Food-Climate Nexus in the North River Basin of Afghanistan: A Case Study of the Qush Tepa National Irrigation Canal

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ABSTRACT

Thoughts and steps on implementing one of Daud Khan's five-year plan projects, named the Qush Tepa canal, began during the final years of the Islamic Republic of Afghanistan. These plans then provoked concerns among the stakeholders of the Amu Darya with the Taliban takeover in August 2021 and the acceleration of canal construction. There was a pressing need to study the canal for its opportunities and challenges. This research, adopting a mixed-method approach, examined how the canal impacts the livelihoods of locals and agricultural productivity under a changing climate. The findings indicate that the canal is vital for Afghanistan, primarily to maintain food security for a growing population projected to reach 100 million by the end of the century. The canal is estimated to contribute around 400 million USD annually to Afghanistan's GDP. Additionally, if utilized correctly, the canal generates significant opportunities, enhancing food security and availability for Afghanistan and the region. Climate change has reduced cultivation areas since 2001, with reduced water flow, increased water usage, and decreased rainfall. The research concludes by acknowledging the annual reduction of around 6.5 billion m^3 of water to downstream countries due to the new canal while highlighting the significant opportunity for mutual economic benefits for Afghanistan and Central Asian countries resulting from the canal's emergence.

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Table of Contents

List of Tables

List of Figures

Introduction

Afghanistan's strategic geographical positioning encompasses five major river basins, four of which—namely, the Kabul, Helmand, Harirud Murghab, and Panj-Amu—are transboundary in nature, traversing into neighboring countries; however, the fifth, which is North, does not mainly discharge into neighboring countries. These river basins are of paramount importance not only for the country's water management and agricultural practices but also for the intricate dynamics of regional cooperation and geopolitical relations. The intersection of food security with transboundary water governance introduces complex challenges that are further compounded by decades of warfare, political instability, and infrastructural degradation in Afghanistan. Post-1978 conflicts and insecurity period have left Afghanistan with fragile political governance systems, severely impacting its hydrological infrastructure and institutional capacity in water resources management up to the overthrow of the Taliban regime in October 2001. The establishment of the interim administration in December 2001 that then transitioned into the Islamic Republic of Afghanistan paved the developmental avenue for some time until its collapse in August 2021, in which Afghanistan was equipped in terms of educated Afghan experts on water management, food, and climate while inadequately equipped with necessary technical tools to make the best of use of the personnel. Efforts made by the Islamic Republic of Afghanistan and the international community to enhance human capacity, acquire hydro-meteorological data, and develop mechanisms for managing transboundary waters to promote economic growth and regional cooperation resulted in working on the projects that aimed to construct in previous administrations. One of the projects that came under the focus of the Islamic Republic of Afghanistan was the construction of the Qush Tepa National Irrigational Canal with a budget of around 1 billion dollars, throwing chains across the North River Basin starting from Balkh, continuing to Jawzjan, and ending in Faryab. This effort did not halt after the collapse of the Republic in August 2021; instead, it was further exacerbated under the second rule of the Taliban in Afghanistan, as the construction budget was maintained from local sources. Experts have identified six primary reasons driving the construction of the Qush Tepa National Irrigation Canal. Firstly, there is a growing competition for water resources among agriculture, industry, and municipalities. Secondly, a significant challenge is posed by the mismatch between water availability and demand, particularly in the agriculture and livestock sectors in the North River Basin. Thirdly, the return of refugees from neighboring countries has led to an increased demand for food and water. Fourthly, Afghanistan's heavy reliance on large imports of comestibles to sustain its population underscores the need for diversification toward self-sustainability. Fifthly, there is a critical need for sustainable management of the country's water resources. Lastly, the unprecedented population growth, as projected in Figure 1, to exceed 100 million by 2100, necessitates proactive measures to meet the rising food and water demand.[1]

[1] Focus group with a former minister of Afghanistan and two experts on water affairs of Afghanistan, online, December 2023.

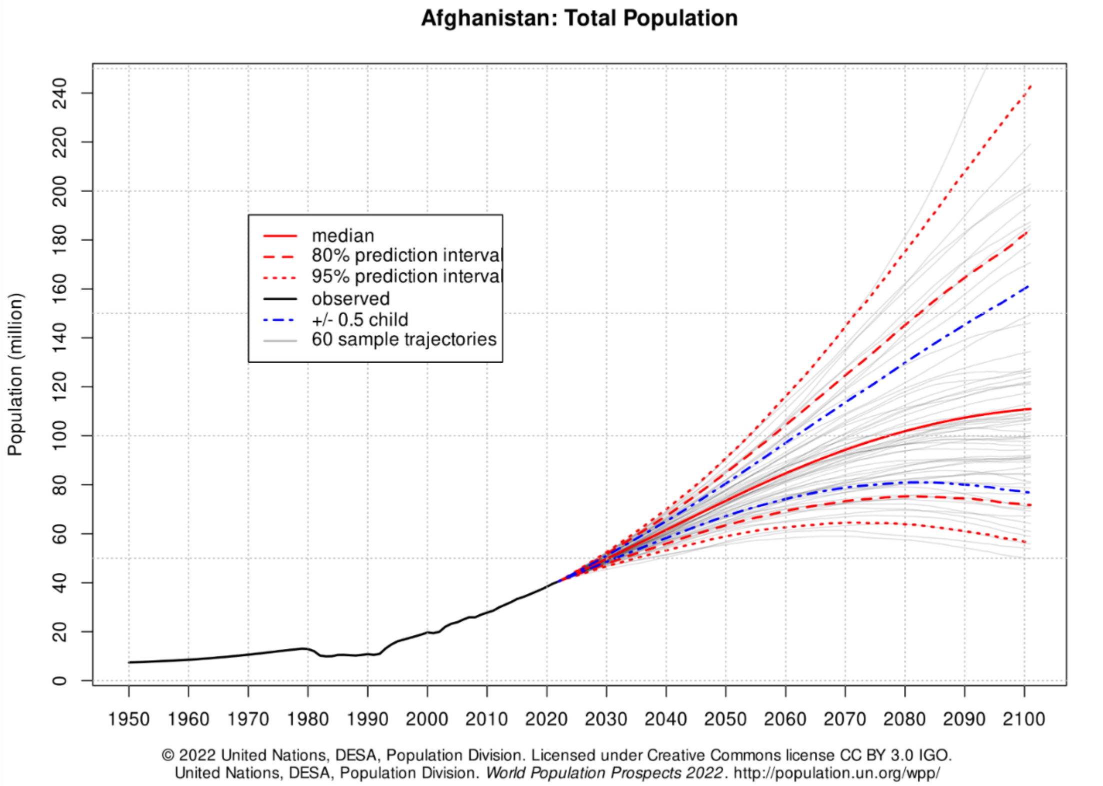


Figure 1: Projection of Population of Afghanistan

Against this backdrop, this study starts with narrating and describing to what magnitude and gravity some water transfer projects exist across regions and the globe, in order to demonstrate the existence of engineering projects not only showcase human creativity in navigating geographic and climate barriers but also emphasize the considerable environmental, social, and economic effects they may trigger. By presenting these examples, the study seeks to illuminate the broader discussion, particularly focusing on the Qush Tepa National Irrigation Canal, which might be viewed as contentious by neighboring nations, even as similar projects are frequently built or could be envisioned for the future. Furthermore, the study, with a focus on the North River Basin of Afghanistan, studies it comprehensively from dimensions of population and community, geology, hydrology, climate, food, and glaciers. These points are selected for building this study on them because they have a significant impact and are considered major factors for initiating this canal (food insecurity and climate change). They are the drivers for taking steps towards digging the canal. For example, cryosphere melting stabilizes the situation in the short term but will increase conflict and reactions over the long term as it shrinks. Additionally, mountain communities are severely impacted by glacier recession and decreasing meltwater, affecting irrigation, agriculture, hydropower production, livelihoods, and cultural elements (Carey et al., 2017). To elucidate further, population growth increases future food demands, while currently, the country faces a deficit in food availability and production. These factors are strongly influenced by climate change, with the area experiencing severe droughts (Shih, 2023) and high temperatures in recent years. Moreover, hydrology is affected by climate change, and the geology of the area has a major impact on the profitability and decisions regarding the implementation of this canal to generate long-term revenue (Barnett et al., 2005; Pecl et al., 2017).

This study then continues with a special focus on the Qush Tepa National Irrigation Canal as the case study, analyzing the impact of climate change primarily on the canal and to a lesser extent on its sources. It also examines the yield of the area before and after the canal's construction, taking into account the effects of climate change. Based on observed, under prediction it unravels further what kinds of crops suit well the areas to get cultivated under the climate change tendencies. It also encompasses an economic and political analysis of the canal, claiming that this canal will reduce poverty, enhance the socio-economic situation in Afghanistan, and open a new chapter of collaboration and cooperation among Afghanistan and Central Asian countries. It concludes by providing suggestions for the Afghan administration and neighboring Central Asian countries.

Why this report?

The necessity to study the Qush Tepa National Irrigation Canal stems from a multifaceted set of challenges and opportunities that this infrastructure presents to the region it serves and it does not. These challenges and opportunities required an overarching study. The function of the canal in diverting water from the Amu Darya River, as argued by Central Asian countries (mainly Uzbekistan & Turkmenistan) bordering the north with Afghanistan, underscores challenges related to water availability for them and their agricultural growth (Ilkhamov, 2023; Mushtaq, 2024). However, the construction of the canal is closely connected to the larger socio-economic landscape and prosperity of Afghanistan, where the canal shall operate, impacting its food security and cross-border water management strategies. In addition to relying on their own agriculture and certain imports from other nations, Central Asia is home to over 100 million people. Over the last 50 years, either under the Soviet Union or after independence Uzbekistan, Turkmenistan, Tajikistan, and Kazakhstan have particularly depended heavily on irrigated agriculture, primarily drawing water from the Amu River. None of these nations seemed prepared or even aware of how Afghanistan would rethink to construct the Qush Tepa canal and divert water supplies to the nations downstream and take this action in light of its commitment to the United Nations Convention to Combat Desertification, which it joined in 1995. This convention mandates Afghanistan to combat desertification, mitigate the effects of drought, and promote sustainable development practices.[2] From another perspective complementary to the aforementioned, the aspect of food security, crop growth, and lushness, particularly in the context of the North River Basin of Afghanistan and the broader Central Asian region, is critically dependent on the availability and efficient and equitable water use of the shared water resources. The construction of the Qush Tepa canal, without adequate information among the northern neighboring Central Asian nations and Afghanistan per se, has highlighted the need for studies to explore the canal's impact on water distribution, agricultural productivity, and food security resulting from its

[2] Focus group with a former minister of Afghanistan and two experts on water affairs of Afghanistan, online, December 2023.

construction on Afghan territory. Such understanding is crucial for clearing up misunderstandings and knowing the extent to which water is being diverted from the Amu Darya River Basin toward Afghanistan in a manner that supports the livelihoods of millions while also assessing the canal's efficiency.

To address the abovementioned intricate concerns and demand for further understanding, the current research project builds on the implementation of the Qush Tepa National Irrigation Canal (QTNIC) in the North River Basin of Afghanistan. It seeks to respond to the following questions*. i) What is the impact of the Qush Tepa National Irrigation Canal on the livelihoods of local communities under a changing climate? ii) How does the Qush Tepa National Irrigation Canal impact food production and security in the North River Basin of Afghanistan?; Will there be any changes in crop yields or agricultural production? and iii) How does climate change impact the Qush Tepa National Irrigation Canal's agricultural food productivity?* By responding to these questions, it seeks to fill the gap in the i) understanding of the (QTNIC) and its potential impacts on the economy, food availability, water resources, and local communities' livelihood. ii) Canal's impact on downstream countries, and iii) explore the impacts of the Qush Tepa National Irrigation Canal on riparian stakeholders economically and politically.

Methodology

The research methodology of this study is built on a mixed-method approach that encompasses three parts. Firstly, the research began with a thorough literature review to assess the existing overarching knowledge on Afghanistan's river basins, North River Basin, and the case study area, which is Qush Tepa National Irrigation Canal and projects regionally and globally akin to Qush Tepa over the topics relevant, interconnected and helpful to the study's objectives and the research is grounded in the most current understanding of the topic. This step was crucial for identifying knowledge gaps and setting the research foundation because literature reviews are essential for understanding the scope of existing research and avoiding duplication, thus ensuring that new research adds value to the existing body of knowledge. The literature review spanned a broad spectrum of sources to ensure a holistic overview of the topic, including a feasibility study of the Qush Tepa by Strengthening Watershed and Irrigation Management (SWIM), peer-reviewed articles, Afghan governments and NGO's reports, documents in English, Persian and Pashto languages, and set of research conducted by Ministry of Agriculture, Livestock and Irrigation of the Islamic Republic of Afghanistan and Ministry of Public Works.

Secondly, by combining quantitative data with qualitative insights from interviews, focus groups, and surveys, the research adopted a mixed-method approach. For this study, 19 semi-structured anonymous interviews with locals, including farmers (8), shepherds (2), and local residents (9), and six anonymous interviews with site engineers and workers of over the Qush Tepa canal in Balkh, 17 semi-structured anonymous interviews with local residents of the districts the canal passes through in Jawzjan and eight semi-structured anonymous interviews with the locals of Andkhoi district in Faryab conducted in the course of July, August and September 2023. Moreover, an online focus group with a former minister of Islamic Republic of Afghanistan and two experts conducted. In each province of Balkh, Jawzjan, and Faryab, 13, 5, and 4 focus groups were also conducted, respectively. Furthermore, a livelihood survey among the locals of the districts that canal passes through also conducted. The inclusion of primary data and stakeholder perspectives (locals, farmers, shepherds, engineers, experts and workers) ensured that the findings are grounded in local realities, enhancing the relevance and applicability of the research outcomes.

Thirdly, the study's methodology focused on projecting future climate scenarios, including a) utilization of Google Earth Engine (GEE) for projecting climate change scenarios, analyzing NDVI, TSI, and changes in cropland areas in the North River Basin and b) specifically targeting the agricultural regions impacted by the Qush Tepa National Irrigation Canal by studying the monthly data from the two stations named Hairatan and Andkhoi (2012 - 2017). These two stations on the ground are located at the beginning and at the end of the canal. These steps were pivotal in understanding the potential climatic changes that could influence agricultural productivity and food security in the region. Moreover, the statistical downscaling to translate global climate model (GCM) outputs into local-scale projections was employed in the study. Then, the bias correction based on linear regression between air temperature at the stations and the GCM dataset was applied to projections. Next, climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP6) were selected, which provides the latest suite of global climate models. These models are chosen based on their performance in simulating key climatic variables (e.g., temperature, precipitation) over Afghanistan and their ability to capture the regional climate dynamics. Consequently, the study utilized Representative Concentration Pathways (RCPs) 4.5 and 8.5 to project climate scenarios. RCP 4.5 represents a moderate mitigation scenario leading to a stabilization of radiative forcing by 2099, while RCP 8.5 is a high greenhouse gas emissions scenario. These scenarios allow the research to explore a range of potential futures, from more optimistic to more severe impacts of climate change. Data is sourced from international climate modeling centers participating in CMIP6, ensuring access to the latest projections. Historical climate data (2006 - 2022) from CHIRPs v.2 daily data set for Andkhoi & Hairtan meteorological stations in Afghanistan also provided the baseline for bias correction. Climate data for the scenarios is also downloaded from the global database of CORDEX which offer comprehensive climate datasets.

1. Literature Review: Regional and Global Water Transfer Projects

The transportation and control of water over extensive distances through engineering projects have always been a fundamental aspect of human progress. From ancient aqueducts to contemporary small-to-large-scale endeavors, the capacity to convey water from regions of abundance to those facing scarcity has transformed terrains, sustained growing populations, and stimulated economic advancement. This review of literature explores four distinct yet equally remarkable water transfer undertakings that encompass various parts of the world. Each case study, ranging from the extensive irrigation systems within China's Project 635 to the engineering excellence demonstrated in Finland's Päijänne Water Tunnel, and the transformative influence of the Karakum Canal in Turkmenistan, underscores the distinctive obstacles and resolutions involved in managing one of humanity's most valuable resources. By studying these projects, the objective is to reveal the technical, environmental, and social complexities associated with water transfer initiatives, showcasing not only their importance in mitigating water scarcity and supporting agricultural activities but also their role in promoting regional development and environmental sustainability.

1.1 Project 635, China:

The Project 635 Dam with its canal, positioned in Fuhai County, Xinjiang Uighur Autonomous Region of China, and situated approximately 56 km east of Beitun, is one of three dams on the Irtysh River. It forms an embankment dam that generates a reservoir, crucial for supplying water to the Irtysh–Karamay–Ürümqi Canal. This canal, spanning 134 km and originating from the dam, is a vital component of a larger 560 km network, including a 420 km segment in the east and a shorter 5.4 km section in the west. Additionally, the infrastructure comprises several tunnels, aggregating to 5.7 km. Aimed at irrigating 140,000 hectares, this project significantly contributes to the regional water management system, incorporating the Irtysh River Diversion to Urumqi Project. This diversion initiative, crucial for mitigating water scarcity, channels water from the Irtysh River to Urumqi, Karamay, and Ürümqi, thereby enhancing groundwater quality and reducing arsenic pollution in these areas, as reported by (e.g., D. Wang et al., 2022; Zheng et al., 2018). This canal has created vas area of greenary with cultivation of various crops which enhanced the livelihood and economic of the farmers. Also, due the reduction of flow in the trench, it has iclreasded salinity and other environmental degradations (Liu et al., 2024).

1.2 Päijänne Water Tunnel, Finland:

The Päijänne Water Tunnel, an impressive engineering feat in Finland, notably serves as the second-longest tunnel after the Delaware Aqueduct in the USA, stretching over 120 km. Initiated in 1972 and completed in 1982 at an estimated cost of 200 million euros, this project is positioned between 30 to 100 m underground. The tunnel begins at Lake Päijänne, Finland's second-largest lake with an area of 1,080 km^2 and culminates in a water treatment plant. With its 16 m^2 cross-sectional area, it transfers ten m^3 of water per second and has the capacity for emergency water storage. Implementation of this tunnel had impact on mitigating drought and climate change (Veijalainen et al., 2019).

This significant infrastructure project, apart from ensuring the efficient delivery of water to major southern Finnish cities like Helsinki, carries profound socio-economic and environmental impacts. The construction and operation of the tunnel have fostered local economic growth through job creation, infrastructure development, and increased economic activity. The importance of the Päijänne Water Tunnel extends beyond its role in water supply; it's a testament to advanced construction techniques and materials used to handle high water pressure and maintain water quality, thus contributing significantly to the region's sustainable water management (Archer et al., 2010; Lipponen, 2007; Lipponen et al., 2005).

1.3 Karakum Canal in Turkmenistan:

The Karakum Canal, also known as the Karakum River, is a major hydraulic engineering project in Turkmenistan, conceptualized in the 18th century and realized in the mid-20th century. This canal, stretching approximately 1375 km and constructed between 1954 and 1988, was designed to connect the Amu Darya, Murghab, and Tizen rivers, creating a unified water system. The primary goal was to harness the waters of the Amu Darya River to irrigate the Karakum Desert, with the canal diverting about 13 km^3 of water annually. The project, one of the world's most substantial hydraulic engineering endeavors, has significantly impacted Turkmenistan's economy and landscape (Berking et al., 2017).

The canal has enabled the expansion of irrigated lands for growing crops like cotton, fodder, vegetables, and melons. It has also facilitated the development of fishery farms, the irrigation of desert pastures, and extensive cattle grazing, transforming the arid Karakum Desert into a productive agricultural area (Bekchanov & Lamers, 2016). Large pumping stations were constructed to support these extensive cropping areas. Furthermore, the availability of water from the Karakum Canal has been pivotal in supporting industrial and power engineering activities within the region. The construction and utilization of the canal have not only reshaped the desert landscape but have also contributed significantly to Turkmenistan's economic growth and sustainability (Berking et al., 2017).

Constructing the water conveyance projects that the above three canals were part of overall has pros and cons which are as:

Table 1: Pros and Cons of similar big canals.

Pros	Cons
Increases food and community security in the region.	The quantity of water going to the down stream is dropping, leading to failure of efforts to maintaining the downstream environment
Increases groundwater level and supports sustainable water reservation for the basin area.	Agrarian lands along the path of the tail water will not receive the same amount of water as before.
Mitigates desertification and transforms barren lands into agricultural green areas.	Potential rise in transboundary water conflicts among the neighboring states and stakeholders.
Creates employment opportunities and revitalizes the ecology and environment.	Efforts by international organizations to protect environment and ecosystem may be rendered ineffective.
Prevents internal displacement (IDPs) and international migrations.	
Vegetation impact on climate change resilience (reduces GHGs) and contributes globally.	
Enhances water governance and cohesion between Water Users Associations (WUAs) and Irrigation Associations (IAs).	
Boosts the local economy.	

2. Overview of the North Rivers Basin of Afghanistan

2.1 Background

Afghanistan, situated in Southwest Asia (some scholars consider it part of Central Asia), spans approximately 652,000 km^2. It shares its northern borders with Turkmenistan, Uzbekistan, and Tajikistan, and China lies to its far northeast. Pakistan is located to the east and south of Afghanistan, while Iran is on its western side. The country is characterized by a rugged terrain, with an average elevation of 1,100 m above sea level. Elevations vary widely, from 250 m to as high as 8,000 m, with a quarter of Afghanistan's territory being over 2,500 m above sea level. Afghanistan contains five river basins: the North River Basin, the Helmand River Basin, the Kabul River Basin, the Harirud-Murghab River Basin, and the Panj Amu River Basin, as displayed in Figure 2.

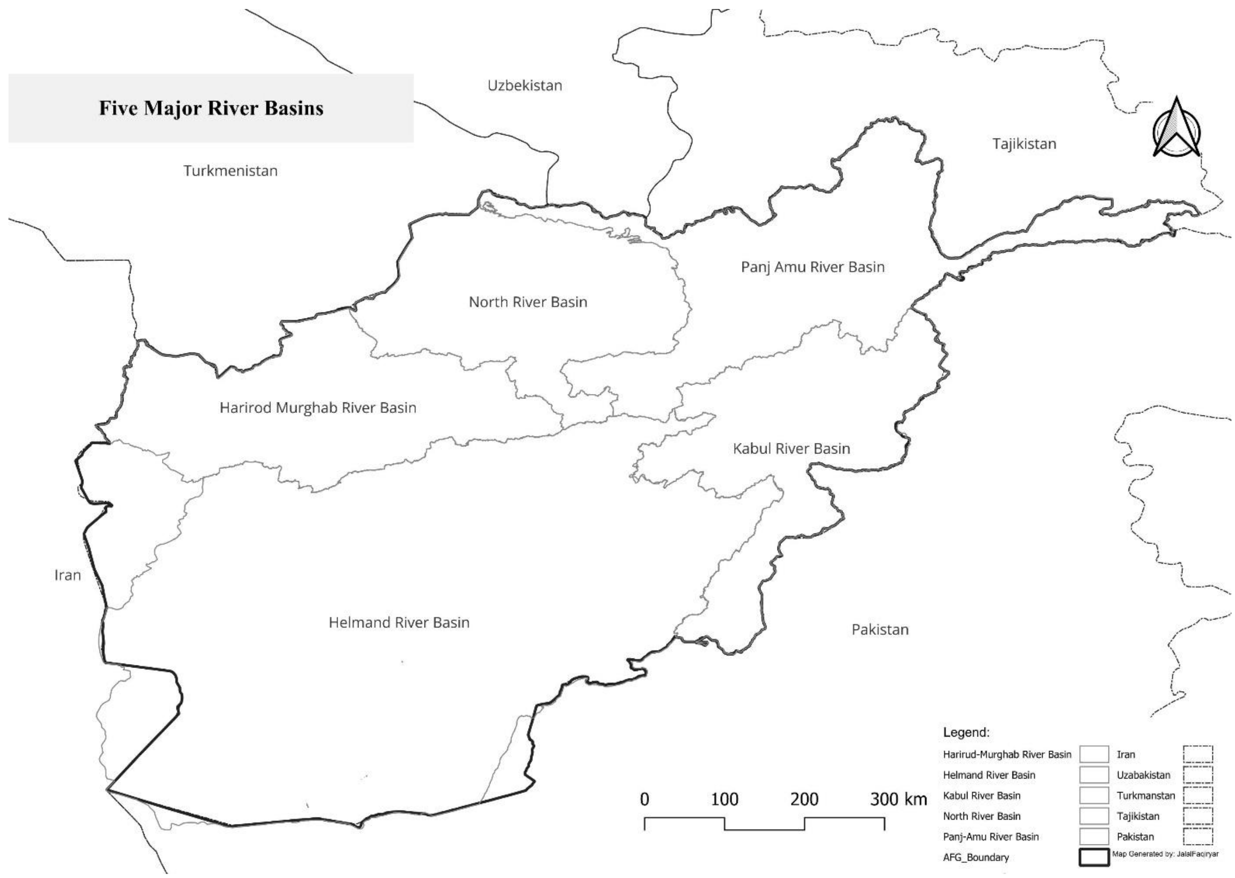


Figure 2: Major River Basins of Afghanistan

These basins are essential components of Afghanistan's hydrological system and play a critical role in the management of its water resources. The shared nature of these river basins with neighbors of Afghanistan presents Afghanistan with challenges in administering water resources, including the need to establish agreements with neighboring countries and to foster cooperation on both bilateral and regional scales. Managing water resources in Afghanistan has been further complicated by a range of factors, particularly the country's prolonged periods of conflict and instability, which have negatively impacted its governance and administration of water-related issues and lack of transboundary frameworks for sharing (Akhtar & Shah, 2020a).

