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Rising Waters, Shifting Risks: A Comparative Hydro-meteorological Analysis of the 2010 and 2022 Floods in the Kabul River Basin

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ABSTRACT: The Kabul River Basin, which covers eastern Afghanistan as well as the northwestern corner of Pakistan, has witnessed two of the most disastrous flood incidents in 2010 and 2022. This paper offers a comparative hydro-meteorological analysis of these floods with emphasis on rainfall intensity, runoff surface, river discharge, and the spatial scale of floods. The research presents significant changes in the behavior of floods in both events using secondary datasets of NASA MERRA-2, PMD, GlobeLand30, and the Khyber Pakhtunkhwa WAPDA Department, GIS mapping, and hydrological modeling. The total amount of monsoonal rainfall in 2010 was 606 mm, and in 2022 it significantly grew to 826 mm, which shows the influence of the changes in rainfall and land use due to the expansion of urban areas. Though in 2010 the peak discharge was higher (135,075 cusecs vs. 127,384 in 2022), what made 2022 evident is higher average flows and a longer period of high discharge. The results credit this increase in flood hazards in relation to climatic fluctuations, glaciers, and decreasing infiltrations under man-made stresses. They suggest strengthened early warning systems, land-use policies; transboundary watershed management, and adaptive planning of infrastructure would strengthen resilience and could be used to reduce the effects of future floods in vulnerable South Asian river basins.

KEYWORDS: Hydro-meteorological Analysis, Kabul River Basin, Monsoon Floods, River Discharge, Climate Variability, GIS Mapping, Flood Risk Management

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Introduction

Floods are one of the common and devastating natural calamities experienced around the world, which cause major human loss, interruption of human activities, and ecological destruction. According to reports by the United Nations, floods affected many individuals more than any other form of weather-related disaster between 1995 and 2015 and were largely responsible for 53% of all disaster-related impacts in the world (UNISDR, 2015). Severe floods in South Asia have been preconditioned by the complex of climate change, rapid urbanization, land use changes, and poor disaster preparation. The country of Pakistan is particularly susceptible among South Asian countries to natural disasters, owing to the fact that it is geographically vulnerable, has a weak infrastructure, and relies on river systems as a source of agricultural production and for providing water supplies. Having its parts located in eastern Afghanistan and the northwestern part of

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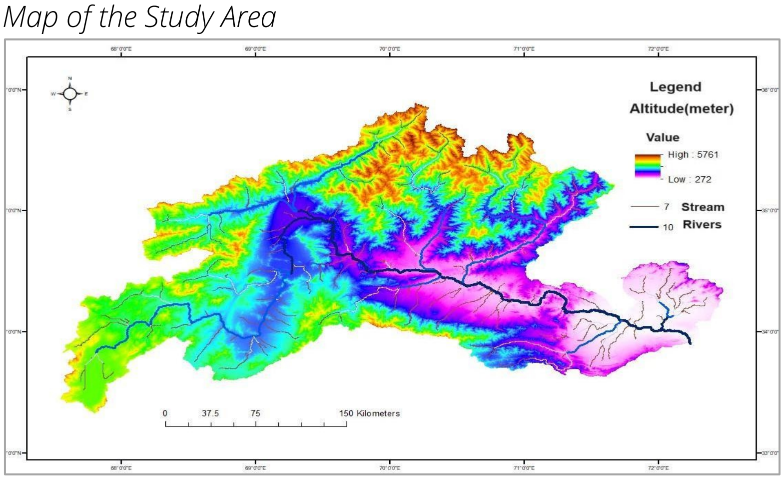
Pakistan, the Kabul River Basin is significant in supporting farming, livelihoods, and hydrological stability in the Mohmand Basin area. Nevertheless, it is also quite prone to hydrometeorological risks, especially seasonal floods caused by monsoon showers and glacial melt (Raulfs-Wang, 2017). The fact that the region has a complex topography (mountainous on one hand and alluvial plains on the other hand), and with the rise in climate variability, augments the risk of floods and makes the management even more difficult.

