Cause and Damages Assessment of 2022-Flood in Khyber Pakhtunkhwa, Pakistan

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Floods are among the most devastating hazards, occurring globally and impacting many regions annually. Pakistan is frequently affected by floods, including the significant floods of 2022 in Khyber Pakhtunkhwa (KP). This study assesses the causes and damages of the 2022 floods in KP using data from NASA Worldview and USGS, complemented by Geographical Information System (GIS) analysis. The study considers the role of climate change and the topography of KP in making it prone to floods. It examines weather patterns, environmental factors, and local vulnerabilities that contributed to the floods, as well as the extent of damage to communities, infrastructure, and the environment. Flood and precipitation data were collected from two satellites and analyzed using ArcGIS. The study identified massive rainfall and increased temperatures as the primary causes of the flood. Significant damage was recorded in District Dera Ismail Khan, followed by Tank and Swat. The floods resulted in approximately 300 fatalities across various districts of KP and caused total economic losses estimated at 201,414 million Pakistani rupees. Public sector losses were estimated at 121,283 million PKR, with house damages amounting to 23,780 million PKR. The peak flooding occurred in August during high rainfall. Understanding the root causes and damages of the 2022 KP flood is crucial for developing effective prevention and mitigation plans, as well as for assessing the impact on communities, infrastructure, and the environment. This study provides critical insights and comprehensive data to inform disaster management and policy-making for future resilience. Its novelty lies in its exclusive focus on the 2022 KP floods, a topic not previously studied in detail. In conclusion, the research effectively analyzes the causes and assesses the damages of the 2022 Khyber Pakhtunkhwa flood, offering essential insights for improving flood management strategies.

Keywords: Floods; Causes; Damages; GIS; KP; Pakistan.

Introduction:

Floods and water-related disasters are escalating globally, causing severe economic and social damage, particularly in rural and low-income communities [1]. Over the two decades leading up to 2015, water-related disasters represented nearly 90% of natural disasters worldwide, affecting approximately 3.2 billion people and resulting in an estimated $300 billion in economic losses. By 2050, floods are expected to impact 40% of the global population [2][3]. These disasters, one of the most devastating forms of natural calamity, affect millions annually. The frequency and severity of floods have increased in recent decades, partly due to climate change, leading to greater economic losses and human suffering, especially in developing countries [4]. Pakistan, highly vulnerable to flooding, faces annual floods that impact millions. Approximately 30 million people live in flood-prone areas. This study examines the floods in Khyber Pakhtunkhwa (KP), a region of Pakistan prone to flooding almost every decade since 1950. These floods have resulted in numerous fatalities, widespread home destruction, massive displacement, and disruption of livelihoods [5].

Pakistan has experienced severe floods in the 1950s, 1960s, 1970s, 1980s, 1990s, and most recently in 2022. The 2010 flood was particularly devastating, lasting six months and affecting 45 of the country's 135 districts. It caused an estimated $9.7 billion in damages, displaced 20 million people, destroyed 1.1 million homes, and damaged 432 healthcare facilities [6]. The 2022 flood also had a profound impact, affecting over 30 million people and causing approximately $30 billion in damages. Major causes included excessive rainfall and glacier melting [7]. KP, one of the hardest-hit provinces, saw nearly 3 million people affected and about 1 million displaced [8].

KP has faced numerous catastrophic floods in recent years, including those in 2007, 2010, and 2012 [9]. The province's flood vulnerability is exacerbated by tributaries such as the Swat and Kabul rivers, which frequently cause significant floods, particularly in Charsadda, leading to severe human and environmental damage [10][11]. The 2010 flood notably damaged the Munda Headwork, built during British rule, which was crucial for water supply in Charsadda [12].

The 2022 floods in KP were among the most severe in the province's history [13]. Heavy rainfall and glacial meltwater led to widespread flooding and landslides, displacing millions and causing extensive damage to homes, infrastructure, and crops (National Disaster Management Authority of Pakistan). The floods affected over 33 million people nationwide, with more than 8 million displaced from their homes [14]. The estimated damage to infrastructure and crops was around $14.9 billion (World Bank, 2023). KP, located in the foothills of the Himalayas, is highly vulnerable to floods due to heavy rainfall and glacier melt, which have been exacerbated by climate change, making floods more frequent and severe [15]. The 2022 floods were the worst in KP's history, causing extensive damage and worsening existing food insecurity and poverty [16]. This research focuses exclusively on the 2022 floods in KP, utilizing satellite data, rainfall analysis, and ArcGIS for a comprehensive understanding of the flood's impact. The study provides valuable data and insights for disaster management and policy-making in KP.

Study Area:

Khyber Pakhtunkhwa (KP) is located in northwestern Pakistan, bordering Afghanistan to the west and north, Azad Kashmir and parts of northern and eastern regions, Punjab to the southeast, and Baluchistan to the southwest [17]. KP's provincial capital is Peshawar. It shares borders with the Federally Administered Tribal Areas to the west, Gilgit-Baltistan to the northeast, and Azad Kashmir, Islamabad, and Punjab to the east and southeast. The province is situated at coordinates 34.00°N 71.32°E. KP is Pakistan's third-largest province in terms of population and area, covering 101,741 km² and home to over 35 million people. It consists of mountain ranges, hilly areas, and plains surrounded by hills. Known for its cooler climate, KP has an average high temperature of 29 degrees [18] (Figure 1).