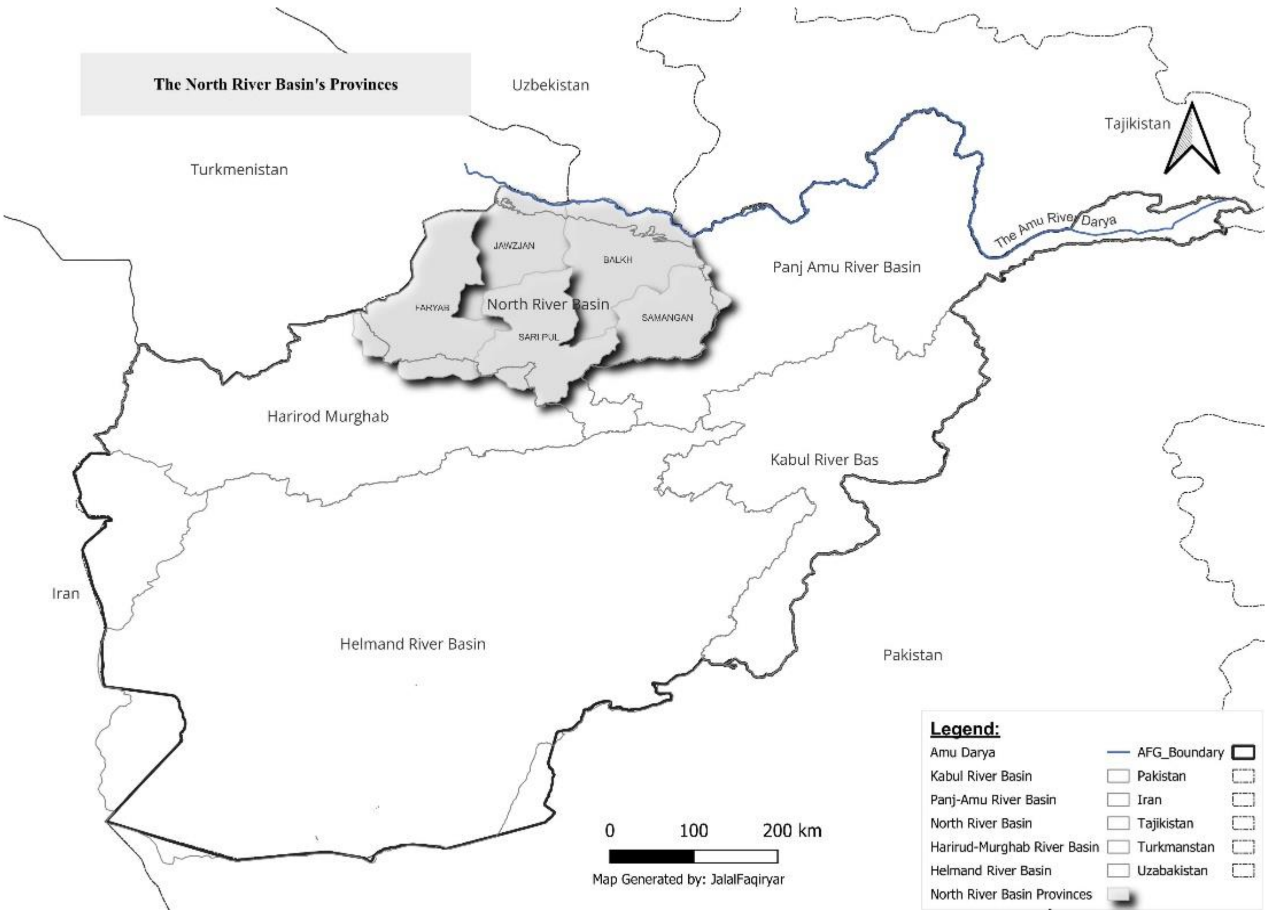


Figure 3: Amu Darya and Five Major River Basins of Afghanistan including the North River Basin Provinces

Five major river basins of Afghanistan have been experiencing a decrease in precipitation, which directly affected and impacted the agriculture and livelihoods of the residents. The North River Basin, which is located on the left bank of the Amu Darya, as displayed in Figure 3, has almost the lowest capacity in terms of water resources (Frotan et al., 2020). However, this basin, with an area of 71000 km^2 in the northern part of the Baba and Hindukush mountains, basically receives more rainfall. With an elevation range of 250 – 4455 m from south to north, it decreases to plain deserts, which do not have enough rain to irrigate and compensate for the need for the residence. Mainly, this river basin includes the provinces of Samangan, Sar-e Pul, Balkh, Faryab, and Jawzjan, as displayed in Figure 13, which the Amu Darya passes on the bank of two of them. In the past, Afghanistan had a significant amount of water resources which were flowing from the Hindukush mountains (Kamil, 2021). In the North River Bain, there are four rivers, Khulm, Balkhab, Sar-e Pul, Shirin Tagab - flowing from south to north as of the Amu Darya River flows from east to west on the north side of the basin. These four rivers are depicted in Figure 4 and extensively elaborated followingly.

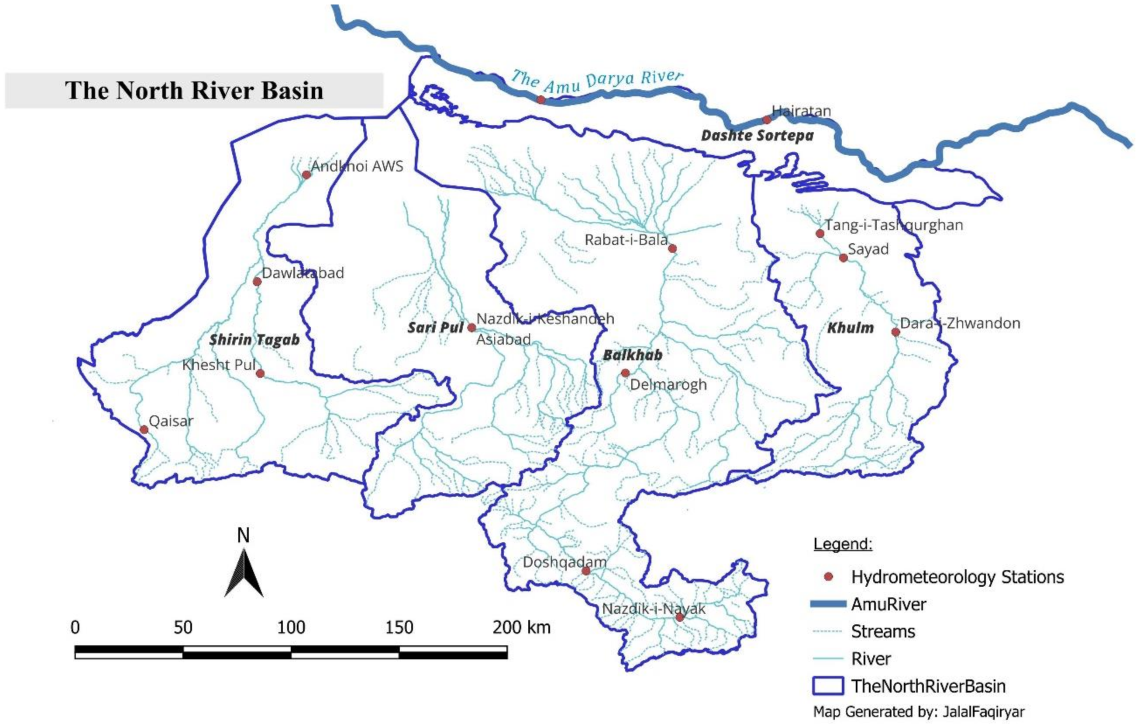


Figure 4: Hydrometeorology Stations in the North River Basin

2.1.1 Amu Darya River

The Amu Darya and Syr Darya are Central Asia's most significant water sources, with the latter originating in Kyrgyzstan. The Amu Darya's source lies in the Panj River's tributaries in Afghanistan's northeastern mountains, specifically from the Wakhan glaciers at an elevation of about 4,900 m. The Ab-i Pamir River, a tributary of the Amu Darya in the north, originates from Zor Kul Lake, which is jointly located in Tajikistan and Afghanistan. The southern tributary, known as the Wakhan River, originates from Chakmatin Lake (Ibrahimzada & Sharma, 2012).

It travels approximately 2,540 km northwest, with 1,250 km of its length within Afghan territory, marking the international border between Afghanistan and its northern neighbors. Major northern tributaries of the Amu Darya include the Vakhsh, Kafirnigan, Surkhan rivers, and Sherabad, while in Afghanistan's southern part, the Murghab and Balkhab rivers, among others like the Kokcha and Kunduz, contribute to the Amu Darya basin. Consequently, Afghanistan and Tajikistan are primary contributors to the Amu Darya's flow.

Other rivers within this basin, not directly feeding into the Amu Darya, are found in Afghanistan, Turkmenistan, and Uzbekistan. These rivers often dry up within their respective countries, earning the moniker 'dead rivers.' Notably, Afghanistan does not have any formal treaty or commitment with its neighbors concerning the regulation of Amu Darya's water usage, while it is the second largest contributor of water resources. Historical negotiations have primarily focused on the river's role as an international boundary rather than on water consumption issues.

The Amu Darya's average water flow stands at about 75 billion m^3 (Ahmad & Wasiq, 2004a; Badescu & Schuiling, 2010), with seasonal variations reaching up to 108 billion m^3 in summer and decreasing to 47 BM^3 in winter. Afghanistan's usage is less than 7% of this total flow, despite being entitled to a 22.5% annual share. By contrast, the anticipated shares for Uzbekistan, Turkmenistan, Tajikistan, and Afghanistan are 29.6 km^3, 22 km^3, 9.5 km^3, and two km^3, respectively (Ahmad & Wasiq, 2004a; Glantz, 2005).

Figure 5 below details the dependency of surrounding countries on the Amu Darya's waters. Uzbekistan and Turkmenistan are the primary users, with 14 million of Uzbekistan's 28 million population and 4 million of Turkmenistan's 5 million population (Central Intelegence Agency, 2021) relying on this water source. Both countries extensively use the Amu Darya for agricultural development, significantly impacting their economies.

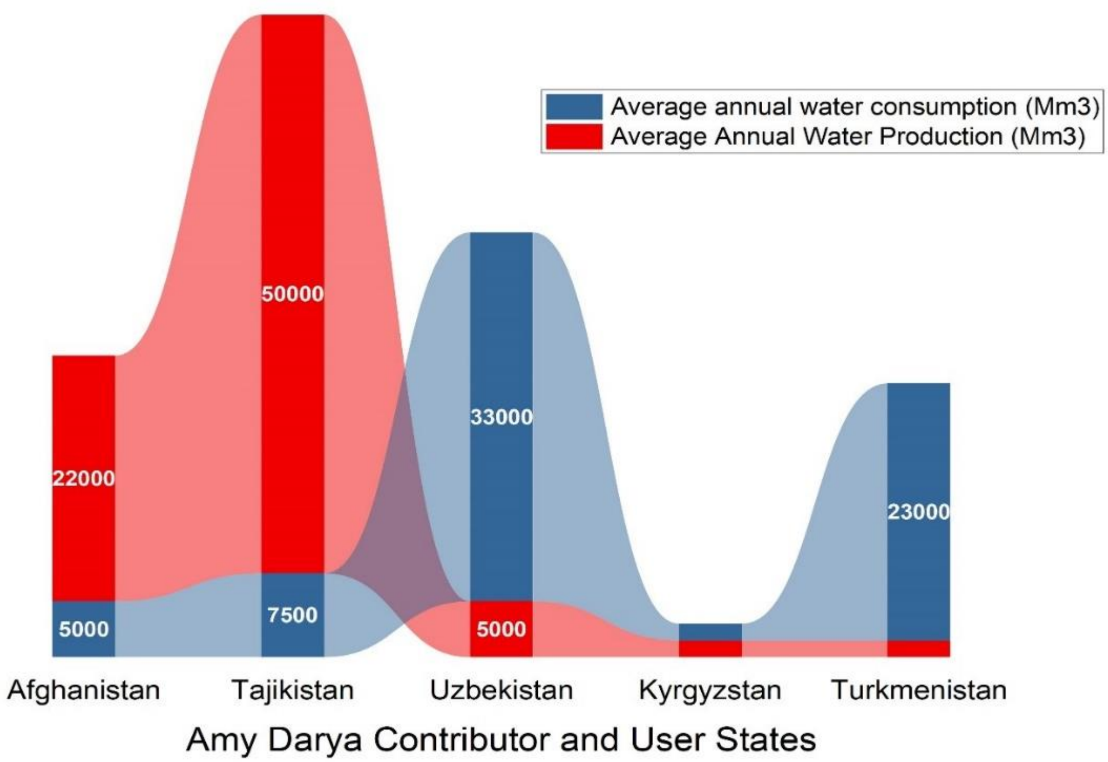


Figure 5: Amu Darya River Contributor and User states. Source: (Ahmad & Wasiq, 2004b)

Afghanistan intends to exercise its rights by constructing dams and expansive irrigation channels, affecting the Amu Darya's water flow. The plans include the development of irrigation and hydroelectric dams on the Kokcha River in Takhar Province, on the Kunduz River in Baghlan Province, and on the Amu Darya in Kunduz Province. Collectively, these projects aimed to utilize up to 6,000 million m^3 of water, enhancing Afghanistan's share by 1.4% (Ministry of Planning, 1976). This increment, when compared to the current average water flow from Afghanistan to the Amu Darya, represents a minimal amount depending on duration and deviated time from the main river and is expected to have a negligible impact downstream. Moreover, the Qush Tepa National Irrigation Canal, drawing water from the Amu Darya to extend to Andkhoi in Jawzjan Province, is projected to consume about 9,000 Mm^3 at peak usage. However, the variability of weather patterns in the region and predictable climate trends are causing concerns among Afghanistan's neighbors, particularly Uzbekistan and Turkmenistan. These countries, having the highest dependency on the Amu Darya's water resources, view Afghanistan's escalating water extraction initiatives with apprehension, worrying about the long-term implications of these plans.

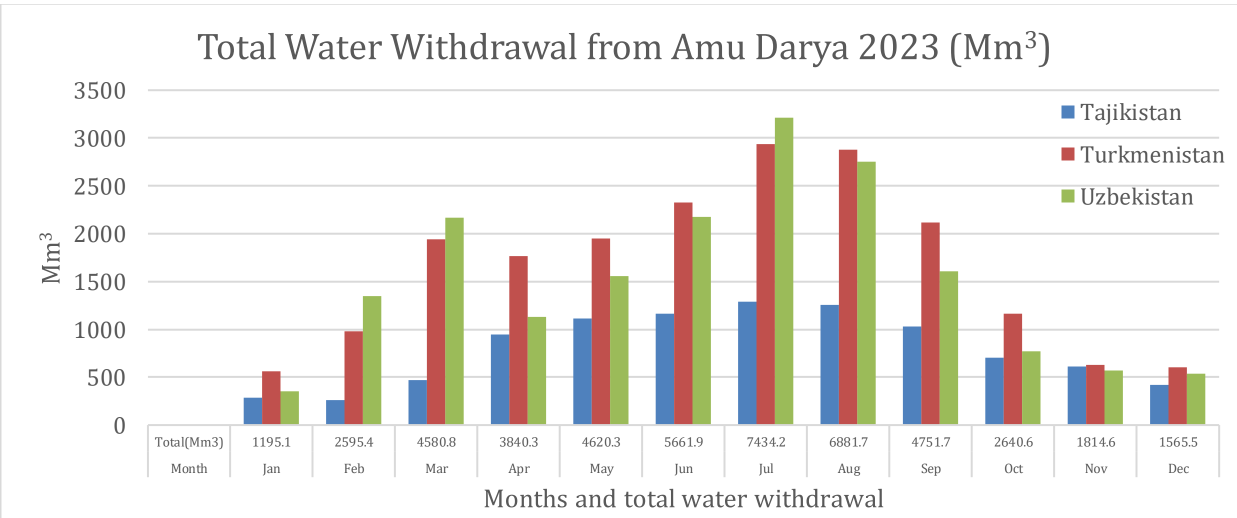


Figure 6: Total water withdrawal from the Amu Darya Source : http://www.icwc-aral.uz/reports_amudarya.htm

The above graph illustrates the recent water withdrawal from the Amu Darya, with total water withdrawal of 47,582 Mm^3 an with comparison to other statistical data and resources, it does not seem realistic with almost 50% reduction in total water flowing or the missing being used by other stakeholders which still do not have any changes in their irrigation fields or water extractions.

To date, Afghanistan lacks a formal agreement with the Central Asian countries regarding the allocation or utilization of the Amu Darya's waters. Discussions held in 1977 in Tashkent between Afghanistan and the Soviet Union did not yield a fruitful outcome. Afghanistan's request for 9 km^3 of water was met with a counteroffer of 6 km^3 from the Soviet side, and no agreement was finalized. This absence of formal treaties or agreements adds complexity to the situation, particularly as Afghanistan progresses with its water extraction endeavors, potentially impacting downstream nations like Uzbekistan and Turkmenistan, which rely heavily on the Amu Darya for their water needs.

2.1.2 A Geographical Outlook on the Source of the Amu Darya River

Afghanistan, with a population of 42 million people as of 2023 according to WorldOmeter.org, has a predominantly rural demographic, with 79% residing in rural areas. However, only 27% of the

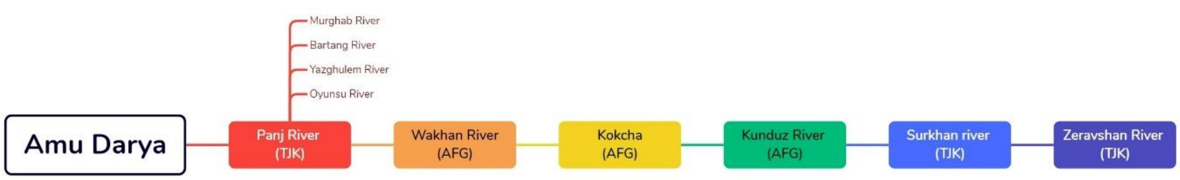
Afghan population has access to clean water sources, a figure that declines to below 20% in rural regions, positioning Afghanistan among the countries with the lowest access rates to clean water globally. A contributing factor to this dire situation is the extensive damage and degradation to the country's infrastructure, exacerbated by internal conflicts between 1992 and 1996, which not only devastated cities but also further impaired water infrastructure.

In the broader context, water stands as a pivotal element for economic conditions in both the region and Afghanistan and plays a strategic role in international affairs. The Amu Darya and Syr Darya rivers are the principal water suppliers in Central Asia. The Amu Darya, in the south part, originating from its tributaries in Afghanistan's Wakhan glaciers and in the north tributary, originates from Kyrgyzstan and flowing through Tajikistan, marks half of its course along Afghanistan's border with northern countries. The river begins its journey from the confluence at the Wakhan glacier region with the Panj River, originating from Lake Zorkul from Kyrgyzstan (Eastern Pamir) which is the longest river in Tajikistan, and upon joining with the, Gunt, Bartang, Vanj and Vakhsh River from Tajikistan, it is thereafter known as the Amu Darya, eventually draining into the endorheic Aral Sea.

Within Afghanistan, the Amu Darya Basin is divided into three sub-basins, comprising several major rivers including the Wakhan, Pamir, Badakhshan, Kunduz, and Kokcha, which are the primary contributors to the Amu Darya's flow in northern Afghanistan (Ahmad & Wasiq, 2004a). Additionally, adjacent river systems such as the Khulm, Balkh, Sar-e Pol, and Shirin Tagab, mainly utilized locally, and to a lesser extent contribute to the Amu Darya, are collectively referred to as the 'Kur' river system. Moreover, the basin encompasses several transboundary river systems that move northward but do not feed into the Amu Darya, including the Murghab River, which connects to the Qaraqum Canal drawing from the Amu Darya, and the Hari River, which also forms part of this intricate network.

2.1.3 Rivers that flow towards the Amu Darya:

In its eastern section and source region, the Amu Darya River is fed by several significant tributaries. These include the Kunduz River, with a catchment area of 31,300 km^2, the Kokcha River, whose catchment area varies between 21,100 and 21,900 km^2; and the Badakhshan Rivers, covering an area of 30,800 km^2. Additionally, upstream of the Amu Darya lie the Wakhan and Pamir rivers, with the Badakhshan rivers encompassing the Pamir and various smaller rivers (Refer to below as brief and to Figure 22 for detailed).



The Kunduz River originates from the Shibar Pass in the Hindu Kush mountains. It has two left tributaries, Saighan and Kamard, while its right tributaries include the Andarab River, originating from the Uak Pass at an elevation of 1,366 m, with two main tributaries of its own, Arzu and Banu. Another right tributary, the Khanabad River—which includes tributaries like Warsaj, Host, Chal, and Nark—joins the Kunduz River near the village of Yakali Zad, flowing through a narrow valley toward the village of Chori. The Khanabad River spans 400 km, reaching a width of 150-200 m and a depth of three meters downstream.

The Kokcha River, formed by the confluence of the Jirm, Warduj, and Zardav rivers near Faizabad, the capital of Badakhshan province, flows through a narrow valley. After Faizabad, it is joined by the Daryim, Kishim, and Toshkan rivers, eventually emptying into the Amu Darya near the village of Kal Zanum. This river stretches over 320 km, with a width of 10-12 m and a depth of 1-2 m along its course.

Furthermore, the Wakhan River, upstream of the Amu Darya, begins at an elevation of 4,900 m from the Wakhan glaciers. After merging with the Pamir River, it forms the Panj River, and upon joining the Vakhsh River, it becomes known as the Amu Darya, highlighting the interconnectedness of these waterways and their crucial roles in the region's hydrology.

2.1.4 Influent/blind Rivers

The Amu Darya basin encompasses local river systems, referred to as "blind rivers," which include the sub-basins of Khulm, Balkh, Sar-e-Pul, and Shirin Tagab, covering an area of 49,000 Km^2, mainly there are national rivers and consumed withing the country. The flow from these rivers is fully utilized within their respective sub-basins and does not contribute to the Amu Darya. These rivers are termed "blind" because they do not naturally discharge into the Amu Darya or any other significant river system, instead disappearing into the desert. A distinct area of 72,500 km^2 lies between the Amu Darya and these blind rivers, characterized by a lack of surface water sources and outlets as seen in Table 1.

The Khulm River, originating from the Koreh Kotal at an elevation of 3,600 m, traverses a narrow valley before widening near Tash Qurghan. Its total length is 320 km, draining a basin of 8,400 km^2. The Kabul to Mazar-i-Sharif Road runs parallel to this river.

The Balkh River, known locally as Band-e Amir (Guz Dara), springs from five lakes fed by abundant underground water in limestone-rich areas. Midway through its course, it is called Vadaab, with the Darya-ye Suf as one of its significant right tributaries. The river spans 400 km, covering a basin area of 18,700 Km^2.

Originating from the Baba mountains' springs, the Sar-e-Pul River, also known as Safid, converges near the city of Sar-e-Pul. It stretches 215 km, with its width ranging from 15 to 20 m in the middle sections and a depth of 20 m. The basin area is estimated to be between 7,800 and 9,400 Km^2.

The Shirin Tagab River begins from the Tirbandi-Turkestan mountains' northern slopes near Gorzamin, with Maimana, fed by the Abu Qaisar and Almar streams, as one of its tributaries. The basin area is approximately 13,600 Km^2.

Acknowledging the critical nature of Afghanistan's water resources, particularly in northern provinces like Balkh, Jawzjan, and Faryab, which face drought and water scarcity, is essential. Accurate identification and understanding of the Amu Darya's water potential are vital for planners to optimally utilize this resource. Recognizing the geographical sources of the Amu Darya is crucial for policymakers and negotiators to uphold Afghanistan's water rights amidst neighboring countries' opposition. Afghanistan is entitled to 27.5% of the Amu Darya's annual flow based on its contributing rivers and tributaries, yet current utilization is less than 8%, with neighboring states often opposing Afghanistan's endeavors to use its share of the Amu Darya's waters.

2.2 Hydrology

The Amu Darya, recognized as Central Asia's most expansive river and the second longest in Afghanistan, flows across six countries: Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. Stretching 2,540 km from its origins at the sources of the Panj (Pyandzh) River to its terminus at the Aral Sea, its name is officially given at the point where the Panj and Vakhsh rivers converge in the Pamir Mountains. Originating in Afghanistan, Tajikistan and Kyrgyzstan, it serves as a vital resource shared by these nations. Along its journey, it is fed by important tributaries like the Kunduz and Kokcha rivers on its left side, and the Kafirnigan River on its right, enriching the ecosystems and communities it passes through.

The Vakhsh River, coming from the Kyzyl Suu in Kyrgyzstan, holds the distinction of being Tajikistan's longest river, running from the northeast to the southwest across the country, starting from an elevation above 3,500 m in some of Tajikistan's most elevated regions. The name Vakhsh originates from where it meets the Surkhob and Obikhingob rivers. The Panj River, a major contributor to the Amu Darya, rises from the Pamir Mountains, forming almost the entire Tajikistan-Afghanistan border. After joining with the Vakhsh River, the river is named the Amu Darya, which then flows about 100 km before leaving Tajikistan, delineating the border with Uzbekistan.

Hydrologically, the upstream catchment area of the Amu Darya Basin, which feeds into the main river, encompasses 309,000 km^2, as measured at the Kerki Gauging Station in Turkmenistan.

