Spring 5-2025

Monitoring the Qosh Tepa Canal Project: A Geospatial Timeline of Taliban Water Diversion

Enerel L. Crosslin
University of South Dakota

MONITORING THE QOSH TEPA CANAL PROJECT: A GEOSPATIAL TIMELINE OF TALIBAN WATER DIVERSION

by

ENEREL LEE CROSSLIN

A Thesis Submitted in Partial Fulfillment
Of the Requirements for the
University Honors Program

Departments of Biology and Political Science
The University of South Dakota

May 2025

The members of the Honors Thesis Committee appointed

to examine the thesis of ENEREL LEE CROSSLIN

find it satisfactory and recommend that it be accepted.

Dr. Ranjeet John
Department of Biology
and Department of Sustainability & Environment
Director of the Committee

Dr. Timothy Schorn
Department of Political Science

Dr. David Burrow
Department of History

Acknowledgements

I would first like to thank Dr. Ranjeet John, who, in addition to directing my thesis paper, also took me under his wing and actively taught me, a student outside of his area of expertise. His enthusiasm and support for this project were vital to this study's strengths. I came to him with a surplus of energy and little concrete data, and he guided this energy toward creating a short, practical, and intuitive paper. I am proud of the impact of this research, and it is a direct product of Dr. Ranjeet's guidance.

I would also like to thank Abhinav Chandel for his help since the start of work on this paper. Abhinav's early GIF of the Qosh Tepa Canal, which he initially composed, set the foundation for the direction of this study. The whole way, Abhinav took time out of a busy schedule to provide the code for images, work with me to designate the Study Area and Areas of Interest, and advise me on image formatting. Without his help, I would not have been able to achieve the quality and detailed imagery of this paper.

Because this paper marks the conclusion of my undergraduate studies, I wish to add a short thank-you letter to my family. I cannot in life reflect on any achievements without first thinking of them. To my wife, Kaname, who encouraged me through every win and loss since the first day we met, and heroically continued to do so while learning to be a full-time nurse. My worries, minuscule compared to those of her patients, continued to matter to her, and I am eternally grateful for her presence in my life. To my parents, Joshua and Tsagaanaa, who from my earliest memories supported me and continue to do so. Though I possess no shortage of weaknesses, I can confidently state that willpower, thanks to them, is not one of them. They gave me a sense of duty and responsibility that, more than any passion for a specific subject, drove me to work hard and diligently learn. To my younger sister, Hope, who supported me with humbling remarks. Lastly, I would like to thank my grandpa, Robert, for his dedication to ensuring that we four grandchildren could have a college education. I strive to never take that privilege for granted.

Monitoring the Qosh Tepa Canal Project: A geospatial timeline of Taliban water diversion

Enerel Lee Crosslin

Director: Dr. Ranjeet John

ABSTRACT

The World Food Program states that “acute malnutrition in Afghanistan is above emergency thresholds in 25 out of 34 provinces and is expected to worsen”. Aiming to support agriculture, the Taliban began to build the 285 km “Qosh Tepa Canal” to divert 17% of the Amu Darya, which supports the livelihoods of millions of people in downstream Uzbekistan and Turkmenistan. The World Bank estimated that roughly 2.4 million Central Asians could become climate refugees by 2050. Our objectives are to create a timeline of satellite imagery of the canal’s construction. Our research questions are (1) Can we characterize water diversion efforts through high-cadence satellite imagery? (2) Are there any significant integrity issues with the QT canal? (3) What is the rate of canal construction? After constructing a timeline, we then review the estimated impact of the canal and briefly summarize the literature on the Amu Darya’s history with water diversion as it relates to the Qosh Tepa Canal. This study shows that excavation reached 70% completion in 2024, indicating possible operation in 2026, two years ahead of schedule. Additionally, a breach in the canal wall has created a 10-kilometer-long lake, at its farthest points, in the desert, posing questions about the wall’s structural integrity, made up of the excavated sediment heaped on each side and, in some areas, eroding in the wind. Due to the large spill indicating unreliable canal walls, it is ultimately possible that the QT Canal will remain closed until 2028 or longer. However, the decision to begin the canal’s diversion of up to 17% of the Amu Darya will lie with the Taliban leadership after the 285-kilometer excavation concludes in 2026.

1. INTRODUCTION

1.1 Declining Climate Conditions in Afghanistan

Afghanistan is facing some of the most extreme impacts of the changing global climate as temperatures have increased since 1950 by an average of 1.8 °C, far above the global average of 1.1 to 1.2 °C (Safi et al., 2024). Reduced yields in rain-fed agriculture and increasing crop water stress are directly worsened by the rising temperature, as precipitation patterns, river flows, groundwater, land temperature, and soil humidity are all impacted. “In Afghanistan, wheat yields, the most important crop, have already decreased by 5.5%” (Safi et al., 2024).