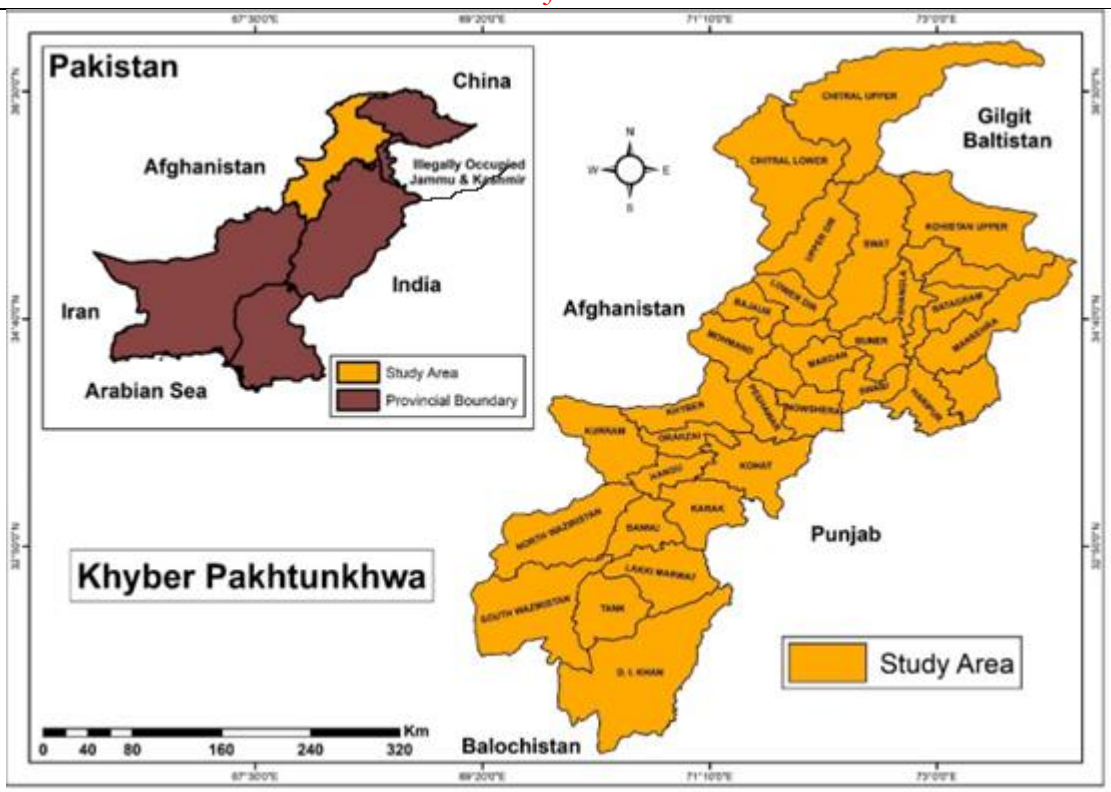

Figure 1: Location of Study Area

Research Problem:

Since its independence, Pakistan has experienced frequent and severe floods, causing substantial damage across all its provinces. Khyber Pakhtunkhwa (KP) is one of the provinces that has been repeatedly affected by flooding. This study investigates the causes and consequences of the 2022 floods in KP, focusing on their impact on infrastructure, the environment, and local communities. The goal is to develop strategies to enhance flood preparedness and resilience in KP.

Research Questions:

- What were the primary causes of the 2022 flood in Khyber Pakhtunkhwa, Pakistan?
- How did the 2022 flood impact various sectors of the economy in Khyber Pakhtunkhwa, Pakistan?

Research Objectives:

- To analyze the causes of the 2022 flood in Khyber Pakhtunkhwa, Pakistan.
- To assess the damage caused by the 2022 flood in Khyber Pakhtunkhwa, Pakistan.

Materials and Methods:

Data Collection:

Secondary data on the 2022 flood in KP was gathered from multiple sources, including TERA Climate, NASA, EOSDIS Worldwide, Provincial Disaster Management Authority (PDMA), National Disaster Management Authority (NDMA), KP-EPA, research papers, and the Pakistan Meteorological Department (PMD). This data provides insights into the extent of water spread across different regions of KP. Flood data for August 30, 2022, were obtained from various governmental and private organizations.

Data Processing:

The collected data was processed and entered into an Excel spreadsheet for detailed analysis. It was then presented through tables, graphs, and maps, which offered a comprehensive evaluation of the flood's extent and impact in KP. Comparative analysis with data from other years was also conducted to assess the damage more thoroughly.

Data Analysis:

Descriptive statistical analysis was employed to evaluate the damage caused by the 2022 floods in KP. ArcGIS was utilized to illustrate the extent of the flood in different areas of KP and to map rainfall data (Figure 2).

