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WATER SECURITY IN THE INDUS BASIN UNDER CLIMATE STRESS: FUTURE CHALLENGES, GOVERNANCE, AND CLIMATE ADAPTATION

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ABSTRACT

The Indus River is one of the world's most important river systems. It benefits over 300 million people. Its water plays a fundamental role in agriculture, domestic supply, power generation and industrial use. But climate change is now threatening water security in the region, as evidenced by events such as retreating glaciers in the Himalayan mountains, changes in monsoons, floods and droughts. This article comprehensively analyses these challenges and examines future scenarios. Various key findings suggest that glacier melt may lead to short-term increases in water availability, but there are risks of long-term decreases in water availability after 2050. Per capita water availability in some parts of the basin is already below 1,000 cubic meters. The population living around the basin is expected to reach 283 million by 2050. Per capita water availability will further decrease by 2050 due to increasing population and climate change. The 1960 Indus Water Treaty seeks to review data sharing, joint monitoring and benefit sharing, otherwise this water treaty may become obsolete in the face of non-stationary hydrological conditions. The future strategy for the Indus Basin in the face of climate change should rely on the development of its infrastructure (For example, new dams like Kalabagh Dam and Diamer Bhasha), which will improve irrigation efficiency and save 20 to 30 percent of water. For a secure future of the Indus Basin, cross-border cooperation through informal diplomacy and administrative diplomacy should be promoted. Climate change in this region calls for resilient governance. The metabolic rift theory explains how capitalist production has disrupted the relationship between life and nature. Due to this disruption, the Indus Basin has become vulnerable to climate change because most of the Indus Basin, which is located in two large countries, is also vulnerable to climate change. Because the per capita presence of trees in both Pakistan and India is very low. And the water storage capacity is also low, especially in Pakistan. Due to industrial development around the world, the Indus Basin is completely vulnerable to climate change.

Keywords: *Water security. Water resources management. Climate change. Glacial melt. Monsoon variability. Metabolic rift theory*

1.1 Historical Background

One of the world's oldest civilizations flourished along the banks of the Indus River in 4500-5200 BC. But Giosan et al claim that this civilization declined due to climate change. The Indus Valley civilization was agricultural, but the Harappans did not build extensive canal systems to control water resources. Their agriculture depended on

rivers flowing with the monsoon. As the monsoon weakened and its rivers dried up, rain-fed agriculture also suffered.

The cities of Harappa and Mohenjo-daro, dating back to 3300 BC, represent the Indus Valley Civilization. The Indus Valley Civilization, representing the oldest settlements in the world, stretched from northeastern Afghanistan to Pakistan and northwestern India. More than 1052 settlements have been found in the Ghaggar-Hakkara River basin to date. These settlements included Harappa and Mohenjo-daro, as well as Lothal, Dholaveera, Guneriwala and Rakhguri. 40 sites in the Indus Valley have been discovered on the Indus and its tributaries, and seals in the Indus script have been discovered on the banks of the Indus River.

The history of the Indus Basin shows that ancient settlements were inhabited around it and developed cities were also inhabited, but the livelihood of the people who settled around it was always agriculture and these people depended on the monsoon rains to irrigate their crops because these people did not have any canal system nor did they have any dams etc. to store water, so they depended on the rains. For this reason, these settlements and these people sometimes migrated and sometimes they fell victim to the merciless waves of the Indus because the Indus Basin has been a victim of climate change since the beginning.

1.1.1 Colonial Era and Building Irrigation system in Indus Basin

The British built a canal system in western Punjab in the late 19th century. The canal system built by the British included diversion barrages. No dams were built to store water in this system. In 1935, the Sukkur Barrage was built in Sindh. Thanks to which Sindh became agricultural. The total length of the canals in the Indus Basin Irrigation System is about 60,000 km. After the partition of India, in 1960, Tarbela dams were built on the Indus River in Pakistan and Mangla dams on the Jhelum River in Pakistan. But the construction of Kalabagh dam could not be completed due to provincialism. (Rasheed, B. 2013).