The last two decades have contained two of the most disastrous floods in the history of Pakistan: the super floods of 2010 and the monsoon floods of 2022. The impacts of the 2010 flood, resulting from the unusual rains during the monsoons and glacial melt, displaced over 6 million people, killed over 2,000 people, and impacted over 20 million people in total (Balloch, 2018). It flooded two hundred percent of the nation, destroyed more than 1.8 million households, and caused economic losses of 9.7 billion dollars. The flood of 2022 produced yet more devastation in the area just twelve years later. The 2022 flood that was caused by record monsoon rains and the escalated melting of glaciers uprooted more than 33 million inhabitants, killed over 1,700 people, and resulted in an economic loss of more than 30 billion (Otto et al., 2023). Although the single effects of these events have been described in a few studies, scarce literature is available that comparatively analyzes the hydro-meteorological causes/characteristics of these events in the context of a certain basin. Such comparative analysis is particularly important in the case of the Kabul River Basin, which is associated with an extensive variety of threats due to its strategic value and constant exposure and the dynamics of climate, hydrological, and human agglomeration activities (Ahmed et al., 2022).

This paper will fill this gap by giving a detailed comparative account of the 2010 and 2022 floods in the Kabul River Basin. It addresses rainfall intensity, seasonality, runoff production, and discharge behavior of water, but especially spatial-temporal patterns and extreme precipitation. It also looks into how geomorphology, turnover in land use, and human-made stressors develop flood hazards. The study provides a strong scientific investigation of the two disasters by applying secondary data sources, i.e., available precipitation data provided by the NASA-MERRA-2, the discharge data provided by the irrigation department, and land cover data provided by GlobeLand30, together with the analysis using GIS. The identification of superficial divergence and convergence between these floods is vital in the determination of flood hazard management in the future, flood warnings, and transboundary waters management. The lesson of this study will assist in increasing flood resilience of vulnerable river basins and aid the implementation of integrated disaster risk reduction (DRR) strategies in Pakistan and other developing nations.

Figure 1

Map of the Study Area



Literature Review

Global Context of Flood Disasters

The floods are one of the most common and devastating natural hazards worldwide, with almost 33 percent of disasters, which include, more often than not, massive losses of life, infrastructure, and economies. Floods have affected over 1.4 billion people with about 100,000 deaths according to the Centre for Research on the Epidemiology of Disasters (CRED) in the 20th century. The impact of climate change has augmented the hydrological cycle, leading to an escalation in the bases and extremities of violent weather incidents, such as floods, especially in the Global South. The large population of the entire world, which is in South Asia, is highly prone to Hydro-meteorological hazards because of its high population density, poverty, and mostly the monsoon-limited agriculture in the region (Memon, 2012). In South Asia, 332 events of floods were registered since 1979, which affected over 135 million people. An instance like floods in any region, especially in Bangladesh, Sri Lanka, and Pakistan in the year 2010, and in India and Pakistan in 2022, highlights the growing flood vulnerability of the region due to climate stress (Waseem & Rana, 2023).

Pakistan And Its Floods

The geographic, climatic, and geomorphic attributes predispose Pakistan to flooding a great deal. The Indus river system, and its tributaries such as the Kabul, Swat, and Chenab Rivers, are especially vulnerable in the monsoon season. Pakistan is the country most affected by floods, and over the last 50 years, more than 13 floods of great magnitude have been recorded. The flood risk has been compounded by urban sprawls, deforestation, unsound planning in land use, and climatic variability, particularly in such high-density regions as Punjab and Khyber Pakhtunkhwa (Shahid et al., 2022). National Disaster Management Authority (NDMA) has also pointed out changes in the pattern of monsoon precipitation wherein the areas that previously received rainfall have shifted 80 to 100 km westward towards the Kabul River Basin, thereby raising the threat of flooding in that area.