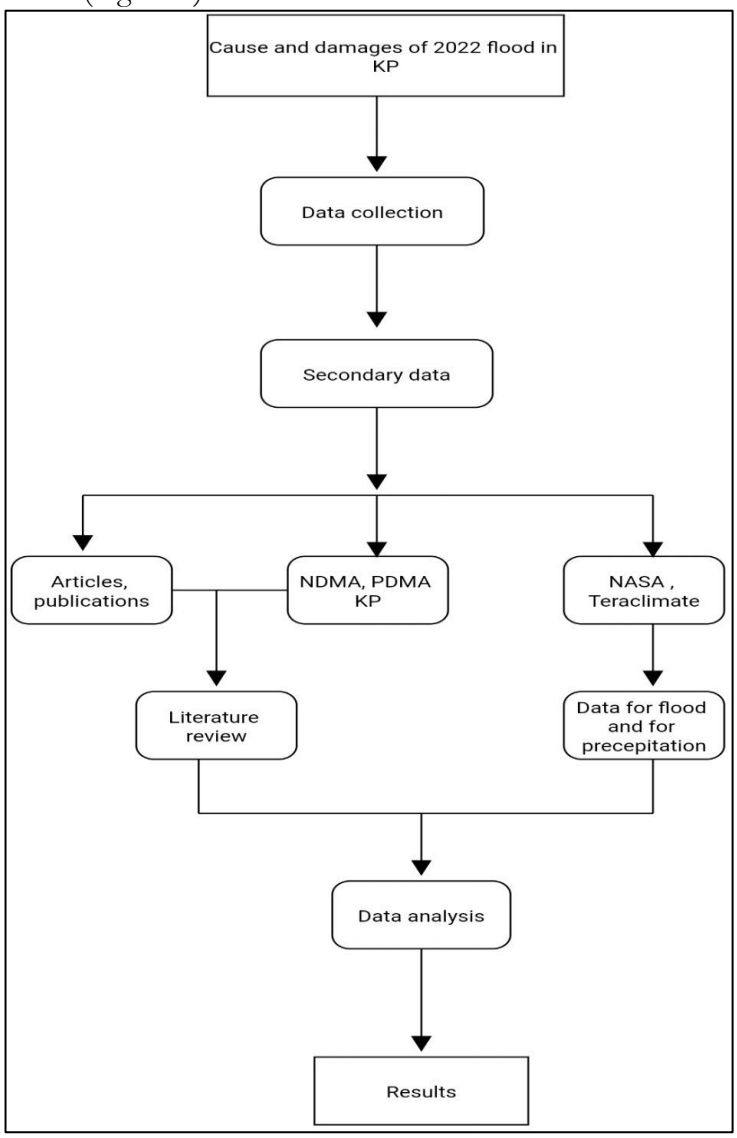

Figure 2: Research Design

Results:

In 2022, Pakistan experienced widespread and intense rainfall, leading to extensive damage across the country. Khyber Pakhtunkhwa (KP) was among the provinces most severely affected by these floods due to exceptionally high monsoon rainfall, resulting in significant harm to both human lives and infrastructure. Nearly 300 people died in KP, and thousands more were severely impacted by the floods.

Causes Assessment of 2022 Flood:

The Monsoon Rainfall:

The impact of climate change has intensified, making floods more severe than in previous decades. Pakistan is among the countries most vulnerable to flooding. In 2022, Pakistan experienced nearly double the average rainfall of the past 30 years. Similarly, KP saw a significant increase in temperature during the same year. On average, Pakistan received 448 mm of rainfall in 2022 (Figure 5). By August, approximately 390 mm of rain was recorded (Figures 3 and 4). This extreme precipitation resulted in nearly one-third of Pakistan being inundated with water.

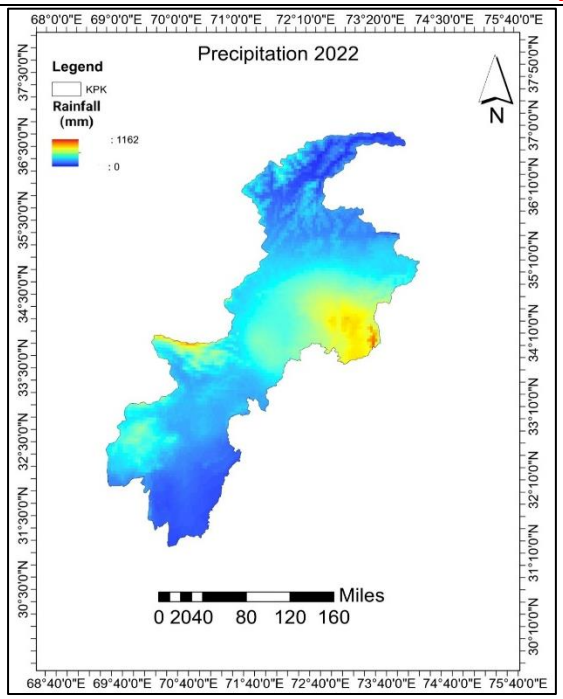

Figure 3: Spatial Pattern of Precipitation in 2021

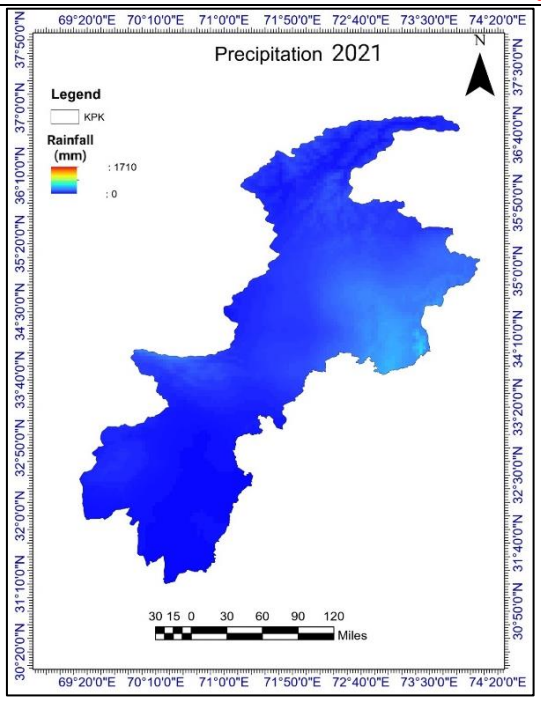

Figure 4: Spatial pattern of Precipitation in 2022

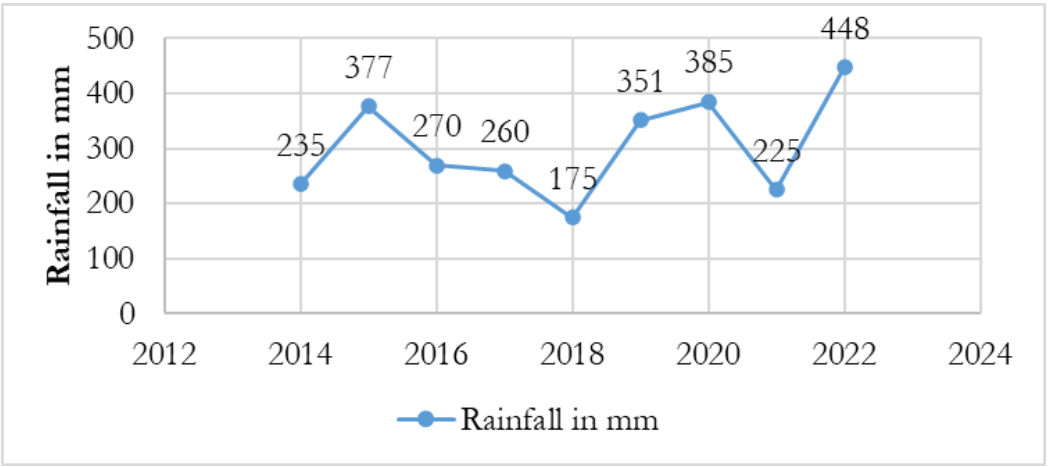

Figure 5: Precipitation Graph of Pakistan (**Source**: Trading economics)