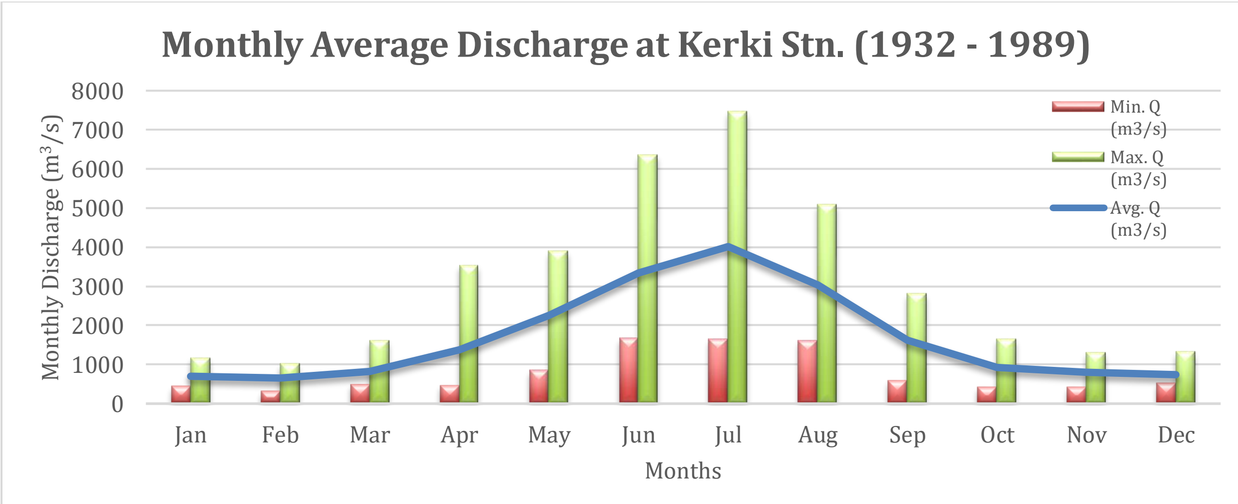


Figure 7: Monthly Discharge at Kerki Gauging Station (1932 - 1989) in Uzbekistan. Data source: https://www.compositerunoff.sr.unh.edu/html/Polygons/P2917110.html

The annual average water resources available in the Amu Darya Basin are estimated 75 Bm^3 (Kamil, 2021; Sanu Khanal, Corjan Nolet, Mehriddin Tursunov, Johannes Hunink, 2023) at 75,000 – 80,000 (Bm^3) for surface water and up to 25,000 hectometers cubed (hm^3) for groundwater. The availability of water resources in the basin varies annually, ranging from 58,000 hm^3 to 109,000 hm^3.

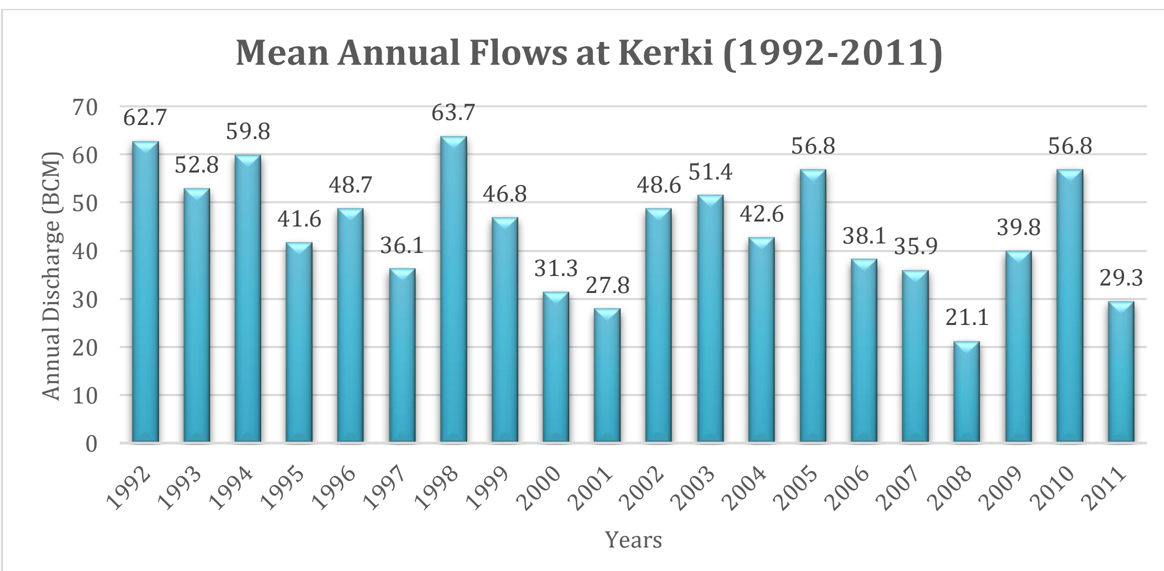


Figure 8: Annual Discharge of Amu Darya at Kerki station. Source: https://www.adb.org/sites/default/files/project-documents//44458-012-tacr-01c.pdf

The water resources mainly flow from the south of the Qush Tepa canal in the North River Basin, where various mountains such as Hindukush mountains and Baba mountains, are located, to the north direction, where the Amu River flows. Figure 9 illustrates the hypsometry of Afghanistan. Each of the flowing streams in each sub-basin is called a river, and they are:

Table 2: Influent/blind Rivers Flowing Toward Amu Darya in the North River Basin.

Sub-rivers	Length (Km)	Area (Km^2)	Discharge (m^3/sec) (2008 - 2017)
Khulm River	230	8400	3.2
Balkhab River	400	18700	53.9
Sar-e-Pul River	215	7800	6.9
Shirin Tagab River	320	13600	2.7

Differences in the annual average discharge of the above rivers compared to flow in 1969-1978 are 12, -21, 25, and 12, respectively (Frotan et al., 2020).

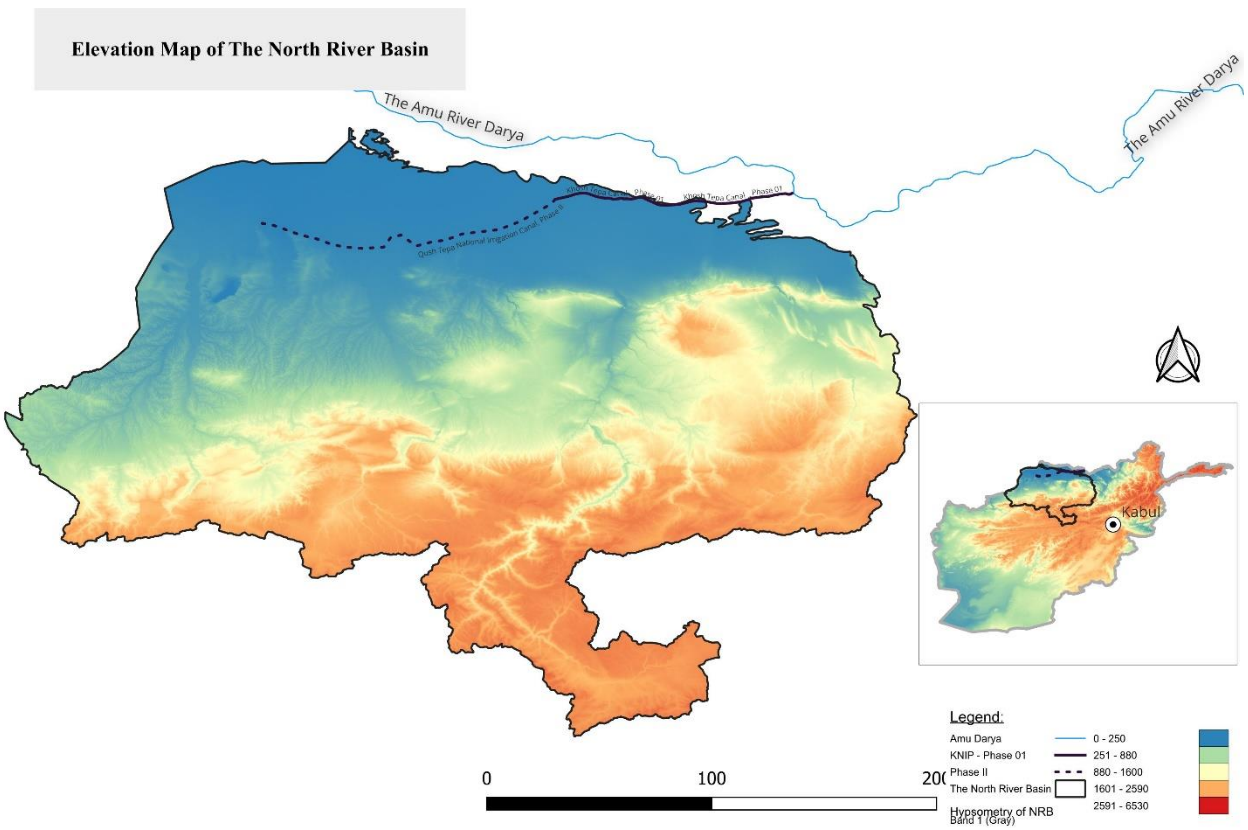


Figure 9: Hypsometry of the North River Basin.

The Khulm River crosses the highway between the two main cities of Afghanistan, Kabul and Balkh provinces, and originates from the 3600 m height of the Hindukush mountains near the Kotal or pass of Kara. This river flows through narrow gorges and small valleys, which finally cross the mountainous part to the plain area of Tash Qurghan town. Similarly, The Balkh River, also called Dare e Gez in the middle regions called Vadkhab, effuses the groundwater and creates natural lakes in the upstream part. Dara-e Soof tributary confluences this river at the upper part. This river also merges with waters flowing from Band-e Amir from Bamiyan province.

Moreover, precipitation accumulation in small mountains creates the Sar-e Pul River, which mainly originates from the Baba mountains and meets all the small streams at Sar-e Pul town, finally establishing this river. Moreover, the range of Tirband-e Turkestan mountains of its northern part establishes the Shirin Tagao River. The main tributaries of this river are the Maimane River, the Abi Kaysar River (Qaisar River) seasonal river, and the Almar River.

The total rainfall in these four sub-catchments, which passes within the four administrative provinces in the North River Basin, drains finally not into the Amu Darya River.

2.3 Geology

In the North River Basin, at the eastern location of the Balkh province in the Kaldar district, across the Amu River toward the southern–west, there are several types of soil qualifications which are already studied in deep followingly:

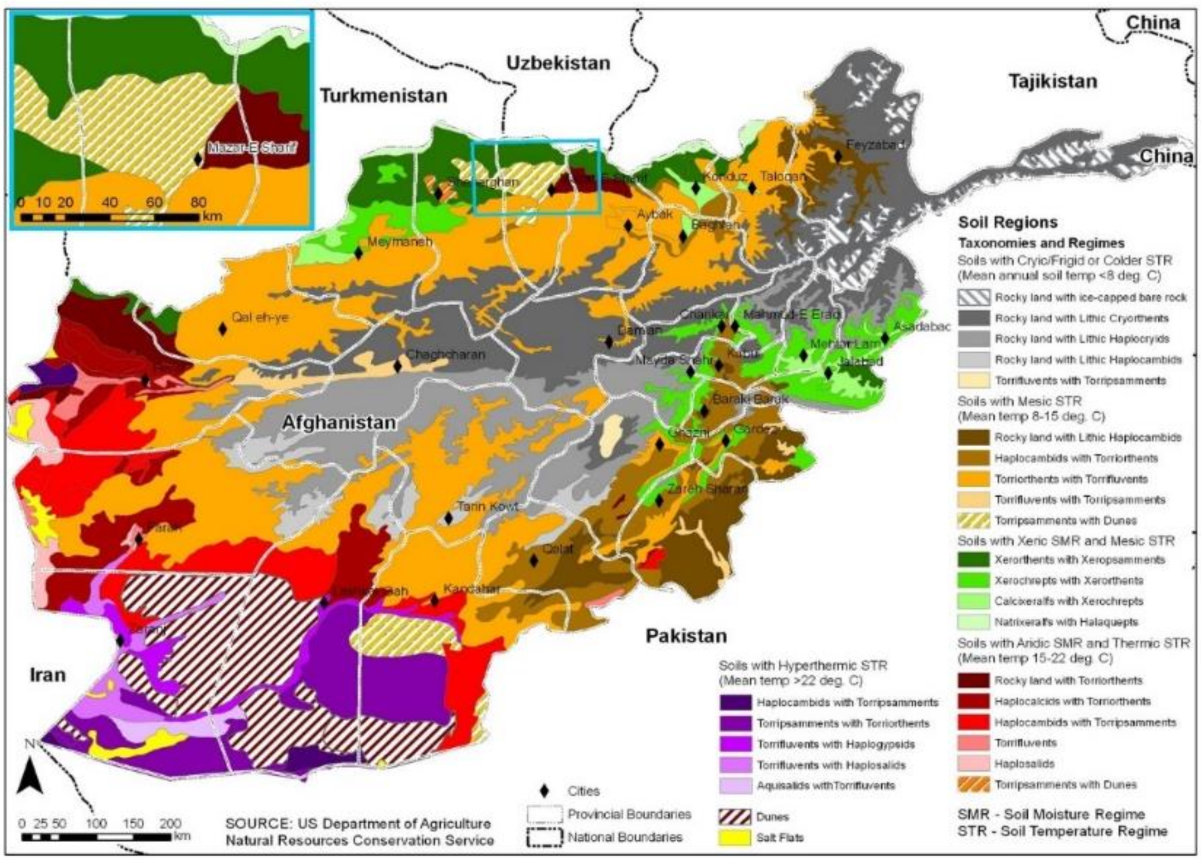


Figure 10: Soil Map of Afghanistan. (source: FAO.org)

At the initiation area of Qush Tepa canal and its headworks, drawing from the research conducted by Meskin (1968) and further elaborated by Banks et al. (2005) and the Ministry of Planning (2016), it has been discovered that the Quaternary sedimentary deposits in the vicinity of Mazar-e-Sharif city measure up to 70 m in depth. These deposits extend to a depth of 170 m in the city's northern regions, characterized by desert and saline soil conditions, and to 90 m adjacent to the Amu Darya River. In the surrounding areas of Mazar-e-Sharif, gravel is the predominant type of Quaternary sediments. Between Mazar-e-Sharif and the central desert, there exists an aquifer comprising conglomerate, gravel, and sand at the Quaternary sequence's base, with most sections being under 20 m in depth. The central desert showcases sandy layers interspersed with clay, where the sand layers at the base increase in thickness significantly as one moves closer to the Amu Darya River. On both the western and eastern sides of this river, the Quaternary deposits are marked by thick layers of gravel, occasionally mixed with clay layers. To the south, along the route of the Qush Tepa canal, sediment depths are recorded at 115 m in TW-340, 123 m in TW-338, and 265 m in the city of Balkh in TW-287. The greatest depths of Quaternary sediments within Mazar-e-Sharif are observed at 286 m and 487 m. Additional information on the canal's downstream area is provided by Banks (2016), with the average sediment depth noted as 108 m. The northern basin's recharge is facilitated through two primary mechanisms:

1- A fixed recharge from groundwater, which is approximately 10% of the yearly average rainfall.
2- The second approach utilizes a higher proportion of the annual rainfall for recharging in softer geological formations, such as Quaternary and Neogene aquifers, as well as in carbonate rocks, with a reduced rate of recharging in solid bedrock. The annual water consumption for agricultural irrigation ranges from 7,000 to 8,000 m^3 per hectare, with an estimated 5 to 10 percent of this volume allocated for residential needs.

In the vicinity traversed by the canal, the geological makeup is characterized by aeolian (wind-deposited) and fluvial (water-deposited) sediments from the Quaternary period, which are prevalent across the northern desert landscapes. The Quaternary sediments are categorized into two main types: semi-fluvial deposits found in hilly and sloping terrains, consisting of sandy and gravelly terraces adorned with widespread cobblestones that blanket the entire area.

Within this geographical region, eight distinct subgroups of Quaternary deposits have been identified, out of which only four are of significant hydrological importance. These crucial groups comprise loam and sandy loam layers interspersed with clay and sand, situated under dense and unbroken gravelly debris layers. The loam and sandy loam layers, with their intermittent positions and occasional sandy loam interlayers, frequently encapsulate rock and loam fragments of varied sizes. In certain areas, these deposits are also notable for their gravelly composition beneath the clay and sand interlayers.

Furthermore, focusing on Mazar-e-Sharif's surface geology, it exhibits a diverse soil composition. Specifically, the Q34 unit in Mazar-e-Sharif comprises conglomerates and sandstones (ranging from Lutetian to Late Pleistocene periods) alongside alluvium, broken deposits, gravel, and sand, which are found in greater quantities than silt and clay. The geological makeup along the Balkh

River, from its confluence with the lower Balkh system to its termination in the Aqcha area, is represented by the Q4a unit. This unit mirrors the composition of the Q34a unit but lacks the older Pleistocene formations (Muradi et al., 2013).

2.4 Precipitation

Several hydrometeorological stations are positioned along or near the Qush Tepa Canal, from its origin to its terminus in the North River basin, as shown in Figure 4. The Hairatan Station, situated at the Amu Darya's headwaters, along with Rabat-i-Bala in the midpoint and the Andkhoi station at the canal's end, each plays a crucial role. Their strategic locations at the canal's start and finish are vital for accurately estimating precipitation levels and other hydrometeorological patterns. These stations are essential for analyzing and forecasting the water situation in the canal, including its command area.

The monthly mean precipitation recorded at Andkhoi Annual Weather Station (AWS) is provided in Figure 11. The annual average precipitation recorded at Andkhoi is in the order of 117 mm for an observation period between 2012 and 2017. According to the patterns, the basin's hydrology has undergone substantial change over, such as population, land cover and hydrological declination the course of the last several decades (Akhundzadah et al., 2020).

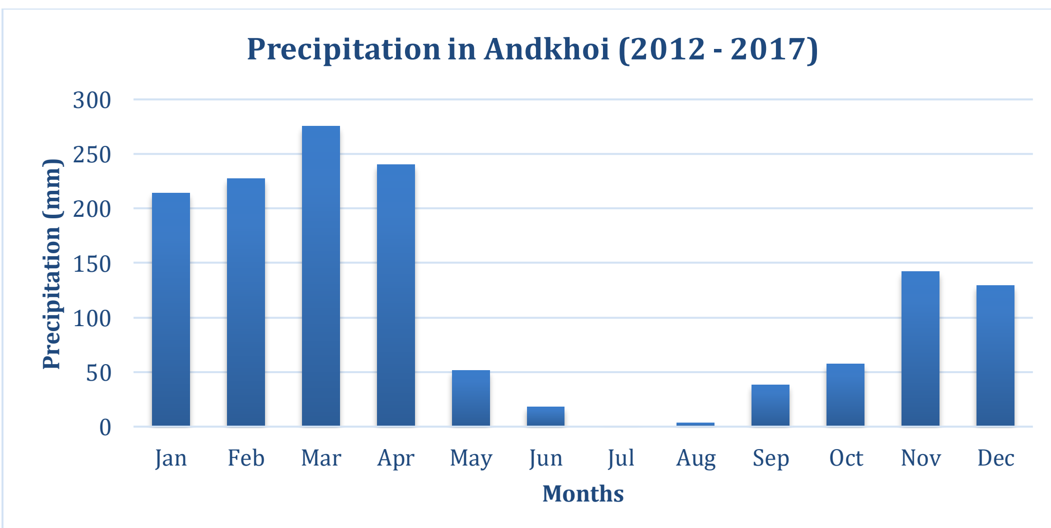


Figure 11: Total Rainfall at Andkhoi Station for (2012 - 2017)

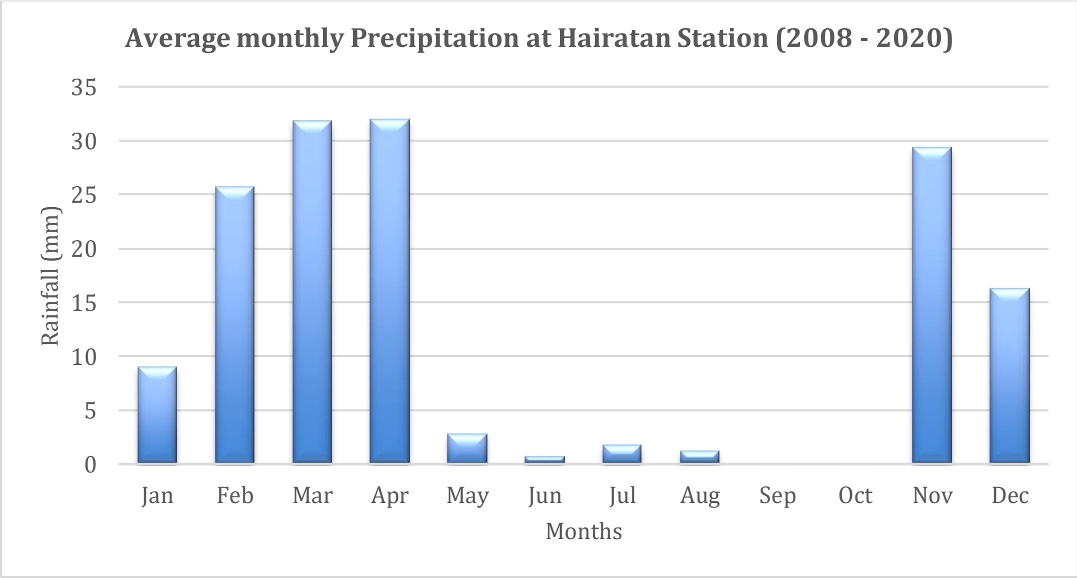


Figure 12: Average Monthly Precipitation at Hairatan Station.

Figure 12 depicts the average monthly rainfall at Hairatan stations which is located near the Amu Darya in adjacent to Uzbekistan. This station is significant for studying the croplands which are located nearby and frequently data is recorded at this station.

2.5 Humidity

The monthly mean relative humidity (%) recorded at Andkhoi AWS is shown in Figure 11. The mean relative humidity in the project area ranges from about 76% in winter, 16% during the dry summer months and 45% on average. Humidity is typically highest in the early morning, decreases during the day, and drops down to 10% during hot summer days for most of the region.

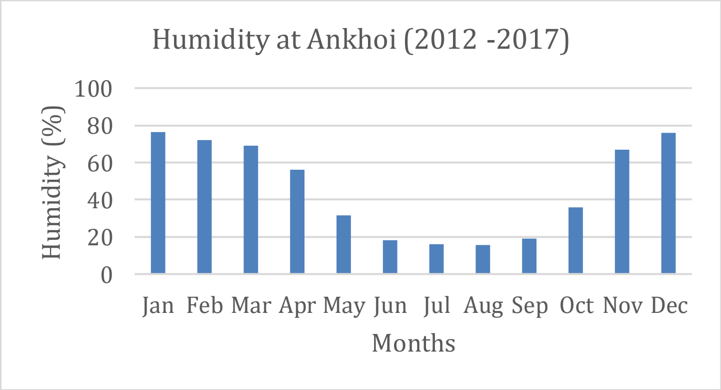


Figure 13: Humidity at Andkhoi Station (2012 - 2017)

2.6 Climate

The climate of Afghanistan varies from one river basin to another, and it is divided into six types. Dry and desert warm, mountainous, Mediterranean, steppe, seasonal, and Thunder Alp. According to experts, Afghanistan is one of the nations with the worst physical water shortage on Earth (Akhtar & Shah, 2020b; Ranjan, 2020) and it is located at sub-tropical latitudes, but the topography, in particular the range of high mountains in the middle of the country, is the determining factor in its climate and precipitation. Areas to the north of the high mountains and ridges have a dry, continental climate. In the northern valleys, annual precipitation averages 300

mm, most falling from December to May, while in the north overall, annual precipitation averages 400 mm/y. The areas to the south of the high mountains are characterized by a less continental climate: summer is relatively cool, winter is relatively moderate, and rainfall is higher. Precipitation in the east and southeast is near 800 mm annually, concentrated in the summer when the monsoon brings rain, and elsewhere in the south, annual precipitation averages 170–196 mm. The average annual precipitation on the northern plains is 125 mm, and the average on the southern plains is 110 mm.
While the overall national average temperature in July is +32 °C, and in January −2 °C, temperatures drop to −50 °C in the Hindu Kush mountains, while in the deserts (Dasht-e Margo), summer temperatures reach +50 °C.

In the North River Basin from Kaldar district in Balkh to Andkhoi district in Faryab are influenced by the local steppe climate (Shroder, 2014). The average annual temperature in Andkhoi is 18.9°C. Temperatures fall below freezing during winter nights and rise sharply in spring, reaching up to 50°C during summer. The highest temperatures are due by mid-July, whilst the lowest temperatures occur in December and January. In Andkhoi, the average annual rainfall is in the order of 233 mm (about 9.17 in), which, in fact is far below the requirements of the region.

Within the mentioned site and its close vicinity, Andkhoi Automatic Weather Station (AWS) and Hairatan AWS are the meteorological stations with the current records. Andkhoi AWS, which was installed at elevation 306 msl, represents the climatic conditions of the irrigation area at tail water of the canal, while Hairatan being located at elevation 300 msl, characterizes the conditions at the proposed intake location. The project area is mainly located in between these meteorological stations. The location of these meteorological stations and thematic maps of climate properties sourced by historical meteorological stations are presented in Figure 04 and Figure 12, respectively.

Our analysis in Figure 14 examined the average temperatures in the Hairatan station between 2006-2023 with the RCM 4.5 and 8.5 models. The average annual temperatures during this period were found to be 18.3 and 18.2 °C, respectively. This research argues that the average temperature by 2050 will be 18.7 and 19.2 °C for the respective models, and by the end of the century, it will reach 19.4 and 21.0 °C. These results indicate that the temperature at this station will increase by 1.1 and 2.8 °C with average temperature, respectively.

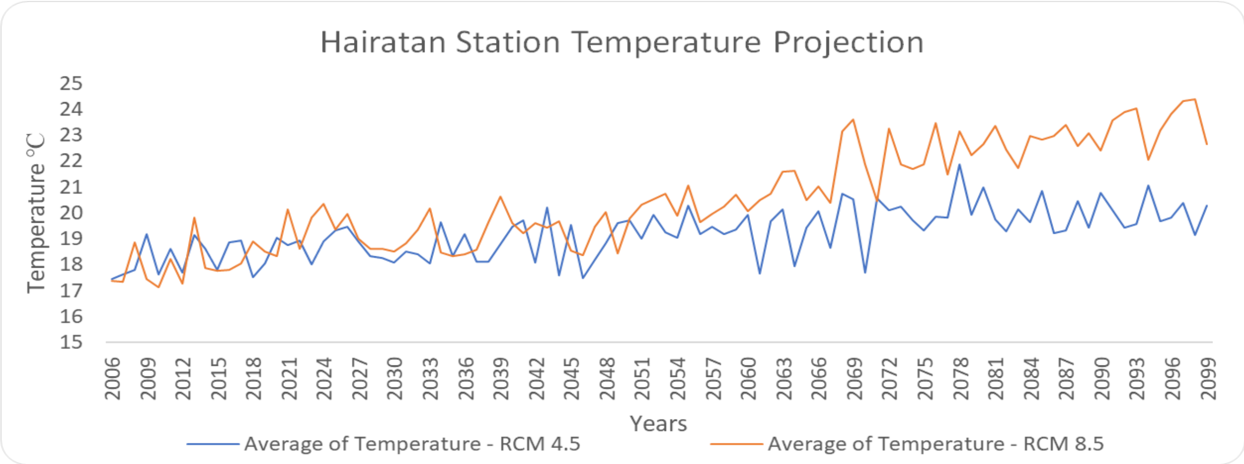


Figure 14: Projection of Climate Change to the End of the Century.

