Amu Darya Hydrologic Assessment – The Case of Agricultural Land Expansion, Cooperation, and Unilateralism in the Basin

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ABSTRACT: *Amu Darya River (ADR) is one of the two large rivers that drain into the Aral Sea. With the large agricultural land expansion and withdrawals of water for cotton fields, and the potential Khoshtepa irrigation project in Afghanistan, the Amu Darya River flow will experience a continuing decrease in flow volumes. This paper describes hydrologic analyses of the Amu Darya River flow at Kaldar Station in Balkh Province, northern Afghanistan. The Khoshtepa canal will utilize ~5% of the ADR flow. The largest flow decrease will occur due to climate change and glacier budget exhaustion at the rate of ~20% by the end of the 21st century. This study identifies the difficult trade-off situation between resource depletion and population increases. The study indicated that the low flow reduction is ~ 20.4% and the high flow reduction is ~ 4.5%. This ratio suggests conserving water in reservoirs upstream for further redistribution in low flow season. A road map for constructive dialogue across the basin, and the need for changes to the historic decision regarding collaboration will be important to demonstrate how the limited resources can be utilized.*

KEYWORDS: Amu Darya, water balance, Aral Sea, hydrologic assessment, Afghanistan

INTRODUCTION

Amu Darya River is the largest river in Afghanistan and is one of the two major sources of water draining toward the ‘dying’ Aral Sea. The Amu Darya River is shared between Afghanistan and the Central Asian States of Tajikistan, Uzbekistan, and Turkmenistan. Due to the complexity of the terrain, the lack of previous transboundary cooperation, and the large withdrawals of water for the purposes of cotton crop growth in the Central Asian portion of the Basin, the Amu Darya River almost dries up before it empties into the Aral Sea.

The Amu Darya River (river) is the longest river in Central Asia, entailing ~ 2,540 Km from its origins near Wakhan in Pamir to the Aral Sea in Central Asia (Masoud, 2004). The average flow in the River is ~75 Bln m3/y with a minimum flow of ~ 45 Bln m3/y and a maximum of ~ 104 Bln m3/yr. over the history of record. The peak flow occurs between April and October, while November to March is the low flow season due to freezing temperatures in the headwaters of the Amu Darya River at Wakhan. The river constitutes a natural boundary between Afghanistan and its Central Asian neighbours. There are several bridge crossings over the Amu Darya River from Afghanistan into Central Asia; however, there is no major joint project that utilizes the river water for the common good of the region as well as the communities lying on the banks of the Amu Darya River. Between 1977 and 1989, over one million hectares of additional cotton cropland were added (Kahriz, 2019), involving diversions to irrigate water-intensive agricultural lands, predominantly in Uzbekistan.

Afghanistan has no treaty or agreement on the use and distribution of the Amu Darya River waters (Kamil, 2021). In 1991, the Central Asian Republics decided to establish the Interstate Commission for Water Coordination of Central Asia (ICWC). However, Afghanistan and Kyrgyzstan, the upstream members of the basin, were not included in this commission. Subsequently, the Amu Darya River became more controversial due to its importance as a major water source for the Aral Sea. Many researchers have studied the impacts of the Aral Sea environmental disaster that in part can be directly related to the over-withdrawal from the Amu Darya River over the course of decades.
In 2018, the United States Agency for International Development (USAID), through its Strengthening Watershed and Irrigation Management (SWIM) program, launched a feasibility study for the Khoshtepa irrigation project. This program recommended the development of the Khoshtepa Canal on the Afghanistan portion of the Amu Darya River, a program that will cover the Kunduz, Jawzjan, and Balkh provinces of Afghanistan. This program envisions a 200km canal will be constructed from the Amu Darya River, to provide irrigation of ~ 500,000 hectares of land. The average water requirements for high-efficiency irrigation are ~ 4.5 Bln m3/y.

The Afghanistan government hoped that via the Khoshtepa project, the country would be able to utilize a small portion of its rights on the Amu Darya River waters. The Khoshtepa irrigation project remains one of Afghanistan's top priority goals. The Afghanistan government has prioritized this project in its Afghanistan National Development Strategy (ANDS). Many Afghan governments over time have pledged to build this project, to increase the food production in the northern part of the country. This includes the Taliban who seized power in 2021 and announced that they will start work on this project and pledged to complete the irrigation canal works in five years.
This paper conducts a hydrologic assessment of the Amu Darya River at the Kaldar section and evaluates the hydrologic impact of the future water withdrawal for the Khoshtepa irrigation project from the portion of the Amu Darya River that flows through the Kaldar catchment.

The Kaldar catchment delineation was carried out using a 30 m by 30 m Shuttle Radar Topography Mission digital elevation model (Farr et al., 2007). Five sub-catchments were delineated within the Kaldar watershed based on the key river systems that contribute to the flows of Amu Darya at Kaldar (Figure 1).

Figure 1.Amu Darya River Basin at Kaldar Catchment Key Plan

The catchment's total area is 338,730 km2. The sub-catchment information is shown in Table 1.

Table 1. Amu Darya River flow information at Kaldar Catchment

Sub Catchment	Catchment Area km^2	Catchment Flow m^3/s	River
Panj sub-catchment	153,814	1000	River Panj
Kokcha sub-catchment	32,174	163	River Kokcha
Kunduz sub catchment	57,205	67	River Kunduz and River Taloqan)
Vakhsh sub-catchment	71,030	621	River Vakhsh
Kafirnigan sub-catchment	24,507.44	95.	River Kafirnigan
Amu Darya at Kaldar	338,730.44	1946.9	Amu Darya River

Source: Didovets et al. (2021)

The objective of this study is to assess the flow regime considering the following:

a) To characterize the flow at the Kaldar station in connection with the flow at sub-catchments upstream of the Kaldar station.
b) To determine if the flow has changed over the course of the past fifty years.
c) To determine whether the new Khoshtepa Canal water diversion will have a drastic impact on the flow regime downstream to the Central Asian States and the Aral Sea.
d) To propose a mechanism for Afghanistan and Central Asian states for water sharing and management strategies

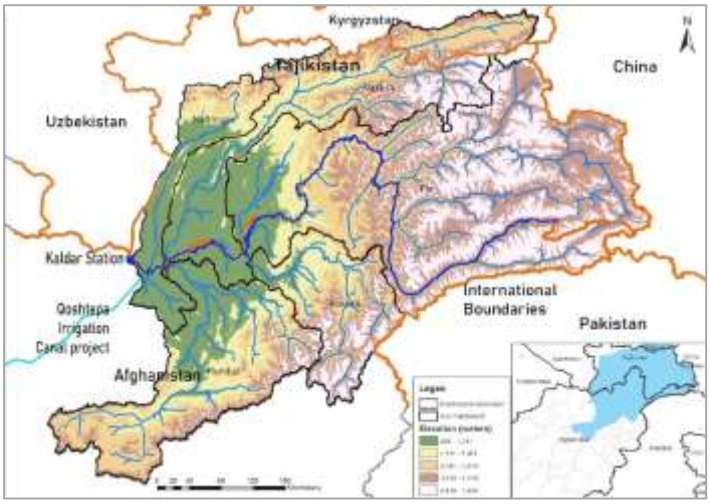

Figure 2: Kaldar catchment Elevation Profile and Main Sub-catchments.