Floods in 2010, Pakistan

The flood in 2010 was brought by unprecedented monsoon rainfall compounded by La Niña situations and Himalayan glacial melting. The heavy rainfall that affected the northwestern area of Pakistan in late July 2010 surpassed the ancient records by more than 300% to overrun the flow of the Indus River and its tributaries (Martius et al., 2013). Over 20 million individuals have been impacted by the floods that destroyed homes of 1.8 million people, resulting in an estimated damage worth 9.7 billion dollars. There is an unprecedented discharge of rivers, sediment transportation, reservoir flooding, and widespread inundation, which is hydrologically unprecedented. It was observed that the disaster was worse because of ill-maintained embankments, the absence of early warning, and informal settlements on floodplains (Hashmi et al., 2012).

Floods in Pakistan 2022

Excessive rain during monsoon and fast glacier wear were key causes of the 2022 floods, a process that is observed when there are ongoing heatwaves in this area. July and August received 181 percent and 243 percent more rainfall than the normal levels, respectively- the highest since 1961. Consequently, over 33 million people were affected by this flood, and at least 2 million were displaced, as approximately a third of the county was underwater (Otto et al., 2023). It had the most severe effects in Sindh and Baluchistan, where they recorded 726% and 590% higher rainfall compared to the normal rainfall. The floods created expansive lakes inside the control and especially in the Indus River region, which caused significant agricultural, infrastructure, education, and community health losses. Researchers have suggested the importance of increasing sea surface temperatures (SSTs) in the Indian Ocean and the atmospheric rivers as increasing factors of severity contributing to the event (Nanditha et al., 2023).

Research Lapses and Comparative Studies

Even though the flooding of 2010 and 2022 has been extensively researched separately, fewer studies are available to compare both floods that occurred in the same hydrographical basin. According to Ahmed et al. (2022), both of the years with the floods had similar interactions in the tropics with the extratropics, surges of the monsoons, and conditions of La Niña. Nevertheless, the 2022 one overtook the 2010 tragedy in spatial coverage, volume, and level of displacement. The developing demand is to address the comparative studies at the basin scale by considering rainfall trends, runoff generation, and land use changes through the approach of hydrological products and geospatial frameworks. The study seeks to fill this knowledge gap by providing a data-driven comparison of both the Kabul River Basin's major floods in a comprehensive and explicit manner in terms of their hydro-meteorological causation, spatial-temporal aspects, and policy implications.

Methodology

The research method of this study was a quantitative and comparative design that focused on the hydro-meteorological aspects of the floods in the years 2010 and 2022 in the Kabul River Basin. The study aimed at comparing the temporal and spatial dynamics of rainfall, surface runoff, and river discharge across the two instances. As a study area, the Kabul River Basin, which covers around 61,729 square kilometers in Afghanistan and Pakistan, was chosen because it is prone to floods, has a very complex hydrology, and is of utmost relevance when it comes to agriculture and water supply in this part of the region (Mehmood, 2021). The study relied on secondary data, which was gathered from a number of credible sources. The Pakistan Meteorological Department (PMD) and NASA MERRA-2 reanalysis dataset provided meteorological data in the form of monthly precipitation and daily precipitation records for the period 2009 to 2022. The WAPDA Department of Khyber Pakhtunkhwa provided hydrological data. Also, spatial data on the land cover and land use were obtained through GlobeLand30 data, that provides land use information globally at a resolution of 30 meters. Hydrographic data and Digital Elevation Models (DEMs) were employed in evaluating the topography of the basin, delineation of the watershed, as well as the investigation of flow paths.