Simultaneously, Afghanistan is recovering from a long and continuous period of civil war. This period impacted water security in many ways. Previously, the absence of government stability needed for infrastructure development greatly hindered the Afghan people’s access to water. Periods of rainfall and snowmelt are short and scarce, and “Afghanistan is unable to use or store most of its water.” “Access to clean water is a dream for many Afghans, due to widespread water mismanagement, continuous war, and corruption” (Safi et al., 2024).

In 2021, the Taliban consolidated power over the fragmented country. Four years later, it stands as a unified, though poorly run, nation-state for the first time in over 40 years. Without war, the Taliban leadership has had to shift its focus and structure from militarism to peacetime governance. The structural chaos of government that this transition to power caused, accompanied by the abrupt end to the flow of international aid, which previously held up the economy, sent the country into a developmental spiral, leaving much of its population with a shortage of necessities, including food and water. Although the Taliban have achieved relative stability in the country, analysts describe it as a state of “famine equilibrium” (Byrd, 2022). The World Food Program, a UN organization, states that “acute malnutrition is above emergency thresholds in 25 out of 34 provinces, and is expected to worsen, with almost half of children under 5 and a quarter of pregnant and breastfeeding women needing life-saving nutrition in the next 12 months” (UNWFP, 2024).

1.2 Qosh Tepa Canal (QTC)

Because of the immediate and worsening water shortage situation, the Taliban quickly began constructing the Qosh Tepa Canal, a long-discussed yet never-implemented solution to the North's increasing water insecurity. This project was first mentioned in the 1970s by the first President of Afghanistan, Daud Khan, and much later evaluated through a feasibility study conducted by the US Agency for International Development (USAID). A press release by USAID in December 2018, the first instance of serious action taken toward the construction of the canal, estimated the projected impact on the Northeastern provinces of Kunduz, Jawzjan, and Balkh (Faizee & Schmeier, 2023). Construction, however, did not begin until the Taliban's takeover of the country. In March 2022, just six months after taking control of the country, construction on the QTC began at a rapid pace. Having taken control, the Taliban began work on a national project justified by stated goals to fix the state of the Afghanistan economy, expand drinking water access, and irrigate fields for more crop growth. This project was estimated to cost more than $600 million (Asia-Plus, 2023).

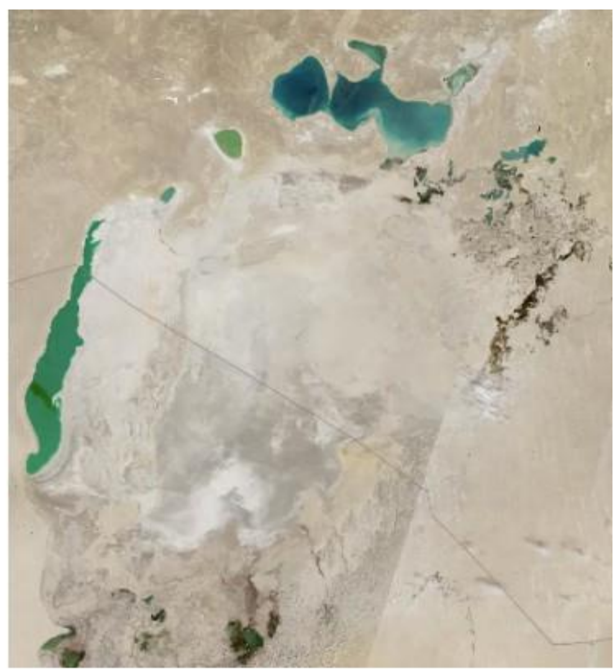
"Upon completion, the proposed irrigation scheme will impact more than 60,000 households, with a 200-kilometer irrigation canal and a cultivated catchment area of 500,000 hectares" (USAID, 2018). Recent sources, however, have expanded the completed QT Canal's planned size. "The planned canal is 287 kilometers long and 8.5 meters deep, with an average width of 100 meters (The canal's width starts at 152 meters and gradually decreases to sixty-four meters at the end)" (Kuchins et al., 2024). Given the scale of water diversion away from the Amu Darya River, the price paid by downstream Uzbekistan and Turkmenistan is predicted to be steep. Operation of the QT Canal, if current trends continue, will likely cause extremely negative consequences and uproot regional water sharing agreements, the framework for which emerged in the 1987 Protocol 566 by the Scientific and Technical Council of the USSR's Ministry of Water Resources. This protocol, which did not include any Afghan government, established a set volume of annual withdrawals for each country, assuming a set withdrawal volume for Afghanistan. Protocol 566, a foundational agreement that provides an understanding of more recent agreements not mentioned here, divided 61.5 km^3 of water withdrawals among the Central Asian Republics after establishing an annual 2.1 km^3 withdrawal for Afghanistan (Kamil, 2021). Once the Qosh Tepa Canal opens, according to

Kuchins' estimate, Afghanistan's share of the Amu Darya's water will increase by six times or more from that figure, to 13.02 km^3 annually, and it will divert anywhere from 8% to 17% of the river's total flow (Kuchins et al., 2024).