The Indus Basin, which provides water to about 90 percent of Pakistan's population, is facing severe water shortages because Pakistan has very little water storage capacity, as India has a water storage capacity of 120 to 220 days, while Australia and the United States have a storage capacity of 900 days. On the contrary, Pakistan has a water storage capacity of only 30 days, which is why Pakistan's future in terms of agriculture is very weak. The effects of floods and climate change can be controlled to some extent through dams.

Gang Khswa

Glacier grafting technique is used in the villages of Gilgit-Baltistan. Through which the snow blocks located at high altitude are grafted. This technique has the potential to make 90,000 hectares of land cultivable per district. This technique is done at an altitude of 1200 feet and costs about 2300 US dollars per glacier. Munir, R., Bano, T., Adil, I. H., & Khayyam, U. (2021). Glacier grafting is called "Gang Khswa" in Gilgit-Baltistan. It is an ancient local technique that protects against climate change to a large extent. This technique is used in Gilgit-Baltistan in Pakistan and Ladakh in India. This technique is also called "glacier marriage" because through this technique, pieces of male and female glaciers are combined to create a new glacier. Through this technique, the shortage of melting glaciers is compensated. New glaciers have been grafted in 'Skardoo' Chondah Valley and other areas to preserve the lifeline of Indus Basin. There is evidence of ancient glacier grafting in Ladakh, India. But in a modern form, Chewang Nurphel created horizontal artificial glaciers in 1987. Glaciers grafting is an excellent local solution against climate change in low cost. Thanks to which water is obtained for drinking and agriculture in dry season.

Introduction

The largest database on water disputes is held by the Pacific Institute. This think tank is located in California. There are about 261 international rivers in the world. When they are divided between people for use, this water causes tension

between countries. Thus, the solution to the water dispute between Pakistan and India is called the Indus Water Treaty (IWT). According to this treaty, the eastern river was given to India and the water of the Indus was given to Pakistan. The Beas, Ravi and Sutlej are called the eastern rivers. While the Indus, Chenab and Jhelum are called the western rivers. 70% of these rivers are given to Pakistan and 30% to India. India can use the water of the western rivers for non-use. India suspended this treaty on 23 April 2025. (Shah, M. 2025)

The Indus Basin is the lifeline of Pakistan and India, but this lifeline is facing serious threats due to climate change. The temperature in this region is increasing rapidly, due to which glaciers are melting and an uncertain series of rains is beginning. In such a situation, an initial increase in the availability of water in the basin is possible, but a decrease is expected in the long term.

India suspended the Indus Water Treaty in April 2025 due to terrorism in Kashmir. Indian Home Minister Amit Shah said in June 2025 that the treaty will not be revived. Pakistan has raised it at other forums including the United Nations. The Permanent Court of Arbitration (PCA) ruled in August 2025 that no party can unilaterally suspend the treaty. According to experts, the 1960 framework is now outdated and the treaty should be updated with regard to climate change. The vast Indus River basin is located mainly in Pakistan. It is spread over four countries. Apart from Pakistan, it includes India, China and Afghanistan. More than 40% of it is above 2000 meters above sea level. According to the International Water Management Institute (IWMI), the total hydrographic area of the basin is 1,137,819 square kilometers. Its estimate ranges from 1,080,000 to 1,218,500 square kilometers. The population of the basin is 237 million. Of which Pakistan comprises 61%, India 35% and Afghanistan 4%. Due to the rugged terrain of the Himalayas, the Chinese population in the basin is low. At certain times of the year, the water of the basin does not reach the sea. The water problem will worsen in the coming time due to the rapidly growing population, industrialization and climate change. The resources of the Indus Basin are facing serious threats due to climate change. The Hindu Kush Himalayan range (HKH) is particularly vulnerable to climate change, as glaciers melt and erratic rainfall patterns cause unpredictable water flows. (Jabeen, M. Z. 2023).

