South America, while eastern Pacific regions like Indonesia and Australia receive excessive rainfall, resulting in floods in Australia like in 1976, 2010, 2017, 2021 and 2022 (James P. 2020, WMO, 2023 and IPCC, 2023).

### **Global Warming**

Environmental scientists and Intergovernmental Panel for Climate Change (IPCC) scientists consider the climate of the earth to be changing due to the rising level of carbon dioxide in the atmosphere, which has resulted in the rising average temperature of the earth. This phenomenon is called global warming. According to the 2007 IPCC report on climate change, during the last 100 years, the global average temperature has increased up to 0.6 degrees Celsius, and if the emission of greenhouse gases (mostly carbon dioxide) continues, the global temperature may rise up to 5.8 degrees Celsius by the end of 2100. The IPCC report of 2023 warns that global surface temperature was 1.09 degrees Celsius higher in 2011–2020 than in 1850-1906, with a larger increase over land (1.59 degrees Celsius) than over the ocean (0.88 degrees Celsius). The global surface temperature in the first two decades of the 21st century (2001-2020) was 0.99°C higher than in 1850–1900. Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years (IPCC, Climate Change 2023). As a result of rising global temperatures, glaciers melt and sea levels rise, causing excessive rainfall and hot weather. Many astrophysics and climate scientists believe that global warming and climate change phenomena are not new. It happened several times in the paleoclimate history of the earth started millions of years ago called ice ages and inter-ice ages. They consider climate change a natural phenomenon linked to astronomical factors like changes in earth-sun orbit and geological factors like massive emissions of greenhouse gases from volcanoes (IPCC, 2007 and 2023).

### **Floods in Pakistan**

Flooding is a natural phenomenon that occurs when excessive precipitation takes place. Water overflows from the water channels either due to the melting of ice or heavy rainfall. Torrential rainfall creates a flash flood situation due to the copious discharge of runoff.

Flooding is universally considered a natural disaster due to the loss of human life, property, crops, and infrastructure (roads, railways, bridges, dams, transmission lines, etc.). Pakistan is a flood-prone region of the world where floods frequently occur. The Indus River basin is the most vulnerable flood region of Pakistan, where excessive summer monsoon rainfall (June to September) and melting water from Himalayan glaciers are the main reasons for floods. However, flash floods due to torrential rain in the mountainous regions of Khyber Pakhtunkhwa (KPK) and Balochistan are often caused by catastrophic losses. The lowland region and poor drainage of Sindh province are the main causes of rain and river floods. In every episode of flooding, the government failed to adopt mitigation measures, and the default economy suffered more disaster. People, by and large, receive meager financial aid as compensation for their losses due to floods. The super flood of 2010 is considered the worst-affected flood in KPK and Punjab. The flood of 2011 seriously affected the Sindh region. The most recent worst-affected flood occurred in July and August in all four provinces of Pakistan. Sindh and Balochistan were the worst affected regions (Akhtar S., and Dhanani, 2011).

### **Flood 2022 in Pakistan**

In the months of July and August 2022, one of the deadliest floods occurred in Pakistan. It was recorded in history as one of the costliest natural disasters in world history. As a result, 1739 people died, and an economic loss estimated more than 3 trillion rupees (\$18 billion) occurred. The immediate causes of this catastrophic flood were melting glaciers in the Gilgit-Baltistan region and abnormally heavy monsoon rainfall in the four provinces Sindh, Balochistan, Punjab and Khyber Pakhtunkhwa, which was linked to exceptional warming of the Indian Ocean and climate change, severely affected 38 districts in Balochistan, Khyber Pakhtunkhwa, Punjab, and Sindh provinces (WMO, 2023).