Analysis of data was done using various methods. Descriptive statistics and time series plots were used to analyse the precipitation records in order to determine patterns, anomalies, and severity of rains during the flood years. The calculation of surface runoff was done by employing the efforts of hydrological modeling, which involves the Rational Method and the Soil Conservation Service (SCS) Curve Number method, incorporating the rainfall intensity, characteristics of land use, and soil types. These runoff approximations assisted in determining the amount of overheat comparable to the floods in the period 2010 and 2022. The discharge analysis was performed theoretically, by analyzing the data on river flows to monitor changing magnitudes of flow, peak discharges, and hydrographs of floods. The flow duration curves were intended to learn more about the frequency and intensity of high flows on the occurrence of both flood eventsGeographic Information System (GIS) tools have been used especially ArcGIS to visualize the land cover distributions and map the areas, which are likely to flood as well as monitor changes on the individual watershed conditions during the two periods. The data from remote sensing was also used to carry out an evaluation of the land use changes, urban growth, and their influence on the flood vulnerability. But there were limitations to this study. High-resolution, real-time meteorological and hydrological information, especially in the upstream Afghan lands, was not easily available due to political and logistical issues. There were also some gaps or inconsistencies in some hydrological datasets, and in these cases, interpolation and cross-validation were applied. Moreover, although hydrometeorological dynamics were effectively considered in the research study, detailed socioeconomic vulnerability assessments were not examined, yet they could help bring a more comprehensive picture of flood risk. Notwithstanding these limitations, the approach taken in this paper provides an effective framework for interpreting and comparing the 2010 and 2022 Kabul River Basin flood disasters, and this can add value to future studies and policy planning on disaster risk reduction and hydrological management.

Results

This part is an overview of the examined differences in a hydrometeorological description of the Kabul River Basin flood in 2010 and 2022, including a description of rainfall patterns, surface runoff, discharge of rivers, and spatial distribution of flood effects. The results rely on the secondary data analysis, GIS mapping, and hydrological estimation models.

Rainfall Patterns in Basin

The evaluation of monsoon rains means that 2010 and 2022 were exceptionally wet years with optimal rainfall localized in the months of July and August. The following are the rainfall data that have been recorded in several stations in the basin:

Table 1

Comparative Monthly Rainfall mm-July-September

Year	July (mm)	August (mm)	September (mm)	Total (mm)
2010	236	281	149	606
2022	299	314	157	826

When the monsoonal rainfall in the Kabul River Basin is compared between the years of floods in 2010 and 2022, considerable differences in the flood intensity and spatial pattern of rainfall can be observed. In 2010, the total amount of rainfall received in the period July, August, and September was 606mm, whereby 236 mm was received in July, 281mm in August, and 149 mm during September. The year 2022 comparatively had more rainfall with 299 mm in July, 314 mm in August, and 157 mm in September, therefore, adding up to the total of 826 mm. This indicates a significant change in the total average rainfall of about 36.4 per cent, an increase compared to 2010. The acceleration of precipitation recorded in 2022, particularly in July and August, played a significant role in impacting the increased degree of surface runoff, decreased level of infiltration, and more serious conditions of floods throughout the basin. This is associated with an increase in rain, where such an increase could be due to an increase in monsoonal activity, regional climate conditions, such as La Niña, and the increase in the sea surface temperature, which significantly contributed to the increase in the intensity of the flood event of 2022. These data were used to reflect the obvious change in the mechanism of rainfall distribution, when there is an upward linear tendency of the volume of precipitation and its intensity over a certain period of years, and the message is a warning of increased hydrometeorological risks of the Kabul River Basin.

Surface Runoff Estimation

The estimation of surface runoff was based on the SCS-CN model and the Rational Method, including land use and soil characteristics. The infiltration rate decreased remarkably, and the volume of runoff was expanded by the land use alterations that happened from 2010 to 2022, including urbanization.

Table 2
Surface Estimation Runoff

Land Use	Area (sq m)	Manning's Value	Rainfall 2010 (mm)	Runoff 2010 (m³)	Rainfall 2022 (mm)	Runoff 2022 (m³)
Cultivated Land	8,470,270,050	0.07	606.03	359,326,643.10	826.26	489,905,173.20
Forest	4,801,456,893	0.06	606.03	174,589,615.20	826.26	238,035,106.30
Grassland	24,308,306,797	0.06	606.03	883,893,790.10	826.26	1,205,098,894.00
Shrub land	2,821,392,635	0.06	606.03	102,590,914.70	826.26	139,872,232.70
Water Bodies	211,359,804.1	0.03	606.03	3,842,711.46	826.26	5,239,144.55
Artificial Surface	822,548,758.6	0.02	606.03	9,969,784.48	826.26	13,592,782.75
Bare Land	20,293,422,520	0.05	606.03	614,921,142.50	826.26	838,382,164.60
Total	61,728,757,457			2,149,134,601.54		2,930,125,498.10