The Indus basin covers an area of about 1.12 million square kilometers. Its source is the Sangre Khabab ("Lion's Mouth") near Lake Mansarovar. Its source is near the Tibetan Plateau. The river flows through the Himalayas, Hindu Kush, and Karakoram ranges, passing through Ladakh (India) and entering Pakistan. The basin begins in Tibet and ends in the Arabian Sea in the Sindh province of Pakistan. The Indus Basin provides water, food and energy security to over 268 million people. But the future of the Indus Basin is at risk due to climate change and treaty disputes.

Research Objectives

1. Assess the Projected Impacts of Climate Change on Indus Basin
2. Analyze Transboundary Risks and Cooperation Opportunities

Literature Review

1.1 Water Security and Indus Basin

Water security is essential for the security of every state. Because adequate water supply maintains human health and the ecosystem. According to a United Nations report, the availability of quality water is not available to one-sixth of the total population. Only 2% of the total water on earth is quality water. While 98% of the water is salty. Another interesting thing is that 70% of quality water is ice. And 30% of it is groundwater. This proportion of water is affected by climate change. According to an estimate, by 2030, 50% of the total population will be concerned about food and energy due to climate change. (Chaudhry, K. T., & Javed, U. 2019).

If practical steps are not taken regarding water security in the Indus Basin, there is a fear that by 2050, Pakistan will face water and food shortages and people will be forced to migrate. Pakistan should take immediate steps towards water security. In view of these steps, Pakistan should

build large dams, improve the irrigation system, focus on glacier grafting and water conservation.

The Indus River basin has become polluted. The Indus Basin has reached the second position in pollution. One of the major reasons for this is plastic pollution. Diseases are spreading due to pollution in water, which is affecting the development of children. The main reason for this is that chemicals and sewage from factories in Pakistan are mixed into the river without treatment. Due to these reasons, only 20 percent of the total population in Pakistan is drinking quality water and more than 80 percent of people in Pakistan are using contaminated water.

In the past decade, water security has seen significant academic debate and policymaking by international organizations. The Global Water Partnership, the World Economic Forum, and UNESCO's Institute for Water Education have conducted research on water security. In 2007, the Asia-Pacific Water Forum held its first formal meeting on water security, entitled "Water Security Leadership and Commitment." The concept of water security emerged in the 1990s in the context of military security, food security, and environmental protection. But in 2000, the Global Water Partnership proposed a coherent definition of water security that takes into account human needs and environmental health. (Cook, C., & Bakker, K. 2012).

Climate change poses serious threats to Indus Basin water security. The lifeline of Pakistan and India is being severely affected due to the effects of climate change. Therefore, the region needs to take urgent measures on water security and food security because due to the rapid melting of glaciers, water availability is expected to decrease by 50% by 2050, which will severely affect Pakistan's food and energy needs. Water security is also at risk from changes in rainfall patterns. Due to climate change, salt intrusion into water is increasing and pollution is increasing. Seawater intrusion is increasing in the Indus Delta. All these aspects are calling for focusing on water security so that quality drinking water can be obtained in the future.

The water supply of the Indus Basin is under pressure. This is due to the growing population and increasing development. In Pakistan, the annual water withdrawal in 1975 was 153.4 km3. This increased to 183.5 km3 in 2008. While in 1977, the per capita renewable water resources were 3,385 cubic meters (m3). Now in 2011, the per capita renewable water resources have come down to 1396 cubic meters (m3). In the same period, India has doubled its water withdrawal - from 380 km3 in 1975 to 761 km3 in 2010. While the water resources have come down to 1,539 m3 in 2011-13. According to hydrologists, the per capita water requirement is 1700 m3. According to the United Nations Environment Programme (UNEP), the annual renewable water availability in the Indus Basin is 1329 m3. According to the International Centre for Integrated Mountain Development (ICIMOD), the annual per capita water availability in the basin is 978 m3. These figures indicate that the inhabitants of the basin are facing severe water stress. Iqbal, A. R. (2013).