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Study Area

Hydrologically, Kaldar catchment consists of two regions: the mountainous region of water nourishment and the lowland region, an area of water depletion. The headwaters of the Kaldar are located in the mountains of both Tajikistan and Afghanistan, among the snowmelt and glaciers of the Pamirs and the Hindu Khush, where elevations range from 5,000 to 7,000 meters. The glacier melting at the Wakhan heights between 4000 m Mean Sea Level (MSL) and 5000m MSL in the Amu Darya River is an important component of the flow regime. The river's two main tributaries namely, the Vakhsh River and the Panj River contribute over 80% of the Amy Darya River (Didovets et al. 2021) (Figure 2). The other tributaries of Amu Darya such as the Kunduz, Kokcha, and Kafirnigan Rivers contribute a total of less than 20% of the Amu Darya River discharge at Kaldar station. The Amu Darya's annual flow is such that between March to September, the River has high flows, where the river flow increases from March to May. High flows occur when the snow melts on the plains and rainfall increases. The flow is further augmented in summer due to ice and snowmelt in the mountain ranges. The flow gradually declines between September and February. Ice dams form along the banks of the river's upper reaches during the winter times. The river's downstream sections freeze completely for more than two months each year. As the ice floes begin to disperse in February and March, the River downstream forms natural ice dams. These ice dams sometimes burst catastrophically and cause major flooding (Mergili et al., 2013). In its upper course, the river's flow is stable; in its lower course, flow is influenced by continuous freeze and thaw and the variations of the hydraulic radius of the river sections.

Further, the patterns of flow in the downstream reaches in the Central Asian states of Uzbekistan and Turkmenistan are substantially modified by diversions and reservoirs to serve the cotton industry of the Central Asian states.

Kaldar catchment watershed elevations vary from 258 to 7,454 m AMSL (Figure 2), with a mean elevation of 3,020 m. Approximately 33% of the catchment area is above the 4,000 m elevation level. This elevation level is important because the snowline starts at the elevation range of 4,000 m to 5,000 m. Snow and glacier melting are the key sources of river water in the catchment.

Climate of Kaldar Catchment

The climate of the Kaldar catchment is heavily influenced by the mountains in the Pamirs and the Hindu Khush (Masood and Mahwash, 2004). The climate ranges from sub-tropical at the base of mountains, to continental, at the highest elevations where permanent ice and snow exist become glaciers. Precipitation falls mainly as snow during winter and helps feed the glaciers in the source areas of the Amu Darya, at the highest elevations in the Pamirs and the Hindu Kush, where annual precipitation may exceed 1,015 mm. Alternatively, the average annual precipitation is ~ 300 mm at the base of the mountains, with 90 percent of the rainfall occurring during winter and spring seasons (i.e. from December to May).

The average minimum temperature can reach -2°C at the base of the mountains during January and is rarely below -5°C. Meanwhile, in the higher mountain elevations in the Pamirs and the Hindu Kush, temperatures drop to -50°C. The average maximum temperature at the base of mountains reaches 39°C during the month of July and is rarely above 42°C.

Soils of Kaldar Catchment

The bulk of the Kaldar catchment is covered by loam soils followed by clay loam and clay soils (other soil types include sandy clay loam and sandy loam but to a much lesser extent (FAO, 2007)). In general, the Kaldar catchment largely has soil group C; these soils have moderately high runoff potential when thoroughly wet. Water movement through the soil is restricted in areas where there are high percentages of clay and loam. The soils typically have between 20% and 40% percent clay and less than 50% sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures (USDA, 2007). The Kaldar catchment area soil map is shown in Figure 3.

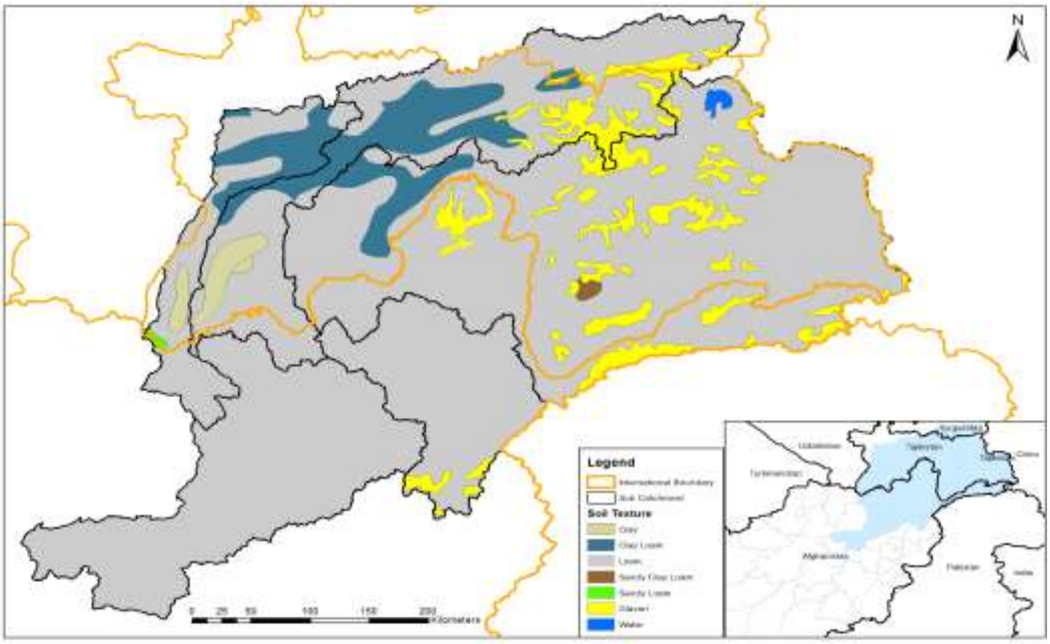


Figure 3: Kaldar catchment soils (FAO, 2007)

Estimation of Amu Darya Flow at Kaldar

Selection of Observed River Flow Data

Hydrologic evaluations are needed to determine the water resource potential at a particular location since there are often large fluctuations in river flows over time and space, particularly so, for this geographical location, varying from flood to drought. Knowledge of the magnitude and time distribution of river flow is essential for all aspects of water management and environmental planning (Olson and Sether, 2010).

River gauging began in Afghanistan in the mid-1940s, starting with a few sites, and further river gauging gradually increased over the years until the late 1970s. Within the Afghan region of Amu Darya, gauge stations were located in the sub-catchments of Kunduz and Kokcha with none in the Panj sub-catchments (Figure 4). Flow monitoring was discontinued in 1980 due to the Soviet invasion and civil war. Thus, no river flow data were collected after September 1980 until being relatively re-established in 2010 (i.e. many starting again from the year 2005). These gauging locations are now being operated by the Afghanistan Ministry of Energy and Water (MOEW).