The comparative review of average annual surface runoff in Kabul River Basin in 2010 and 2022 has shown that the volumes of the runoffs increased significantly, mostly because of the rising rainfall levels and land use patterns. The projected surface runoff was 2.15 billion cubic meters in the year 2010, and it had drastically increased to about 2.93 billion cubic meters in the year 2022, hence an increase of 36%. This flood is associated with the rise in the annual rainfall from 606.03 mm in 2010 to 826.26 mm in 2022, which implies that stronger precipitation events trigger greater water release on the land surface. Grassland is among the land uses that gave the highest runoff in the two years, despite the moderate value of the runoff coefficient (Manning value of 0.06), because of its covering extent, adding more than 1.2 billion cubic meters in 2022 alone. Other significant contributors included bare land and cultivated land, which contributed about 838 and 490 million cubic meters of runoff in 2022, respectively. Such high values can be explained by the size of their surface areas and a comparatively high potential for runoff. Water bodies and artificial surfaces, on the other hand, made the least contribution to the surface runoff because of their low runoff generation capacities, as they have Manning values of 0.03 and 0.02, respectively. The comparison can show that not only has the intensity of rainfall increased, but also concerns the runoff response of land, which, because of anthropogenic activities like urbanization and deforestation, has less infiltration and more impervious areas as well. This intensification of hydrological reaction highlights an increased exposure to the risk of floods within the basin. Data highlights the use of land use management with techniques of adaptation to the expected changes in climate in order to reduce the growing runoff and the resulting effects of flooding in the area.

River Discharge Analysis

The records of daily discharge of the Warsak dam reveal that there is a significant variability in river behavior in the case of floods.

Table 3

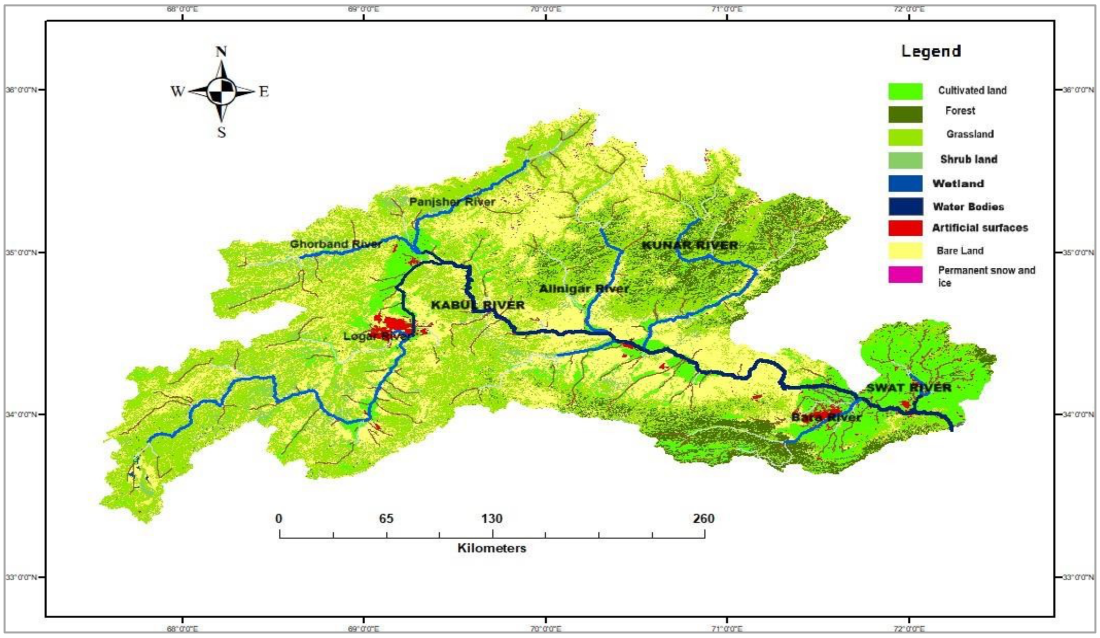
Peak Discharge (cusecs) – Warsak Station