Indus Water Treaty

Both India and Pakistan are facing water shortages, so in 1960, both countries signed the Indus Water Treaty managed by the World Bank. Despite geopolitical tensions, both countries are still implementing the Indus Water Treaty. However, Pakistan is facing more restrictions than India. That is why India has the capacity to store water for 170 days, while Pakistan can store water for only 30 days. If we look at other countries, Egypt has the capacity to store water for 700 days. Ul-Durar, S., Shah, M., De Sisto, M., & Arshed, N. (2023).

On September 19, 1960, Indian Prime Minister Jawaharlal Nehru and Pakistani President Ayub Khan signed the Indus Water Treaty. The agreement, brokered by the World Bank, divided six major rivers into two categories. According to the agreement, India got control of 20 percent of the flowing water and Pakistan got control of 80 percent.

The agreement is a successful water-sharing agreement, but analysts say the technical details of the agreement need to be revised to address climate change.

Despite the wars and conflicts between India and Pakistan, the Indus Water Treaty has not been violated. Although only India can violate the treaty because Pakistan is a lower river state. India claims that it has not violated the treaty but has improved the use of the water system by building barrages and dams. But Pakistan complains about these Indian constructions in international forums.

Indus Water Under Climate Stress

The water crisis is also increasing due to the growing population and climate change at the global level. It is not possible to provide clean water to 1.1 billion people. Due to the growing population in developing countries, water use has also doubled. On the other hand, floods, droughts and landslides have increased dramatically. That is why the term water security is being used in the world today. Overcoming water crisis and balance has become the most important challenge. The United Nations Water Agency's definition of water security also includes the resolution of disputes over shared waters. (Mishra, B. K., Kumar, P., Saraswat, C., Chakraborty, S., & Gautam, A. 2021).

The Indus Basin is the world's most important water system, providing water to Pakistan, India, China and Afghanistan. Climate change is severely affecting water quality and flow. The basin is under severe stress due to melting glaciers, changing rainfall patterns and increasing droughts. This climate change poses serious threats to food security, water security and energy security. Glaciers in the upper reaches of the Indus Basin provide 50 to 70 percent of the water. Due to increasing temperatures, glaciers in the Himalayas, Karakoram and Hindu Kush are melting rapidly, which will initially increase water availability, which will cause floods, but later a severe shortage of water is expected in the basin.

Due to climate change, annual rainfall has been reduced by 11.9%, but according to future projections, rainfall will increase in the Karakoram and decrease in the southwestern Hindu Kush and western Himalayas. Due to this climate change, the intensity of the monsoon will increase and the risk of severe floods will have to be faced. The intensity and duration of droughts in the lower Indus Basin is increasing. Water availability in this part may also be less than 25%, due to which water stress will increase in the dry season.

According to IPCC (2007), there is a clear possibility of freshwater depletion in major river basins due to climate change 'by the 2050s'. Due to this, there is a clear reduction in the water discharge in the Indus River. A decrease of 0.02-million-acre feet (MAF) has been identified in the annual water discharge from Tarbela Dam. The annual discharge of the Indus River is decreasing significantly due to climate change. (Khan, S., & Khan, M. A. 2019).

The availability of water in the Indus Basin is also largely due to the melting of ice and glaciers. The temperature is increasing day by day, so the melting of ice and glaciers will increase further, which may initially lead to a sharp increase in the river flow, but with the melting of glaciers and their disappearance, this flow is expected to decrease significantly. Therefore, attention should be paid to glacier grafting. This local technique should be adopted at the government level so that the future of the basin is secure.