The study furthermore in Figure 14 examined the precipitation at Hairatan station from 2006 to 2023 using RCMs of 4.5 and 8.5 models. The average precipitation recorded during this period was 149.15 and 204.8 mm/year, respectively. The analysis of the models revealed a slight decrease in rainfall at this station in the years 2050 and 2099. The average precipitation by 2050 with these models will be 146 and 148 mm, with slight differences for the respective models. By the end of the century, it will reach 138 and 145 mm/year, respectively. This indicates a reduction in rainfall of 12 and 60 mm/year, respectively.

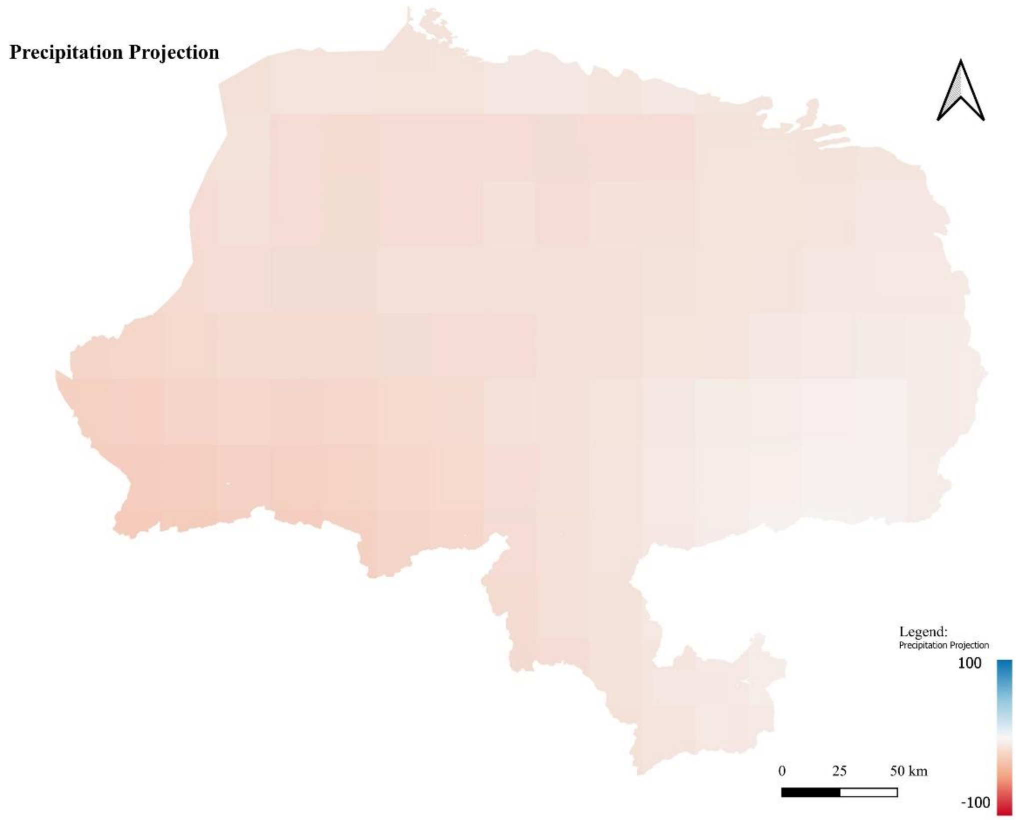


Figure 15: Precipitation projection for the North River Basin Utilizing GEE

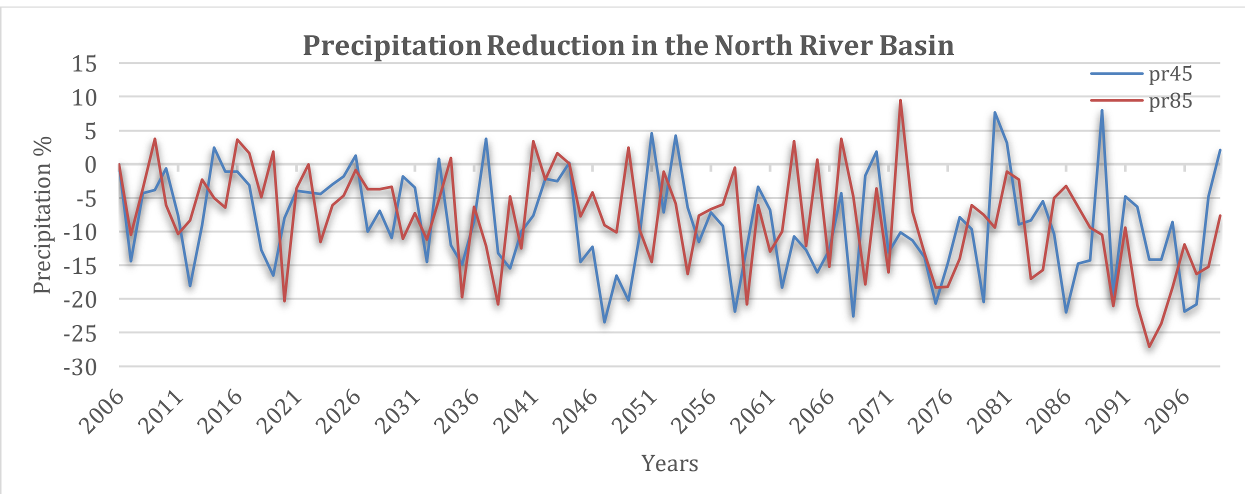


Figure 16: Precipitation Reduction Percentage over the Years Utilizing GEE.

Figures 15 and 16 illustrate the precipitation projection and the percentage reduction in rainfall throughout the century in using RCMs of 4.5 and 8.5 models. They reflect a significant reduction in rainfall across the years, showing that two decades later there will be an almost 25% reduction in rainfall, and this trend continues forward. The below figure projects specifically the rainfall at Hairatan station in the North river basin.

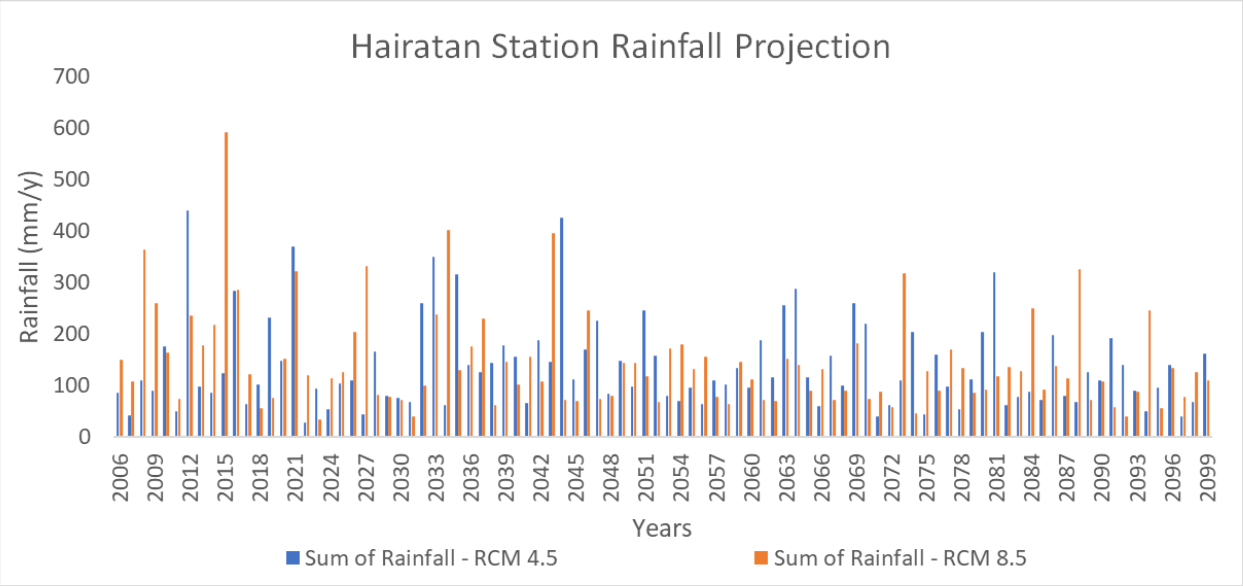


Figure 17: Rainfall Projection at Hairatan.

2.7 Cropland Monitoring in the North River Basin

Over the two decades from 2001 to 2022, the cropland area, based on band 12 and 14 MODIS products in the region, has experienced significant variations. Initially, there was an increase in cropland from 2001 to 2003, indicating a period of agricultural expansion. However, following this period, there has been a noticeable reduction in cropland areas across the entire region. This decline in agricultural land points to a significant reduction in vegetation cover, which raises concerns regarding hunger and food insecurity within the country. The decrease in cropland not only impacts the availability of food but also highlights the vulnerability of the region's agricultural sector to changes, potentially driven by factors such as environmental degradation, climate change, or socio-economic shifts. Addressing these challenges is crucial for ensuring future food security and sustainable agricultural development.

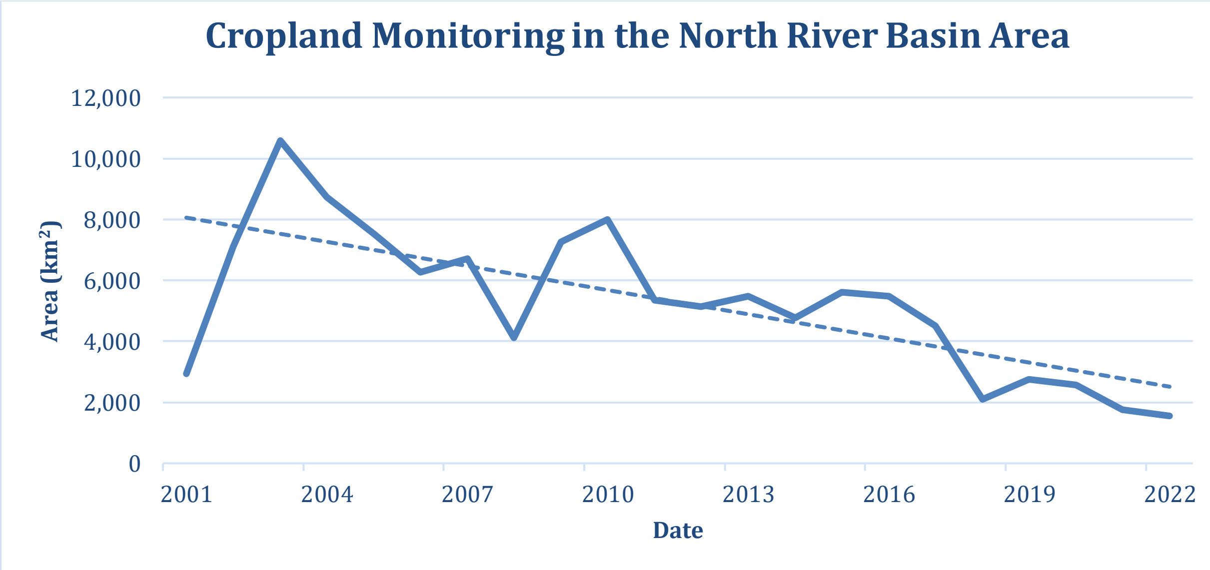


Figure 18: Cropland Analysis and Monitoring in the North River Basin

2.8 Drought Analysis of the North River Basin

For the north basin of Afghanistan, this study utilized Google Earth Engine (GEE) for several key indices to assess vegetation health and conditions: NDVI (Normalized Difference Vegetation Index), VCI (Vegetation Condition Index), TCI (Thermal Condition Index), and VHI (Vegetation Health Index). These indices were derived from MODIS (Moderate Resolution Imaging Spectroradiometer) satellite imagery, which provides data at a 1 km spatial resolution. Our analysis is based on a time series spanning from 2001 to 2024, formatted on a monthly basis.

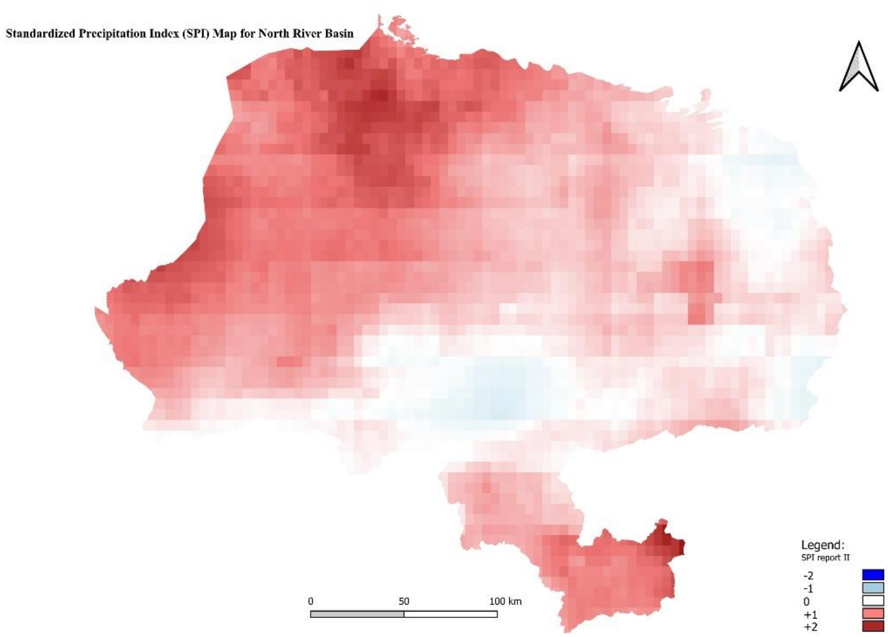


Figure 19: Standardized Precipitaton Index (SPI) Map for the North River Basin

The above figure illustrates the severity and intensity of droughts where precipitation is reduced and droughts are apparent. GEE is utilized to indicate the Specific Precipitation Index (SPI) based on 16 days images into monthly periods.

The NDVI data, which indicate vegetation greenness, were processed from 16-day composite MODIS images using a scale factor of 0.0001 to ensure values fell within the correct range (-1 to +1). This adjustment is crucial for converting the raw MODIS NDVI readings into usable indices that reflect actual vegetation health.

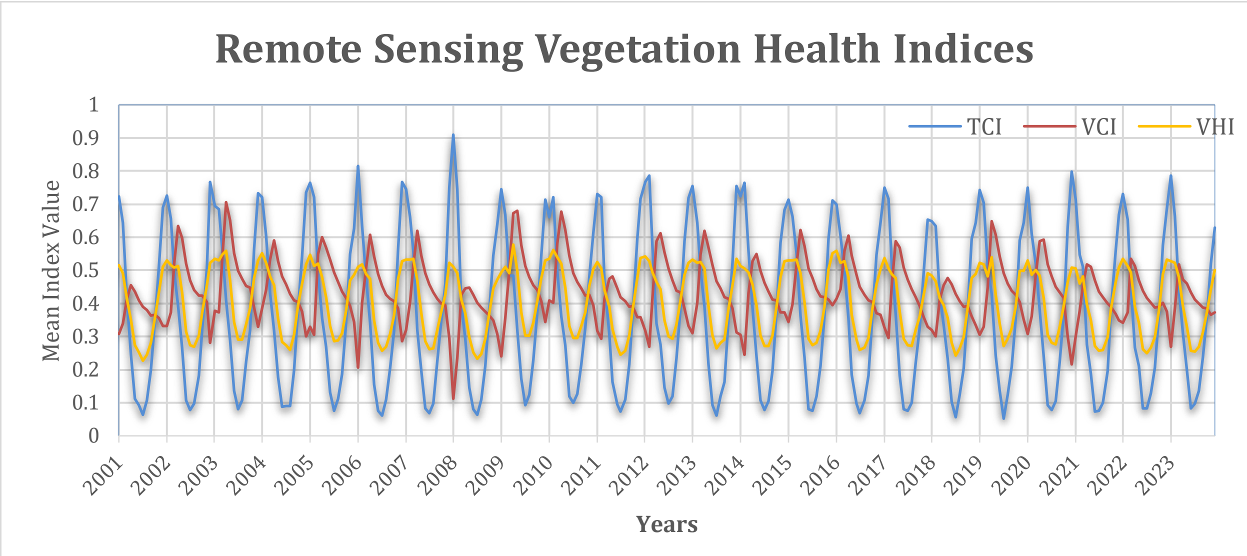


Figure 20: Composition of TCI, VCI and VHI for the North Basin Using GEE wi 16 days Return Period.

For temperature data, which affects the TCI, we opted for 8-day composite averages due to the original daily images being plagued by various inaccuracies such as errors, noise, cloud cover, and sensor issues. Applying a scale factor of 0.2 to these images helped mitigate such problems, enhancing the reliability of the temperature data.

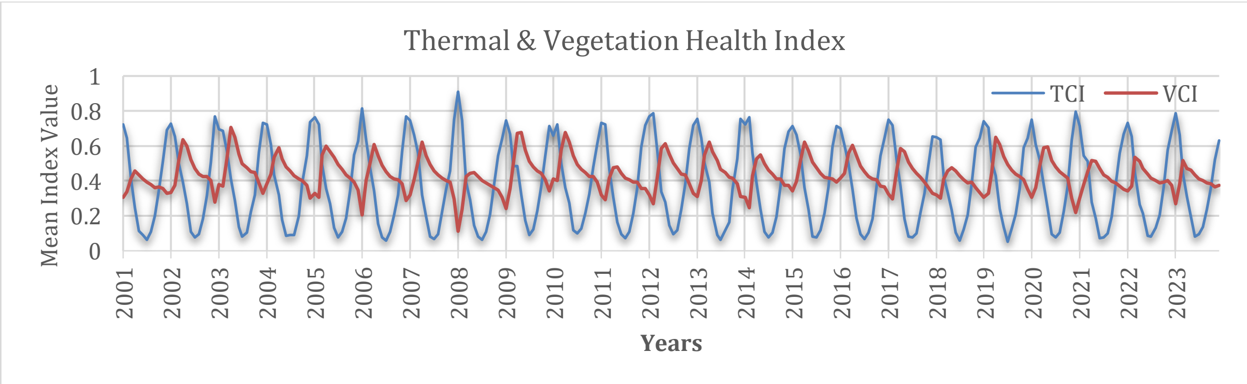


Figure 21: TCI and VCI Illustration for the Vegetation in the North Basin with reduction of 16 days images into monthly Periods.

High TCI values signify increased dryness in vegetation, which can be interpreted through temporal fluctuations as changes in the level of dryness over time. Similarly, the VCI, depicted in red plots, gauges moisture content within the vegetation. An increasing VCI indicates rising moisture levels, whereas a decreasing trend suggests a reduction in vegetation moisture.

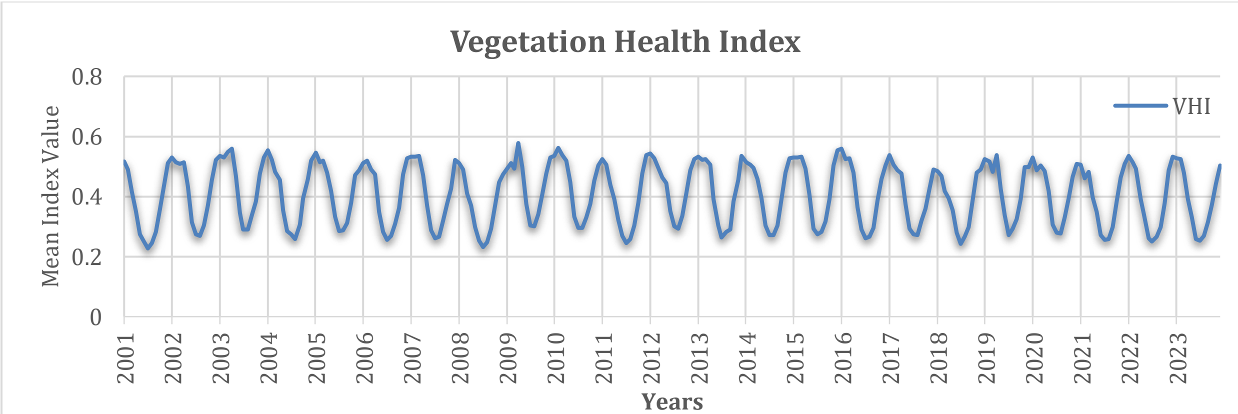


Figure 22: Vegetation Health Index Illustration for the North Basin.

VHI, on the other hand, provides a comprehensive measure of vegetation health. High VHI values, which coincide with abundant vegetation cover and chlorophyll presence, denote healthy vegetation conditions. Conversely, low VHI values signal poor vegetation health or a lack of vegetation, indicative of unfavorable conditions. It's normal for VHI to fluctuate with the growing season, peaking during optimal growth periods and declining afterwards. However, a long-term downward trend in VHI suggests deteriorating vegetation health in the region, which is a concerning indicator for the north basin's ecological stability.

Based on the World Bank, (2024) report, Afghanistan is facing a warming trend that exceeds average global rates, with temperatures projected to increase between 1.4 and 5.4 C° by 2090.

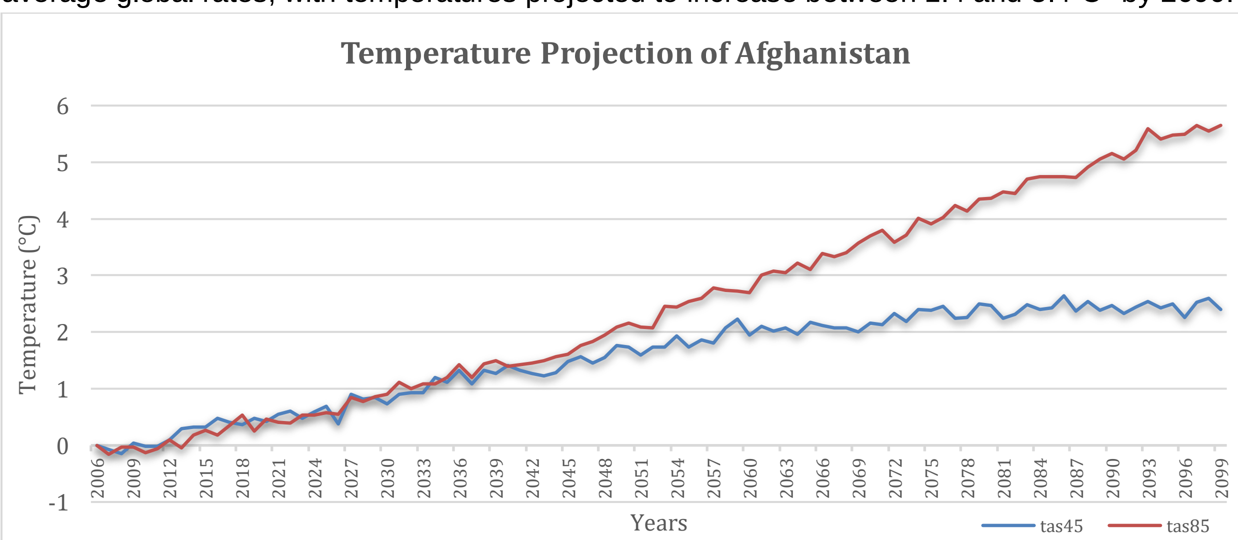


Figure 23: Temperature Projection of Afghanistan- Projecting Temperature. (Source: World Bank, 2024)

Climate change represents a universal threat to human health and nature, standing as one of the most significant challenges humanities has ever encountered. This anthropogenic crisis, exacerbated by population growth, insecurity, and an unstable economy, has expanded faster than predicted, disproportionately impacting the poor and developing countries. Afghanistan, among the countries most vulnerable to climate change, exemplifies these struggles, suffering from the phenomenon's onset (Aich et al., 2017). Both natural and human-made contaminants pose increasing threats to the viability of Afghanistan's water resources. The country's reliance on rapid snow melting during the final weeks of spring and in summer as primary means of replenishing water resources highlights its susceptibility (USAID Sustainable Water Partnership, 2021).

The socio-economic impacts and challenges of climate change in Afghanistan are manifold, affecting both natural and human systems. These challenges include alterations in temperature and precipitation patterns, a rise in the frequency and intensity of extreme weather events, and shifts in ecosystems and biodiversity (Jawid & Khadjavi, 2019). Such changes wield significant socio-economic consequences, particularly in vulnerable areas like Afghanistan, where agriculture—a critical income source for many—faces threats from changing climate conditions. These threats encompass reduced crop yields, increased pest and disease prevalence, and altered water availability for irrigation, severely undermining food security and livelihoods (Jawid & Khadjavi, 2019). Beyond agriculture, climate change impinges on other economic sectors by affecting water resources, diminishing hydropower generation capacity, and impacting industrial activities. Moreover, extreme weather events like floods and droughts inflict damage on infrastructure, disrupt transportation networks, and displace communities, exacerbating urban and rural vulnerabilities.

Afghanistan's significant development challenges are further intensified by climate change, leading to heightened poverty and inequality. The Notre Dame Global Adaptation Index 2021 ranks Afghanistan as the twelfth most susceptible nation to the effects of climate change (Dost et al., 2023) and from two million people in food need in 2018 with 40% population of Afghanistan to poverty (Ansar, 2018) to currently 50% of Afghan population are in poverty is huge change in the recent year (Hakimi, 2024).

Vulnerable populations, in particular, find themselves disproportionately affected by climate change's ramifications (Jawid & Khadjavi, 2019). As evidenced by Hakim Haider & Kumar's (2018) study, the period from 2011-2016 saw an increase in poverty and a shift in the distribution of urban areas toward the impoverished. This overview underscores the dire need for concerted efforts to mitigate climate change impacts and bolster resilience among Afghanistan's communities, particularly in the face of such an overwhelming global threat.

