Impacts of Climate Change on the Indus Basin Water Resources

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ABSTRACT

Considering the socioeconomic significance of the Indus Basin, the effect of climate change on its water resources is a crucial concern. This study explores the effects of changing climate on the basin, looking at hydrological fluctuations and possible dangers to water supply. With its intricate hydrographic system, the Indus Basin faces difficulties like changing precipitation patterns, retreating glaciers, and an increase in the frequency of extreme weather events. The delicate balance of water supplies, which is essential for agriculture and a significant driver of the region's economy, is at risk due to these changes. The study highlights the need for adaptive measures by examining the complex effects on infrastructure, food security, and livelihoods. This paper seeks to provide important insights into the complex relationship between climate change and water resources in the Indus Basin, as well as the gaps in the Indus Water Treaty (IWT) under Homer Dixon's Scarcity Model.

KEYWORDS

Indus Basin, Climate Change, Food Security, Indus Treaty, Dixon's Theory

Introduction

The sprawling Indus River Basin, spanning across four countries, is primarily located in Pakistan, with significant upstream contributions from India, China, and Afghanistan. Over 40% of the basin lies at an elevation of over 2,000 meters above sea level. The International Water Management Institute (IWMI) defines the basin's total hydrographic area at 1,137,819 square kilometers, with estimates ranging from 1,080,000 to 1,218,500 square kilometers from other sources (Mustafa, 2021). The basin's population

of approximately 237 million is distributed among Pakistan (61%, or 145 million), India (35%, or 83 million), and Afghanistan (4%, or 9 million) (Sahaar, 2013).

The population density in the Chinese portion of the basin is constrained by the rugged Himalayan terrain. 60.9% of the 228,694 square kilometers (21% of the total area) that is under irrigation in the basin is located in Pakistan, 37.2% in India, 1.9% in Afghanistan, and 0% in China (Mustafa, 2021). Pakistan and India have the highest water demands, and the Indus Basin Irrigation System (IBIS) is the largest irrigation network in the world. The southern slopes of the Himalaya-Karakoram-Hindu Kush (HKH) mountain range are the wettest areas in the Indus basin; the lowlands and the northern mountain ranges, which include Ladakh in India, are extremely dry. Across the basin, the aridity index varies from humid to hyper-arid. The polar area of the basin is estimated to be 37,134 square kilometers based on the DCW database, demonstrating its significance (Arjjumend, 2013). However, the GLIMS-Database, which excludes glaciers from India and Pakistan, provides a more accurate figure of around 22,000 square kilometers or 20,325 square kilometers based on other sources that rely on GLIMS. These revised estimates offer a more realistic understanding of the basin's glacial extent

One of the most severely depleted water systems globally, the Indus River Basin is with some periods of the year witnessing no water flow reaching the ocean, effectively transforming it into a closed basin. Significant water scarcity issues currently exist in the region, and these issues are expected to worsen over the next several decades as a result of factors like population growth, fast urbanization, industrialization, environmental degradation, inefficient water use, poverty, and the effects of climate change.

Climate change poses a severe threat to the Indus Basin resources, a vital lifeline for millions of people. The melting of glaciers and changing precipitation patterns are causing unpredictable water flows, disrupting irrigation systems and agricultural practices. The Hindu Kush Himalaya (HKH) range, home to the Indus River and other important waterways, is particularly vulnerable to these climate-driven changes (Asif, 2013). The HKH region, encompassing over 2000 square kilometers in Asia, provides water for nearly one billion people across Nepal, India, Bangladesh, Pakistan, China, and Bhutan. While some studies suggest increased glacial melt could lead to higher river flows, this is likely to be offset by overall reductions in water availability. The Indus Basin's reliance on snow and glacial melt for over 45% of its water flow further amplifies its vulnerability (Pritchard, 2019). The monsoon season, particularly between May and September, accounts for over 85% of the Indus Basin's discharge. The unpredictable nature of water flows and the increasing frequency of extreme events like floods (as seen in 2010 and 2022) highlight the need for urgent action. Implementing effective water management

techniques, constructing new reservoirs for water storage, and optimizing water resource allocation are crucial steps. Additionally, adopting mitigation measures to address climate change is essential to secure water resources in the region.