Temperature:

Another factor contributing to the 2022 floods in Khyber Pakhtunkhwa was the increase in temperature, which led to heavy rainfall. Data shows that in June 2022, temperatures in District Peshawar, DI Khan, and Lakki Marwat reached nearly 47 degrees Celsius or higher. By August, although temperatures decreased, humidity levels soared. The mean maximum and minimum temperatures ranged between 48 degrees Celsius and 18 degrees Celsius during June, July, and August. KP experienced a heatwave before the monsoon, with May 15, 2022, recording a high of 42 degrees Celsius, which was six degrees above the normal and eight degrees higher than the same date the previous year. The temperature differences between 2021 and 2022 in KP were notable.

Pre- and Post-Flood Maps:

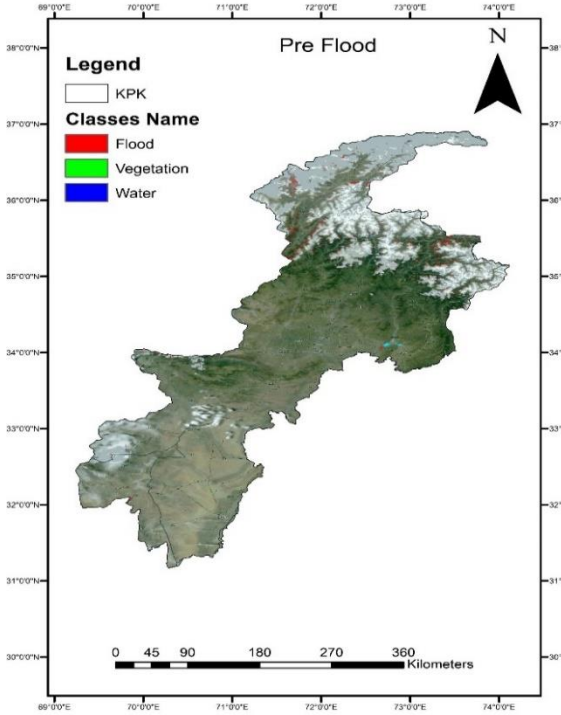

Figure 6: Pre-Flood

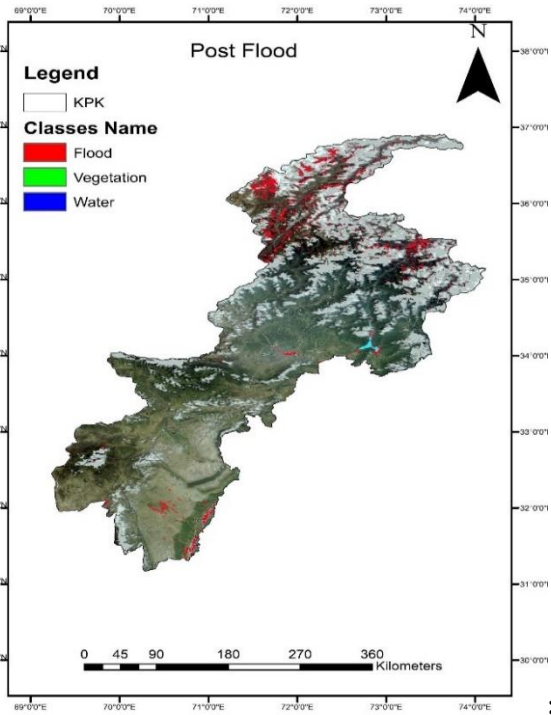

Figure 7: Post Flood

Damage Assessment of 2022 Flood:

Human Losses:

According to the Provincial Disaster Management Authority (PDMA), the floods and rains caused significant damage in the province, destroying 35,123 houses and partially damaging 52,327 houses. Among the 289 people who lost their lives due to the floods and rains, 139 were men, 109 were children, and 41 were women. The number of injured included 139 men, 130 children, and 79 women (Figures 8 and 9).

Damages to Houses:

In Khyber Pakhtunkhwa, a total of 34,406 houses were completely destroyed, and 40,444 were partially damaged. Dera Ismail Khan was the most affected district in terms of infrastructure, with 31,367 houses completely destroyed and 40,444 partially damaged (Table 1).

Table 1: Damages to Houses in KP during 2022 Flood

Name of District	Completely Damaged	Partially Damages
Dera Ismail Khan	31367	40444
Tank	1662	1723
Khyber	303	270
Upper Dir	289	350
Upper Chitral	181	231
Lower Chitral	175	230
Charade	160	221
Marden	90	170
Swat	88	145
Nowshera	66	132
Laki Marwat	25	88
Total	**34406**	**44044**

