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The Impact of Climate Change on Sultan Dam

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ABSTRACT

The Sultan Dam, located in the Jaghatu District of wardak province of Afghanistan, is a crucial water resource supporting irrigation, hydropower generation, and domestic and industrial water supply. However, the dam is increasingly vulnerable to the impact of climate change. This study assesses the specific impact of climate change on the Sultan Dam during the period of 2015 to 2023. By employing a multidisciplinary approach, including historical climate data analysis, hydrological modeling, and GIS, the study examines changes in water resources, sedimentation patterns, and reservoir dynamics. The analysis focuses on climate change-related effects such as shifts in precipitation patterns, temperature variations, and changes in the frequency and intensity of extreme weather events like droughts and floods. The findings highlight the significant challenges faced by the dam and its water resources due to climate change such as a lack of water capacity, the collapse of the wall of sultan dam, lack of agricultural products, heavy rains, increase of floods and soil erosion and so on. Recommendations include enhancing water management practices, upgrading dam infrastructure, and integrating climate-informed operations. Incorporating an integrated water resource management approach, promoting public awareness, and investing in ecological restoration efforts are crucial for improving the dam's resilience and ensuring sustainable water availability. The study's outcomes provide valuable insights for policymakers, decision-makers, and researchers working towards effective climate change adaptation strategies for the Sultan Dam and similar water resources in the region.

Keywords: Climate Change, Sultan Dam, Water Resources, Hydrological Impacts, Adaptation Strategies

INTRODUCTION

Climate change has emerged as one of the most pressing global challenges, with wide-ranging consequences felt across the world. The impacts of climate change are particularly significant in the Jaghatu District of Afghanistan, where the Sultan Dam, a vital water resource, is located. This study aims to provide a comprehensive analysis of the impact of climate change on Sultan Dam over the past eight years, specifically focusing on the period from 2015 to 2023.

The Sultan Dam plays a crucial role in providing irrigation water, generating hydropower, and supplying water for domestic and industrial purposes in the region. However, the changing climate patterns have raised concerns about the dam's sustainability and its ability to meet the growing water demands of the area. Climate change-induced alterations in the hydrological regime have resulted in changes in water availability, quality, and storage capacity of the dam. These changes include shifts in precipitation patterns, alterations in temperature regimes, and variations in the frequency and intensity of extreme weather events such as droughts and floods.

Understanding the impact of climate change on Sultan Dam is essential for developing effective adaptation and mitigation strategies to ensure its long-term viability. This study will utilize a combination of historical climate data, hydrological modeling, and satellite imagery analysis to assess the changes in water resources, sedimentation patterns, and reservoir dynamics of the dam. By analyzing these factors, the study aims to provide insights into the specific effects of climate change on the Sultan Dam and its associated water resources.

Furthermore, it is important to consider the historical context and characteristics of the Sultan Dam. The dam has a rich history dating back thousands of years. Initially constructed during the reign of Sultan Mahmood Ghaznavi, it was subsequently destroyed and later rebuilt by Amir Habibullah Khan in the early 20th century. The current dimensions of the dam span approximately 2000 meters in length and 500 meters in width, with an estimated total area of 100 ha. The dam serves as a water source potable for approximately 5,000 households and irrigates around 15,000 hectares of agricultural land. However, the dam has faced challenges such as sedimentation due to floods, leading to a decrease in its water capacity. These sources include the Gorbat, Barikab and Rashidan Rivers, all of which are seasonal rivers arising from snow melting in the spring and early summer. The water flow in these rivers varies at different times, affecting the overall water availability and inflow into the dam.

By examining the historical and current context of Sultan Dam and evaluating the impact of climate change on its water resources, this study aims to provide valuable insights for policymakers, decision-makers, and researchers. The findings will contribute to the development of effective strategies and measures to address the challenges posed by climate change and ensure the long-term sustainability of Sultan Dam and its associated water supply

The water source in Sultan dam is rain, snow and spring water. According to the location of the dam, the water source of sultan dam can be divided into three parts: one a river flowing in the central part and called the Gorbat River the second is the Barikab River, which flows near the western part of Jaghatu district and the third is rashidan river which is located in the western of Jaghatu district in Rashidan district of Ghazni province. These rivers are seasonal, resulting from the melting of the snow that occurs in the early and late days of spring and early summer, and the percentage of water in these rivers varies at different times.