Overall, the paper provides a comprehensive overview of the climatic effects on the Indus River Basin, the challenges in water management and the IWT gaps with focus on Pakistan primarily, and the potential applicability of the Homer-Dixon's Scarcity model (HDS) in assessing water scarcity in this critical region.

Climate Changes and the Indus Basin Resources

In the extensively populated semi-arid and hyper-arid lowlands, water from the sparsely populated mountainous parts of the Indus basin is vital for an extensive irrigation system. In many mountainous basins, seasonal assessments of the management of water resources are required because the lowlands rely significantly on the seasonal storage of water in snow and ice. Similar to monsoonal basins, seasonal water resources management assessments are also necessary in monsoonal basins such as the Indus basin since water availability and water demands change over time (Laghari, Vanham, & Rauch, 2012). The summer months are when the basin's total surface water availability peaks, and the winter months often see decreased water availability. The average monthly surface water availability is approximately 10 cubic kilometers during the winter months of November through February, and over 30 cubic kilometers during the summer months of July through September (Jain, Agarwal, & Singh, 2007). Averages can be deceiving in systems where water availability and demand vary significantly. Without a doubt, the availability of water resources, the Hydrologic Cycle, and agricultural productivity will be impacted by climate change.

1. Availability of Water Resources

It is difficult to conduct studies on the rate at which glacial melt enters the Indus River Basin because of the rough terrain and high elevations of the Himalayas. Nonetheless, estimates of the glacial mass-balance and hydrological modelling point to a decrease in the upper Indus River's mean upstream water supply. About 18% of the Indus River's flow is attributed to glacial melt, while the remaining 82% is primarily derived from snowmelt (Pritchard, 2017). In the downstream Indus region, snow and glacial melt account for 151% of the entire naturally generated discharge, according to the Normalized Melt Index (NMI) data taken between 2001 and 2007. A Dutch research predicts that the melting glaciers will cause the Indus River to flow 8% less by 2050 (Orr, Ahmed, et al., 2022). The decline in water flow is alarming since the Indus River supplies the majority of the water for the Indus Basin downstream. Furthermore, groundwater, with an average availability of 287 km3 and around 1,329 m3 per capita, makes up around one-third of the renewable water supply. By 2050, the amount of renewable water available per person is expected to drop due to climate change to less than 750 m3. The Indus River Basin's

population of over 300 million people and heavy reliance on agriculture make it particularly vulnerable to the effects of climate change on water resources.

2. Hydrologic Cycle

As a result of variations in runoff and precipitation patterns triggered by climate change, some areas are becoming more vulnerable to extreme weather events. For example, changes in winter precipitation mostly dictate the amount of flow from winter snowmelt, whereas energy availability at the glacier surface throughout the melt season affects the amount of meltwater produced. Reduced precipitation across the lower Indus Basin is predicted by scientists to result in drought-like conditions and a general warming effect. Although projections on climate change in this area are imprecise, trends indicate that this pattern is probably going to persist. Communities and agriculture along riverbanks in the Indus Basin will be destroyed by extreme flooding. Floodwaters will change the composition of the soil, increasing the likelihood of erosion and deterioration in the surrounding areas, contaminating streams and reducing agricultural productivity (Hasnat, Kabir, & Hossain, 2018).

3. Agricultural production

Freshwater systems are especially susceptible to the effects of climate change, according to the Intergovernmental Panel on Climate Change. It is anticipated that increased precipitation and variability will increase the likelihood of floods and droughts, which will have an impact on water infrastructure and food stability. Pakistan is in danger since it depends so largely on the Indus River System and doesn't have any other reliable water source in the event that the Indus runs out of water. About 68% of Pakistani rural population depends on agriculture for their livelihood, which generates 23% of the country's total income (Ahmad, & Farooq, 2010). The 300 million people who reside in the Indus River Basin depend on the irrigation and agricultural industries that the Indus River System, which provides about 154.3 MAF of water annually, is essential to.