### **Causes of Flooding**

The two main causes of flooding were the rapid melting of ice and glaciers due to hot weather conditions in June in the mountain glacier region of Gilgit-Baltistan, Pakistan. The Ghizar and Yasin valleys were seriously affected due to glacial melting. 2. The second

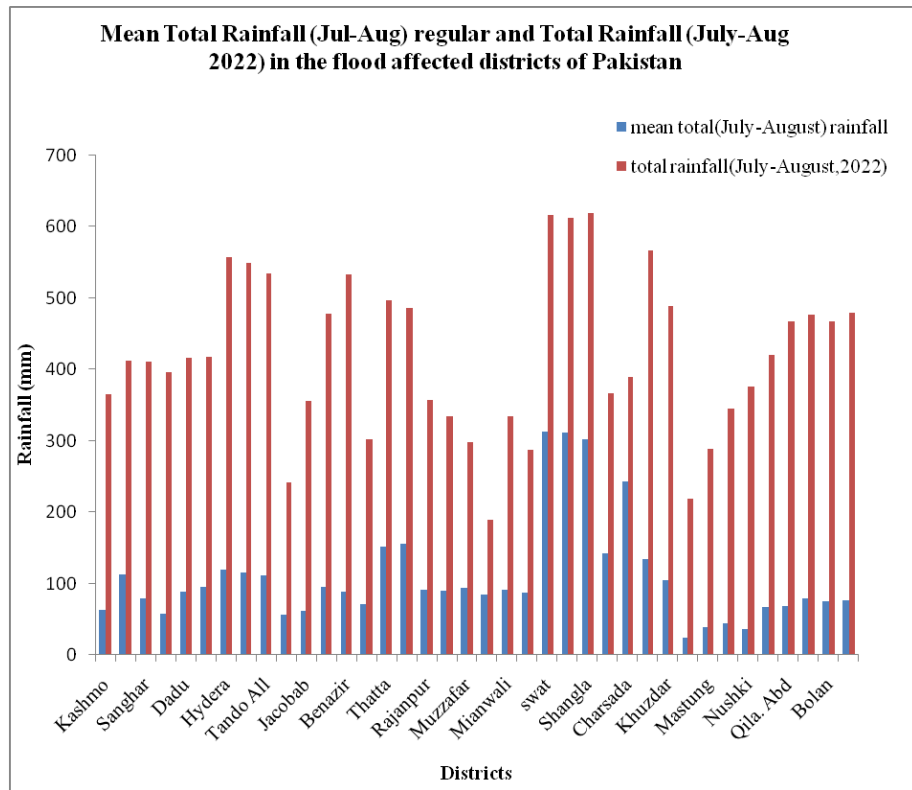
important cause was the summer monsoon rainfall in the Balochistan, Sindh, Khyber Pakhtunkhwa, and Punjab provinces from July 20 to August 28. Balochistan and Sindh received exceptionally heavy rainfall. Balochistan normally receives low rainfall in the summer monsoon season, but due to the change in the normal path of monsoons from India due to extreme heat, low pressure developed over Balochistan, and the moist winds of the Arabian Sea deflected towards Balochistan. As a result, Balochistan received a total mean of 350 mm (July–August, 2022) of rainfall, seven times more than the normal mean total of 50 mm (July–August). Similarly, Sindh received July-August 2022 total mean rainfall of 370 mm, five times more than the normal mean total July-August rainfall of 75 mm. This was because rising temperatures and hot weather caused low pressure to develop over the Rajasthan desert and Sindh, resulting in an abnormal diversion of moist monsoon winds from the Arabian Sea and the Indian Ocean towards Sindh, Balochistan, and the southern Punjab regions of Pakistan. Eventually, heavy, non-stop, three-day torrential rain occurred in Sindh, southern Punjab, and eastern Balochistan. In the last week of August, the Kabul and the Swat rivers swelled and flooded Swat, Charsadda, and Naushera, while medium to high level floods occurred in the Indus River System (NDMA, 2022).

**TABLE-1**  
**RAINFALL, ECONOMIC LOSS, PERFORMANCE OF NDMA**  
**AND FLOOD INTENSITY INDEX**

Regions	Normal Rainfall Mean Rainfall mm. (July-Aug)	Rainfall (mm) (July-August, 2022)	Economic Loss (infrastructure, Houses, crops etc. (billion \$US)	Performance of NDMA 1 Satisfactory 0 Unsatisfactory	Flood Intensity Index
<b>SINDH</b> Province <u>Districts:</u>			<b>9.8</b>		<b>0.54</b>
Kashmore	63.0	357.0	0.4	0	0.022
Jamshoro	113.0	413.0	0.6	0	0.037
Sanghar	79.0	411.0	0.7	0	0.038
Mirpurkhas	58.0	305.9	0.3	0	0.016
Dadu	89.0	417.5	0.6	0	0.033
Kamber	95.0	418.7	0.6	0	0.033
Shahdadkot					
Hyderabad	120.0	558.8	0.9	1	0.049