The Hindu Kush, Karakoram and Himalaya (HKH) mountain range contains a large number of glaciers. 50% of the water flowing into the upper Indus Basin is due to melting snow. The eastern and central HKH glaciers have lost a significant amount of area due to general retreat. On the other hand, in the last decade, glaciers have been reported to advance in the Karakoram. The upper Indus Basin is filled by the melting of large glaciers. While the entire catchment is located in Gilgit-Baltistan. This catchment has several glaciers covering 28% of the basin area. The two main glaciers are the Biafo Glacier and the Baltoro Glacier. Soncini, A., Bocchiola, D., Confortola, G., Bianchi, A., Rosso, R., Mayer, C., ... & Diolaiuti, G. (2015).

Climate change is having an environmental, social and economic impact on Pakistan, which is why it often faces floods, storms and droughts. Pakistan ranks 135th in the world due to a two-fold increase in greenhouse gas emissions in Pakistan. The increase in greenhouse gas

emissions has occurred in the last two decades. Geographically, the proportion of rainfall in this region is not uniform, which is why it faced drought due to low rainfall in 2009, while in 2010, more than 20 million people were affected by a devastating monsoon. This flood caused a loss of 10 billion US dollars. In 2011, 1.2 million people in Sindh were affected by devastating rains. The 2012 floods destroyed lands and houses in areas of Khyber Pakhtunkhwa, southern Punjab and lower Sindh. 100 people died in 2012 and 80 people in 2013. In 2014, the catchment areas of Punjab, Gilgit-Baltistan and Azad Kashmir were hit by a slab. According to a recent study, 49.6% of Pakistan's population and 22.8% of its land are at risk due to climate change. Chauhdry, K. T., & Javed, U. (2019).
Greenhouse gases are the main cause of global warming. These gases are increasing due to deforestation and industrialization. Due to these greenhouse gases, the temperature is increasing. In simple words, these greenhouse gases are causing climate change. The Indus Basin is affected by these greenhouse gases from the Himalayas to the Karakoram and India to the Arabian Sea. Due to this climate change, the hydrology of the basin is changing. This climate change is a challenge for water security and food security. Due to this climate change, the peak flow of summer will decrease and spread to other seasons, due to which groundwater is facing shortage and pollution.

Future of the Indus Basin under Climate Stress
The future of the Indus Basin is presenting a scenario of drought. Due to this drought, the per capita availability of water will also decrease significantly. People dependent on this basin will be forced to migrate. To protect the Indus from the effects of climate change and for its better future, it is necessary to take several steps.

Short to Long Term
There is a risk of large-scale landslides due to melting glaciers and untimely monsoon rains. Pakistan should build dams to control this flow rate, but the long-term water shortage will be due to the shrinking glaciers. Even then, the water stored in the dams will be useful for a certain period of time.

Transboundary Tensions
The Indus Waters Treaty (1960) did not include any strategy regarding climate change, but now Pakistan and India should review this agreement and update it according to future needs so that it can be protected from the effects of climate change.

Ecological Restoration
The solution is to restore the Indus Basin ecosystem to its natural state. By eliminating or reducing the disruption that the capitalist production system has created between nature and life, restoring the nature of the Indus can make it safer from climate change.

Glacier Grafting
The ancient method of glacier grafting should be adopted at the government level and new glaciers should be created from it to combat climate change

Theoretical Framework
Metabolic rift theory examines, in Marxist thought, how capitalist production disrupts the natural metabolic processes between society and the environment. In the case of the Indus Basin, this theory explains how the legacy of colonialism, geopolitics, and climate change have strained relations between Pakistan and India. The theory suggests that collective strategies are needed for the future of the Indus Basin. It is time to move beyond the traditional hydrological model and reconsider the Indus Water Treaty in the context of climate change.
Metabolic Rift Theory is an ecological concept in Marxist thought that argues that the capitalist system of production disrupts the natural metabolic processes between human society and nature, leading to environmental degradation. This theory was proposed by Karl Marx. Foster, J. B. (1999).
Marx articulated the metabolic rift theory. This theory explains the consequences of industrial capitalism between humans and nature.