Figure 4: Key River gauge stations in Kaldar catchment.

In general, two sets of data are available. The older (1940s to 1970s) and the most recent, data show that there is a general consensus that the flows in the tributaries of Amu Darya have been, and still are, diminishing (Konovalov, 2007; Begmurod, 2002; Bedford, 1997). The reductions are caused by a combination of factors including:

- Shrinkages of the glaciers which are important for maintaining flow during summer.
- The rising snowline which will free upland areas on which plants will grow, and will consume significant quantities of water due to evapotranspiration;
- The changing patterns of flow as snowmelt, with its slow release, increasingly falls as rainfall which encourages rapid runoff.
- Increased diversion of water for purposes of irrigation as older, dilapidated schemes are rehabilitated and new ones constructed.

These flow reductions across the Amu Darya Basin are anticipated to be within the range of 10 to 30 percent (Masood and Mahwash, 2004). Figures 5 and 6 illustrate the trend of declines in the flow of Amu Darya upstream at Nizhniy, (Figure 5) and downstream at Kerki, (Figure 6) as described by (Fuchinoue, Tsukatani and Toderich, 2002).

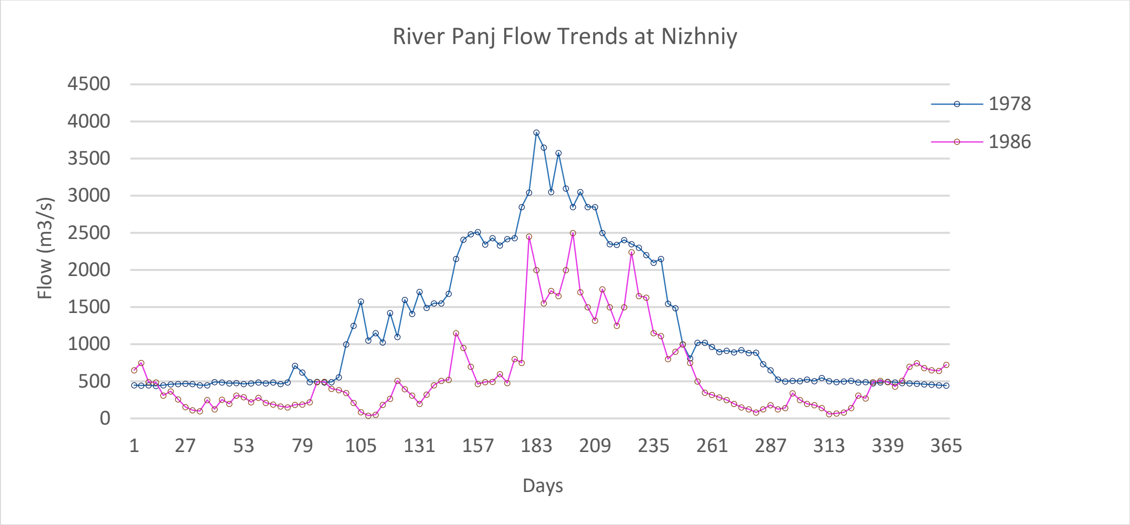


Figure 5: Trend of decline in flow of River Panj at Nizhniy –m^3/s

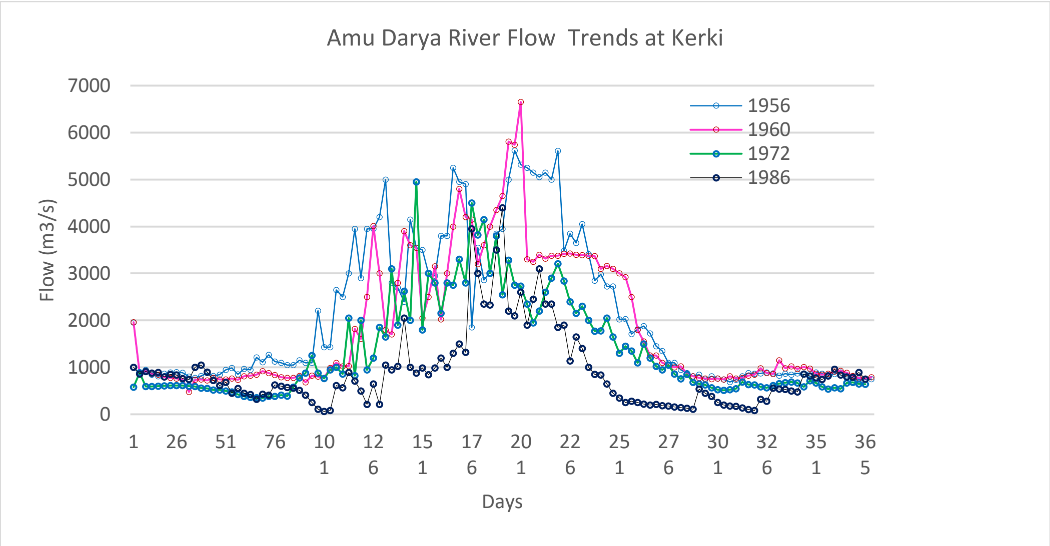
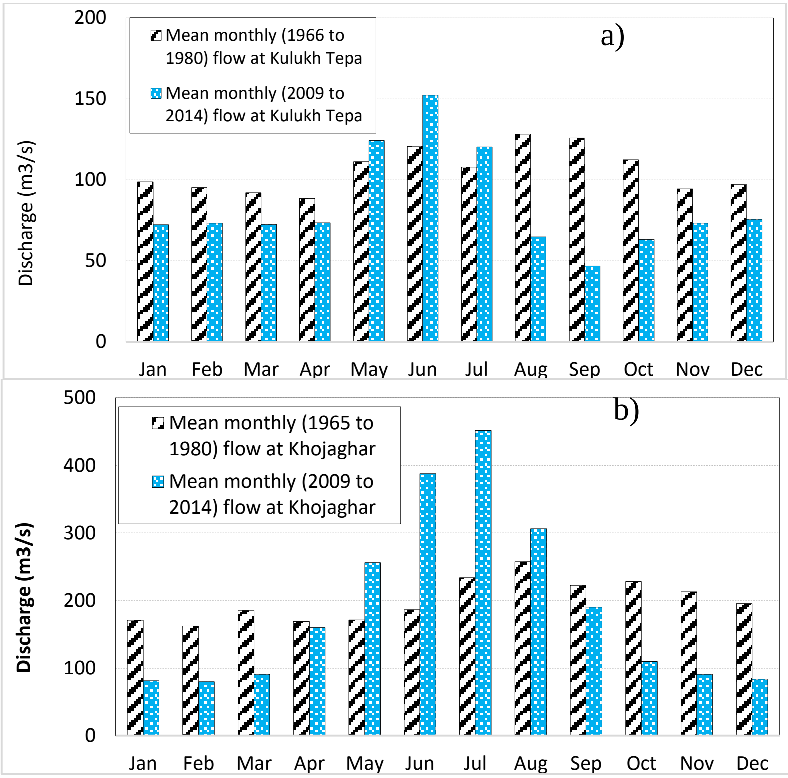


Figure 6: Trends of decline in the flow of Amu Darya at Kerki, further downstream (m3/s)

To decide on the most appropriate data series for this research, correlation analyses of the old and most recent flow records for the Kaldar catchment were carried out. In the old period (i.e. 1940 to 1980), flow monitoring in the Afghan region of the Amu Darya catchment was carried out along Kunduz and Kokcha Rivers, but none on Panj River. However, recently (i.e. from 2005), flow monitoring has been extended to the Panj River. Thus, the old and recent Kaldar catchment flow records could only be compared based on records at Kunduz and Kokcha subcatchments.