Matiari	116.0	547.9	0.8	1	0.044
Tando	112.0	535.8	0.8	0	0.044
Allahyar					
Sukkur	56.8	242.9	0.2	0	0.011
Jacobabad	62.1	356.8	0.4	0	0.022
Naushero	95.6	478.9	0.7	0	0.038
Firoze					
Benazirabad	98.5	534.9	0.9	0	0.049
Larkana	71.6	302.3	0.3	0	0.016
Thatta	152.4	497.9	0.8	1	0.044
Sujawal	156.3	486.8	0.8	1	0.044
<b>PUNJAB</b>			<b>1.3</b>		<b>0.07</b>
Province					
<u>Districts:</u>					
Rajanpur	92.4	358.9	0.4	1	0.022
Dera Ghazi	89.6	303.6	0.3	1	0.016
Khan					
Muzaffargarh	94.5	248.7	0.2	0	0.011
Leiah	84.2	189.9	0.1	0	0.005
Mianwali	92.7	301.7	0.3	0	0.016
Multan	87.2	247.9	0.2	0	0.011
<b>KPK Province</b>			<b>2.4</b>		<b>0.132</b>
Province					
<u>Districts:</u>					
Swat	313	537	0.8	0	0.044
Buner	312	529	0.7	0	0.038
Shangla	302	356	0.4	0	0.022
Nowshera	143	312	0.3	1	0.016
Charsadda	243	302	0.2	1	0.011
<b>Balochistan</b>			<b>4.6</b>		<b>0.254</b>
Prov.					
<u>Districts:</u>					
Lasbella	134.6	567	0.9	0	0.049
Khuzdar	105.4	489	0.7	0	0.038
Awaran	24.6	219	0.1	0	0.005
Mastung	38.9	289	0.1	1	0.005
Washuk	45.5	345	0.2	0	0.011
Nushki	36.5	376	0.2	1	0.011
Pishin	67.6	421	0.4	0	0.022
Qila	68.8	467	0.5	0	0.027
Abdullah					
Jhal Magsi	78.8	477	0.7	0	0.038
Bolan	75.7	467	0.8	1	0.044
(Kachhi)	76.2	479	0.4	0	0.022
Nasirabad					

Source: NDMA and Field Survey



**Impacts of Flooding**

The 2022-flood in Pakistan is one of the most catastrophic floods in the history of Pakistan in terms of economic and human loss. The flood affected 33 million people, causing the deaths of 1739 people, over 2.1 million people were homeless, 897014 houses were destroyed, and 1164270 livestock were killed, most of them in Balochistan. Sindh, Khyber Pakhtunkhwa, and southern Punjab. Epidemics of malaria and waterborne diseases were reported in the flood-affected areas. Floods destroyed 13115 kilometers of roads and 439 bridges, while 22,000 schools were damaged or destroyed. The government of Pakistan has estimated that 30 billion US dollars is required for reconstruction. Despite pledges from international donors like the European Union, Asian Development Bank, World Bank, UNDP, etc., Pakistan has not yet received the required financial assistance (Pakistan Economic Survey, 2023).