MATERIALS AND METHODS

Study Area

The study area for the impact of climate change on Sultan Dam during the last eight years (2015-2023) is the located in Jaghatu and Rashidan districts, Wardak and Ghazni provinces of Afghanistan.

Samples Collection

The sample collection for the impact of climate change on Sultan Dam have involve the collection and analysis of various types of data. Historical climate data, including temperature, precipitation, and other meteorological variables, have be obtained from local weather stations or national meteorological agencies. Data on water inflow, outflow, and storage levels of Sultan Dam have been collected from relevant authorities responsible for monitoring the dam. Satellite imagery have been obtained from remote sensing platforms to assess changes in land cover, reservoir extent, and sedimentation patterns around the dam. Field surveys may also be conducted to collect additional data on sedimentation rates, vegetation cover, and ecological parameters. These data sources have provided comprehensive insights into the changes in climate, water availability, water quality, and ecosystem dynamics, enabling a thorough assessment of the impact of climate change on Sultan Dam

Statistical Analysis

The statistical analysis involves various techniques. Descriptive statistics summarize climatic and hydrological data. Correlation analysis examines relationships between variables, and spatial analysis, utilizing Geographic Information System (GIS) tools, analyzes imagery and survey data to identify spatial patterns, land cover changes, and sedimentation rates near Sultan Dam. Additionally, statistical modeling explores the impacts of climate variables on water availability, storage, and quality.

The impact of climate change on dams

The impact of climate change on dams has been a subject of increasing concern and research in recent years. Dams play a crucial role in water resource management, providing water supply, hydropower generation, and flood control. However, the changing climate patterns and associated extreme weather events pose significant challenges to the functionality and sustainability of dams worldwide. One of the primary concerns regarding climate change and dams is the alteration of precipitation patterns. Intensified rainfall events and increased variability can lead to higher inflows and sedimentation rates in reservoirs (Milly et al., 2008). A study by Kundzewicz (2018) examined the impacts of changing precipitation patterns on dams in Europe, highlighting the need for adaptive strategies to manage increased flood risks.

In addition to changes in precipitation, rising temperatures associated with climate change can lead reduced snowpack, affecting the availability and timing of water supply for dams (Immerzeel et al., 2020). This has significant implications for regions reliant on snowmelt as a water source. For example, a study by Barnett et al. (2005) assessed the impact of climate change on water availability in the Western United States, highlighting the potential decrease in snowpack and subsequent water supply reductions for dams in the region.

Extreme weather events such as droughts and floods, which are projected to increase in frequency and intensity under climate change, pose significant risks to dam infrastructure and operations (Fluixá et al., 2018). Droughts can lead to decreased reservoir levels, reduced hydropower generation, and compromised water supply for various sectors (Biemans et al., 2013).

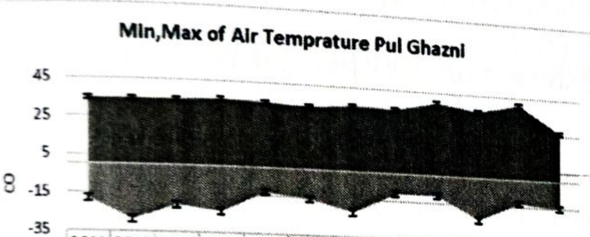
To address these challenges, researchers and practitioners have emphasized the importance of integrating climate change considerations into dam design, operation, and management strategies. Adaptive measures such as flexible operational rules, improved sediment management techniques, and enhanced flood control infrastructure have been proposed (Perera et al, 2021). Furthermore, incorporating climate projections and risk assessments into dam planning processes can help identify vulnerable areas and inform decision-making (Wurbs, 2020).