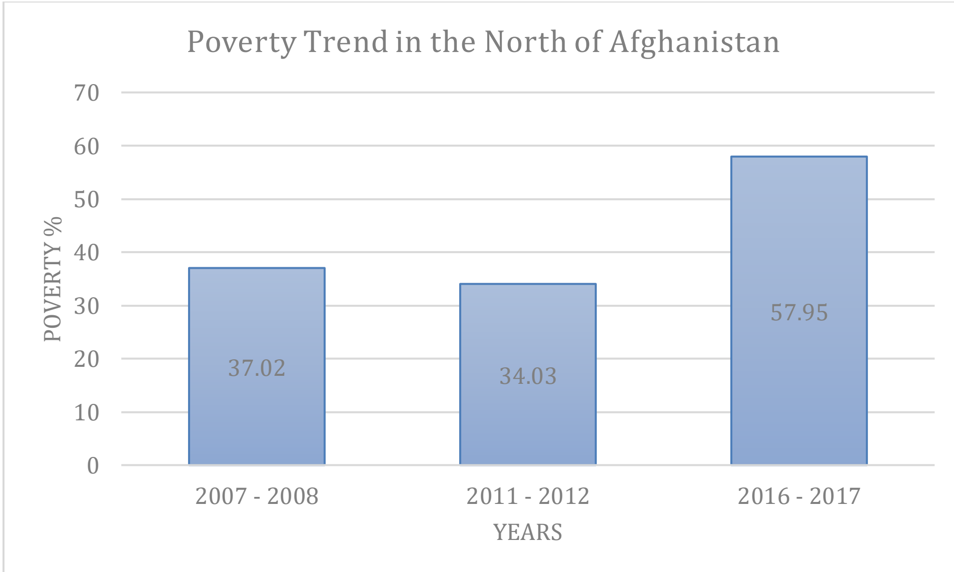


Figure 24: Source: CSO, World Bank staff estimates, NRVA 2007, 2011 and ALCS 2016

The bar chart depicting the poverty trend in northern Afghanistan reveals a critical need for strategic poverty alleviation efforts, particularly following a significant rise in poverty rates from 34.03% in 2011-2012 to 57.95% in 2016-2017. Given the region's reliance on agriculture, enhancing agricultural productivity could be key to reversing this trend. Investment in efficient water management is also essential, as water scarcity can severely impact crop yields and thus the livelihoods of many.

Afghanistan's vulnerability to climate change is demonstrated by alterations in temperature and precipitation patterns, an increase in the frequency and intensity of extreme weather events, and shifts in ecosystems and biodiversity. These changes have substantial socio-economic consequences, notably in agriculture, a vital sector for Afghanistan's economy and livelihoods. Climate-induced modifications in agricultural practices are evident, where rising temperatures and changing rainfall patterns have led to water scarcity, affecting irrigation and reducing crop productivity. This scenario has severe implications for food security and income for farmers across the country (Jawid, 2020).

The North Basin of Afghanistan has experienced mass migration due to these challenges, placing additional strain on the fragile social and political systems. Furthermore, climate change has fostered increased competition over scarce resources such as water and land, heightening tensions and conflicts within Afghanistan and with neighboring countries, particularly over resources like the Qush Tepa National Irrigation Canal. These dynamics underscore the interconnectedness of climate change impacts with regional insecurity and socio-political stability.

Studies, including those by Stulina & Eshchanov (2013) and Wang et al. (2016), have documented the decline in Amu Darya runoff, attributing it to the adverse effects of climate change. A significant finding by Hu et al. (2014) reveals a 0.39 °C/decade increase in temperature, which crucially impacts agriculture and the environment, further emphasizing the urgent need for adaptive strategies in the region.

Addressing the economic impacts, a Ricardian analysis conducted in the central highlands of Afghanistan by Jawid (2020) highlights the adverse effects of climate change on agricultural productivity and income. The study advocates for the importance of adaptation strategies, such as changing cropping patterns, utilizing drought-resistant crop varieties, and implementing efficient water management techniques, to mitigate the impacts of climate change on agriculture.

Moreover, climate change's reach extends beyond agriculture, affecting water resources and other sectors of the economy. Changes in temperature and precipitation patterns have led to water scarcity, impacting hydropower generation and industrial activities, with cascading effects on the overall economy and livelihoods (Jawid, 2020).

2.9 Food

Afghanistan is a mountainous country, with 75% of its terrain covered by mountains. These geographical features result in varied climates across its different river basins, each with unique rainfall patterns. This variation in rainfall is crucial, as it forms the backbone of Afghanistan's agriculture and food production and for many years, agriculture has been the backbone of Afghanistan's economy and a major driver of its development (Nori, 2020). In years with sufficient precipitation, or watery years, Afghanistan experiences mass production of agricultural and livestock products. This production plays a significant role in determining the country's level of poverty and food security.

However, in years of low water and low yield, Afghanistan faces challenges in food availability. The shortage in food availability is often addressed through imports, which significantly impact the price and availability of goods in the markets. Given the income levels and unemployment rates in the country, it is not feasible to increase the prices of goods and food for all sections of society. Consequently, the poor people of Afghanistan suffer from serious problems of lack of access to food in these years.

These issues highlight that food security in Afghanistan does not meet the components of food security, which include availability, access, utilization, and stability. Food security, according to the definition by the Food and Agriculture Organization (FAO) in 1996, is achieved when everyone, at any given moment, has both physical and economic access to enough safe and nutritious food to fulfill their dietary needs and preferences for an active and healthy life.

Longstanding challenges in food availability and the securitization of food have been major hurdles for Afghanistan. The political instability affecting the country's borders with neighboring countries has further complicated the import and export of necessary food items, such as wheat and rice. In recent years, these borders have become politicized, leading to instability in their openness to imports.

The United Nations Food and Agriculture Organization (UN-FAO) announced in 2019 that more than half of Afghanistan's population is in the food-insecure zone of their assessment. This situation has deteriorated, especially after the government collapse in 2021, with over 75% of the population living under the hunger line. Furthermore, the World Food Programme, in its latest report (2024), revealed that around 15.8 million individuals in Afghanistan are expected to experience acute food insecurity in the last six months, while 3.6 million people are categorized under Integrated Food Security. Furthermore, there are four million individuals who are now experiencing acute malnutrition, with 3.2 million of them being children under the age of 5 (World Food Programme, 2024).

Suryavanshi et al (2022) examines the pattern and trend of seasonal and annual precipitation along with extreme precipitation events in Afghanistan during the period from 1979 to 2013. The study reveals that spring and winter precipitation in Afghanistan has decreased, which could have serious implications for agriculture and rural livelihoods. Additionally, the precipitation indices also indicate drier conditions in Afghanistan. This situation may contribute to water stress and scarcity of water resources in many regions of Afghanistan.

Despite efforts, stability, access, availability, and utilization of food have never been fully achieved in Afghanistan, especially in the last 40 years. To achieve food security in all four dimensions, innovative thinking and the effective utilization of available water and land resources are required. The lack of development in the country's agricultural infrastructure has significantly affected Afghanistan's food security, livelihoods, and agricultural productivity. A shortage of water, as indicated by many studies, has a profound impact on food insecurity, livelihoods, and agricultural revenue in Afghanistan.

3. Case Study: Qush Tepa National Irrigation Canal

3.1 Introduction to the Canal

Originally, Qush Tepa (as a location) is situated on the banks of the Amu Darya river, between Kunduz and Samangan provinces. It spans around one million hectares of arable land. Afghanistan undertook a study that predicted the growth of these lands with the use of advanced irrigation techniques. However, insufficient funding for the implementation of such a substantial project has not been identified. Khush Tapa is the most extensive land development project in Northern Afghanistan (Ahmad & Wasiq, 2004a). Later, under the program for the development of large irrigation projects aimed at fostering continuous economic growth, a cornerstone of the first republic government of Afghanistan's seven-year development plan from 1976 to 1983, there was an initiative to survey and construct projects to expand arable land in northern Afghanistan. At that time, surveys identified 217,800 hectares of land already being irrigated, with an additional 83,600 ha identified as potentially irrigable. However, estimates indicated that approximately 800,000 ha of land in the Balkh and Aqcha rivers area could be irrigated using water from the Amu Darya. Of this, 100,000 ha were planned to be irrigated by a water pump project known as the Qush Tepa project, which involved pumping 110 m^3/s of water from the Amu Darya. Furthermore, the project included the construction of an irrigation canal, 200 km in length, with a capacity of 110 m^3/s, totaling 220 m^3/s when combined with the pump project, for further development purposes. The feasibility study report of the Qush Tepa Project was initially signed between Afghanistan and the Soviet Union, involving Selkhozpromexport, with a duration of two years and one month, and was undertaken by Afghan and Russian experts. It encompassed the headworks, pump station, main conveyance canal, and sedimentation canals. Between 1976 and 1982, activities such as surveying, project planning, building the pumping station, a segment of the canal, and other essential tasks were scheduled for completion. At that time, it was estimated that the construction of this project would require a total investment of Afs. 7.8 billion. Of this amount, 4.9 billion AFN was expected to be funded by the Government Budget, while an additional 64 million USD was to be secured as foreign aid from the Soviet Union (Ministry of Planning, 1976).

Following years of conflict and the implementation of the seven-year Qush Tepa project plan, the Islamic Republic of Afghanistan, in 2016, aimed to revive the 1976 development initiative. This initiative, originally set to launch during the country's first republic era, sought to irrigate extensive areas in the northern plains using water from the Amu Darya, with the goals of increasing agricultural output, bringing unused fallow lands into production, and enhancing the quality of existing agricultural lands. This was part of a proposal made in 2016 to re-examine canal studies. The original financing plan in 1976 involved securing long-term loans from the Soviet Union. However, contrasting with the situation 45 years earlier, where there was a reliance on Soviet Union assistance and the national budget, the Islamic Republic of Afghanistan aimed to fund and complete the canal through a combination of international banks, institutions, and its national budget. Before the Republic's fall to the Taliban, progress included the completion of 8 km of canal work in northern Afghanistan. It is significant to note that in December 2017, the re-financing of the Qush Tepa canal's feasibility study was confirmed through USAID at the Arg Presidential

Palace in Kabul. The signing ceremony was attended by President Ghani, various cabinet ministers, the US ambassador, and the deputy head of USAID, and the study was to be carried out by SWIM (Strengthening Watershed and Irrigation Management).[3] This feasibility study by SWIM project has been serving as a foundational document for the post-2021 to continue canal construction up to the present day.

The first phase of the Qush Tepa canal, spanning 108 km, constitutes the main excavation work through the deserts in northern Afghanistan. This phase also encompasses the development of branches, secondary canals, and tertiary canals in the project's second phase. This extension includes digging an additional 177 km of canal towards the Andkhoi district in Faryab province which started on Oct of 2023 (BBC, 2023; TOLOnews, 2023). The third phase involves distributing adjacent lands and preparing the command area for cultivation, including plans for setting up processing factories and other necessary infrastructure.

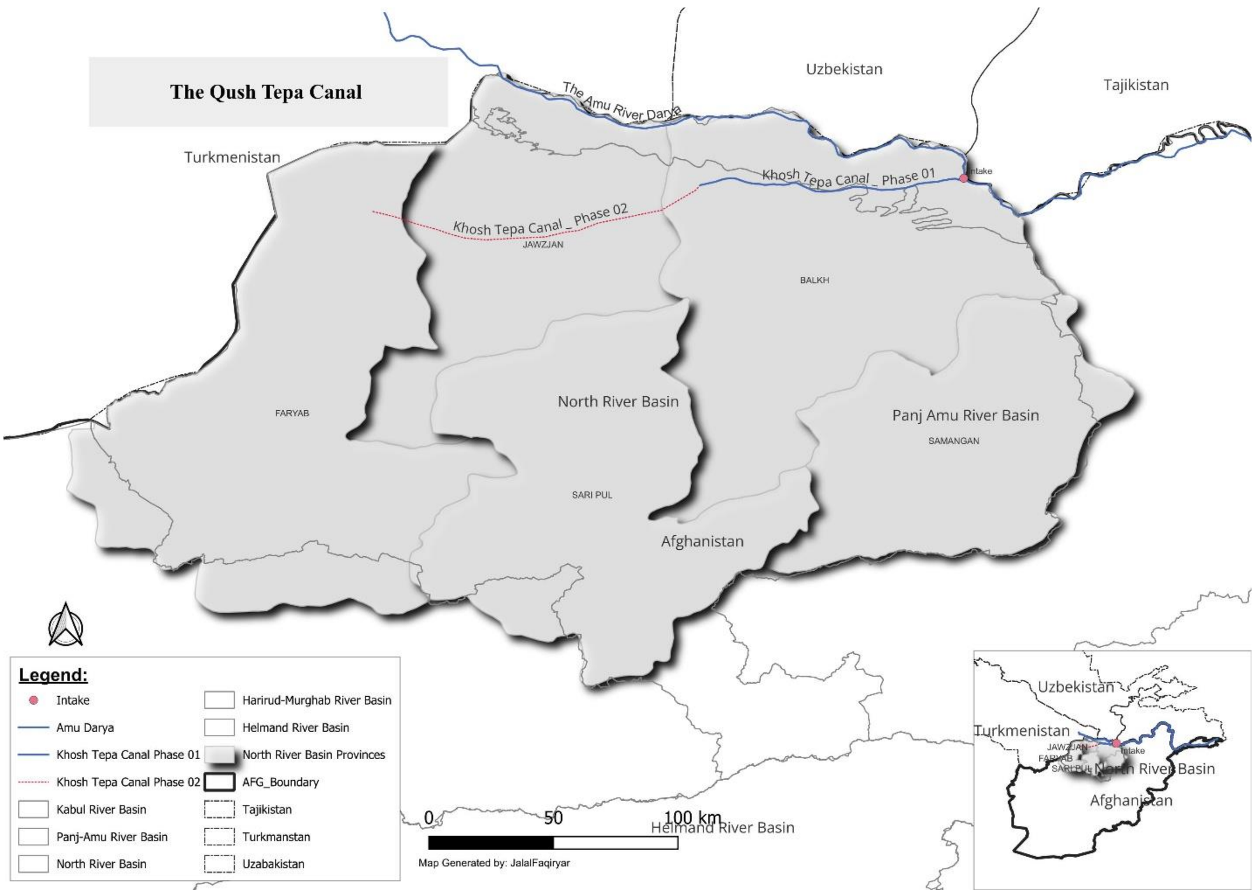


Figure 25: The location and Phases of Qush Tepa National Irrigation Canal in Afghanistan.

Under the plan in 2017, the Qush Tepa National Irrigation Project aims to deliver water to Andkhoi, a district located approximately 180 km northwest of Mazar-i-Sharif City and about 65 km from Sheberghan City in Afghanistan. Geographically, Andkhoi is located within the expansive terrains

[3] Participant observation of this research’s Principal Investigator.

of Afghanistan, characterized by an arid to semi-arid climate that results in distinct weather patterns throughout the years.

One of the debatable topics related to this project is the land surrounding the canal. With the commencement of canal operations, the prices of these lands have increased. Although the distribution of these plots remains suspended until full canal utilization, during the first phase of the canal, plots are rented out for decades to lessees for agricultural purposes.[4] Overall the locals and on-site individuals believe that the Taliban de-facto government should manage these lands properly, and a portion of them should be allocated to the private sector for improving the country's economy and attracting more investment around the canal.[5]

3.1.1 Hydro and Geopolitics of the Qush Tepa National Irrigation Canal

Since ancient times, water has been a sacred substance in various societies and has been used as a tool for war, defeat, and victory against each other. For example, the first recorded water war dates back to 2500 BC, and the latest incident occurred in Palestine in 2024 (Pacific Instituite, 2024). Throughout this time, contemporary Afghanistan, despite being a dry country, has managed to produce and distribute the necessary water for its downstream regions and countries such as contemporary Iran, Pakistan, Turkmenistan, and Uzbekistan through rivers that flow across and beyond its borders. Of the five major river basins in Afghanistan, only one - the Helmand River - has an official treaty with a downstream neighboring country, Iran, known as the Helmand/Hirmand Treaty, which was concluded in 1973 between the prime ministers of these two countries, both of whom were executed for various reasons. Regarding the North River Basin located in the north of Afghanistan, there were previously commitments and treaties with the Russian Federation in seven articles which was signed in 19 July 1964, which ceased to exist after its collapse and the independence of the Central Asian countries (Tajikistan, Uzbekistan, Turkmenistan, Kazakhstan, and Kyrgyzstan), to the extent that the Central Asian countries excluded Afghanistan from the Amu Darya water division in the Almaty Agreement in 1992, depriving it of these rights among themselves. Subsequently, Afghanistan was engaged in a series of imposed and internal wars that prevented the development of its agricultural and economic infrastructures and the focus and maximum use of its surface and groundwater management while the Central Asian countries, taking advantage of the opportunities that arose and with the support, language, and cooperation history of the Soviet Union, constructed several dams on the main and tributary branches of the Amu Darya (FAO, 2012), diverting a large amount of water and bringing a lot of bare land under cultivation.

[4] Interviews with the farmers and local residents of Balkh, Afghanistan, August and September 2023.
[5] Interviews with the local residents and workers on the canal in Balkh, Afghanistan, July 2023.

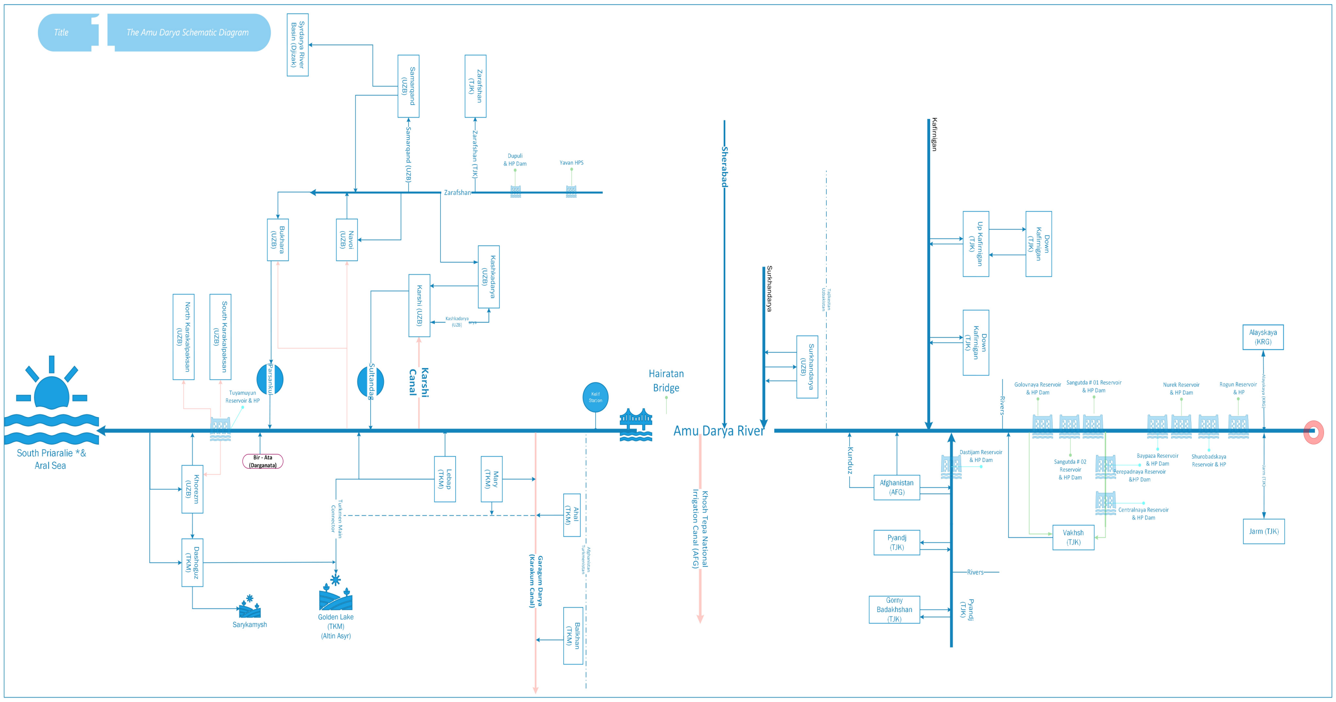


Figure 26: Schematic Diagram of Amu Darya and constructed dams over it with Qush Tepa canal.

The Islamic Republic of Afghanistan, which collapsed in August 2021 and the Taliban that regained control of Afghanistan for the second time, strenuously continued the work on this agricultural canal to the extent that in one year, 100 km of the canal route was dug without technical consultation of international experts, but mainly with the support of Afghan local engineers. This rapid canal digging raised concerns among neighboring countries downstream of the Amu Darya, even preventing them from reconsidering their water resources management and efficiency during the canal's construction phase to protect themselves from its potential and significant impacts. Additionally, with rising temperatures, the demand for water in the region is increasing, and Central Asian countries, including Afghanistan, which mainly rely on snowmelt for water, will ultimately face major problems with water division and use. Over the past 45 years, downstream countries accustomed to free and undisturbed water use and pass now face some dissatisfaction and disputes that this canal is being built. Although the canal was established with the goal of creating jobs, ensuring regional security, and reducing food insecurity, its development has potential to cause regional tension, reduces water flow to downstream countries while climate change causes temperature rises and decreases in natural glacier flows, negatively affecting agriculture and food security in the region (Faizee & Schmeier, 2023; Murzakulova, 2023). Meanwhile, the concerns of neighboring countries downstream of the Amu Darya have resonated so much that a month before the inauguration of the second phase of the Qush Tepa canal, Shavkat Mirziyoyev, the President of Uzbekistan, reminded of the impacts of constructing the Qush Tepa agricultural canal, stating that this canal "actively being built by Afghanistan fundamentally changes the water situation and balance in Central Asia" (Daryo, 2023, p.1). The Taliban's response, via the Ministry of Energy and Water, is that "currently, in the Amu Darya basin, we (Afghanistan) have no treaty with anyone" (TOLOnews, 2023b, p. 1), while Taliban's defense minister called the completion of this major canal "the realization of a decades-long dream of the Afghan people" (Afintl.com, 2023, p. 1).

Jennifer Murtazashvili argues that examining former bilateral inter-Afghan-Central Asian projects highlights the win-win nature of those initiatives. However, the Qush Tapa project is different due to its zero-sum nature (Rickleton, 2023). Albeit Faizi & Susan (2023) argue that backing Afghanistan necessitates the continuum of the development of this canal. Notably, there is vast potential in front of the Central Asian countries to make the utmost use of the canal in Afghan soil. This can be achieved if these countries think outside the box and pursue different ways of mutual economic benefit and betterment of relations. Despite hunger and poverty trends going on in Afghanistan, it is estimated that about 18-20 billion AFN will be spent in the second phase and part of the third phase of this canal (TOLOnews, 2024).

Farmers across the regions that the canal passes through believe that once water flows into the canal, their groundwater levels will increase. They are relatively optimistic about the canal's profitability, anticipating it will double. They add that if they use more agricultural fertilizer, they can plant two seasons in one year—otherwise, they will have one harvest season. According to residents around the first phase of the canal in Balkh, the current water level is 30 m below ground, which they expect will rise to 15 m after water flows into the canal.[6] The number of solar panels along the Qush Tapa canal is increasing, and farmers use them to pump water from the canal for irrigation. It is worth mentioning that this canal has divided the lands into two parts, separating farmers from their agricultural fields and creating a major commuting problem. Farmers use boats to pass from one side of the canal to the other. Currently, only two bridges are available: Hairatan Bridge and Dowlat Abad Bridge (Qarchighak area).[7] Vehicles can only pass through these two bridges from one side to the other. The people's request to the current government is for one more bridge to be built in their area over the canal. For example, the village of Jungle Saziq, which is located 65 km down from the intake, with a population of about 200 people living in it. The lack of jobs and weak economy are considered their major problems, and the crossing of the canal and separating them from the surrounding lands and cutting off their access to the center of Dowlat Abad district – without a bridge – have added to their existing problems. They cross with a handmade boat without a motor, which is moved by human force through a cable installed on both sides of the canal, transferring their motorcycles and belongings from one side of the canal to the other, including women and children.[8] The project officials say that several bridges for commuting will be built, a total of 6 bridges. The construction of the third bridge from Dowlat Abad to Shur Tapa is ongoing after Hairatan Bridge for traffic and trains, which will be built in ten months.[9] People from nearby provinces come to visit the canal, while in the second phase of the route, ancient sites and people's homes are being tried not to be affected by the construction of the project.[10] The second phase starts from Dowlat Abad district of Balkh province to Andkhoi

[6] Interviews with the farmers, shepherds, and local residents of Balkh, Afghanistan, August and September 2023.
[7] Interviews with the farmers, workers, and local residents of Balkh, Afghanistan, August and September 2023.
[8] Interviews with the farmers and local residents of Jungle Saziq in Balkh, Afghanistan, July 2023.
[9] Interviews with the engineers and workers of the canal in Balkh, Afghanistan, August and September 2023.
[10] Interviews with the local residents of Jawzjan, Afghanistan, September 2023.

district of Faryab province. The people of these areas hope to get rid of the brackish groundwater of their areas and benefit from the sweet water of the Qush Tapa canal.[11]

According to the National Development Company's plan, from the start of the headwork to the end, 18 pump stations, 12 tertiary canals, and four branch canals will be built to deliver water to the surrounding lands. These branch canals will also have other sub tertiary canals. The canal is not confined with above mentioned structures and will have other clusters. Taliban has assigned a 200-person unit to secure this canal so that the construction of this canal proceeds in a completely secure environment, and the staff also have no worries from this area.[12]

3.2 Description of the Provinces Through Which the Canal Flows

3.2.1 Faryab

Faryab is a mountainous province predominantly composed of highlands, mountains, hills, or dirt mounds, with some flat and uneven lands, except for its plains. Faryab has an area of 20,797.6 km^2 and administratively consists of 14 districts. In terms of agriculture and livestock, Faryab is a province with a moderate climate and favorable conditions for farming and development. The total agricultural land area of this province is 357,400 hectares, including 164,600 hectares of irrigated land and 192,800 hectares of rain-fed land. The eastern and northern parts of Faryab are dry, water-scarce, and suitable for rain-fed farming, while the southern and western parts are greener with relatively sufficient water. The total forested area in Faryab, according to a 1980 survey, is 177,300 hectares, which are irrigated annually by rain and floods.