While experts disagree on whether a full-scale conflict over water is possible, they do agree that environmental stress can make violence worse. Water is used in many different ways and is an essential resource for many facets of existence. According to Wolf, the more parties engaged, the less likely it is that mutually acceptable solutions will be found (Wolf, 2001). The more severe the water shortage, the more obvious this pattern is. Agriculture, industry, and public health are predicted to suffer as a result of climate change's predicted effects on the amount and quality of drinkable water. The effects of climate change will worsen and become more obvious as it continues. The availability of water will be reduced, which will have the most effect. Weather patterns will become more unpredictable, there will be less water available for animals and agriculture, and the quality of the water will degrade. Since water is essential to life in both Pakistan and India, it is

imperative that we take the threat posed by climate change seriously. Renegotiating the Indus Waters Treaty is necessary to adjust to the evolving circumstances. New disputes over water are expected to arise as a result of climate change, and a treaty to lessen these conflicts has to be drafted (Eckstein, 2009).

The Indus Water Treaty (IWT) and Homer-Dixon's Scarcity Model

Eight years of discussions between India and Pakistan to resolve the conflict over the use of the Indus River Basin resulted in the signing of the Indus Water Treaty (IWT) in September 1960. A lot of people consider it to be an effective example of cooperative global water management. It has remarkably withstood three wars, including the Kargil battle in 1999. Concerns over the treaty's long-term sustainability have been raised, though, as water scarcity grows more severe and floods and droughts becoming more intense (Wolf, 2001).

India and Pakistan have different uses of rivers and canals according to the Indus Water Treaty (IWT). The rights to the three western rivers the Indus, Jhelum, and Chenab belong exclusively to Pakistan. The three eastern rivers the Ravi, Beas, and Sutlej remain under Indian sovereignty. Pakistan was also guaranteed a ten-year supply of water without interruption by the deal. Pakistan constructed numerous dams at this time, partially funded by long-term World Bank loans and compensation funds from India. Three multipurpose dams Warsaw, Mangla, and Tarbela were constructed in accordance with the agreement. Along with remodelling the already-existing canals, an eight-link canal system was constructed. This deal also included the construction of five barrages and a gated siphon. The treaty has been effective in many ways, but it's also possible that the broader delineation it contained only reflected the "unfinished business" of the 1947 territorial division. In that case, there's a greater chance of renewed conflict given the added stress that humans and natural forces have placed on the water system (Homer-Dixon, 1991).

When it comes to water, Homer-Dixon's scarcity model raises the possibility of interstate war as a result of water stress under specific circumstances. These conditions include the following: the upstream state having a history of using water as a coercive mechanism, the downstream state being prone to using military force, the downstream state being more powerful than the upstream state, and the two countries sharing a river. According to this theory, growing rivalry for resources could lead to flashpoints, straining the international system and double the complexity of resolving conflicts (Homer-Dixon, 1991).

The Indus River Basin is of mutual relevance to Pakistan and India. India has more power to regulate the water flow in the basin because it is the riparian country upstream. Pakistan, the riparian country downstream, is more dependent on the Indus River for its

agricultural industry. Actually, the Indus River Basin provides 80% of Pakistan's agricultural production. Pakistan uses 97% of its water for agriculture, making it the country in the region with the largest per capita water consumption (Kahlown, & Majeed, 2003). Pakistan is disadvantaged in terms of water security as a result. Pakistan, a lower riparian state, sought to have its concerns addressed by the 1960 Indus Water Treaty. Nonetheless, the notion of the Indus as a "lifeline" has persisted in Pakistani politics, and its association with the Kashmir dispute suggests that the Indus water system would need to be taken into account in any future agreement between India and Pakistan (Indurthy, 2019).