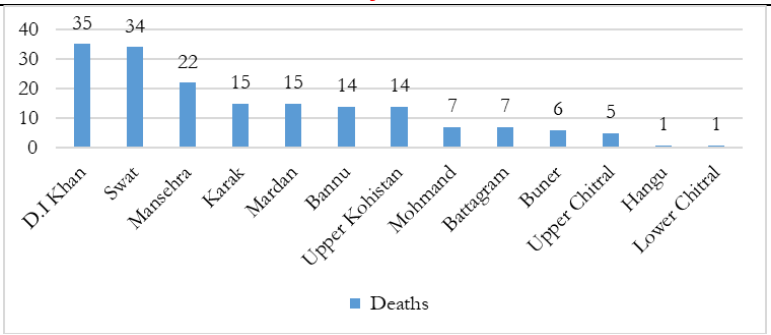

Figure 8: Number of Deaths in KP in 2022 due to Floods

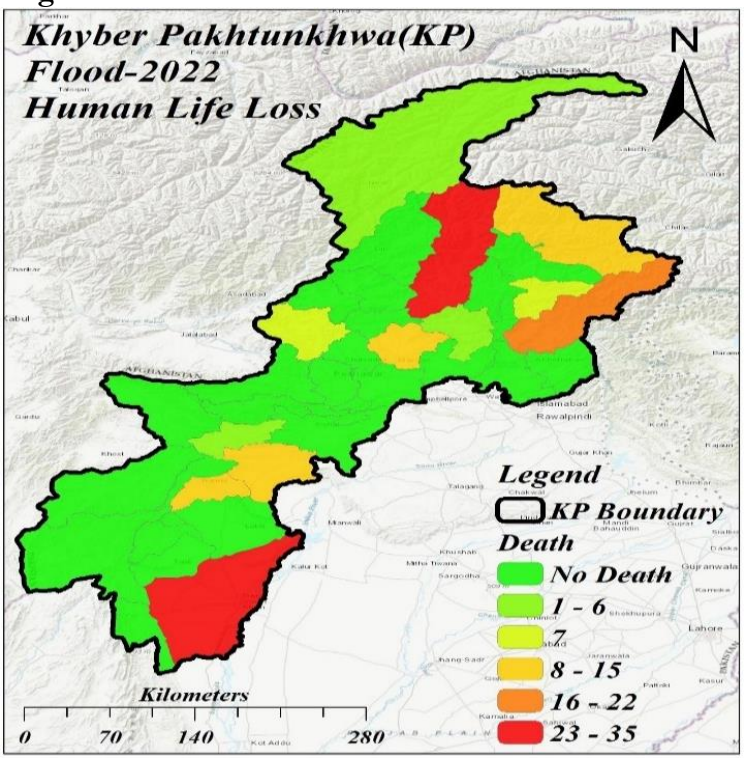

Figure 9: Number of Deaths in KP in 2022 due to Floods

Damages to Livestock:

According to data from the Pakistan Veterinary and Medical Association (PVMA), the 2022 floods in Khyber Pakhtunkhwa resulted in the loss of 22,059 animals. The highest number of losses was recorded in District Tank, with 10,801 animals lost, followed by District Dera Ismail Khan, where 9,099 cattle were affected (Figure 10 and 11).

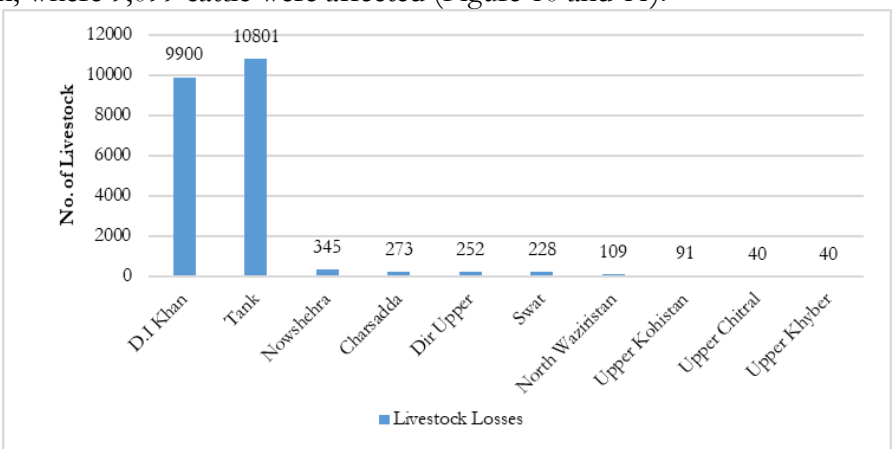

Figure 10: Livestock Losses

Damages to Communications and Works:

Information from the Communication and Works Department indicates that the 2022 floods completely destroyed or damaged 1,500 km of roads and 117 bridges across 31 districts of KP. Dera Ismail Khan experienced the most severe road damage, with approximately 226 km of roads affected, followed by Tank, Karak, and Swat (Figure 12 and 13).