Year	Peak Flow (cusecs)	Average Flow (Jul–Sep)	Days Above 50,000 cusecs
2010	135075	32,000	40
2022	127384	38,000	9

The two floods of 2010 and 2022 reflect different hydrological conditions based on the comparison of discharge wartime at Warsak Station. Certainly, the Kabul River had a higher peak discharge in 2010, which was 135,075 cusecs, in comparison to 127,384 cusecs in 2022. Although there was more cumulative rainfall in 2022, the peak flow was intense in 2010, showing that there was a more severe and concentrated flood event that was probably caused by the sudden monsoonal pulse mixed with glacial melt. Nonetheless, during the period of monsoon (July to September), the average flow of the river was higher in 2022, that is, 38,000 cusecs, in comparison to 32,000 cusecs in 2010. This is an indication that the 2022 flood episode, though recording a low peak discharge, lasted high-flow levels for a longer period of time, probably as a result of continuous precipitation and delayed drainage in urbanized and saturated catchment areas. Interestingly, the days when the flow was over 50,000cusecs were far more in 2010 (40 days) than what it is in 2022 (9 days). This means that the high-intensity surges in 2010 were more intense and regular and lasted longer, and in 2022, the intensity was steady yet less impressive in the amount of discharge. In general, the statistics indicate a transition towards floods of lower intensity with longer duration (2022) compared to previous ones (2010) due to the development of the hydrological regime in the Kabul River Basin that should be analyzed in relation to future flood control and flooding infrastructure design.

Figure 2

Flood Prone Zone Mapping



The flood-prone regions are consolidated at the river banks in Peshawar, Charsadda, and Nowshera regions, which experienced severe floods in 2010 and 2022. In 2022, the flood area grew wider because of the increased runoff and the presence of encroachments on natural floodplains.

Comparative Overview of 2010 vs. 2022 Floods

Table 4

Comparative Analysis

Aspect	2010 Flood	2022 Flood
Precipitation	74 mm to 340 mm (July-August)	77 mm to 296 mm (July-September)
Snowmelt Influence	High impact due to the ongoing snowmelt season	High impact due to concurrent snowmelt season
Peak Discharge	135,078 cusecs (July 30)	127,374 cusecs (August 28)
Runoff Volume	2.15 billion m³	2.93 billion m³
Flood Dynamics	Immediate impact from intense rainfall and snowmelt	A gradual increase in discharge, affecting a larger area
Impact Area	More localized	Larger area with multiple flood events
Management Implications	Need for immediate response to intense events	Emphasis on adaptive strategies for gradual changes

The hydrological profile of the 2010 and 2022 floods in the Kabul River Basin in comparison provides significant dissimilarities in the dynamics of floods, spatial scale, and management recommendations. In the 2010 flood, there was a daily maximum of 340 mm and 74 mm of precipitation concentrated in the months of July and August. On the same note, the flood in 2022 was characterized by huge downpours, which measured between 77 and 296 mm in July, August, and September, respectively. The periods of heavy rains in both instances coincided with the snowmelt season, thus producing a cumulative impact of the two events in increasing the flow of rivers, even causing floods. The effect of snowmelt played a very crucial role in increasing the runoff volume in the upstream catchments. The hydrological nature of the 2010 flood had the marked characteristic of capriciousness, followed by an instantaneous effect as a result of intense rainfall and sudden snowmelt, which had a point-like change in the river discharge. The highest amount ever discharged on July 30, 2010, was 135,078 cusecs, which is 0.4 percent above what was discharged in the 2022 flood (127,374 cusecs) on August 28. Nevertheless, the volume of the runoff was higher, even though the peak discharge value was lower in 2022; it is estimated to be 2.93 billion cubic meters and 2.15 billion cubic meters in 2010. It is an indication that the intensity of the 2022 event was more gradual in onset, but had prolonged high water flow and therefore a larger volume of water and an extended flooding situation.