Faryab's spring is marked by heavy rainfall, with the average annual rainfall estimated at 700 mm. Summers are hot, with temperatures usually reaching 36 °C and sometimes up to 45 °C during droughts, while winters are cold. Faryab enjoys between 2,600 to 3,000 hours of sunshine annually, with the rest of the year characterized by cloudy, partly cloudy, and rainy weather.

In Faryab province, despite being dry and water-scarce, existing water resources have led to the construction of dams. The largest and most important dam is the Sar Howz Dam, the sole reserve for agricultural and drinking water in Faryab, located in the Sar Howz area of the Pashtun Kot district. The dam has three water control gates and one silt control gate with a diameter of 30 cm, a basin length of 2,460 m, and a width of 1,200 m. Due to sedimentation, the water storage capacity of the dam has been reduced from 25 Mm^3 to 9 Mm^3. There are five small diversion dams in the province, which include:

1- The Jan Qara Diversion Dam in the Shirin Tagab district with an irrigation capacity of 2,000 hectares.

[11] Interviews with the local residents of Aqcha and Andkhoi in Jawzjan and Faryab, respectively, Afghanistan, September 2023.

[12] Interviews with the engineers and workers in Balkh, Afghanistan, September 2023.

2- The Kismah Aslim Diversion Dam in Khwaja Sabz Push district with an irrigation capacity of 5,000 hectares.
3- The Kate Qishlaq Diversion Dam in Khwaja Sabz Push district with an irrigation capacity of 1,000 hectares.
4- The Ghazari Diversion Dam in Khwaja Sabz Push district with an irrigation capacity of 1,500 hectares.
5- The Jir Qala Diversion Dam in Dawlat Abad district with an irrigation capacity of 290 hectares.

The Maimana River, which is fed by the melting snows of the Turkistan Range, irrigates the valleys of Maimana, Qaysar, Garziwan, and Shirin Tagab. The farmers and orchardists in Qaysar, Garziwan, Belcheragh, Khwaja Sabz Push, Shirin Tagab, and Dowlat Abad districts irrigate their crops with water from springs, snow, and seasonal rains originating from the foothills of Faryab, but face water scarcity in the summer season.

It should be mentioned that although agriculture is the main profession of most people in this province, most farmers are only able to earn enough for their basic living expenses through agriculture. As a result, most families dependent on agriculture face economic insecurity. Overall, 40% of the population in Faryab lives in food insecurity. Alongside agriculture and orcharding, many people in Faryab are engaged in livestock farming. However, due to the dry and water-scarce conditions of Faryab, nomadic livestock farmers residing in this province face water shortages in the summer, which severely impacts the breeding and raising of livestock.

Agricultural and Livestock Products in Faryab: Faryab is one of the most capable and favorable provinces for agriculture and livestock farming. The soil of this province is sandy and suitable for cultivation. The economy of the people in this province is based on agriculture, livestock farming, and the carpet weaving industry. Approximately 85-90% of the population in this province is engaged in agriculture and livestock farming. The province produces a variety of fruits, such as apples, grapes, melons, watermelons, figs, quinces, peaches, apricots, plums, almonds, pistachios, and mixed nuts. Potatoes, various types of cumin, sesame, cotton, tobacco, and cereals such as wheat, barley, sorghum, chickpeas, lentils, beans, and millet are among the major agricultural products of Faryab.

The table below shows the major agricultural products of the rural areas and their annual production in Faryab:

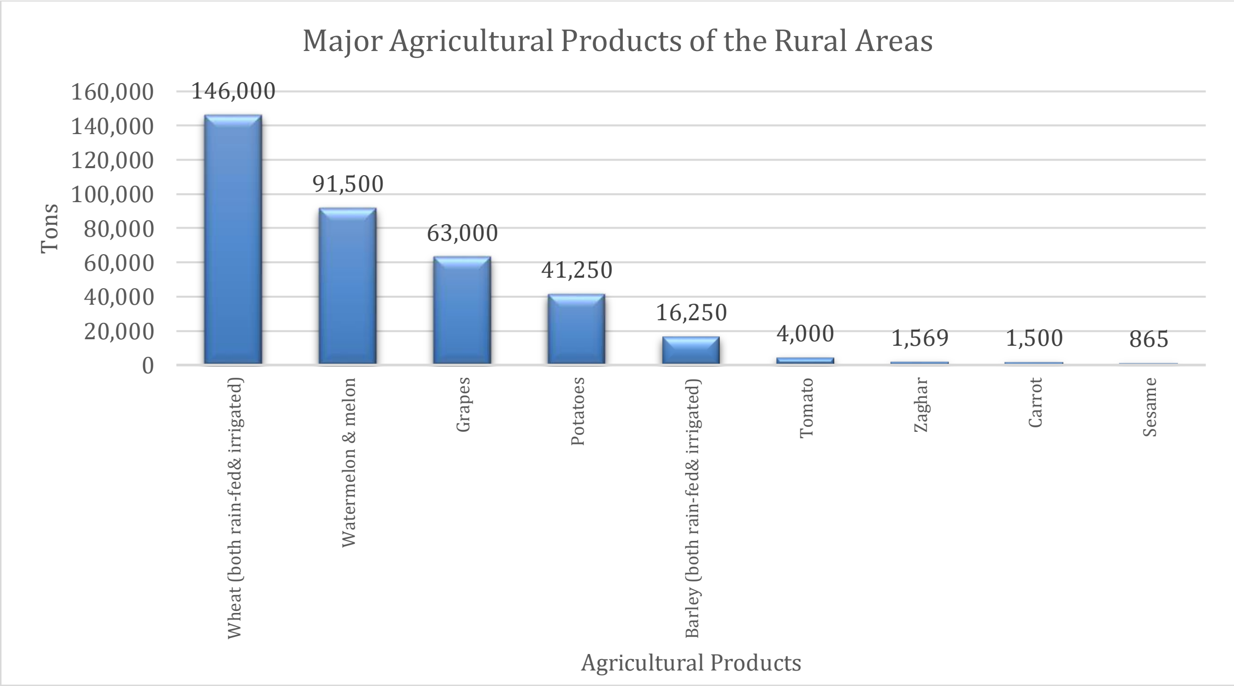


Figure 27: Major Agricultural Products of the Rural Areas of Faryab.

It should be noted that the production of crops in Faryab varies annually due to water scarcity and the lack of agricultural water reservoirs.

Dowlat Abad District: This district is among the warm regions of Faryab, with a total agricultural land area of 91,463 hectares, of which 85,095 hectares are rain-fed, and 6,368 hectares are irrigated. Additionally, there are 60,000 hectares of pastureland in this district. The groundwater in this district is salty due to its proximity to a salt mine and lacks agricultural water. Some of the lands are irrigated by floods during the spring season. The main professions of people in this district are agriculture, livestock farming, and carpet weaving. Cereals are among the major agricultural productions of this district, and its fruits, such as apricots and grapes, are particularly renowned (Ministry of Economy, 2019b).

3.2.2 Jawzjan

Jawzjan has a continental climate, with a moderate and humid spring, a hot and dry summer with temperatures reaching up to 46 °C, and a cold winter where temperatures can drop to -15 °C. The temperature variations are uniform across the province, and wind flows are present throughout all seasons. The average monthly rainfall in this province reaches up to 40 mm.

Since Jawzjan is flat and surrounded by arid land, with approximately 75% of its lands reclaimed from the desert, it is seriously at risk of natural disasters such as droughts, floods, and severe freezes. This province experiences the most flood events in Afghanistan.

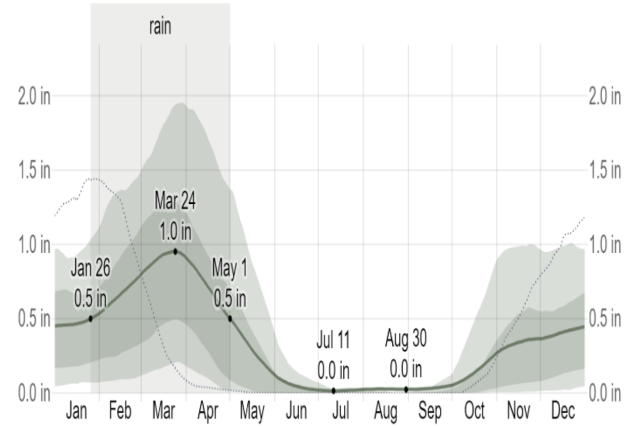


Figure 28: Average Monthly Rainfall of Jawzjan province. (source: weatherspark.com)

Jawzjan covers an area of 11,291 km^2. It has 215,753 - 229,375 hectares of agricultural land, of which 167,760 hectares are irrigated, and 40,000 hectares are rain-fed. The province includes 2,600 hectares of artificial orchards, 10,000 hectares of natural forests, and 155,965 hectares of pastures. However, it should be noted that elsewhere, the area of orchards in this province is reported as 19,555 hectares, and the forest area as 1,033 hectares. Although 90% of Jawzjan's lands are arable, due to the lack of irrigation water, less than 60% are cultivated, and climate changes and droughts have led to the desertification of many lands. If irrigation and drinking water from the Amu Darya are transferred to the five districts of Aqcha and Sheberghan city, all uncultivated lands would be cultivated, and 100 hectares of pastures and forests would be revived, turning Jawzjan into a hub of agricultural production.

Water Resources of Jawzjan: Jawzjan province lacks reliable water sources, and its agricultural and drinking water is supplied from the rivers of the Sar e Pol and Jawzjan provinces. However, this water is insufficient, and the inhabitants of cities and villages, especially farmers, face the problem of water scarcity. Drinking and agricultural water scarcity is a major issue for the residents of Jawzjan. Only 50 - 69% of Jawzjan's inhabitants have access to safe drinking water. The province lacks large agricultural water reserves, and irrigation water is supplied from rivers, canals, and groundwater. Agricultural lands in the districts of Faizabad, Mardyan, Mengjak, Aqcha, and Khanqah are irrigated from the Haji Nahri River of Balkh province, central villages, and Khwaja Du Koh districts alternately from the Sar-e Pol River, and agricultural lands in the Qarqin and Khamyab districts are irrigated throughout the year from the Amu Darya River. The agricultural lands in the Darz Ab and Qush Tepa districts are rain-fed, with some areas of orchards and lands irrigated from snow accumulation, rainfall, and springs.

According to information provided by the Directorate of Agriculture and Livestock of Jawzjan, there are 99 irrigation canals in the province, but exact details about their capacity are not available. Additionally, there are ten diversion small dams and 31 water dividers in the province.

Agricultural and Livestock Products of Jawzjan: Agriculture is a significant source of income for Jawzjan, with approximately 44.3% of the province's population engaged in farming and livestock rearing. The major agricultural products of this province include wheat, barley, sorghum, zaghar (a type of grain), sesame, cotton, cumin, chickpeas, mung beans, melons, watermelons, pumpkins, eggplants, and other vegetables. Wheat is one of the most important crops; in favorable weather and sufficient rainfall, its production can reach around 120,000 tons, which exceeds the consumption of the local population. Barley and sorghum also hold their importance, and cotton is widely cultivated. Approximately 1,990 hectares in this province are dedicated to sesame cultivation. Dried fruits, especially raisins, are among the most important export products of this province, and Jawzjan is also known for its sweet melons and watermelons, which are mostly grown in the fertile areas of the province.

The average value of Jawzjan's agricultural products is estimated at 2,287,857,23 AFN (MAIL, 2019). The table below shows the production volume of agricultural products in this province:

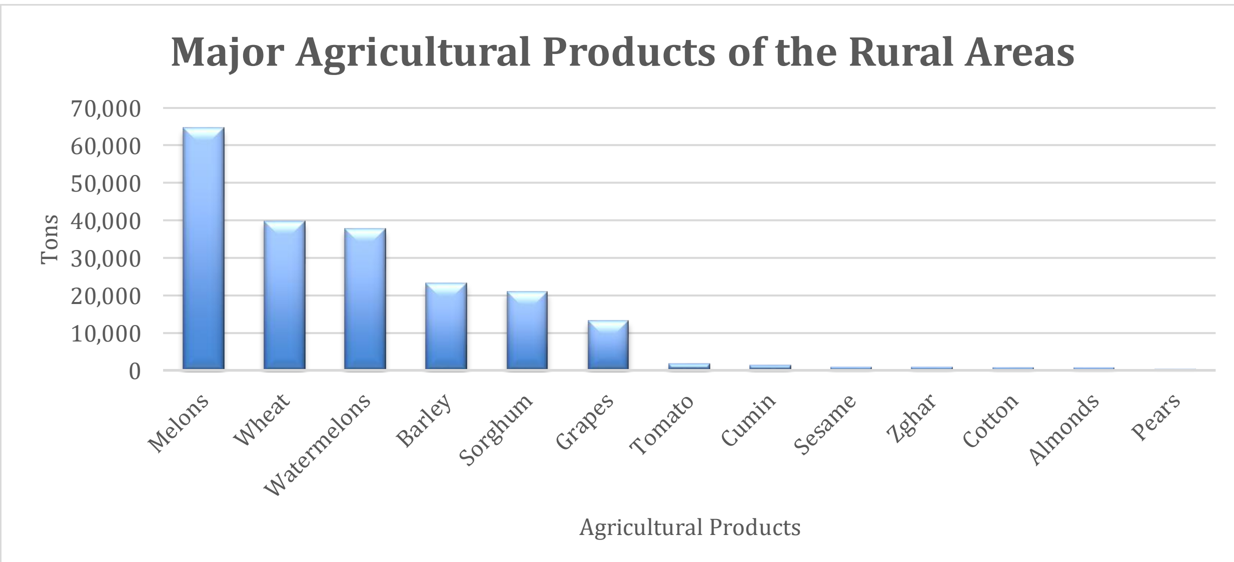


Figure 29: Major Agricultural Products of the Rural Areas of Jawzjan Province.

Fruit trees such as almonds, apples, apricots, peaches, nak (pear), 64 types of grapes, pomegranates, seedless pomegranates, quinces, jujubes, pistachios, dates, pine nuts, and figs are compatible with the different climates and areas of this province. Additionally, medicinal plants such as Hing (asafetida), sweet-smelling plants, zarak (a type of herb), wild rue, and the like naturally grow along the Amu Darya River and other parts of the province.

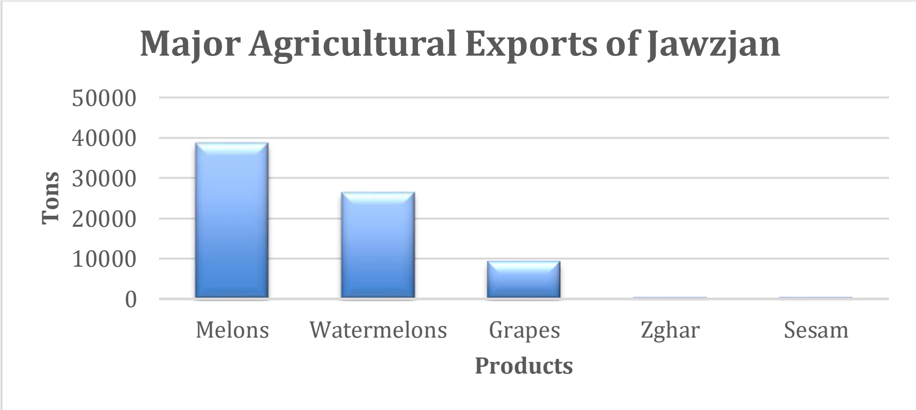


Figure 30: Major Agricultural Export of Jawzjan Province

The most important agricultural products of this province are wheat and rice, with annual imports reaching 57,450.21 tons of wheat and 29,172.15 tons of rice.

In addition to agriculture and orcharding, animal husbandry, especially of the Karakul sheep, goats, cows, mules, horses, camels, and various types of poultry, is common in this province. Some animal products, such as tanned hides, Karakul, and wool, are exported abroad. There are 1,124,412 heads of various types of livestock in this province, including 838,119 sheep, 150,795 goats, 77,046 cows, 17,752 horses, and 20,907 others. The numbers varies each year.

In this province, there is one Karakul sheep farm with a capacity of 280 head, one silk farm with an area of 48 Jeribs (approximately 19.2 hectares), 240 poultry farms for meat production with a capacity of 1,000 to 2,000 chickens per farm, and two companies for the production and breeding of seed grains with a capacity of 119 hectares and an annual production of 290 tons of wheat. Moreover, Jawzjan has 299 greenhouses of various capacities, covering an area of 1,955.5 hectares of fruit orchards with various fruits and 913.5 hectares of grape orchards with different types.

It must be noted that the economic growth of Jawzjan in recent years has seen a slight improvement, mainly due to agricultural production. However, farmers in this province struggle with poverty due to traditional farming practices, water scarcity, and delays in getting their products to market. According to existing statistics in a survey report on the living conditions of the people, 347,899 individuals, constituting more than 60% of Jawzjan's population, lack food security (Ministry of Economy, 2019c).

3.2.3 Balkh

Balkh is a province in northern Afghanistan, bordering Uzbekistan and Tajikistan. It is one of the oldest and most historic regions of the country, with a rich cultural and religious heritage. Balkh is also an important agricultural area, producing wheat, cotton, melons, and grapes. The main source of irrigation water for Balkh is the Balkh River, which originates from the Hindu Kush mountains and flows into the Amu Darya. The Balkh River Basin covers about 11,000 km^2 and supports about 1.5 million people. However, the basin faces many challenges, such as water scarcity, climate variability, poor infrastructure, weak governance, and conflict. These factors affect the livelihoods and food security of the farmers and the rural population (Torell & Ward, 2010).

The Balkh province has 273,000 hectares of irrigated land and 150,000 hectares of rain-fed land. It encompasses 115,000 hectares of natural forests, mainly located in mountainous districts such as Marmul, Charkint, and Zari, and there are also 138,600 hectares of pastures. Although the province has vast plains, not all of these lands are cultivated due to water scarcity. The agricultural lands in Balkh require 400 m^3 of water per second, but the flowing rivers in the province can only provide 30 m^3, resulting in nearly 60% of the country's agricultural lands being left uncultivated each year. Generally, the spring in Balkh is rainy and humid, with monthly rainfall of up to 43 mm. Summers and autumns are dry with little rain and temperatures reaching up to 43 °C, and winters are very cold, averaging down to -2 °C in January.

The area of this province is 16,840 km^2, comprising 15 districts.

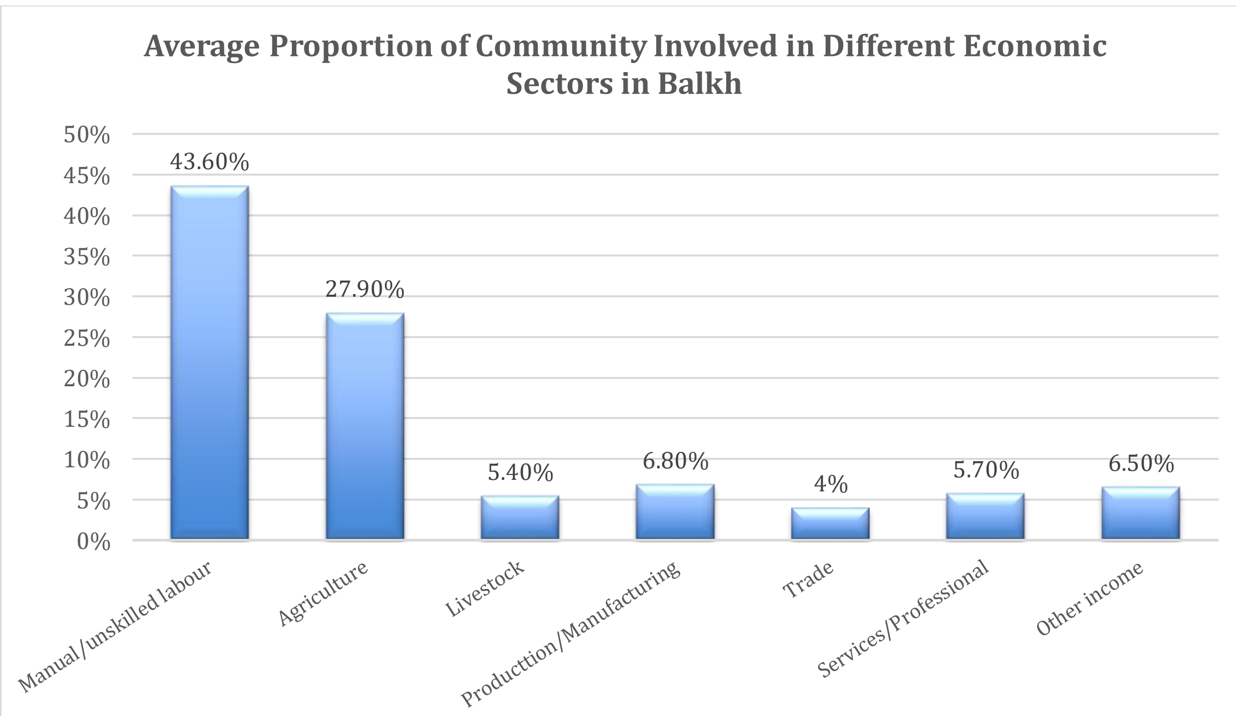


Figure 31: proportion of community involved in different economic sectors in Balkh province.

Agricultural and Livestock Products in Balkh: Agriculture is the most important source of income for the people of Balkh. Farming is the occupation of 70% of the province's population, including 60% men and 10% women.

Wheat, barley, sorghum, and rice are important agricultural products of Balkh. Pistachios are also very important, and Balkh is known for its sweet melons and grapes. In addition to these products, fruits such as apricots, plums, quinces, almonds, apples, mulberries, peaches, watermelons, cherries, figs, and other fruits are well-produced in this province. Balkh's lands are unparalleled in grain production. Other important products with good yields in this province include cotton, saffron, and soybeans. The annual cotton yield is 45,000 tons, usually sold as cottonseed by farmers in the markets of districts and Mazar-i-Sharif city, and the saffron yield reaches 45 kg/year.

The table figure shows the production volume of agricultural and rural products in this province:

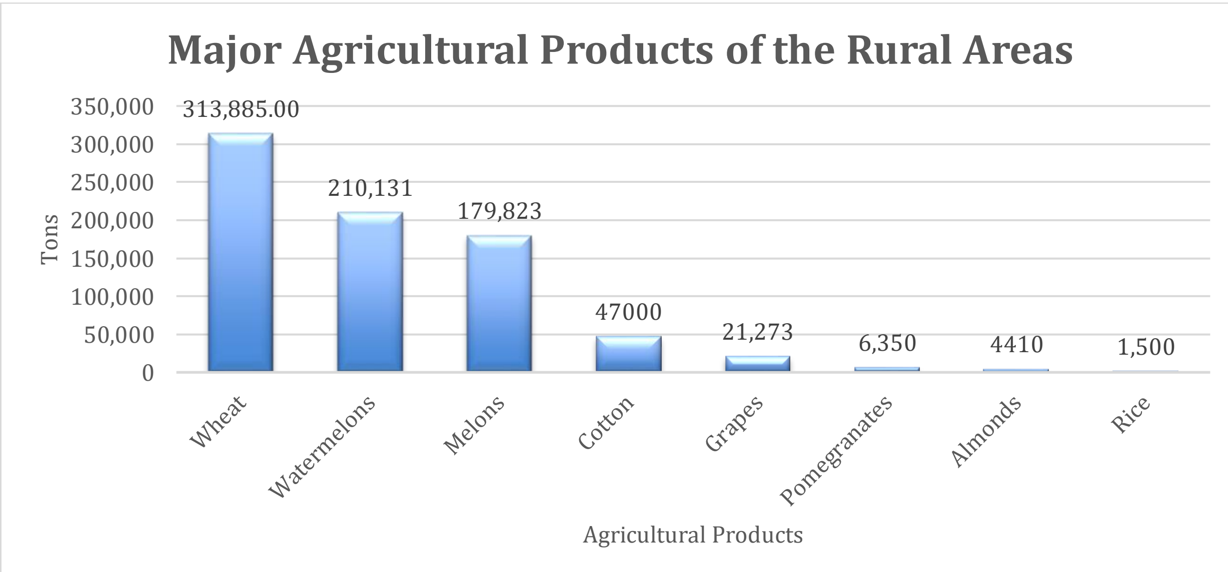


Figure 32: Major Agricultural Products of the Rural Areas in Balkh Province.

It is important to note that many of Balkh's export items include agricultural products such as raisins (468 tons), cooked (96 tons), vegetables (560 tons), medicinal plants (103-150 tons), and fresh fruits (61 tons). All these yields result from traditional farming practices despite limited water resources. It should be mentioned that only 30% of Balkh's population enjoys food security. Another very important sector in the Balkh province is livestock farming. There are seven agricultural farms and 174 poultry farms in Balkh. The livestock in Balkh includes 932,741 sheep, 357,758 goats, 97,989 cows, 9,497 camels, and 16,436 horses (MAIL, 2019).

The water needs of the city of Mazar-e-Sharif are supplied through two sources: surface water (Balkhab river) and groundwater (Mazar-e-Sharif aquifer). In the Balkh province, there are three water basins: the Amu Darya, Balkh River, and Khulm River. The Amu Darya, with an annual water capacity of 80 Bm^3, is located in the north of the province and is used for irrigating limited areas of the Shor tepa and Kaldar districts. The second basin is the Kashinda-Dowlat Abad (Balkh) basin, with an annual capacity of 2,006,438,40 m^3, irrigating the western parts of the province, including the districts of Kashinda, Zari, Sholgara, Charkint, Chamtal, Dehdadi, Charbolak, Balkh, and Dowlat Abad. From this point, there are eleven irrigation canals or rivers, including the Balkh, Siah Gerd, Mushtaq, Abdullah, Chamtal, Dowlat Abad, Charbolak, Faizabad, Aqcha, Imam, and Shahi canals. The third basin is the Khulm basin, located in the east of the province. It originates from the Samangan province and covers the entire Khulm district. The eastern and western canals are the two main channels of this basin.