### Areas hit by monsoon rains

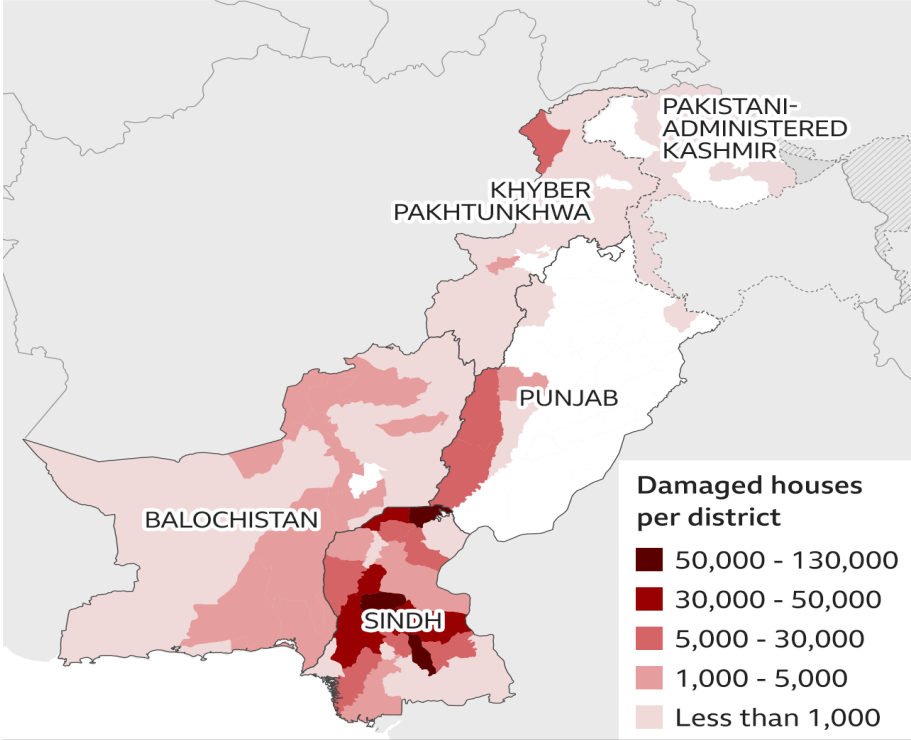
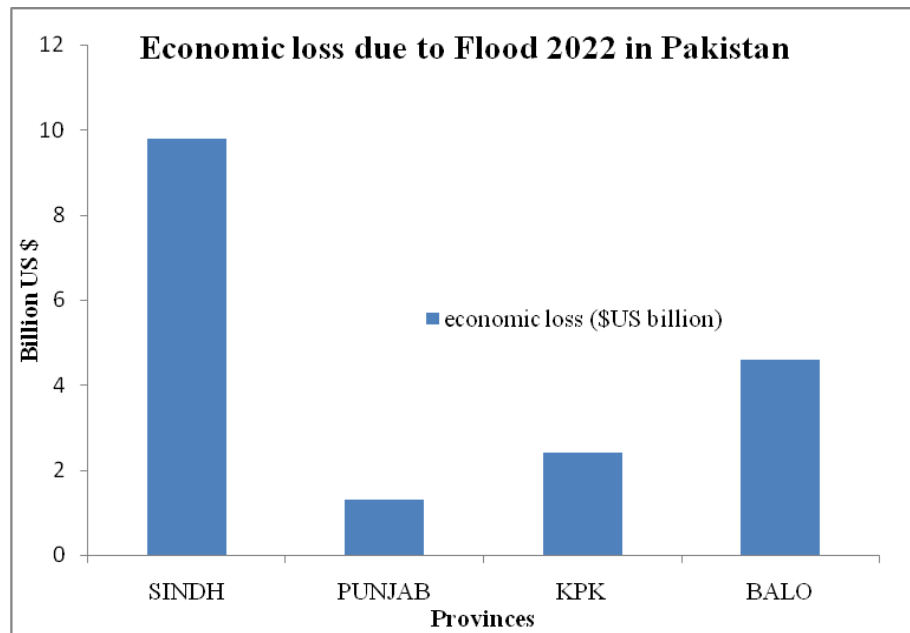


Fig 2: Flood affected regions of Pakistan.



Source: NDMA (Fig 3: Economic loss due to flood2022 in Pakistan).

**Gilgit-Baltistan**

The exceptionally hot weather of June affected the glacier melting in the region, and eventually, flash floods occurred. The districts of Ghizar, Nagar, Diamer, Ghanche and Astore were the worst affected regions. 23 people died, and 420 homes were destroyed. Two bridges in the Nagar district and one bridge in the Ghanche district were destroyed (Fig 5).