The below pul Ghazni date shows a significant increase in the amount of water flows or water discharges, per year was 18 million cubic meters per year in 2015. The discharge rate has risen to 75.7 million cubic meters in 2021. It indicates a considerable increase.

The impact of climate change on dams is a complex and multifaceted issue. Changing precipitation patterns, rising temperatures, and increased frequency of extreme weather events pose significant challenges to the functionality and resilience of dams worldwide. Addressing these challenges requires integrated approaches that consider climate change projections, risk assessments, and adaptive strategies for dam design, operation, and management.

RESULTS AND DISCUSSION

The study reveals significant changes in temperature and precipitation patterns over the eight-year period. This includes trends indicating rising temperatures, alterations in seasonal rainfall distribution, and shifts in extreme weather events such as droughts and floods.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
MAX	34.4	34.4	34.5	35.3	34.5	33.4	35	34.3	39.6	35.8	40.8	26.6
MIN	-18	-29	-21	-24	-13	-16	-22	-11	-11	-23	-13	-15

Figure 1: Temperature

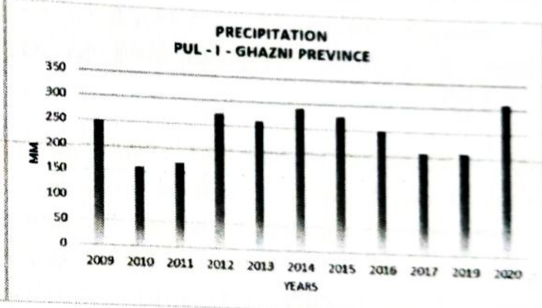


Figure 2: precipitation

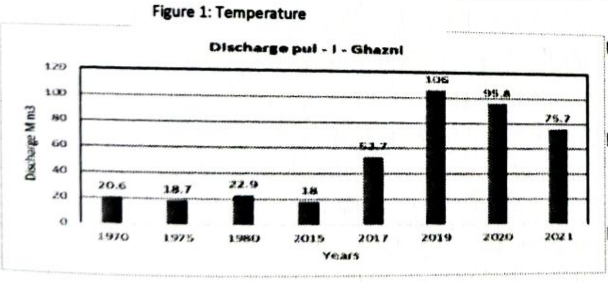


Figure 3: Discharge

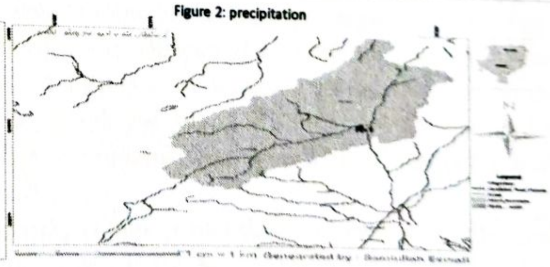


Figure 4: sultan dam watershed map

The analysis uncovers the impacts of climate change on the hydrological regime of the Sultan Dam. This involve identifying changes in storage levels, as well as variations in water availability and reservoir dynamics over the study period.

The spatial analysis, utilizing GIS tools, reveal changes in land cover patterns, sedimentation rates, and erosion patterns in the vicinity of the Sultan Dam. This information help assess the extent of environmental changes and their implications for dam operations and maintenance.

CONCLUSION

Given the fact that this dam is the only source of water for the entire region, the impact of climate change on Sultan Dam. The findings highlight the significant challenges posed by climate change on the dam and its associated water resources. The study reveals potential changes in climate parameters, hydrological impacts, water quality, spatial patterns, and sedimentation rates. These findings emphasize the need for proactive measures and adaptive strategies to address the impacts of climate change on the Sultan Dam. To mitigate the effects, there is a need to develop a comprehensive plan for the watershed management, , and integrate climate-informed operation strategies. Adopting an integrated water resource management approach, promoting public awareness, and education can contribute to sustainable water allocation and conservation. Needless to add that the sultan dam is a tourist attraction destination. it can also support local economy and livelihood. Furthermore, ecological restoration and continued monitoring efforts are vital to preserve the ecological balance and assess the long-term implications of climate change on the dam and its surroundings.

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