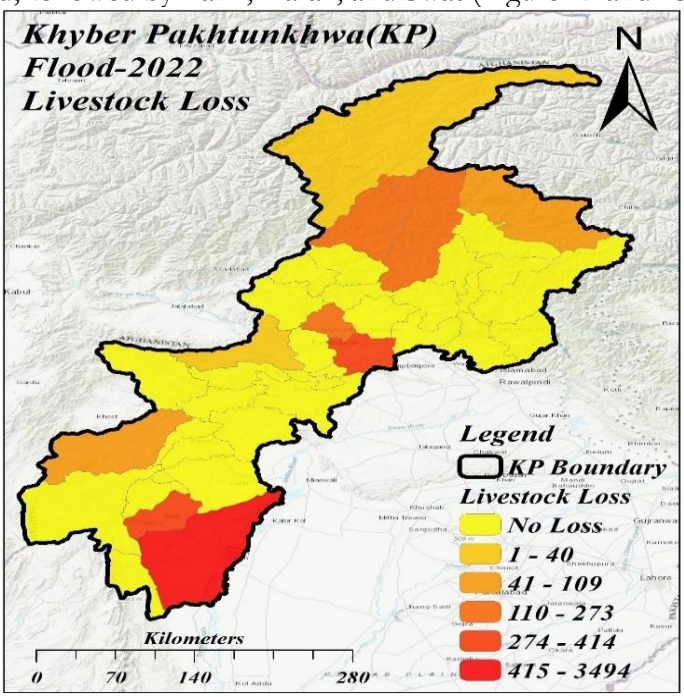

Figure 11: livestock losses

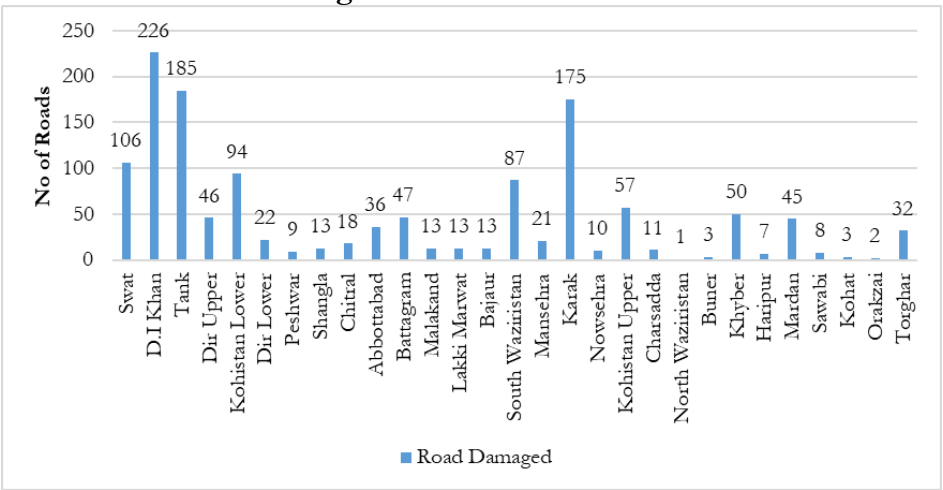

Figure 12: Road Damages in KP

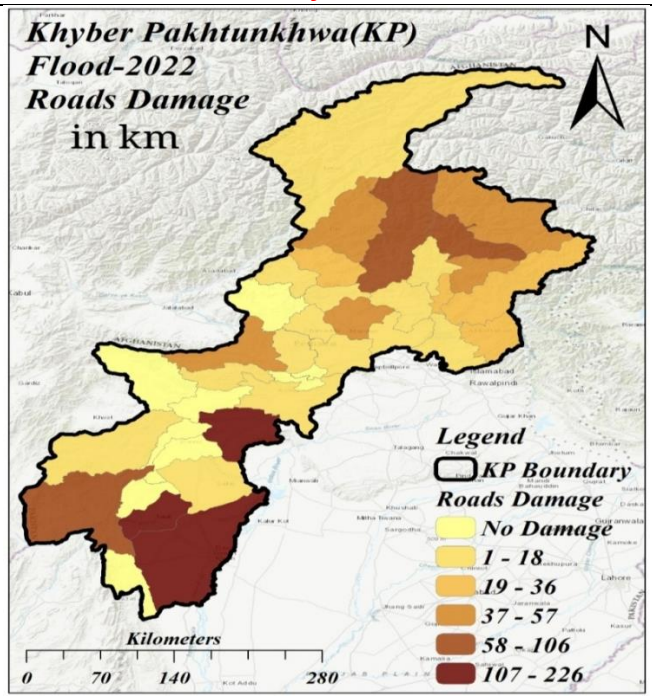

Figure 13: Roads Damages (in km)

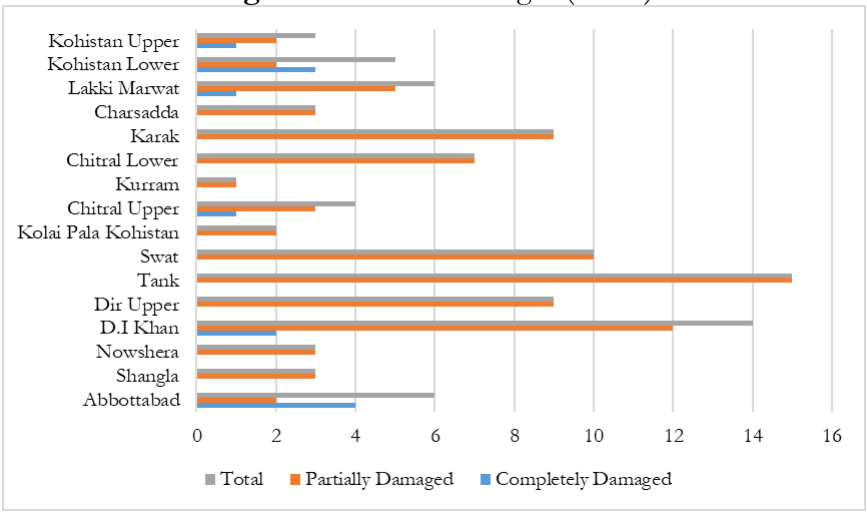

Figure: 14: Health Facilities Damages

Damages to Health Facilities:

The floods severely impacted health infrastructure across several areas of Khyber Pakhtunkhwa, disrupting healthcare services for those already suffering due to the extreme monsoon rains. Many health facilities were either partially or completely damaged. The Department of Health's Planning Cell, in collaboration with District Health Officers, confirmed the damage, which affected 158 health facilities across 17 districts—about 50 percent of the province. The most extensive damage occurred in District Tank, followed by DI Khan, Swat, and Dir Upper (Figure 14 and 15).

Agricultural Sector Damages in KP:

The estimated loss in crop production across Khyber Pakhtunkhwa was 16,171 million rupees. Watercourse damages totaled 707 million rupees, affecting 1,116 watercourses and channels as well as 44 water storage tanks. The Gomal Command Area Development Project reported damages amounting to 978 million rupees, with 99 watercourses completely destroyed and 113 partially damaged. Additionally, 2,888 acres of land were affected. The most significant

land damage was recorded in District Dera Ismail Khan, with 99,873 acres affected, followed by Nowshera, with 14,000 acres (Figure 16, 17, and 18).