**Sindh**

The three days of continuous rainfall in August and the hill torrents of the Kirthar mountain range of Balochistan flooded most of the districts of Sindh. The failure of the saline water drainage located on both banks of the Indus River, RBOD (Right Bank Outfall Drainage) and LBOD (Left Bank Outfall Drainage) inundated most of the districts, and rainwater was blocked because of poor drainage, roads, construction of embankments, and diversion of flood water to cities and villages of poor farmers to save croplands of political elites and feudal lords. The most affected districts were Hyderabad, Matiari, Tando Allahyar, Jamshoro, Sanghar, Khairpur, Nawabshah, Thatta,

Sujawal, Qamber-Shahdadkot, Naushero Feroze and Shaheed Benazirabad. Floods in Sindh killed 799 people, 57,496 houses were destroyed, 830 cattle were killed and 6200 square kilometers of farmland were under water. The total economic loss is estimated at about 9.8 billion US dollars which is the highest among all four provinces of Pakistan (Table 1 and Figs 2 and 4).

**Gilgit-Baltistan**



**Shahdadt Sindh**



Hingol River, Lasbela district, Balochistan Bolan River, Bolan district, Balochistan

Fig 5: Flood disaster in the provinces of Pakistan





Lasbela district, Balochistan Pishin district, Balochistan



Rajanpur district, Punjab



Jamshoro district, Sindh



Sanghar district, Sindh; Dadu district, Sindh  
Fig 6: Impacts of flood hazards in the provinces of Pakistan.



### **Khyber Pakhtunkhwa**

The three days of continuous rainfall that occurred from August 25th to August 28th resulted in flood conditions in the Kabul River and Swat River. Swat, Buner, Shangla, Charsadda and Nowshera districts were badly affected. 309 people died, 600,000 people were displaced, 326897 houses were damaged, and 7742 cattle died. The total economic loss is estimated at about 2.4 billion US dollars (NDMA, 2022).

### **Punjab**

The southwestern districts of Rajanpur, Muzaffargarh and Dera Ghazi Khan were badly affected by the hill torrents of Balochistan. The torrential rainfall over the Sulaiman Mountain range of the Punjab-Balochistan border created flash floods in the bordering districts. 223 people died and 7200 sq. km of farmland were lost. The estimated economic loss is 1.8 billion US dollars.

### **Balochistan**

At the end of July and beginning of August, continuous monsoon rain and hill torrents created flash floods while the rivers of Hub, Porali, Hingol, Zhob and Bolan swelled. Lasbella, Khuzdar, Pishin, Qila Abdullah, Bolan and Jhal Magsi were badly affected. 103 small dams were breached or destroyed. Hill torrents and streams, and surface floodwater coming from Afghanistan and Iran breached bridges, railways, and roads in Noshki, Khuzdar, and Mastung districts. Balochistan was disconnected from the other provinces. Hub Bridge and Bela Bridge, which connected Karachi to Balochistan and Afghanistan, were badly damaged, and road traffic was disconnected. Railway bridges in Sukkur-Sibbi-Quetta were destroyed. A total of 2000 kilometers of roads were destroyed. Mobile, internet service, gas, and power supplies were disconnected. Flooding in Balochistan killed 336 people, many families were displaced, 426897 houses and 1230 sq. km of croplands were destroyed (Fig. 6). The estimated economic loss is 4.6 billion US dollars (Fig. 6 and table1).

### **ANALYSIS OF FLOOD HAZARD**

The analysis of the causes and economic loss of the flood hazard in 2022 was carried out on the basis of the statistical techniques

mentioned in the methodology. The statistical techniques of product moment correlation and multiple correlation were applied to examine the relationship between economic loss, heavy rainfall, and the performance of the NDMA. The coefficient values of product moment correlation ( $R = 0.89$  and  $R = 0.67$ ) were computed to reflect a strong correlation between economic loss and rainfall and a significant correlation between economic loss and the performance of the NDMA. The multiple correlation value  $R = 0.71$  indicates a significant relationship between economic loss, rainfall, and the performance of the NDMA. The hypotheses that i) abnormal excessive rainfall was the main cause of the flood disaster of 2022 in Pakistan and ii) failure of the National Disaster Management Authority was the secondary factor causing economic and human loss were statistically tested and found significant.