Industrialization creates a metabolic rift, which results in ecological degradation. Applying this theory to the Indus Basin, it can be seen that increasing population, industrialization, and economic development have created a metabolic rift with the effects of climate change.

Implications

The metabolic rift theory covers the natural and human-caused disruptions to the future of the Indus Basin. 47 percent of the Indus Basin is in Pakistan, 39 percent in India, eight percent in China, and six percent in Afghanistan. This basin is completely vulnerable to climate change because a large part of the basin is in Pakistan and India, and both these countries are vulnerable to climate change. Heatstroke is constantly increasing in both these countries, due to which glaciers are melting because trees have been destroyed on a large scale for industry, housing societies, and other development projects in both these countries. Today, there are five trees left per capita in Pakistan, while there are 422 trees per capita in the world, although a fixed 900 trees are needed. On the other hand, there are 28 trees left per capita in India, due to which these countries are vulnerable to climate change. There is a severe shortage of dams in Pakistan, due to which floods occur and the water of the basin is wasted. For these reasons, the Indus Basin is the second most polluted in the world. The river system is a global system. Due to greenhouse gases, parts of the basin in China and Afghanistan are also vulnerable to climate change. These countries should make a strategy for capitalist production, looking at the future of the basin, so that the Indus Basin is not further affected. In particular, Pakistan and India should review the Indus treaty so that the Indus Basin can be assessed with regard to climate change.

Research Methodology

This study adopts a qualitative methodology that works with an analytical approach to consider the future of the Indus Basin in the context of water security and climate change. This analysis examines the literature and theories on water security and analyzes what strategies the parties adopt for the future of the basin due to the impact of climate change. Because of the decrease in per capita water supply in Pakistan, there is a need to improve the infrastructure of the basin. It is necessary to build new dams here, which will stop the loss of water due to temporary climate change. We study the future of the basin in terms of water security and climate change through secondary data, including books, research articles, research reports, analytical reports, etc.

Conclusion

Due to climate change, the future of the Indus Basin depends on the development of its infrastructure, along with cross-border cooperation to strengthen water security, as the basin benefits 300 million people in Pakistan, India, Afghanistan and China. The basin is facing serious threats due to climate change. From this study, we have learned that the basin is vulnerable to climate change due to melting glaciers, increasing heat, and changing monsoon patterns, which causes large-scale floods in Pakistan, causing deaths and property damage. Large-scale gardens and crops in Pakistan are destroyed by floods because there are no dams to control the floods in the basin to prevent water loss. Due to this, four percent of Pakistan's GDP is lost annually to climate change. The Indus River irrigates 80 percent of the area in Pakistan, it generates hydroelectric power, and this basin is the source of livelihood for two-thirds of the population. Along with climate change, the demand for water is increasing due to increasing population. On the other hand, per capita water availability is decreasing. Reduction in per capita water availability. Floods, displacement and food security. Re-examination of new dams and transboundary basin relations is necessary.

Recommendations

The following are some important suggestions for the future of the Andes Basin, which has been affected by climate change due to the lack of dams, deforestation, heatstroke, and melting glaciers.

1. The Indus- Treaty should be updated in terms of climate change so that the future of the

Indus Basin remains secure despite climate change. The scope of cross-border cooperation and meetings should be expanded. The data sharing mechanism in these meetings should be improved. Water flow, glacier melting and now wind forecasts should be monitored through satellites and ground stations.

2. Investments should be made in storage, infrastructure and conjunctive use in the Indus Basin to prevent floods and increase water storage capacity. This will benefit the residents of the basin.

3. The canal system should be improved to avoid water wastage.

4. The Indus Basin, which covers parts of Pakistan, India, Afghanistan and China, is now completely vulnerable to climate change. The four countries should share data with each other regarding the future of the Indus Basin, such as droughts and melting glaciers. In particular, Pakistan and India should update the Indus Water Treaty in the context of climate change. Both countries should ensure real-time data sharing and monitoring of the Indus.

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