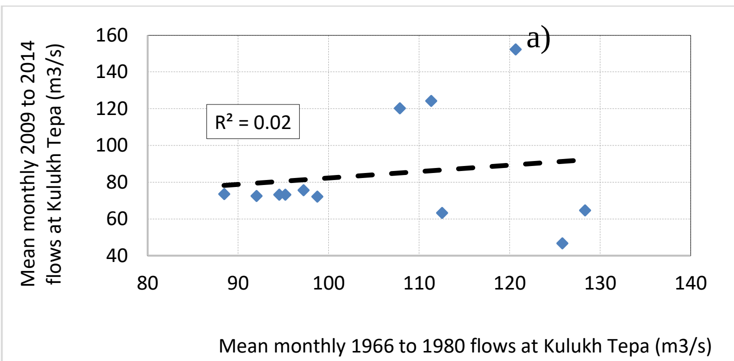
For comparison, the most downstream gauge stations at Kunduz and Kokcha sub-catchments (i.e. Kulukh Tepa and Khojaghar gauge stations, respectively, Figure 8b) were chosen to examine the differences between the upstream and downstream flows. Figures 7(a) and (b) show plots of the old and recent mean monthly flows at Kulukh Tepa and Khojaghar gauge stations along Kunduz and Kokcha Rivers respectively.

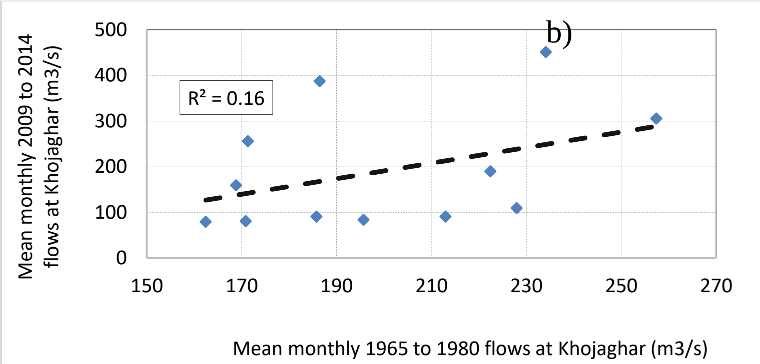


***Notes: a)** Comparison of old (1966 to 1980) and most recent (2009 to 2014) river flow data at Kulukh Tepa on Kunduz River. **b)** Comparison of old (1966 to 1980) and most recent (2009 to 2014) river flow data at Khojaghar on Kokcha River.*

Figure 7: Comparison of old (1966 to 1980) and most recent (2009 to 2014) river flow data at Kunduz and Kokcha Rivers.

The results show that at both Kulukh Tepa and Khojaghar gauge stations, the low flows have decreased while the high flows have increased. Further, Figures 8 (a) and (b) show scatterplots of the old and recent mean monthly flows at Kulukh Tepa and Khojaghar gauge stations, respectively. The plots show that there is a poor correlation between the old and recent flow data (i.e. R^2 of 0.02 and 0.16, respectively).





Notes: a) : *Scatter plot of old (1966 to 1980) and most recent (2009 to 2014) river flow data at Kulukh Tepa on Kunduz River.* ***b)*** *Scatterplot of old (1965 to 1980) and most recent (2009 to 2014) river flow data at Khojaghar on Kokcha River.*

Figure 8: Scatterplot of old (1965 to 1980) and most recent (2009 to 2014) river flow data at Kunduz River and Kokcha Rivers.

The volume of mean annual flow was 3.3 Bln. and 6.21 Bln. m^3 at Kulukh Tepa and Khojaghar gauge stations, respectively, between 1965 and 1980. These volumes decreased to 2.63 and 5.93 Bln m^3 respectively, between 2009 and 2014, indicating a decline of 20.4 % and 4.5 %, respectively. Due to the significant decreases in flows over time, the most recent data have been selected for the research of hydrologic analyses since they are the best indicators of current water availability in the two catchments.

Catchment Modelling Methodology

The various sub-catchments contributing to the flows of Amu Darya have several operating irrigation canals, barrages, and dams. The sub-catchments contribution to the basin is generally kept proportional to the sub-catchment area, its elevation, and the location from starting point to the main Amu Darya River catchment area. This has a direct implication regarding the setting up and parameterization of a hydrologic model that mimics the catchment's hydrology. Such a model is only feasible if flow diversion/regulation measurements are available at the various main canal offtakes, barrages, and dams. Since these data are not available, this demonstrates that it is not possible to calibrate/parameterize a catchment-based model that can meaningfully simulate the current state of the catchment.

Given the preceding, to estimate Amu Darya River flow at Kaldar, the contribution of each sub-catchment was quantified based on the flows from the most downstream gauge station in each sub-catchment. The most downstream gauge station was chosen since the effects of upstream river diversions are already reflected in the records with the use of the transposition method of flow. Figure 4 shows the locations of the most downstream gauge stations on the Afghanistan side of Kaldar catchment, including Kulukh Tepa gauge station in Kunduz sub catchments, Khojaghar gauge station in Kokcha sub catchments and Sheghnan gauge station in Panj sub catchments. Flow data were not available for the sub catchments of Vakhsh and Kafirnigan given that the gauging stations are located in Tajikistan and due to the lack of transboundary cooperation, the flow data are not shared amongst the basin members. This is an indication of poor data exchange and cooperation environment around the ADRB that must be studied. The gauging stations in Afghanistan were therefore used to estimate the contributions of Vakhsh and Kafirnigan Rivers with the assumption that the Kaldar catchment is homogeneous and the extent of river diversions and regulations are similar in the various subcatchments. Further, the assumption has been made that the catchments' flow surge is proportional to increases in the catchment area upstream of Kaldar station. Thus, the method of transposition for estimating river flow in ungauged locations of a catchment was adopted. This method is applicable for hydrologically similar watersheds (i.e. homogeneous) and for higher discharges, which are generally independent of catchment geology (McMahon et. al., 2002). Furthermore, the ratio of the discharges is assumed to be proportional to the ratio of the catchment areas to the power 'b'. Mathematically, the method of transposition is expressed as:

$$Q_u = Q_g (A_u/A_g)^b \quad \dots\dots\ (1)$$

Where,
Q_u and Q_g are the discharges at the ungauged and the gauged sites respectively (m^3/s);
A_u and A_g are the respective areas of ungauged and gauged sites (km^2).
The exponent 'b' varies widely and reported values range from 0.5 to 0.85. A value of 0.6 was adopted as recommended by McMahon (1982).
The Amu Darya flows at Kaldar were estimated by applying the method of transposition of flow at various periods and upstream gauge stations flow as shown in schematic fashion in Figure 9.