Geographically, the flood of 2010 was more localized, taking place mostly in the main river channels. Conversely, an extended effect was produced in the 2022 crash, whereby there was more than one flood occurring in many localities, mostly in the low-lying towns across the country. Such diffuse and prolonged flooding in 2022 is possible due to surplus water run-off in the urbanized areas, slow drainage, and prolonged monsoon in 2022. Management-wise, the 2010 development weakened the functionality of immediate response mechanisms in emergencies when there are rapid increases in the flood levels of the river. Conversely, the 2022 flood pointed out the need to have adaptive and flexible plans to cope with the long-term flood scenario. These can be enhanced early warning mechanisms, flood zoning, preservation of wetlands, and enhanced integration of land use planning with the future projections of climate hazards. All of these differences together support the changing nature of the flood risk in the Kabul River Basin due to climatic variability and also due to anthropogenic changes.

Discussions

The results of the present study can contribute to the dimensions of the hydrometeorology drift of the Kabul River Basin as compared to two of the most devastating flood events to ever take place in Pakistan: the 2010 and 2022 floods. Although the two floods were related to the high level of monsoonal rainfall accompanied by melting snow, the two events are highly contrasting with respect to flood characteristics, flood spread pattern, and hazard and risk management of the floodsThe relative data of rainfall display that above-average precipitation occurred in both the years, but cumulatively there was increased rainfall during the monsoon months (770 mm and 666 mm in 2010). Nevertheless, 2022 rainfall was more concentrated and violent, especially in July and August, a factor that resulted in increased volumes of surface runoff Volume 2010=2.15 billion m^3, 2022=2.93 billion m^3). This is not only an indicator of the increase in the intensity of rainfalls but also an indicator of the infiltration capacity that has been lower as a result of the continuous land use change especially the urbanization in and deforestation of the basinRegarding discharge, the highest runoff during 2010 (135,078 cusecs) was slightly lower than it was during 2022 (127,374 cusecs), but the overall volume of runoff was bigger in 2022, which means that conditions of high-flow prevailed longer. This caused an even longer and broader flood effect in 2022, which covered more than 33 million people compared to the 20 million in 2010. Such trends indicate that flash flood-type events were shifting to more sustained multi-wave flooding that was probably induced by shifts in the monsoon patterns and upstream hydrological processes.

An important detail is the presence of simultaneous snowmelt at each of the events. The coincidence of the flood season with the maximum glacial melt-out days in July and August heightened downstream run and lowered the buffering capability of the basin. Besides, the climate phenomena like La Niña, the rise in sea surface temperatures, and pre-monsoon heatwaves experienced in 2022 caused additional destabilization to the hydrological balance, enhancing the severity of floods. Spatial analysis with the help of GIS demonstrated that the areas vulnerable to floods have grown massively during 2022, particularly in those districts that have already been urbanized, including Peshawar, Charsadda, and Nowshera. Lack of proper drainage, invasion of riverbanks, and neglect to implement land use policies have subjected these areas to frequent floods. The fact that the number of days when more than 50,000 cusecs of discharge occurred were greater this year (13) than in 2010 (8) also indicates that high-risk flood conditions have been found to be more persistent than ever. These results agree with the past literature that attributes the rising frequency and extent of floods in South Asia to climate variability and an increase in anthropogenic pressure (Ahmed et al., 2022; Mehmood et al., 2019). Nevertheless, this research is exceptional because it presents an analysis of the entire two mega floods side-by-side basin-scale comparison that is integrated with meteorology, hydrology, and geospatial information. Disaster management perspective requires that when a disaster (a flood in this case) approaches suddenly, an emergency response is needed, as happened with the 2010 flood, but with a progressive disaster like the 2022 flood, adaptive and long-range plans need to be put in place. The most appropriate strategies to mitigate future flood susceptibility would be using early warning systems, flood zoning, preservation of wetlands, and long-term urbanizing strategies. Noticeably, the repetitive occurrence of such events underscores the necessity of sharing cross-border data between Afghanistan and Pakistan to manage the watershed and conduct forecasts on floods. In a nutshell, the discussion highlights the point that, besides the fact that the natural forces are still very crucial to the production of floods, human intervention and policy-making play a very vital role in making the scale of such calamities so great. Unless communities adapt strategically and invest in resilience, the next floods in the Kabul River Basin will become even more damaging with a changing climate.