Pakistan, the lower riparian country, would always be concerned about its water supplies because of India's strong position as the upstream riparian country. Because of this dynamic, asymmetrical collaboration results, with the stronger nation setting the terms. Pakistan's concerns have not been allayed despite India's cooperation and general observance of the terms of the Indus Water Treaty (IWT). Pakistan has adopted a strategy of emphasizing its victim status in response to India's unilateral activities on water use, which it perceives as a threat (Rizvi, 1993). Although this fear is natural, it's crucial to realize that it can also be used as a pretext to keep India from acting on its own.

Political tensions over water distribution have increased due to the vital necessity of water to Pakistan's agricultural industry and the power of farmers as a powerful pressure group. Rivals between provinces have intensified, especially between Sindh and Punjab, as a result of ineffective inter-provincial accords and divisive dam building. Perceptions of Punjab's political hegemony in Pakistan have been strengthened by Sindh's worries about water being diverted to Punjab. These conflicts have been easily exploited by political players to further their goals. With over 36 million acres of farmed land, Pakistan's irrigation system continues to be the greatest in the world despite these difficulties (Qureshi, & Ashraf, 2019). This extensive irrigation network is anchored by the Indus River and its tributaries, which are further supported by 84 small dams, 19 barrages, 12 inter-link river canals, 45 autonomous irrigation canal commands, and three large reservoirs (Wood, 2007).

Pakistan considers that the current nuclear balance of power provides it the ability to challenge India's asymmetrical relationship over the Indus water, even if it has a history of utilizing military force. Pakistan's domestic voices have grown more aggressive following the 1998 nuclear tests. The two sides view the IWT conflict fundamentally differently: while Pakistan views it as ideological and connected to unsolved Partition issues, India views it as a political quarrel rather than a water issue.

Based on Homer Dixon's theory of scarcity, we can determine that, although there

are alarming indications, there is no immediate danger of violent conflict. Potential hazards are highlighted by Homer Dixon's indicators, which include many international rivers, lower riparian states' substantial reliance on the basin, upper riparian states' stronger power, and downstream governments' historical use of armed force (Burgess, Owen, & Sinha, 2016). These elements must, however, be evaluated in light of the political climate as it exists today. The nuclear balance between India and Pakistan and the possibility of conflict start by the lower riparian, as per Homer Dixon's theory, are particularly relevant (Krtička, 2020). Given the current political situation in Pakistan, it is challenging to envision them engaging in violent conflict with India over water in the near future. It's important to note that this thesis has limitations, such as its exclusive focus on violence and a narrow scope concentrating solely on state relations.

Climate Change and the IWT

In a nutshell the Treaty's antiquated language which ignores the changing environmental conditions brought on by climate change is the main source of concern. The Indus Waters Treaty was not negotiated with climate change in mind when it was first passed, but given the present status of the rivers, a new discussion of the terms of the agreement is required.

There are 300 million people living in the 1.12 million km^2 Indus River Basin, which is shared by China, Afghanistan, India, and Pakistan. The western Himalayan glacial melt is responsible for more than 40% of the Basin's yearly water flow. Predictions, however, show that glaciers will retreat over the course of the next 50 years, increasing river flow initially before the main river, the Indus, experiences a 30–40% decline in water flow (Bocchiola & Soncini 2019). Scientists predict that average rainfall will be significantly impacted by climate change, resulting in greater floods or more severe droughts. For example, Pakistan is predicted to see fewer days with rain but more instances of intense precipitation. The Treaty has to be updated to account for climate change in light of the declining availability of water.

The effects of climate change are already irreversible, so even with solutions to political and economic issues, society will still be burdened by them. In the end, if a treaty is unable to adjust to future changes, climate change may have a significant negative impact on its effectiveness. The capacity of basin states to carry out their obligations may be impacted if treaty variability is not taken into consideration. Health, the integrity of the ecosystem, and human and economic life can all be negatively impacted by the negative effects of climate change, such as decreased food supply.