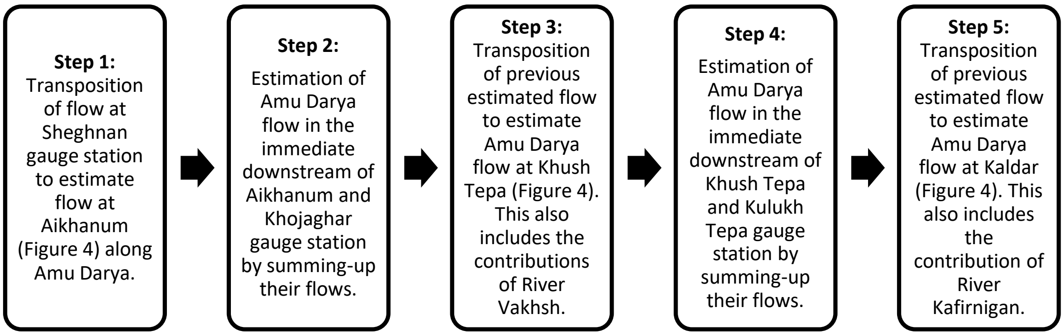


Figure 9: Schematic of application of transposition method for Amu Darya River flow estimation at Kaldar.

Prior to the application of the schematic in Figure 9, the observed flows at Kulukh Tepa and Sheghnan gauge stations were extended from the initial, observed two years flow records (i.e. October 2012 to September 2014) to five years (i.e. November 2009 to September 2014). The observed flows at Khojaghar gauge station did not need extension since they encompassed the entire five-year period. The extension of flow records from November 2009 to September 2012 was carried out using the correlation between Kulukh Tepa and Sheghnan gauge stations and their immediate upstream gauge stations that had flow records from November 2009 to September 2014. Char Dara and Ishkashem gauge stations (Figure 4) were employed during the correlation of the observed flows at Kulukh Tepa and Sheghnan gauge stations, respectively.
Figures 10 (a) and (b) show the correlations between flows at Kulukh Tepa / Char Dara and Sheghnan / Ishkashem gauge stations, respectively. The graphs show that the best fit is attained during periods of low flows.

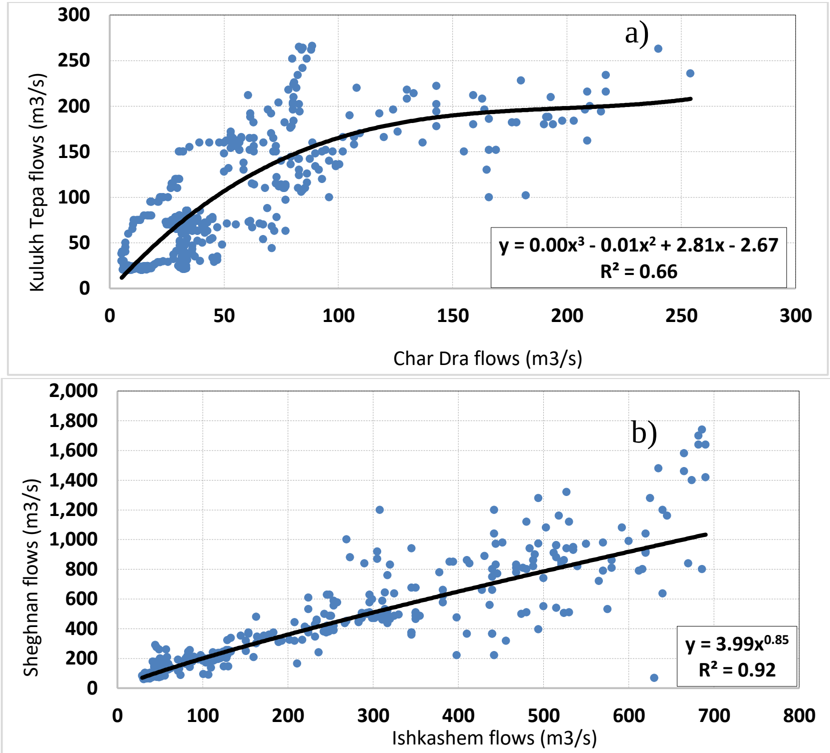


Figure 10: (a) Correlation between observed flows at Kulukh Tepa and Char Dara gauge stations. (b) Correlation between observed flows at Sheghnan and Ishkashem gauge stations.

Hydrograph of Amu Darya at Kaldar Catchment

The estimated Amu Darya flows at Kaldar are shown in Figure 11. The maximum and minimum flows are 4,845 m^3/s and 296 m^3/s respectively, with a mean of 926 m^3/s. The estimated total annual flow through this station varies from 23.03 Bln m^3 to 31.96 Bln m^3 water, with a mean annual flow of 28.94 Bln m^3 meters.

A World Bank study of the contribution of Afghan flows to the Amu Darya indicates that, on average, about 19 Bln m^3 of water is generated from within Afghanistan from a surface area of ~ 242,400 km^2 (Masood and Mahwash, 2004). The Amu Darya catchment at Kaldar encompasses parts of Afghanistan, Tajikistan, and Kyrgyzstan, with a total area of 338,730 km^2. This area is equivalent to ~ 23.23 Bln m^3 of water as per Masood and Mahwash (2004). The equivalent annual flow of ~ 23.23 Bln m^3 of water is corresponding to the estimated minimum total annual flow of ~23.03 Bln m^3 at Kaldar which was calculated based on the upper catchment interpolation and analysis.