In the Balkh province, there are three diversion dam structures:

1. The Shahi diversion dam in Sayajeh, Dehdadi district, with six control gates and a capacity of 750 m^3.
2. The Samarkandian diversion dam in Asyab, Chamtal district, with eighteen control gates and a capacity of 840 m^3.
3. The Bengal diversion dam in the Bengal village, Balkh district, with ten control gates and a capacity of 1,100 m^3.

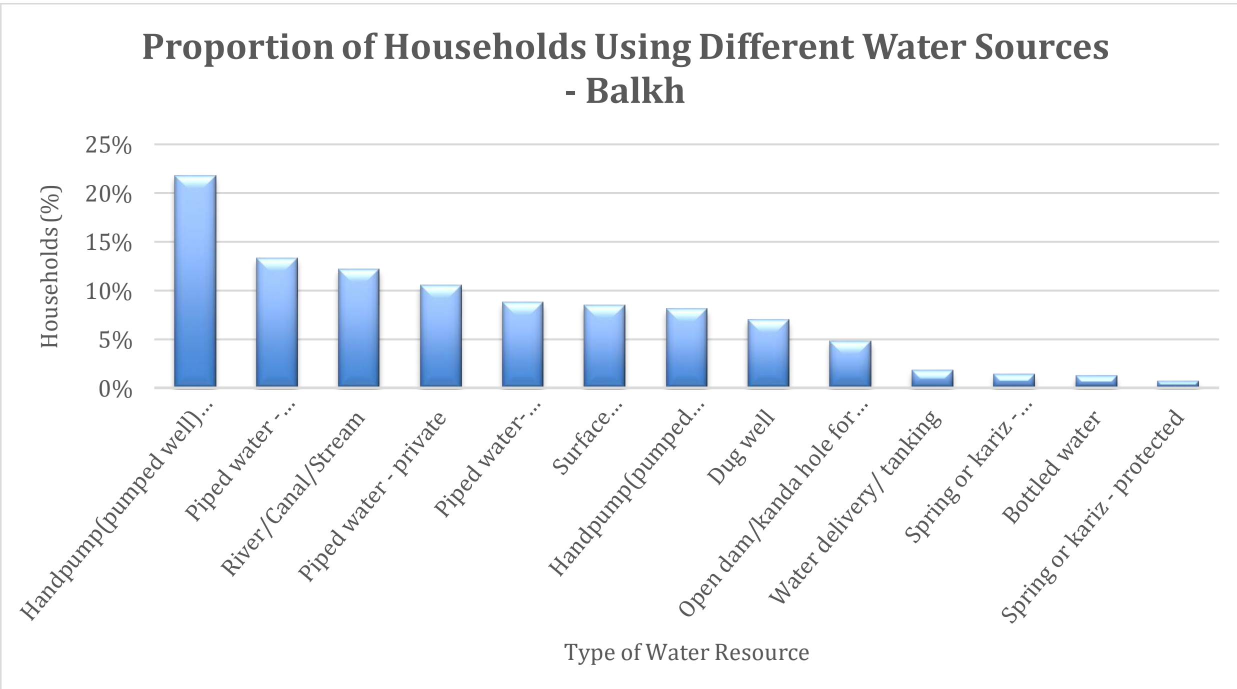


Figure 33: Proportion of Households Using Different Water Sources - Balkh Province.

There are no agricultural water reservoirs in Balkh province, and the water of the two rivers, Sholgara and Balkhab, is so limited that it is insufficient even for the irrigation of existing agricultural lands. Most of the province's agricultural water is supplied by the melting of winter snow and seasonal rains. The majority of farmers in this province prepare large pits in their areas to collect rainwater and use it for irrigating their agricultural lands. In the last two to three years, the problem of water scarcity has been addressed by drilling deep wells in several districts, including Chamtal, Charbolak, and Balkh. Figure 35, illustrates the districts that Qush Tepa Irrigation canal passes them through (Ministry of Economy, 2019a).

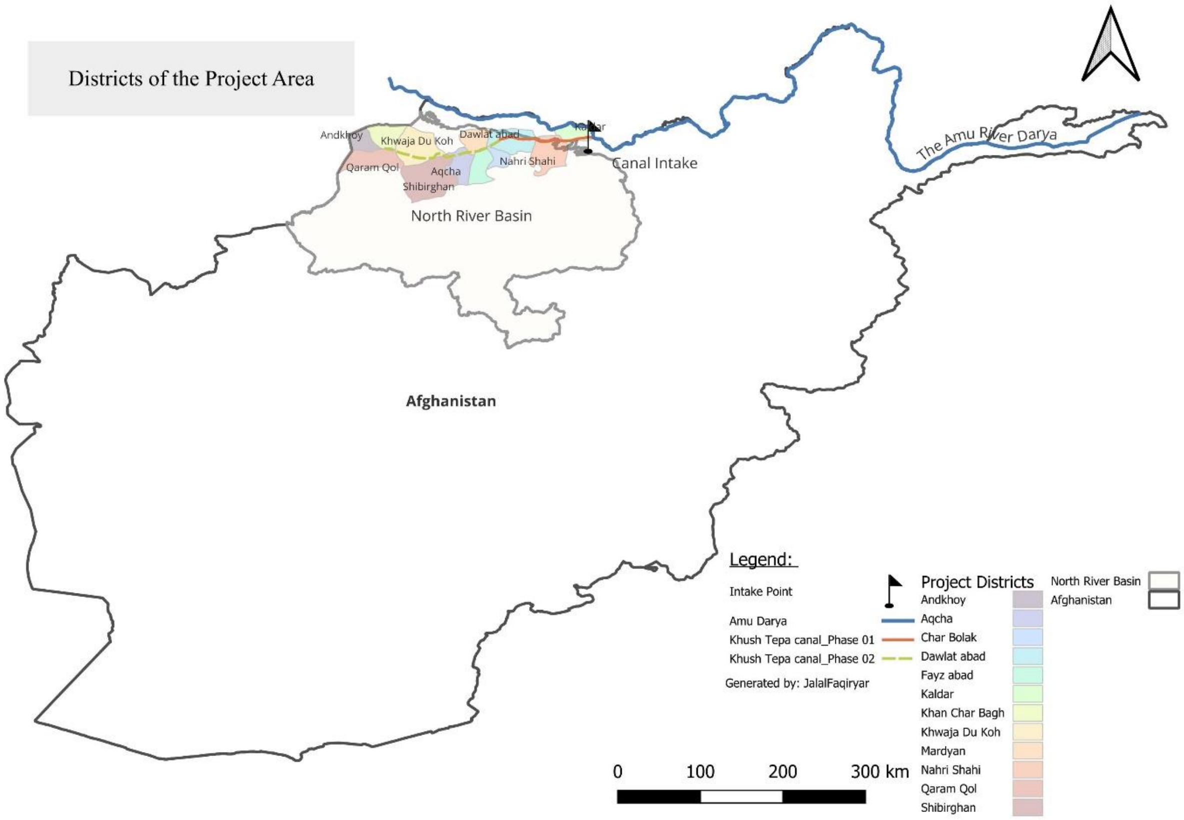


Figure 34: Passage of Qush Tepa Canal through the Districts of Three Provinces in the North River Basin.

3.3 Geological Strata, Hydrology, Glacier, and Subterranean Water Conditions in the Canal Zone

Since the canal is located in the North Basin and this channel extends almost from the middle of this area from east-to-west direction. Due to its considerable length, it possesses several significant features of the river basin. The water source for this channel is the Amu Darya, where most of the water flows during the summer. As the snow melts in the mountains of Afghanistan and Tajikistan, the water levels in the Amu Darya reach their maximum level. The water supply for this channel is directly dependent on the volume of water flow in the mentioned river. Additionally, in the southern parts of the basin, the Hindu Kush mountains are situated which are good sources of water during the summer. However, during the summer season, the water flow from these mountains does not adequately support the cultivation and agriculture of the lands beyond the aforementioned rivers. Consequently, the waters from these seas do not reach the Amu Darya.

Five major river basins of Afghanistan experienced a decrease in precipitation which directly affected and impacted the agriculture and livelihoods of the residents. The North River basin, which is located on the left bank of the Amu Darya, has almost the lowest capacity in terms of water resources (Frotan et al., 2020). However, this basin, with an area of 71000 km^2 in the northern part of the Baba and Hindukush mountains, basically receives more rainfall. With an elevation range of 250 – 4455 m from south to north, it decreases to plain deserts, which do not have enough rain to irrigate and compensate for the need for the residence. Mainly, this river basin includes the provinces of Samangan, Sar-e Pul, Balkh, Faryab, and Jawzjan provinces, which Amu Darya passes on the bank of three of them. In the past, Afghanistan had a significant amount of water resources which were flowing from the Hindukush mountains (Kamil, 2021).

According to study of (Shokory et al., 2023), the glaciers in Afghanistan's Hindu Kush region are receding, a concerning trend attributed to climate change that carries substantial consequences for water resources. This retreat is currently offset by what's termed a "glacial subsidy," where the increased melt of summer ice helps maintain streamflow, compensating for decreased snow accumulation. However, this temporary reprieve is anticipated to cease in the future. A significant portion of the Afghan population depends on snowmelt for irrigation purposes, making the ongoing shrinkage of these glaciers a dire threat to this vital water supply.

4. Food-Climate Nexus Analysis of the Qush Tepa National Irrigation Canal

As previously detailed, the issue of Afghanistan's population in the trend of development and progress is a major topic of discussion. One of the challenges Afghanistan faces is ensuring food and consumable supplies. Despite having vast lands, and natural resources Afghanistan has not fundamentally resolved this pressing issue due to various reasons. Furthermore, climate change, drought, and insecurity have significantly exacerbated the problems and obstacles to progress. Climate change has led to rising temperatures and reduced rainfall across the country, particularly in this region, prompting residents to consider migration, poverty, unemployment, and dissatisfaction with the government. Taking these challenges into account, that republic and de-facto Taliban government decided to revisit and implement the 1976 development plan with regard to irrigation projects, which includes the ambitious the Qush Tepa National Canal. With the construction of this canal, the government aims to achieve four main objectives: first, to curb citizens' migration to neighboring and Western countries; second, to create permanent and stable employment opportunities for those engaged in agriculture and livestock. Third, to diminish the food insecurity and release itself from dependency to first need crops and the fourth, to transform the desert in the north basin to farmlands and pasture. Additionally, it aims to reduce Afghanistan's dependence on other countries that were major exporters of wheat, rice, and other grains, thus striving for short-term independence in agricultural production. The Qush Tepa Canal is being constructed in the arid plains that were previously uncultivated which already, it has significantly impacted land prices in these regions. Recent studies show that the area of vegetation has drastically decreased in the last 10 years. (*See cropland analysis and monitoring topic, figure 18*)

Command Area	Agriculture Area (ha)	Irrigated Area (ha)
1212572	444391.2	68003.28

Major crops	Before project				After project				Revenue difference	Operation cost (8% of total project)	Net benefit for one year	Net Benefit for 10 years
	cultivated Area (ha)	Yield Kg/Ha	Price $/kg	Revenue USD	Area increase	Yield Kg/Ha	Price $/kg	Revenue USD				
Wheat	348,944.00	3000	0.30	$314,049,600.00	399,003.00	2970	0.30	$355,511,673	$41,462,073	$1,658,483	$39,803,590	$398,035,901
Vegetables	23,259.00	200	0.35	$1,628,130.00	310,459.00	198	0.30	$18,441,265	$16,813,135	$672,525	$16,140,609	$161,406,092
Orchard	39,928.20	6000	0.50	$119,784,600.00	155,647.20	5940	0.44	$406,799,522	$287,014,922	$11,480,597	$275,534,325	$2,755,343,250
Pulses	32,260.00	1140	0.60	$22,065,840.00	90,947.00	1129	0.58	$59,532,815	$37,466,975	$1,498,679	$35,968,296	$359,682,958
Total Net benefit for One year											$367,446,820.18	**$3,674,468,201.82**

Table 3: Agricultural Products - Cost - Benefit Analysis of Qush Tepa Canal

As shown in the table 3, by cultivating previously fallow lands and additional areas totaling over one million hectares, Afghanistan generates approximately $400 million in net revenue annually from the development of the North Basin. While this amount is substantial for Afghanistan's economy, it pales in comparison to the country's declined GDP. However, if investments were directed toward other development projects—such as hydropower dams on other rivers (such as the Kunduz River or Kabul River) or railway lines (Hairatan- Torkham or Torghundi to Spin Boldak)—the benefits would be far greater.

Now, the main discussion revolves around determining the water requirements for irrigating for all this command area, considering the significant impact of climate changes on humidity and evaporation. We've classified all agricultural products in this region into four categories: wheat, vegetables, orchards, and cereals/legumes. We recalculated land values both before and after development, considering the construction of this channel, and adjusted product prices to reflect current rates. Factoring in rising temperatures and assuming full operation of this channel with crops at their peak growth and water consumption, along with maximum plant evaporation and transpiration under RCP 4.5 for climate change projection—the average daily water demand for this area amounts to 36.8 Mm^3. To provide perspective, this is approximately equivalent to 426 m^3/s from the Amu Darya River, constituting roughly 23% of the total flow at the Karki station, based on flow data from 1932 to 1989 of Amu Darya, figure 6. This water demand reaches its peak in May for this canal.

Within the course of the hydrology studies, not only the climatic conditions of the project area but also the water potential of the Amu Darya River is assessed. This gives a general idea of the peak water demand and total water required for the full operation of the canal and crops needed over the two years.

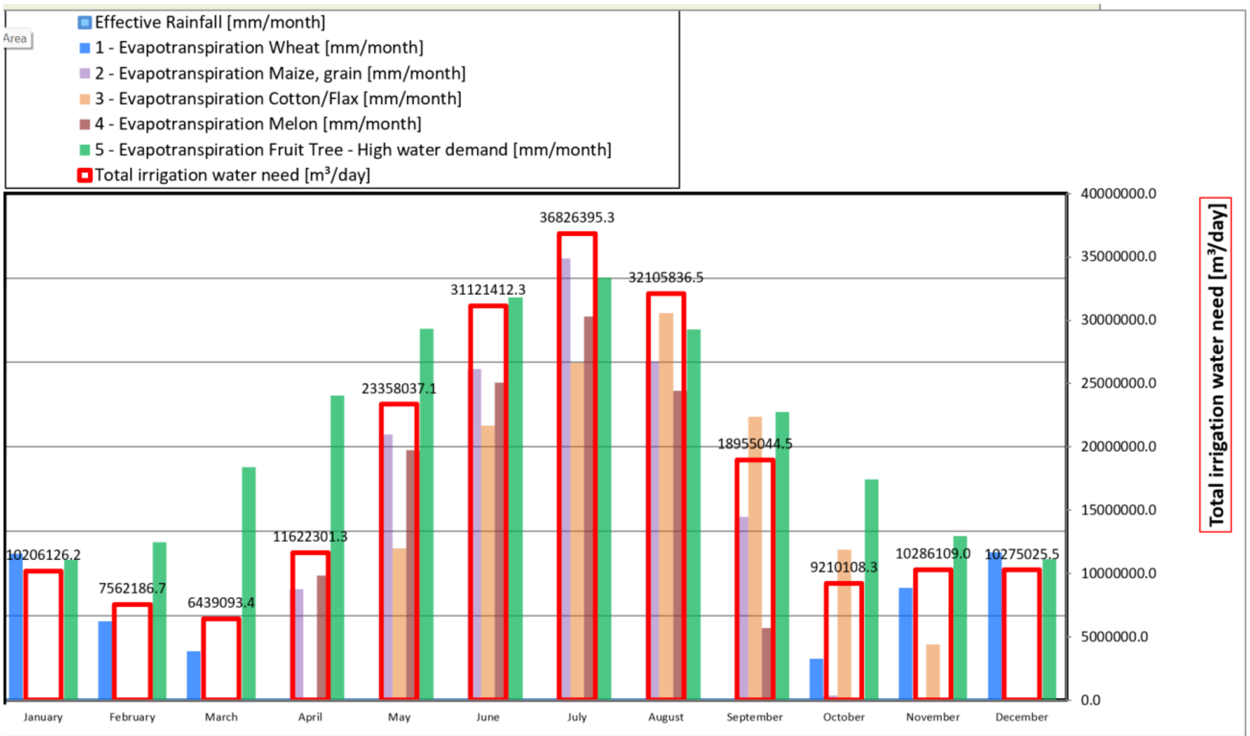


Figure 35: Water Deman for Full Operation of Qush Tepa Canal (Data Source: MAIL, 2020).

The total water required for one year of full cultivation of crops with 60% canal transfer efficiency would be 6,352,326,535 m^3/year, which makes 7.9% of the total water flowing in the Amu Darya River (80 Bm^3) and 28% of total water generated in Afghanistan (22.25 Bm^3) flowing into the Amu Darya River.

To fully utilize the Qush Tepa Irrigation Canal along with its command area for cultivating cereals, orchards, and vegetables, calculations indicate a potential positive shift in the trend of food availability in Afghanistan. Cultivating 350,000 hectares within the command area of the Qush Tepa Canal could lead to the production of 490,000 metric tons of wheat. This significant increase in wheat production could substantially reduce Afghanistan's dependency on importing this crucial food staple. Similarly, the cultivation of vegetables, orchards, and pulses is expected to positively impact the economy and enhance the access and availability of food in the markets of Afghanistan for its residents. The figure below illustrates the revenue generated from the total command area of the Qush Tepa Canal before and after the project's implementation. This initiative represents a strategic move towards improving food security and economic stability in the region.

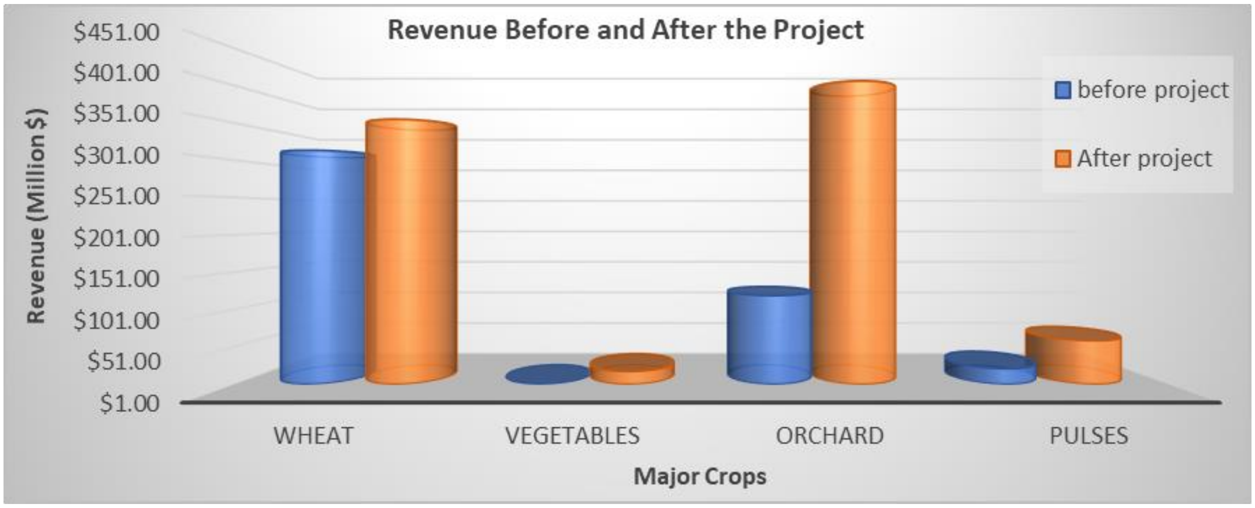


Figure 36: Revenue After the Canal Implementation.

The total command area of the Qush Tepa Canal encompasses 1,212,572 hectares of land. Presently, 21% of this area is irrigable and holds the potential for crop cultivation under specified conditions. Details regarding the soil type and other existing features of the command area are illustrated below:

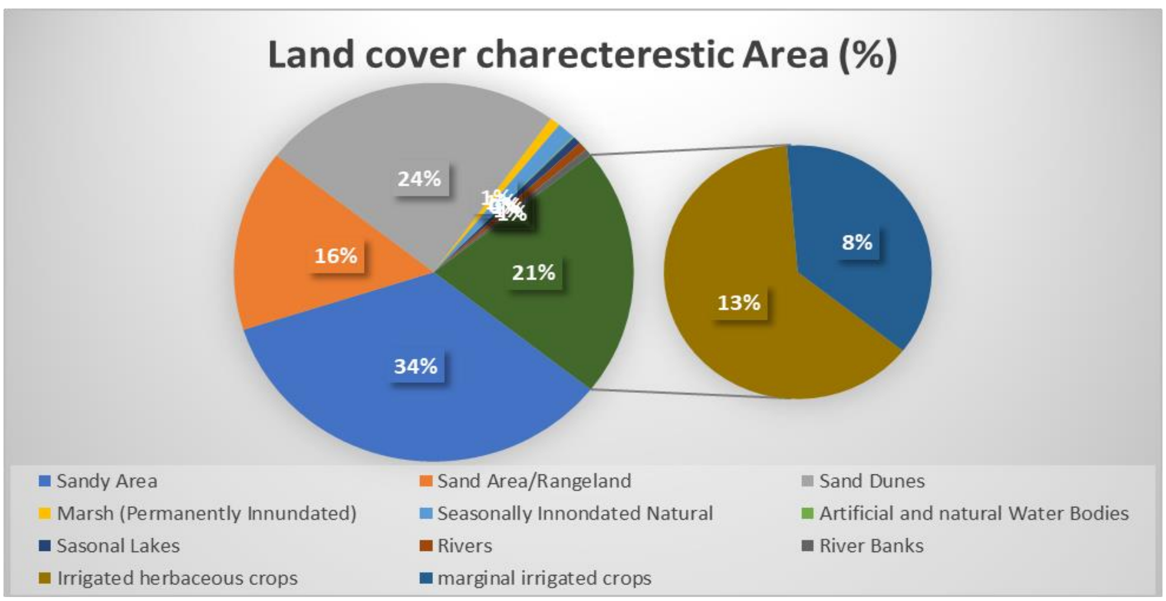


Figure 37: Land Cover Characteristics Area Percentage at the Project.

Given the current conditions and soil characteristics, it is not feasible for most crops to achieve full production, leading to reduced crop productivity. This reduction in productivity could be attributed to increased temperatures or soil infertility within the command area. Thus, the percentage of land suitability for various crops is defined below. The Qush Tepa Canal, which passes through three provinces, supports a diverse range of crop patterns. According to the report by the Ministry of Agriculture, Irrigation, and Livestock (MAIL) in 2020, the major crops produced in these provinces include several key varieties. Notably, the areas dedicated to wheat cultivation and production deserve attention, as they encompass both rainfed and irrigated wheat areas.

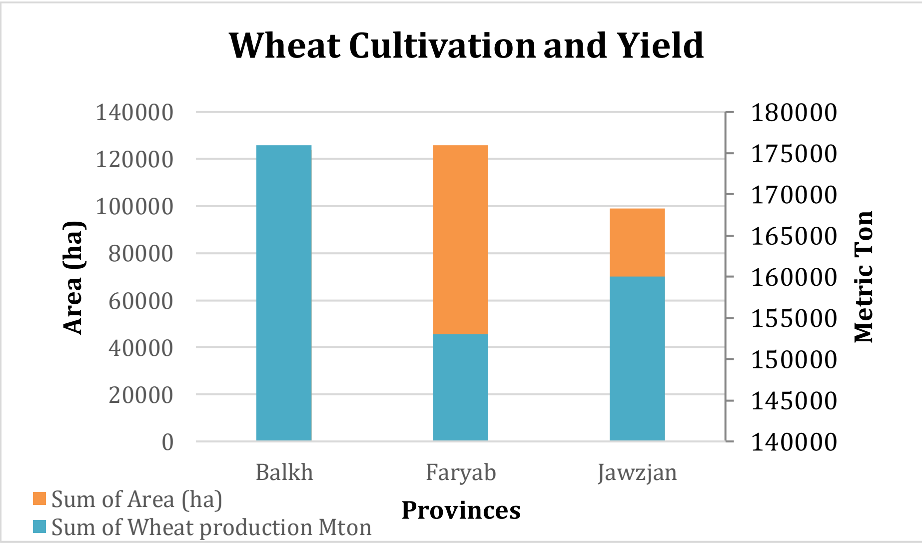


Figure 38: Wheat Production in the Three Provinces.

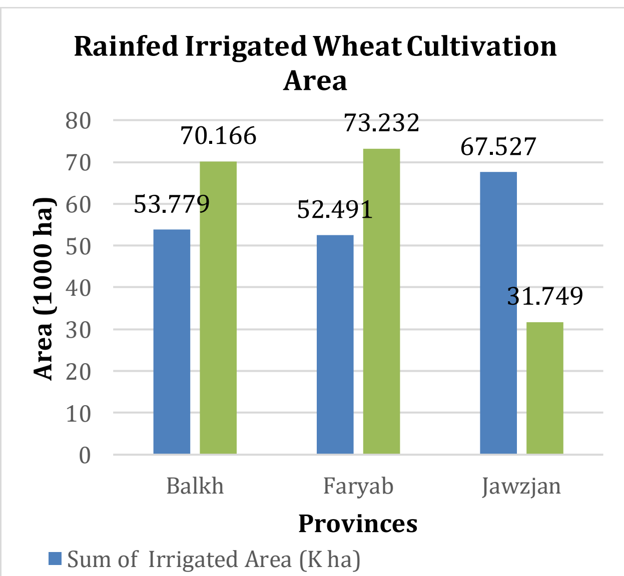


Figure 39: Total Rainfed and Irrigated Area for Wheat Production in the NRB (Data Source: MAIL, 2020)

Based on the provided data, the productivity in metric tons per hectare for the provinces of Balkh, Faryab, and Jawzjan are 1.42, 1.22, and 1.62, respectively, with Jawzjan province achieving the highest yield. The total area of irrigated wheat in these regions amounted to 348,944 hectares, encompassing both rainfed and irrigated wheat.