Though it is not flawless, the Indus Waters Treaty is a notable illustration of mediation. The unexpected threat posed by climate change jeopardizes the authority of the

Treaty. The environment is changing due to climate change, therefore strategies that worked in the past might not work as effectively in the future. The growing threat presented by climate change emphasizes how urgent it is to update the Treaty to address these evolving concerns (Field, 2012).

IWT and International Collaboration

The conflict between Pakistan and India for the Indus water has been effectively managed for nearly fifty years by the Indus Water Treaty (IWT), which has remained a relatively stable framework. However, this stability can be jeopardized by the rising water demands in both countries. Pakistan and India have the chance to work together to protect the welfare of their people by coordinating bilateral development and taking prompt action to resolve any new problems rather than putting them off.

The Permanent Indus Commission (PIC) is in charge of arbitrating conflicts pertaining to the application of the Indus Waters Treaty. The primary method by which this commission resolves conflicts is by holding frequent meetings with engineers and officials from Pakistan and India. The PIC's oversight of development projects in the Indus river basin has been essential in mitigating worries of potential deception between the two nations (Motwani & Sharma, 2020). This involves verifying the correctness of all data exchanged and assisting in adherence to the terms specified in the Indus Waters Treaty of 1960.

Conclusion and Recommendations

Water insecurity is a global challenge, but its severity intensifies with the growing disparity between water supply and demand, coupled with ineffective water-management practices and a lack of additional water resources. Currently, Pakistan faces water stress, and this situation is anticipated to deteriorate further due to the impacts of climate change and a population boom. Moreover, being located in a water-stressed region, Pakistan is susceptible to potential conflicts over water sharing in the future.

The debate that came before it made clear how vulnerable Pakistan is in terms of water security. In addition to the increasing effects of the basin's insufficient water supply, Pakistan and other riparian states in the Indus Basin also risk war over water resources. There are obvious reasons for this fear. Pakistan's socioeconomic foundation is the Indus River System, which provides employment for more than 70% of the country's people and generates 20% of its GDP (Winston, 2013). However, fast population increase, climate change, a lack of diplomacy and collaboration among South Asian riparian nations, and a lack of confidence among Pakistan's provinces all pose threats to water security.

Water is vital for Pakistan's agrarian identity and is a crucial driver of economic growth. Consequently, as a water-stressed nation, Pakistan urgently requires significant

measures to address its water situation for sustainable development, including the formulation of a robust National Water Policy (NWP). Effectively tackling the challenges posed by climate change involves constructing numerous large and small water storages. Additionally, there is a pressing need for improved water management and streamlining bureaucratic processes to expedite project implementation. Furthermore, existing water laws at the federal level in Pakistan do not ensure equitable water distribution. The country must enhance its capacity to store and regulate water in dams, barrages, wetlands, and urban centers, aiming for a minimum storage capacity of 18 million acre-feet (MAF) to ensure water security. This multifaceted approach is essential to address the complex water security issues facing Pakistan.

Regarding water governance, it is essential to develop and implement provincial climate change strategies while concurrently formulating action-oriented resolutions for water-related challenges. One effective approach is to extend the mandate of the Pakistan Climate Change Act to encompass water sector adaptation at local, provincial, and national levels. The establishment of provincial funds is imperative for the successful implementation of adaptation strategies, with an initial focus on climate financing for water sector adaptation projects. Pakistan can explore opportunities to involve the private sector in Climate-Water Sector financing, particularly under China-Pakistan Economic Corridor (CPEC) projects.

Crucially, conducting a comprehensive country-wide vulnerability assessment is necessary to understand water availability, demand, and anticipate future impacts of climate change on the water sector. Finally, these initiatives should be supported by a well-defined institutional framework with legal backing to fulfill the requirements of adaptation strategies. This holistic and coordinated approach is vital for addressing water challenges in the context of climate change and ensuring sustainable water governance in Pakistan.

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