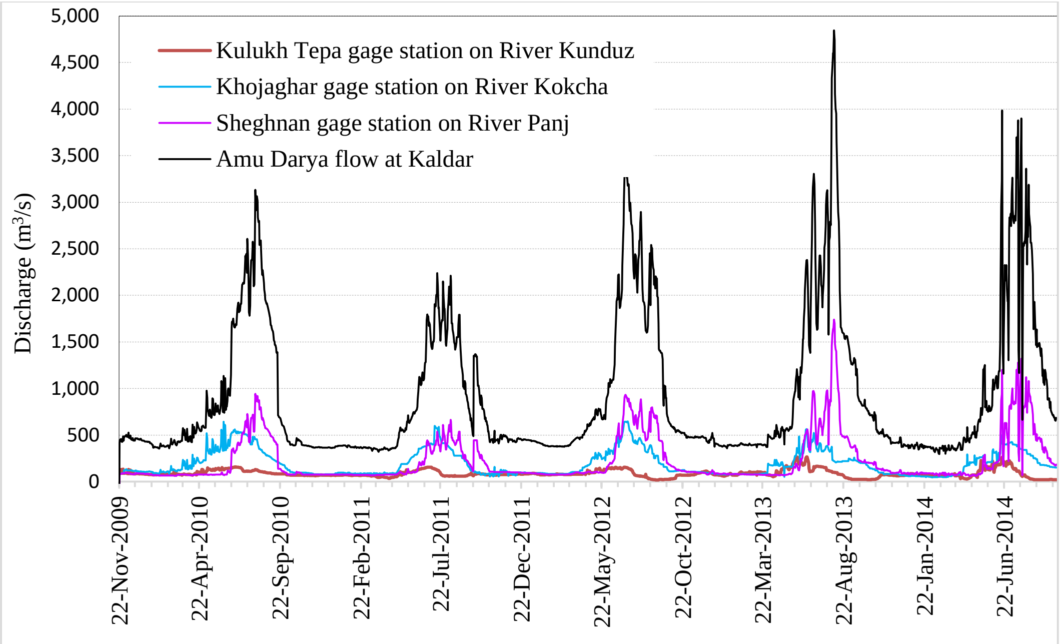


Figure 11: Estimated Amu Darya River flow at the proposed main canal off-take in Kaldar.

DISCUSSION

Amu Darya River is the largest river in Afghanistan and Central Asia by the volume of flow and the second largest by the drainage area. Approximately 17% of the area of the Aral Sea Basin is situated in Afghanistan, with the Amu Darya River being one of the two main rivers that are emptying into the Aral Sea. Amu Darya River's contribution to the Aral Sea has diminished in the past fifty years due to the aggressive expansion of cotton lands in the Central Asia portion of the basin (Khamzina et al., 2008).

The Amu Darya River water allocation amongst the Central Asian States (CAS) namely, Tajikistan, Uzbekistan, Turkmenistan, and Kyrgyzstan was governed by the Protocol No.566 adopted by the former USSR (Kamil, 2021). After the collapse of the Soviet Union and the independence of the Central Asian States, they formed several institutions to allocate the waters of the Amu Darya and Syr Darya Rivers. The Interstate Commission for Water Coordination (ICWC) was established in 1992 as part of the cooperation between the former republics of the Soviet Union which are part of the Aral River Basin. However, Afghanistan was not invited to participate in this commission. The official reason for the move was the ongoing civil war in Afghanistan that made a more complex and bloody turn in 1992.

Prior to the collapse of the Soviet Union, the Central Asian States of Uzbekistan, Turkmenistan, and Tajikistan dramatically increased the cotton croplands under a state plan to increase cotton production. They expanded the irrigated area to 7.2 million hectares in 1975 and to 9.4 million hectares by 1989 (Kamil, 2021; Spoor, 1998). Cotton is one of the most water-intensive crops (Snayed, 2015). Meanwhile, the agricultural expansion on the Afghanistan side of the Amu Darya River stagnated due to prolonged civil wars.

Given the above expansion of irrigation to increase cotton production, studies by Tshukatani (2002) and White (2014) indicate the declining flows in the Amu Darya River. River flows are expected to further decline between 10% and 20 % from current levels (White, 2014); however, the comparison of river flows in this study reveals that low flows will continue to decline while the high flows will increase due to glacier melting and shifts in precipitation seasonality. Several studies predict an increase in seasonal temperature of ~ 4ºC by the end of the 21st century in the basin resulting in glacier melt (Sun et al., 2017) which is in line with the world average temperature increase. However, the annual mean minimum temperature increased by more than twice the annual mean maximum temperature (Guo-Yu, 2017).

Glantz (2005) argues that the Central Asian States are caught in the midst of a cotton production race. These include Uzbekistan and Turkmenistan continuing to withdraw, with Turkmenistan having ~12,706 m^3 per capita and Uzbekistan having ~ 4,527 m^3 per capita (Ahmad, 2004). Another factor in the rapidly changing dynamics of the ADRB is the conflicting interests of the basin members. These interests can be summarized in two modes of cooperation as per Jalilov et al. (2016). Jalilov studied the two modes of water resources management in the rapidly changing Amu Darya River Basin (ADRB) and namely (a) the energy mode and (b) the irrigation mode of operation. According to Jaililov et al. (2016), neither operation mode provides optimal benefits for all countries. The use of the Amu Darya River or its tributaries waters for electricity production may benefit Tajikistan, Kyrgyzstan, and Afghanistan, while the utilization of water for irrigation benefits Uzbekistan, Afghanistan, and Turkmenistan. Afghanistan in this scheme can benefit from both irrigation and hydropower generation of water resources management. However, sharing resources such as electricity and agricultural products may bring significant benefits to all participants, something that has not been exercised not only by all members but also by the ICWC member countries.

The ICWC commission was organized predominantly to manage the distribution of water resources between the downstream states, in particular from the water withdrawal, and agree on the quantities for each downstream member.

In the past four decades, the three upstream countries Afghanistan, Tajikistan, and Kyrgyzstan interests have been overlooked and Afghanistan and Kyrgyzstan were not invited to the Commission. The Commission work opened the door for unilateralism in the Amu Draya River basin which accelerated the process of the Aral Sea environmental disaster. From an environmental perspective, faith in the Aral Sea was predetermined long before the ICWC establishment and during the leap forward for cotton production in these states. If we look at the ADRB from an economic perspective, the unilateral agenda of the commission reverts to the reverse Harmon Doctrine (McCaffrey,1996). This means that the downstream states have taken advantage of the instabilities in Afghanistan and Tajikistan in the 1990s and the delayed development in those countries to advance their economic agendas. In this case, the basin's active members had no agenda for the Aral Sea revitalization. During the 1990s and 2000s, the Central Asian States were rushing to become market economies and signed agreements with Western and South Korean producers for the supply of raw materials such as cotton. The basin environment was set to be a hegemonic water withdrawal and the Amu Darya River stopped reaching the Aral Sea by 2007. The Khoshtepa Canal in Afghanistan will have a negative impact on the water availability in Turkmenistan and Uzbekistan resulting in decreased flow in the Amu Bukharsky, Bagyap, Majyab, Canals in Uzbekistan, and the Great Garagum Canal (Turkmenistan).

The aggressive exploitation of the Amu Darya River waters by the Central Asian States has put Afghanistan in a disadvantageous position. Now that Afghanistan is attempting to use its share of the water resources, the challenges in the downstream CAS will accelerate.

Studies by Taraky et al. (2021a) indicate that the glaciers in the northwest part of the Hindukush Himalayan (HKH) Mountains will deplete at the rate of ~17% under two emission scenarios namely the Representative Concentration Pathways (RCP 4.5) and ~18% under RCP 8.5 by the end of the 21st century. There are over 35 reservoirs in various locations, most of which are in Tajikistan and Kyrgyzstan. The only hydropower project dam on the Afghanistan side of the ADRB is the Shorabak dam on the Kokcha River which is a run-of-river dam constructed to produce electricity for the city of Faizabad. Despite having vast rivers and water resources, Afghanistan is a poor country in terms of hydro infrastructure. The northern Amu Darya River Basin does have the potential as a major source of water where Afghanistan could invest and utilize its share of water resources. However, the prior appropriation of water downstream by the CAS (Uzbekistan, and Turkmenistan) has depleted the Amu Darya River waters that caused the Ara Sea disaster.