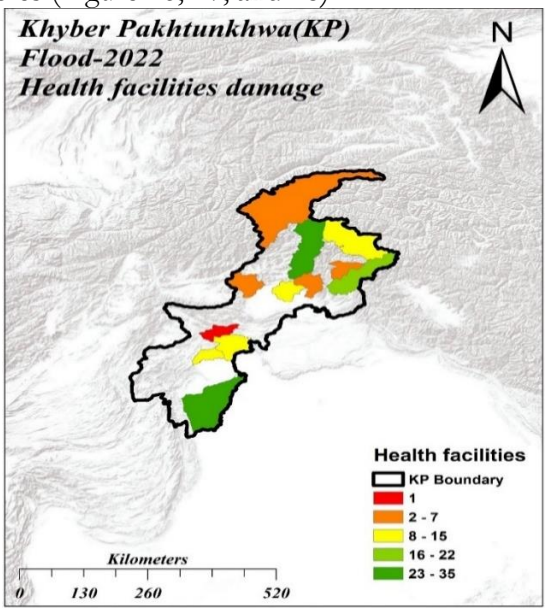

Figure 15: Health Facilities Damages

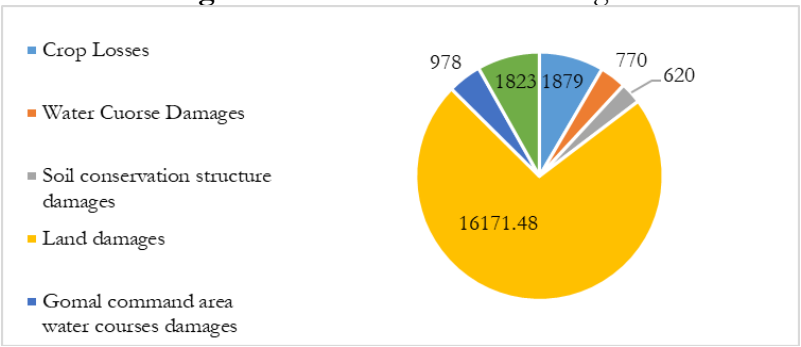

Figure 16: Damages to Agriculture Sector

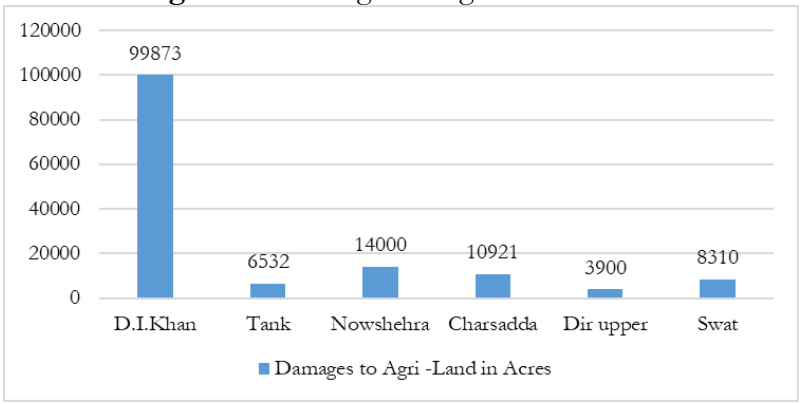

Figure 17: Damages to Agriculture land

Public Infrastructure Damages:

The damage to public infrastructure includes sectors such as communication, irrigation, energy and power, local government, public health, agriculture, sports, higher education, the board of revenue, and food (Figure 19).

Total Economic Loss:

The total economic loss from the 2022 floods in Khyber Pakhtunkhwa is estimated at 201,414 million Pakistani rupees. This includes a public sector loss of 121,283 million PKR and house damages amounting to 23,780 million PKR.