### **i) Flood Intensity**

The intensity of the flood hazard in flood-affected districts can be analyzed with the help of bar-graphs of economic loss and rainfall (Fig 4). Those districts which received high rainfall like Hyderabad, Mityari, Tando Allahyar, Jamshoro, Thatta, Sujjawal, Lasbella, Khuzdar, Jhal Magsi, Bolan, etc., suffered high economic losses (table 1). The Flood Intensity Index (FII) of provinces and 38 flood-affected districts was computed by applying the technique mentioned in the methodology. The values of FII indicate that Sindh is the most affected province, followed by Balochistan, KPK, and Punjab (table 1). The values of FII are categorized into high (0.049–0.044), medium (0.043–0.022), and low (0.021–0.001) flood-affected districts. The high-intensity flood-affected districts in Sindh are Hyderabad, Mityari, Tando Allahyar, Jamshoro, Thatta, and Sujjawal, while Dadu, Sanghar, Naushehro Firoze, Shaheed Benazirabad, Khairpur, Qamber Shahdadkot, Kashmore, and Jacobabad are categorized as medium-flood-affected districts. The low-intensity districts are Mirpur Khas, Sukkur, and Larkana.

In Balochistan, high-intensity districts are Lasbella, Khuzdar, Bolan, and Jhal Magsi; medium-intensity districts include Qila Abdulla, Pishin, and Nasirabad; and low-intensity districts include Noshki, Awaran, and Washuk. In KPK, Swat and Buner districts lie in high-intensity flood-affected districts; Shangla is in the medium-

intensity category, while Nowshera and Charsada are in the low-intensity category. In Punjab, Rajanpur district lies in the medium FII category, while Dera Ghazi Khan, Leiah, Muzaffargarh, Mianwali, and Multan districts fall in the low FII category (table 1).

**ii) Perception of Flood hazards:**

The perception of affected people about flood hazards is an important method to examine the problems and solutions. Field surveys of the affected regions were conducted, and questions related to causes, impacts, and management were asked. All flood-affected respondents in the 38 selected districts considered heavy rainfall to be the main cause of the catastrophic flood of 2022. About 90 percent of correspondents in Sindh and Punjab have considered poor drainage and blockage of rainwater flow due to elevated roads, embankments built by influential political feudal elites to save their settlements, and croplands to be the main causes of floods. In Sindh, the overflow of Manchar Lake and the saline drain channels of RBOD (Right Bank Out Drain) and LOBD (Left Bank Out Drain) are also important factors, while in KPK, the people of Swat Buner consider illegal construction on the bed and along the banks of the Swat River to be an important cause of catastrophic flooding in the area. The people of the flood-affected districts of Balochistan felt that the dismantling of small dams and roads due to below-standard construction and corruption were also important causes of the catastrophic flood of 2022. The people of the majority of districts are not satisfied with the performance of the National Disaster Management Authority (NDMA) in pre-flood warning and evacuation as well as post-flood rescue and relief operations. In the rescue and flood relief operations, people were quite affirmative of the roles of the armed forces and NGOs. In Sindh, flood-affected people had complaints about the malpractice and nepotism of districts' administrations and local ruling political elites in distributing foreign aid like tents. Overall, flood victims are not satisfied with pre-flood and post-flood management.

**CONCLUSION**

The global climate anomalies of the last three decades have affected regions of the world in the form of catastrophic human and economic losses. Countries have been affected by excessive rain and

flooding, exceptionally hot summers, drought, the melting of glaciers, and forest fires. In the years 2021 and 2022, excessive rain and flooding, heavy snowfall and blizzards, an exceptionally hot summer, and drought were recorded globally. Climate scientists hypothesized that such events and anomalies in precipitation and temperature have been caused by global warming either due to human-induced emissions of greenhouse gases, particularly carbon dioxide, or due to natural causes. The ENSO phenomenon is considered a reason for climate anomalies in tropical and subtropical weather patterns, particularly in the southern hemisphere. In July–August 2022, Pakistan was badly affected by exceptionally heavy monsoon rainfall in Balochistan, Sindh, and some districts of KPK and Punjab caused by hill torrents, flash floods, and rain runoff. The region of Gilgit-Baltistan was affected by the melting of ice and glaciers. As a result, the country has suffered an economic loss of more than \$18 billion and a human loss of 2000 people. Sindh was the most affected province, followed by Balochistan, KPK, and Punjab. The performance of NDMA was unsatisfactory in pre-flood warning and evacuation management and post-flood rescue and relief management.

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