In this situation where there is no cooperation and consultation on the water utilization between the CAS and Afghanistan, the latest decision involves starting the utilization of its share of the Amu Darya River waters.

The withdrawal of waters from the Amu Darya River for the Khoshtepa Irrigation project will impact the flow of water to the central Asian cotton fields but will not significantly impact the flow of water to the Aral Sea as the flow of water to the Aral Sea has already been diminished due to prior aggressive withdrawals by the CAS states. Under the current unilateral water utilization circumstances, Afghanistan's Khoshtepa irrigation project can be categorized as an act of sovereign utilization of water resources by a nation that has such rights in an environment of no cooperation nor consultation. With the Khoshtepa Canal development, it is possible to come to an agreement on equitable water sharing that is more focused on regional economic development rather than on unilateral hegemonic development that is local and not focused on regional dynamics. The value of sharing water and its by-products can have dual economic and social effects that are quantifiable and measurable.

It is important to adopt a multifaceted approach that includes three major components:

a) To recognize Afghanistan's share of the Amu Darya River waters so the country can utilize the resources for its agricultural and hydropower needs;
b) To properly evaluate the environmental and economic impacts of the Amu Bukharsky, Bagyap, Majyab, Canals in Uzbekistan and the Great Garagum Canal (Turkmenistan) in light of the current realities and to assess the rights of the member nations in the basin waters; and,
c) To develop a basin-wide roadmap for equitable water resources management

To pave the way for transforming the ADRB from a competing unilateralism to cooperation and sharing of benefits including the rights to utilize the water resources and to allocate the water for environmental, recreational, and recharging purposes. It is important that the entire set of basin members, independent of their political systems and economic and political status, should come together and draw a roadmap that will consider the economic interests of all members and account for the environmental consideration for the entire basin.

The increased seasonal high flows at Kulukh Tepa (from Figure 7) indicate that the increased high flows between April and October and declining flows between November and March will continue for the foreseeable future. The construction of reservoirs could be a solution for retaining excess seasonal waters for projects such as the Khoshtepa irrigation canal and additional distribution downstream. This, apart from flood prevention measures, will allow Afghanistan to utilize its share of water resources in the Khoshtepa irrigation project. A problem of water balancing in the Amu Darya River is the inadequate distribution of water before it reaches the Aral Sea. The dramatic increase of irrigated lands in Central Asia took place without consultation with an important member of the basin (Afghanistan). The withdrawal of the Amu Darya River waters by the Central Asian states is shown in Table 2.

Table 2. Water Withdrawal Quota from Amu Darya River by Central Asian States

Country	% of flow
Uzbekistan	48.2
Turkmenistan	35.8
Tajikistan	15.6
Kyrgyzstan	0.6

Source UN (2004). pp 33-36, Abdolvand et al, 2015)

The Amu Darya River's contribution to the Aral Sea water reservoirs was ~ 36.5 Bln m3/y in the 1960s. This constituted ~50% of the river waters whereas the rest of the flow was used by irrigation in Central Asia (Bartnik, 1999). In the past fifty years, the Aral Sea reservoir shrunk tenfold compared to the lake size. The Aral Sea has lost ~85% of its area and ~ 90% of its water volume (Micklin, 2014). Considering the aggressive expansion of irrigated lands in both Uzbekistan and Turkmenistan it is argued that additional volumes of water were diverted from the Ara Sea and by 2020 this contribution shrunk to ~ 1.1 – 1.5 Bln m3/y.

The additional withdrawal of water from the Amu Darya River by Uzbekistan and Turkmenistan has increased by ~23 Bln m3/y.

Currently, the two major cotton-producing states of Turkmenistan and Uzbekistan have access to 24.36 Bln m3/y and 42.07 Bln m3/y of water while having 3.4 Mln ha of irrigated land and 2.5598 Mln ha of land respectively (Abou Zaki, 2022).

The combined water resources available to Uzbekistan and Turkmenistan is ~ 66.43 Bln m3/y (Abou Zaki, 2022).

In contrast, the Khoshtepa Canal will withdraw around 4.5 Bln m3/y subject to the water tightness of the canal. This will constitute only 7.5% of all the water available to the Central Asian states.

This volume of water will irrigate the ~ 0.5 Mln. ha of land under high-efficiency irrigation. This is less than 5% of the total river flow. Kamil (2021) predicts ~ 5 Bln m^3 of intake by Afghanistan if the Khoshtepa project is implemented. There are two main issues that need to be addressed.

a) The water balance and equitable sharing of water resources – As a result of the Khoshtepa Irrigation Canal project it may become possible to work together and establish a common goal of water sharing rather than water withdrawal. The Amu Darya River Basin members have not followed these principles, resulting in a unilateral aggressive agricultural land expansion taking place in the Central Asian states of Uzbekistan and Turkmenistan.

b) Regarding attempts to deliver more water to the Aral Sea, Levintanus (1992) and Dukhovny (2001) indicate that it is still possible to restore the Aral Sea ecosystem if aggressive environmental measures are undertaken.

In the first instance, the construction of reservoirs and equitable water distribution across the basin may respond to some challenges (Wegerich, 2007). The principle of equitable water resources management entails the obligation to (a) not cause significant harm, (b)encourage cooperation, (c) mandate information exchange, and (d) have peaceful settlement of disputes, and is widely acknowledged by modern international conventions, agreements, and treaties (Rahman, 2009). With the ongoing depletion of glaciers at high altitudes, it is important for the member states to reach an agreement on how to responsibly utilize the existing and future water volumes, considering the environment around the HKH glaciers. The findings from this research show that there will be a decrease in flow rates regardless of the Khoshtepa Canal Project. However, the retention of the water in the upstream reservoirs for the Khoshtepa irrigation canal will offset the negative impacts downstream. The water withdrawals by Afghanistan, a legal right of the country for its share of water resources use) may only harm the multiple canals in central Asia that were built without consultation and due diligence. Since the Central Asian States' cotton-based agricultural lands in the long run, are not sustainable and the water-intensive cotton is being replaced by organic and synthetic cotton (Bobojonov, 2013), sooner or later the issue of Aral Sea revitalization will resurface in the environmental and donor circles. To lay the grounds for the Amu Darya River Basin shared water resources management the following schematic road map is proposed.