Wheat stands as one of Afghanistan's principal crops, occupying a total area of 2.53 million hectares and yielding an estimated production of 4.89 million metric tons. Given the country's population, the demand for wheat in 2020 was projected at 6.32 million metric tons. With the optimistic domestic yield of wheat accounted for, Afghanistan faces a deficit of 1.43 million metric tons, necessitating imports to meet this shortfall.

This analysis assumes that major crops, which are significant consumers of water, would be cultivated within the command area of the project. Initially, the suitability for cultivation in this command area is limited due to the soil's insufficient fertility for high-level crop growth. By adjusting the suitability criteria for crops to beyond 60%, only certain crops such as some varieties of wheat, orchards, vegetables, and pulses become viable options, with a total cultivable area of 130,000 hectares being feasible.

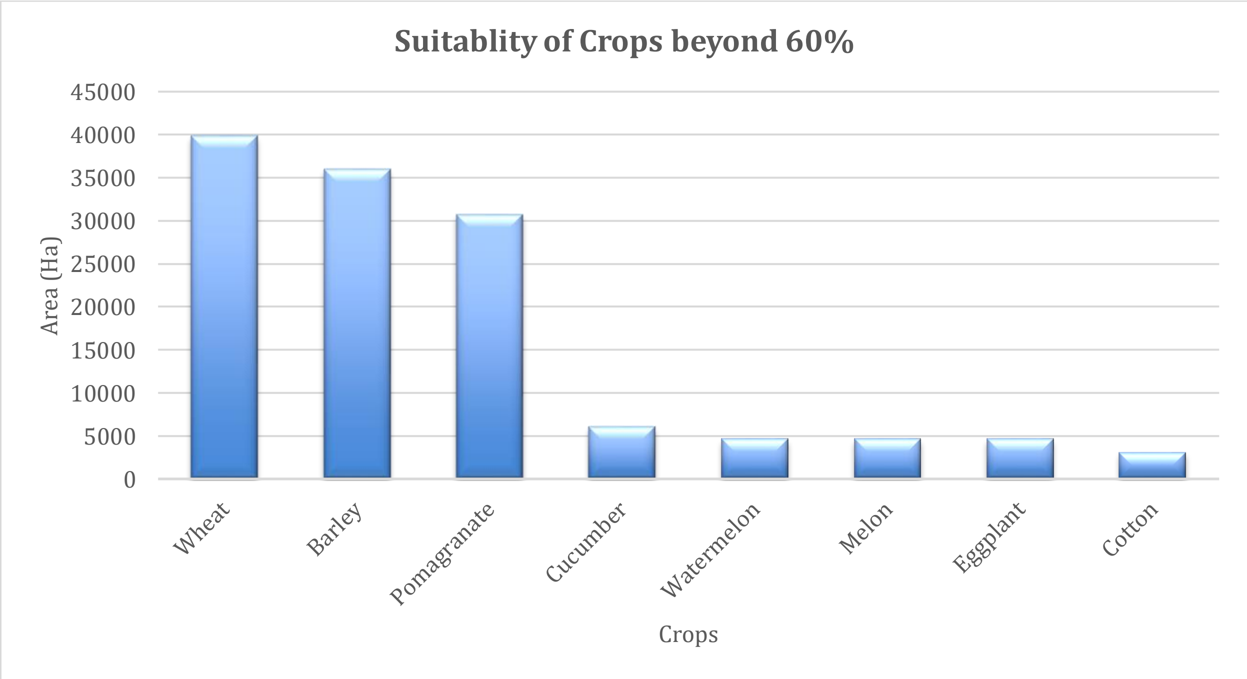


Figure 40: Suitability of Crop Cultivation at Project Area beyond 60%.

Within the specified range, wheat, pomegranate, and barley emerge as the most productive crops, with potential for widespread production across the area. Adopting an optimistic outlook and assuming efforts towards land improvement, soil classification, and enhanced fertility are successful, and by considering land with suitability beyond 40%, there will be opportunities to cultivate a broader array of crops. This expansion of crop cultivation could extend the cultivable command area to 512,000 hectares of land, significantly increasing agricultural productivity and diversity in the region.

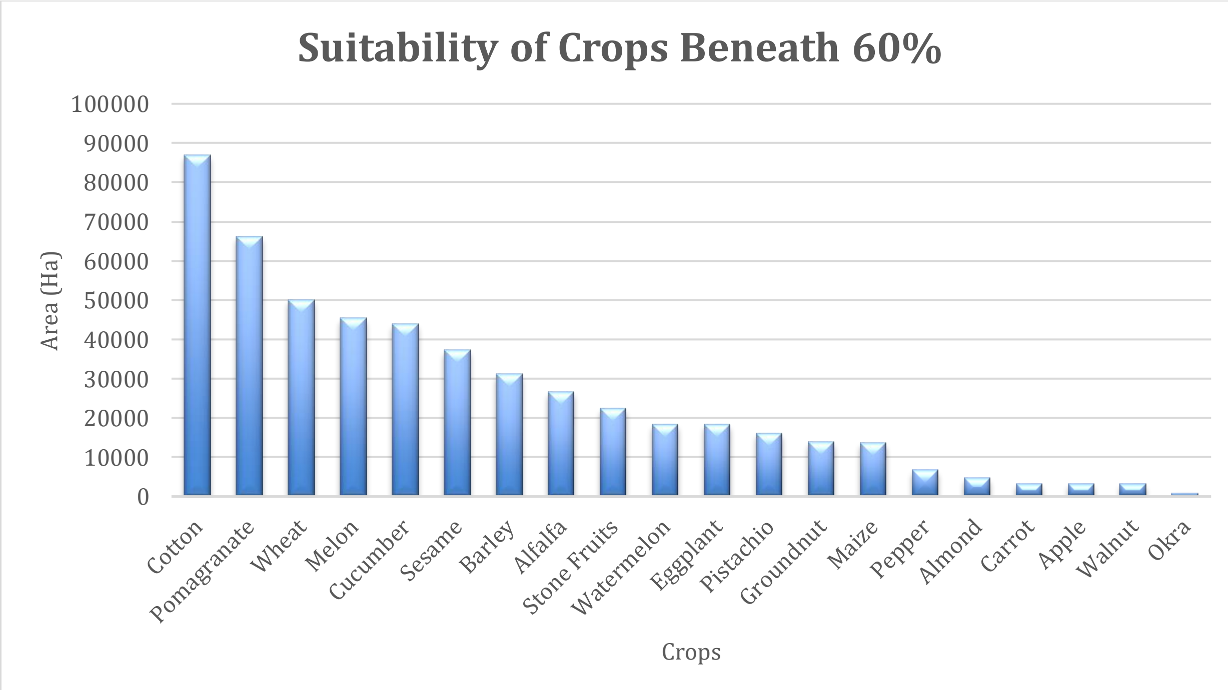


Figure 41: Suitability of Crops Beneath 60% Revenue.

However, beneath 40% suitability, there will be further crops that are not feasible to use. Certainly, climate and temperature will have a significant impact on them. In this scenario, the amount of land will be almost 50% of the total command area of the Qush Tepa Canal project.

Now, we categorize all the possible crops in the command area of the project into four categories, such as wheat, vegetables, Orchard, and pulses. Based on these categorizations, we will develop our economic analysis and calculations.

Since the area is sandy with sand dunes including rangeland, the cultivation of a variety of crops at the beginning of the project is challenging and needs efforts, technology, and research to find out the suitability of crops and production. The below graph shows that.

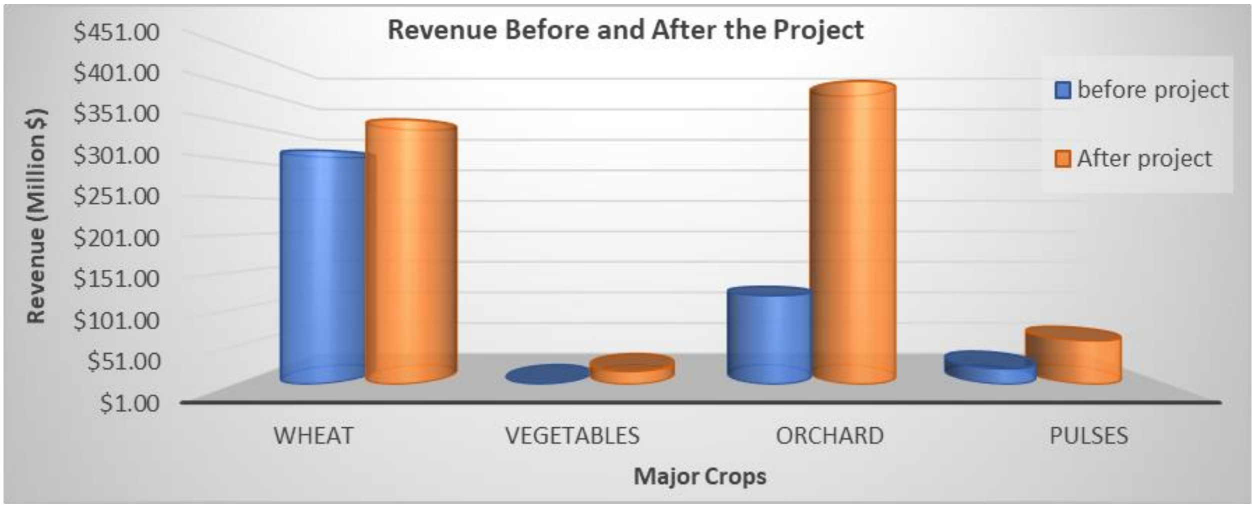


Figure 42: Comparison of Revenue - Before and After the Implementation of the Project for Four Groups of Crops.

Wheat and orchards are identified as the most revenue-generating crops in the North Basin. Although the project is in its initial phase of implementation and may not yield substantial revenue at the onset of harvesting, it is anticipated to have a significant financial impact and generate considerable profit over time.

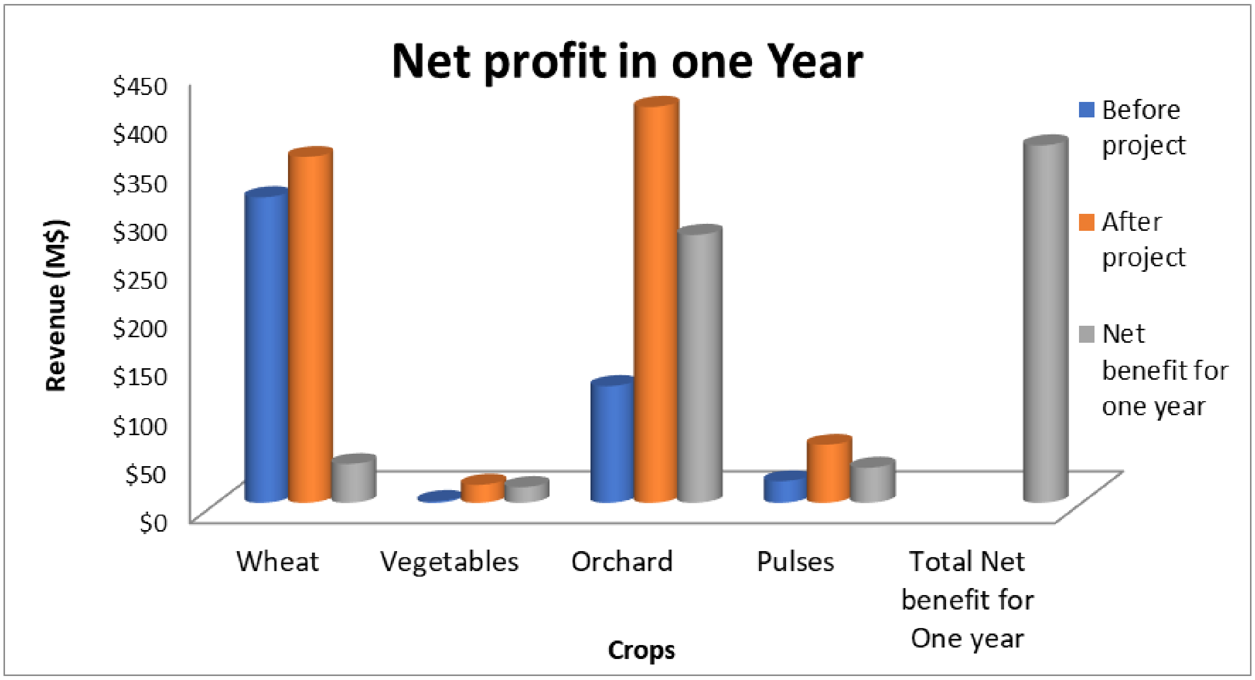


Figure 43: Net Profit in One Year with Current Market Price.

At the elementary stages, this project requires significant investment and meticulous attention, particularly in the operation and maintenance of the canal and its dependencies. Such investments are crucial for enhancing yield and productivity. For this reason, it has been considered appropriate to allocate four percent of the net profit from each major crop towards operation and maintenance costs. Despite the expectation that yield per hectare will remain unchanged before and after the project, it is projected that the net revenue, after achieving full cultivation of the area with efficiency below 85%, will amount to 367 million USD annually. When distributed across the total population of Afghanistan, which stands at 42 million according to the World Bank in 2023, this equates to an almost 10 USD yearly impact on the individual GDP of Afghanistan's residents, which may seem minimal. However, reinvesting this amount into other infrastructure projects, such as diversion dams for irrigation or hydropower production along the Kunar or Kabul River, or into initiatives aimed at increasing crop productivity and yield, could significantly enhance the living standards of the population.

Afghanistan's annual import of 1.2 million metric tons of wheat, accounting for 20% of its consumption (World Bank, 2014), underscores the critical need for increased wheat yield. The World Bank's 2014 report recommends that irrigated wheat offers the best potential for yield improvement, proposing two strategies: expanding the area under irrigation through rebuilding and new investments. Following this recommendation, the Government of Afghanistan has embarked on the Qush Tepa Canal project as part of a self-sufficient strategy for wheat production, aiming to significantly reduce the nation's dependency on wheat imports and other agricultural products.

It is obvious that climate will affect the environment and water resources of the North River Basin and significantly impacts agriculture in the area. Livelihood, and dependency of the residents on agriculture and its productivity is vital. Production of food for households with low income through agriculture will be endangered and moves through famine as result endangers dietary recommendations. The trend of temperature increase and reduction in rainfall up the end of century, Afghanistan will experience higher temperature in the North River Basin with reduction of rainfall. This impact rainfall, cropping pattern and crop harvesting along with productivity. Population growth, and excessive increasing food demand in current state and future requires innovative solutions be seeking which the Qush Tepa is one of them. However, this canal was established more than 50 years ago, but it is necessary for the region to produce enough food for the residence. Climate change impacts the production of primary food need of the residence by reduction in harvesting, however the soil of the command area is not still fertilized to produce the maximum yield. The food production of the canal will have one percent impact on GDP of Afghanistan. However, although it may not be sufficient for per capita use, it is highly beneficial to utilize the revenue generated by the canal to invest in other infrastructure projects. These projects could include hydropower generation dams on the Kunar River, establishing and extending train tracks, and other appropriate domestic infrastructural developments.

5. Discussion

Construction of the Qush Tepa canal has been in the plan of former governments of Afghanistan when there was no discussion of climate change and water reduction. However, droughts were sensible in some parts of the country, but not obvious. The former governments had projections that for self-sufficiency and being independent, there is need for fostering agriculture and livestock. Based on various reports, 75% of Afghanistan population deals with agriculture and it is counted as agricultural productive country. Non-existing of machinery and advanced tools have made agriculture and irrigation in Afghanistan to grow in the form of local and indigenous type which reduced production and harvesting. It also needs many efforts to gain a reasonable harvesting limit. Considering the last 24 years, since 2001, establishment of republic government in Afghanistan, significant steps picked up for managing natural resources especially water, but majority of them did not end up in a way to have continued sustainability and economic productivity. Reinitiation of Qush tepa canal was taken on hand to reduce migration and create jobs for the people of Afghanistan and release the country from dependency to other countries. This is during that antigovernment groups had been spread mostly in rural areas of the country and the neighboring countries, mainly the central Asian as neighbors of Afghanistan had expressed their concerns over the mass migration of the people and insurgents/insurgency from Afghanistan. However, the government of Afghanistan had several proposals for boosting the economy of the country and the region, but due to instability of the political state of the country these plans were not welcomed by the neighbors. Restarting the feasibility study of the Qush Tepa commenced in 2017 from Ministry of Agriculture, Irrigation, and Livestock (MAIL). It was concepts that irrigating the norther deserts of Afghanistan from Amu Darya will significantly reduce the cereals imports, but in return increases the exports. Technical teams from the Ministry of Agriculture, Irrigation and Livestock (MAIL) dispatched to the site to collect basic information, while from previous studies there was no information on hand.

The expectation from this irrigation canal is very high and hopes are that it will create jobs for the people and boost food availability in the markets of the country. Elementary estimations show that cultivating cereals in the newly developed area will significantly decrease the import of cereals from abroad specially the wheat which is the main substance of users. Additionally, Afghanistan will be able to control and use wisely the water resources it has in the possession. While at the time of the republic government only 8 km of the canal was constructed, several letters of the downstream countries specially Uzbekistan had reached to address of Ministry of Foreign Affairs of Afghanistan (MoFA) and requested information regarding the new excavation across the Amu Darya. Later, as the republic government collapsed, and the new regime came to power, the construction of this canal expedited which reached to 108 km in almost two years as the first phase of the project. Similarly, the central Asian countries, mainly the downstream ones, (Uzbekistan and Turkmenistan) continued sending similar letters to the new de facto regime. However, these letters did not reduce the speed of excavation of the canal on the ground. As result, the president of Uzbekistan announced that this canal will change the water rights of the downstream canals and changes the water regime. Water is mainly used in the downstream countries for cultivation of cotton for export. Various challenges exist on the ground for fertilizing the soil and enabling it to produce maximum yield in a short period of time.

Economically this construction of this canal will have a significant increase in production and job opportunities for Afghanistan. Form the other side, it prevents people from migrating out of the country to work outside as farmers, especially in the neighboring countries' farms and greenhouses. It increases the average income of the basins' residences at first step and secures food production and availability for the entire country.

Politically, it is a weighting stone that pressures the downstream countries to consider Afghanistan as a major water contributor and user of the Amu Darya. This position provides Afghanistan power to play significant role in ensuring its valid requests and bilateral interactions. However, using water from Amu Darya to Qush Tepa canal might not significantly harm the down streamers, as in comparison to water waste and inefficient water consumption in Central Asia, but it impacts them in long time when the glaciers melts in upstream. (Murzakulova, 2023) believes there will be 10-15% reduction in water flow to downstream riparian. Additionally, it encourages them to collaborate and cooperate with the new player and consider them as a major stakeholder. In the past, the water of Amu Darya was distributed among the five the Central Asian countries and Afghanistan was not considered as shareholder. Moreover, Afghanistan still do not have any treaty or signed MoU with the Central Asian countries over the shared water.

Afghanistan is geographically close to a large desert area, and the problems of desertification and sandstorms are very prominent. After the completion of the Qush Tepa canal, there is a plan to set large numbers of trees along the canal in the desert area. Through a forestation they can increase soil moisture and improve soil texture thus promoting land restoration and desertification prevention at the same time trees can block sandstorms slow downwind speed and sand erosion turn deserts into fertile farmland to developed agriculture and solve employment problems for more people the goal of grain exports can also be achieved. However, some countries are not optimistic about this plan which involves a vas territory huge investment and is time consuming. Israelis experts analyze that turning desert to fertile farmland is a miraculous project that cannot be realized in the short term. If it wants to complete it as soon as possible, Afghanistan can learn from China’s experience or seek help. China has been very successful in controlling desertification through decades of efforts it has save 700,000 acres of fertile farmland and pasture for the local area. Of course, in addition to China, Australia and Israel are also world leading in desert control technology. They also have rich and successful experience in desert control and can also provide Afghanistan with good suggestion.

6. Conclusion

Within the diverse river systems of Afghanistan, the North River Basin stands out as a pivotal watershed, notably housing the significant city of Balkh, which is a major hub of population. Additionally, this basin shares a border with Uzbekistan, adding to its strategic importance. Over the years, numerous feasibility studies such as the first Afghan republic government in 1976, and later 2017- have been conducted to explore the potential of irrigating the vast, yet untapped, desert plains within this region. The Qush Tepa project, conceived in 1976, remained on the drawing board until 2017 when the Islamic Republic of Afghanistan undertook a fresh feasibility study and initiated its physical construction. This move aimed to reduce food insecurity and domestic water competition, generate employment for returning migrants and citizens, address the mismatch between water demand and availability in the basin, and decrease the nation's reliance on imported wheat and other cereals to sustain food security.

However, the project's progression has heightened concerns among downstream countries, particularly Uzbekistan, due to potential impacts on water distribution. The Afghan governments have consistently argued that it is merely exercising the country's legal water rights and that neighboring countries should comprehend, especially since Afghanistan has no formal water-sharing agreements with Central Asian states. It is projected that Afghanistan will allocate between 7-10 Bm^3 of its 22 Bm^3 contribution to the Amu Darya River to the Qush Tepa canal.

Downstream countries, especially those reliant on the Amu Darya, have expressed worries that the canal's construction will disrupt the established water distribution framework in Central Asia, as outlined in the 1992 Almaty Agreement. Despite these concerns, the canal is deemed essential for Afghanistan to assert its legal water rights, aiming to alleviate hunger and boost agricultural production. This need has become increasingly urgent as the northern regions of Afghanistan have been suffering from severe droughts and climate change impacts over the past decade, significantly reducing cropland cultivation and agricultural output.

This report addresses downstream countries' concerns, highlighting that the areas traversed by the canal (Kaldar – Andkhoi districts) feature diverse soil conditions, which currently yield suboptimal agricultural productivity. Nevertheless, the completion of the canal's first phase, extending 108 km, is a significant milestone. Despite challenges posed by climate change, there is potential for cultivating a variety of crops with productivity increases of 60%, including cotton, wheat, barley, eggplant, melon, watermelon, cucumber, and pomegranate. This could generate an annual net profit of $367.5 million, significantly benefiting Afghanistan's GDP.

Afghanistan is facing the impacts of climate change sooner and more severely than climate models CMIP6, and RCPs 4.5 and 8.5 projections anticipated. Current trends indicate a warming trajectory exceeding global averages, with temperature increases between 1.4 and 5.4°C expected by 2099. This warming is likely to severely affect water resources and agricultural yields, further challenging food availability in the country. Also, there is reduction in precipitation by 25% after two decades from now. The canal, designed to meet the irrigation needs of its command area, requires 6.35 Bm^3 annually, with peak water demand reaching 36.83 Mm^3 under the 4.5 RCP climate change scenario during periods of maximum crop growth. This demand is within the seasonal flow capacities of the Amu Darya and the canal's design, suggesting a thoughtful approach to balancing water use and agricultural needs.

The study has concluded that the Qush Tepa canal is a strategic and innovative endeavor that seeks to tap into the potential of the Amu Darya River, aiming to strike a balance between environmental conservation and the well-being of society. It suggests that the project is poised to significantly influence the livelihoods and resilience of the local population. However, the quantity of water flowing downstream is decreasing, leading to the failure of efforts to maintain the downstream environment. Agrarian lands along the path of the tailwater will not receive the same amount of water as before, potentially increasing transboundary water conflicts.

Furthermore, the Qush Tepa National Irrigation Canal embodies both opportunity and challenge. It has the capacity to revolutionize the North River Basin, yet its successful implementation and management demand meticulous consideration of technical, social, institutional, and geopolitical complexities. Looking forward, it will be essential to monitor its effects on local communities and regional dynamics closely.

In addition to the key insights of this study, another notable aspect is the interplay between food security and climate change within the region, which could variably affect transboundary water conflicts and cooperation, contingent on the specific circumstances and political climate among neighboring countries. The canal not only has the potential to impact the environment, food security, and foster closer ties between neighboring states but also to drive them apart, while unlocking new economic and bilateral opportunities for the region and its sole stakeholder.

7. Recommendations

1. Despite disruptions in the free flow of water to downstream countries, Central Asian countries should maintain and push the policy of economic investment in the Qush Tepa canal or any related infrastructure to yield economic benefits from investing in Afghanistan and specially in the canal region.

2. Among several other reasons and factors, the current agriculture and irrigation systems of the downstream countries are significantly affected by the impacts of the Qush Tepa canal. However, new irrigation and agricultural mechanisms can substantially reduce this impact and even positively influence the agricultural output of these countries. Additionally, to offset income losses, these countries can focus on cultivating high-value crops on their lands. The affected countries, particularly their business communities, can take actions regarding thoughtful investments and creative initiatives to mitigate these changes and use them as a tool to optimize yield profit.

3. Central Asian countries should shift away from zero-sum game perspectives, if they uphold, and seek to adopt win-win perspectives and policies that benefit both them and Afghanistan.

4. Afghanistan must remove bureaucratic obstacles that Central Asian investors face, such as the visa regime and investment bureaucracies. This would enable Central Asian citizens to come to Afghanistan and evaluate investment options. By registering their companies or partnering with Afghan companies, they can take pragmatic investment actions.

5. Afghanistan should change some of its policies and regulations to benefit from the experiences and innovations of the Central Asian countries, especially those neighboring the Amu River, in the agriculture sector. For example, Uzbekistan and Turkmenistan are the largest cotton exporters and have extensive experience in high-yield cotton. Their experiences could be utilized to transform deserts into green fields and agricultural lands. This can be achieved by creating a hub for experience sharing, connecting researchers and stakeholders from both sides of the Amu River, linking farmers to each other, enhancing the capacities of farmers on both sides, and removing unnecessary barriers that are no longer needed. This positive impact can lead to mutual efforts and benefits. Investment by traders from both sides, building trust among the Amu Darya

stakeholders, and unconditional cooperation will ensure that no party loses but rather becomes a winner through this change.

6. Downstream countries should publish a specific and accurate threshold for the water demands and arrange their cultivation and cropping industry based on water availability and coordination with other stakeholders to minimize the negative impacts based on climate change, and other factors. For example, if the stakeholders do not politicize water use (even though it is already politicized), they can generate a joint commission board for coordinating water use activities. As a result, this will help them plan and decide more efficiently for water use and arrange their cultivation plans.

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