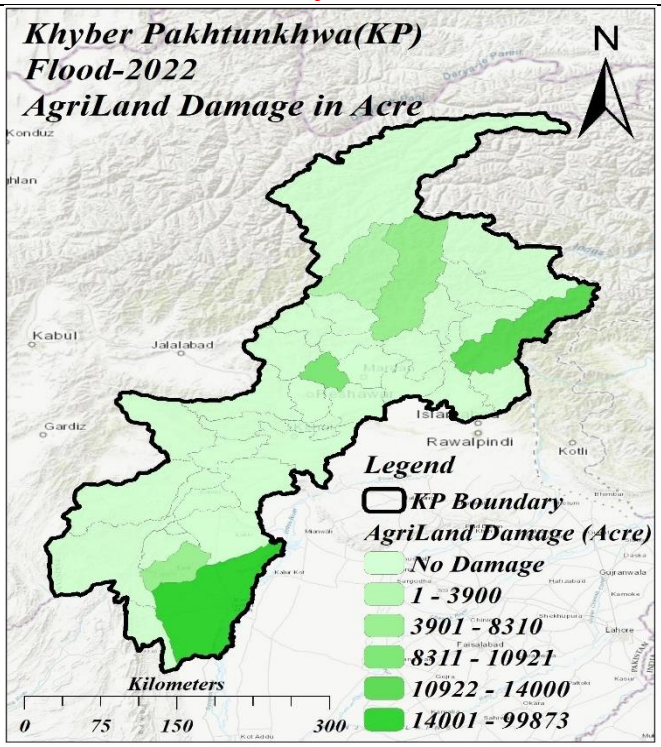

Figure 18: Agriculture land damages in Acre

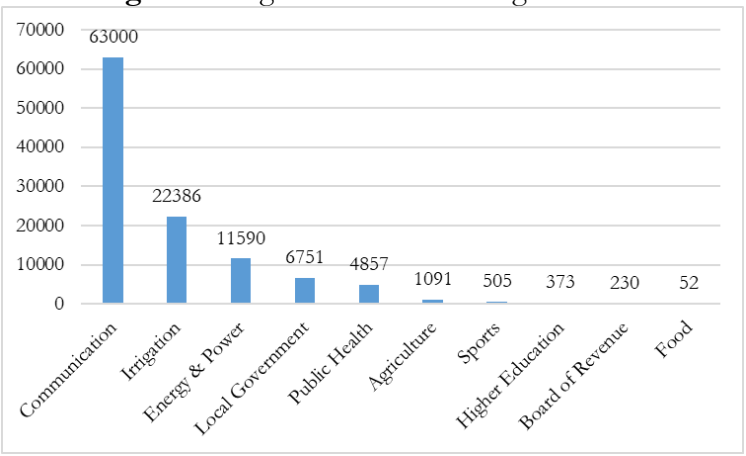

Figure 19: Public Infrastructure Damages

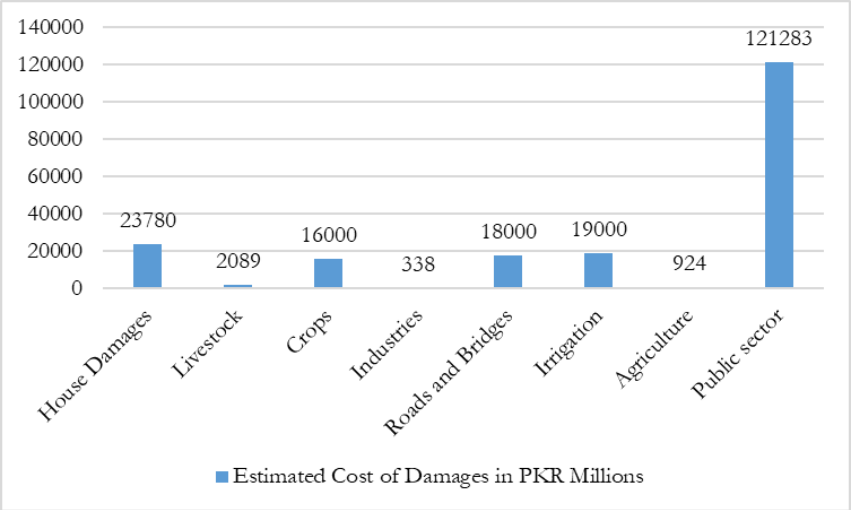

Figure 20: Economic Loss of 2022 Floods

Table 2: Overall Damages Caused by Flood

Districts	Human loss	House Damages	Livestock Damages	Roads Damages	Health Damages	Damages to agricultural land in acres	Estimated economic loss in PKR millions
D. I Khan	35	50000	9800	220		99783	12600
Swat	34	130	10201	106	10	8310	3500
Mansehra	22			21			230
Karak	15			175	8		1900
Mardan	15	530		45			300
Bannu	14						100
Upper Kohistan	14		9	57	3		200
Mohmand	7						
Battagram	7			47			400
Bunner	6			5			90
Upper Chitral	5	230	40		4		350
Hangu	1						
Lower Chitral		270					800
Tank		200	414	185	15	6532	4000
Khyber Agency		400					450
Upper Dir		350	252	46	9	3900	600
Charsadda		230	273	11	4	10921	450
Nowsehra		20	345	10	3	14000	350
Lakki Marwat		50		15			500
North Waziristan			109	1			150
Upper Khyber			40				10
Lower Kohistan				94	5		1000
Lower Dir				22			990
Peshawar				9			600
Shangla				13	3		570
Chitral				18			800
Abbottabad				36	6		500
Malakand				13			400
Bajur				13			350
South Waziristan				87			300
Bunner				3			130
Khyber				50			120
Haripur				7			90
Swabi				8			60
Kohat				3			42
Orakzai				2			36

Discussion:

The 2022 flood in KP posed a significant challenge, resulting in extensive damage to infrastructure, loss of lives, and disruption to communities. The flood's root causes were multifaceted, including heavy monsoon rainfall, exacerbated by climate change and the region's unique topography. Excessive precipitation, combined with rising temperatures due to climate change, led to elevated river levels and flash floods across KP. The impact was particularly severe in districts such as D.I. Khan, Tank, and Swat, which experienced substantial infrastructure damage and loss of life. Approximately 300 lives were lost, and significant damage occurred to roads, bridges, and health facilities. The disruption of health services due to damaged infrastructure further complicated the challenges faced by the affected population, underscoring the need for improved disaster preparedness and resilient infrastructure.

The study utilized data from reputable sources like NASA Worldview and USGS, complemented by Geographic Information System (GIS) analysis, to assess the causes and damages of the floods comprehensively. By examining weather patterns, environmental factors, and local vulnerabilities, the research aimed to provide valuable insights for policymakers, emergency responders, and community stakeholders to develop effective strategies for future disaster management. The findings emphasized the importance of understanding the root causes of natural disasters like floods to enhance prevention and mitigation efforts. This study contributes to building a better understanding of flood management processes and resilience-building in KP.

Conclusion and Recommendations:

In conclusion, rising global temperatures caused by climate change are altering weather patterns worldwide, with Pakistan ranking 8th among the most affected countries. The 2022 floods in KP were driven by heavy rainfall and extremely high temperatures, which were the highest in the region over the past 30 years. The average temperature in KP increased by about 2 to 3 degrees Celsius in 2022 compared to 2021, highlighting the urgency to address global warming and its effects. The rainfall in KP in 2022 was the highest recorded in the last 30 years, with August being the 4th wettest month since 1961. The increased temperatures in recent years contributed to the flood's severity.

The floods inflicted severe harm on human lives, agriculture, and infrastructure, with D.I. Khan experiencing the most significant impact. Approximately 318 people lost their lives, around 30,000 houses were completely destroyed, and nearly 50,000 houses were partially damaged across all districts. The 2022 KP flood was devastating, with over 300 lives lost and thousands displaced from their homes. Record-breaking rainfall and high temperatures were key factors in the flood's severity. Additionally, agricultural land, roads, and residential properties were severely damaged, and farmers faced significant challenges due to crop damage and field destruction.

Recommendations:

- **Improve Regional Early Warning Systems (EARS):** Enhance early warning systems to provide timely alerts of flood events, enabling prompt action by both people and authorities.
- **Land Use Planning:** Avoid constructing on flood-prone land and protect natural drainage systems to reduce flood risk for communities.
- **Climate-Proof Infrastructure:** Incorporate climate-proof designs and construction practices to enhance the resilience of critical infrastructure, including roads and bridges, to flood events.
- **Community Awareness and Education:** Conduct community education and awareness campaigns to inform locals about flood hazards and provide guidance on preparedness and emergency response strategies.

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