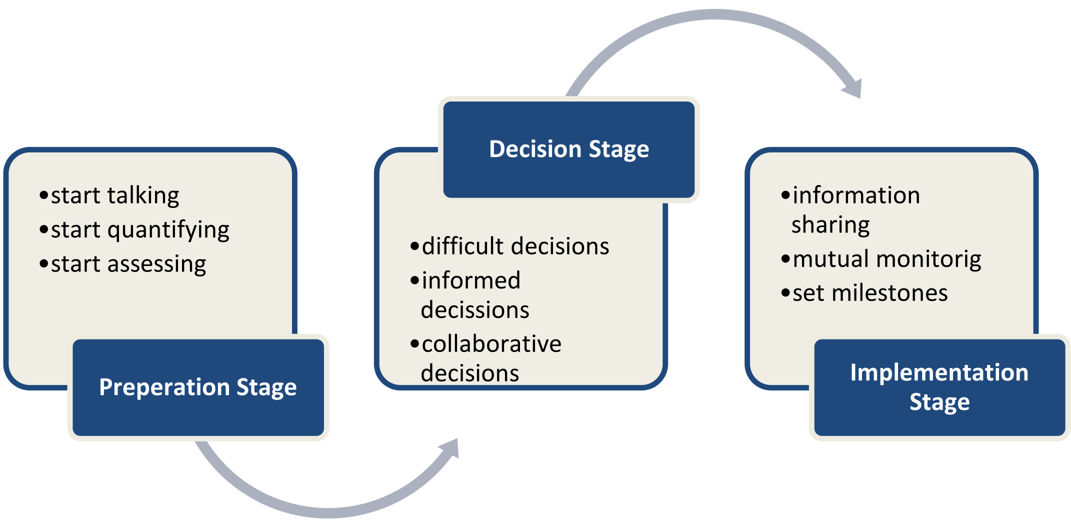


Figure 12:ADRB Schematic Road Map

Glantz (2005) elucidates several questions about the Amu Darya River Basin water resources management considering climate change, geopolitical changes and Afghanistan's attempts to utilize its share of the Amu Darya River waters.
However, in the case of the Amu Darya River, there are multiple challenges and few answers. This study and similar studies (e.g. White et al., 2014) predict a ~10% - ~20% decrease in annual flow excluding any water that will be diverted into Afghanistan's Khoshtepa irrigation canal. The addition of the Khoshtepa canal water withdrawal will result in an additional ~4.5% decrease in flows to downstream areas. The Central Asian States' aggressive agricultural policies have already resulted in the Aral Sea disaster.
Unilateral water resource utilization started in the 1970s. The cotton fields of Central Asia consume most of the water from the Amu Darya River before the water reaches the outskirts of the Aral Sea. The withdrawal of the upstream Amu Darya River including the Khoshtepa canal, is the sole right of

Afghanistan. In an environment of unilateral water resources management Afghanistan does not need to consult or receive permission from the other basin members. The Intestate Commission on Water is not an organization for basin water management. This commission is an organization to distribute the basin waters to the member states. Kyrgyzstan and Afghanistan are not even members of this organization. Tajikistan is an observer and is not benefitting from the decisions of the commission. Until an inclusive and participatory setup is organized it is rightful to call the Amu Darya River Basin a 'treaty and commission less' basin.
In an environment of cooperation and equitable water resources use, Afghanistan still has the potential to exercise its rights for the portion of water for its agricultural and developmental goals. In this case, Afghanistan has ~39% rights on the Amu Darya River and is heavily underutilizing its rights due to many economic, security, and geographic reasons. The use of Amu Darya River waters in a coordinated and informed manner can present many opportunities that may identify a way out of the current unilateral environment.

It is time for all member states to work together and address the future of the basin in terms of environmental revitalization, mutual economic benefits, and food security. The parties can use the steps shown in Table 3 to initiate the dialogue.

Table 3. Amu Darya River Basin Cooperation Framework

Preparatory Period	Discussion Period	Agreement Period
Setting up contact groups between five member states (Afghanistan, Tajikistan, Uzbekistan, Turkmenistan, Kyrgyzstan)	Acknowledgment of the deep economic, and environmental concerns on official capacities	Move to a comprehensive agreement that will include the Aral Sea partial re-vitalization.
Full review of technical data, including flow variations, historical trends, and water withdrawals for irrigation by each member state.	Series of actions such as: - Economic analyses of the cotton field water reduction - Impact of the unilateral water withdrawal by member states - Full environmental study of Aral Basin	Agree on joint investment for the upstream water retention in terms of reservoirs and barrages. Attract donor funds by a joint Amu Darya River Basin (ADRB) authority. Agree on the balanced and transboundary food exchange
Full review of the impact of the cotton field expansion during the Soviet Period.	Acknowledgment of the Afghanistan rights on the Amu Darya Water resources and provision of the rights to explore its share of water resources with the condition of acknowledgment and sharing of information	Establish a Trust fund for the ADRB revitalization Ratify the agreements in the countries' parliaments.

CONCLUSION

Kaldar catchment consists of two units: the mountainous region of water nourishment and the lowland region of depletion. The headwaters are located in the mountains of Tajikistan and Afghanistan, among the permanent snow and glaciers of the Pamirs and the Hindu Kush, where elevations range from 5,000 to 7,000 m. The Khoshtepa Irrigation Canal head is starting in the Kaldar District and continues for over 200 km, and will cover three provinces in Afghanistan, namely Kunduz, Jawzjan, and Balkh. Precipitation falls mainly as snow during winter and helps augment the glaciers in the source areas of the Amu Darya, at the highest elevations in the Pamirs and the Hindu Kush, where annual precipitation may exceed 1,015 mm. The average annual precipitation is about 300 mm at the base of the mountains, with 90 percent of the rainfall occurring during winter and spring seasons. Literature shows that there is consensus that the flows in the tributaries of Amu Darya have been, and still are, diminishing. This flow reduction across the Amu Darya basin is anticipated to be within the range of 10 to 30 percent by the end of the century.

The mean annual flow between 1965 and 1980 was 3.3 Bln. m^3 and 6.21 Bln. m^3 at Kulukh Tepa and Khojaghar gauge stations, respectively. These flows have decreased to 2.63 and 5.93 Bln. m^3 respectively, between 2009 and 2014, representing a decline of 20.4% and 4.5%, respectively. These flows, the most recent data, have been relied upon for hydrologic analyses given they could better depict the current water availability in the catchment.

The maximum and minimum flows of Amu Darya at Kaldar is Max. 4,845 m^3/s and Min. 296 m^3/s respectively, with a mean of 926 m^3/s. The estimated total annual flow varies from 23.0 to 32.0 Bln. m^3, with a mean annual flow of 28.9 Bln. m^3.

The results show that future flows will likely decrease due to glacier depletion, introductions of upstream water intake similar to the Khoshtepa irrigation canal, and flow seasonality. The introduction of the Khoshtepa irrigation system will make an insignificant impact on the flow regime. However, the combined impact of climate change coupled with the water utilization upstream at the Khoshtepa Irrigation Canal project will negatively impact the flow regime to the central Asian states of Uzbekistan and Turkmenistan, which have previously erected a series of their own canals. A solution could be to introduce services of reservoirs to store water in the downstream regions. This could serve a dual purpose of increasing the low flows and balancing the water distribution for all downstream member states.

The study proposes a road map to address the complex water and food security issues considering the sovereign rights of Afghanistan to develop its share of water resources of the Amu Darya River. The study is proposing a serious effort to implement transboundary cooperative measures to prepare for the future.

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