Recommendations

Based on the results of the study, a number of suggestions are made towards the reduction of the future risks of flooding and improved resilience in the Kabul River Basin. First, an urgent necessity to enhance early warning systems by means of better real-time monitoring of meteorological and hydrological situations has to be stated. Kabul River is a transboundary river. Satellite-based weather forecast predictions, remote sensing equipment, and alert propagation systems into the communities are critical elements in enjoying timely as well as effective preparedness against floods. Second, there should be integrated planning of land use and the enforcement of flood zoning rules. Incursions on riverbanks and floodplains have greatly raised the degree of vulnerability of the basin to floods. In addition, risk-informed zoning should be used to help guide urban development so that people avoid living in some of the most hazardous locations, and instead rely on such measures as impervious surfaces and green infrastructure to help collect any surplus runoff.

Also, the flood protection system of the area (embankments, culverts, and urban drainships) needs urgent improvement and must be taken care of regularly in order to process the growing amounts of runoff.

Infrastructure constructed in flood prone areas would also have to be climate resilient and constructed in such a manner that it will be able to sustain future hydro-logical extremes. The information preparation and awareness about floods by the community members is also important in reducing the loss of life and property. It is required to involve the local population here by carrying out awareness campaigns, evacuation training, and setting up local disaster response committees with basic resources and communication devices.

Moreover, it is significant to implement the integrated approach to the management of water under watershed management that should embrace both upstream and downstream flood drivers. Surface runoff can be minimized through reforestation and stabilization of the slopes, as well as soil conservation strategies in the upland regions, whereas downstream measures are to focus on the recovery of the wetlands and natural floodplains. Mainstreaming of climate change adaptation should also be carried out in the policies of the country and provinces. This encompasses allocation of adequate budgetary funds towards flood resilience schemes and incorporation of climate risk assessments during infrastructural building, agricultural planning, and structures of disaster response. Finally, continuous research and scientific monitoring ought to be reinforced to enable it to trace evolving flood trends and sensitivity in the basin. Evidence-based policymaking and adaptive management efforts should keep using GIS, hydrological modeling, and satellite imagery. These exhaustive efforts will ensure that the occurrence and intensity of future flooding in the Kabul River Basin can be significantly eliminated.

Conclusion

This paper was a comparison of hydrometeorological data on the floods that hit the Kabul River Basin in 2010 and 2022, indicating the facts and points of differences and similarities in the way rainfall, runoff, discharge, and place of occurrence. Both floods were also associated with extreme monsoon precipitation and simultaneous snowmelt, but the 2022 flood presented a model characterized by stronger precipitation and larger surface run-offs and geographical extent. Whereas in the 2010 flood, the river discharge increased abruptly because of an intense rain, during the 2022 flood, the hydrological response was more extended, which led to a long period of high river discharge and its broader extent. The results have shown that the transformation of land use, climate change, and poor management of the watershed have aggravated the vulnerability of the basin to floods. The size of the runoff in 2022 was about 24.5 per cent larger than that in 2010, and the high-discharge days were also greater in amount. These changes indicate the tendency towards enhancing flood events and flood repetition in the area. The study highlights that unless there are good adaptation strategies, the Kabul River Basin shall remain in constant danger of extreme and recurring hydrological catastrophes that endanger the lives, livelihoods, and institutions. The study presents a meaningful addition to the overall conversation on flood risk mitigation due to its evidence-based conclusions regarding changes in flood dynamics and management issues. It also highlights the prospects of using the basin-scale, data-driven analysis to guide discovery and disaster preparation in the flood-prone parts of South Asia.

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