1.3 Wider Implications of the Qosh Tepa Canal

Environmentally, the Qosh Tepa Canal is predicted to decimate downstream ecosystems that rely on the Amu Darya; its predicted impact on the Aral Sea, for example, where the Amu Darya ends. The Aral Sea, once the fourth largest lake in the world, shrank dramatically after large canal projects were built starting in the 1920s to divert water from the Amu Darya into irrigation canal systems throughout Uzbekistan and Turkmenistan. The Soviet Union's canal projects included both the Syr Darya and Amu Darya and were implemented to force the nomadic Central Asians into a centralized, more profitable cotton-growing economy (Khalid, 2021). The origin of the Aral Sea catastrophe was the diversion of water away from the Amu Darya, which the Qosh Tepa Canal will further accomplish. The long-term impact of these projects, 85 years since the first canal was built, accompanied by a changing global climate, is well documented below in *Figure 1*.

Aral Sea from space (north at bottom), August 1985. Photo: NASA.



Further area reductions in western lakes, as captured in May 2024. Photo: ESA.

Figure 1 – View of the Aral Sea, situated between Uzbekistan and Kazakhstan, 1985 vs. 2024 (Huseynli, 2024)

A study in 2022 by Wang Z et al. assessed the ecological damage over time from these early Soviet-era canals by measuring water consumption figures for the Central Asian region's main crops and the timeline of agricultural water distribution among the different crops since 1970. The study concludes that after the shock of the Soviet Union's diversion projects, the ecology of the Aral Sea region continued to degrade until the 2010s, when the environment degraded enough to reduce water demand to a sustainable level. (Wang et al., 2022). Thus, the study concludes that Amu Darya's surrounding ecosystems are incredibly vulnerable to water supply changes and that any damage to the river will push the region's ecology into a state of further decline. The Aral Sea and Amu Darya's history provides a clear perspective on the negative ecological and social impacts of large, hastily built canal systems. Because of these canals, one of the largest inland seas in the world has largely disappeared, and the surrounding environment has been left unrecognizable.

The QT Canal is also predicted to lead to an economic crisis for downstream communities in Uzbekistan and Turkmenistan. While it is difficult to obtain data on Turkmenistan, Uzbekistan, the most populous downstream country, relies on agriculture for about 25% of its GDP and 26% of its labor employment (ITA, 2023). The canal is predicted to result in a major crisis, as almost 250,000 jobs in the country will be lost under some estimates on the QTC's water usage (Busch et al., 2023). Even before the canal's developments began, the Amu Darya River was in decline, and "while the [Aral] Sea is gone for good, the Amu Darya, one of two rivers that fed the Aral, is now dying too, stunting crops and impacting millions of people in Uzbekistan and Turkmenistan" (Trilling, 2022).

Agriculture and regional habitability will also be impacted. In a scenario where 25% of the Amu Darya is diverted, "usable cropland is expected to decrease by 18.9% in the Amu Darya basin" (Busch et al., 2023). The World Bank estimated in 2021 that roughly 2.4 million Central Asians could become climate refugees by 2050 (World Bank, 2021). Climate change has also created excess glacial melt upstream that has alleviated some of the water stress, but this will not last. "As those glaciers disappear this century for good, the water level will fall; some scenarios estimate glacial runoff in Central Asia will peak this decade." (Trilling, 2022). With regional temperatures warming at twice the global average, populations booming, and expanding inefficient irrigation systems, Uzbekistan's environmental situation looks to worsen, and the most vulnerable populations are rural people working in agriculture. In Turkmenistan, another downstream country, numerical estimates are difficult to access, but Protocol 566's allocation of 22.0 km^3 annual withdrawal to the country suggests that it is similarly reliant on the Amu Darya as Uzbekistan, which claimed 29.6 km^3 annually. Together, these two countries downstream utilized 84% of the region's total shared water withdrawals from the river (Kamil, 2021).

While a large body of Central Asian water security-related research concludes that Uzbekistan must improve its water-use efficiency to soften the QT Canal's effect, the necessity for diplomatic cooperation over such an essential body of water is urgent, given the fast-approaching completion of the canal. The Qosh Tepa Canal could change regional political dynamics and increase the risk of armed conflict. Link P.M. et al. (2016) analyzed the history of transboundary water resources and how water resource-sharing issues may add pressure toward conflict. They study an older political strain brought about by Tajikistan's construction of a dam upriver from Uzbekistan. Central Asian states, they note, have politically labeled the issue of water security as a matter of "national security," heightening the risk of conflict by making it easier to justify aggression in response to damage to the water supply (Link et al., 2016). Examples of violent conflict, both interstate and internal, abound. A document by the European Parliament Research Service quoted the former Uzbek President, Islam Karimov, as saying that "water-related problems could spark wars" (European Parliament, 2015). Although Link et al.'s study does not focus on Afghanistan, the Taliban government has an especially violent history in relation to water, both using water as a justification for fighting as well as using it as a weapon. In 1998, for example, Taliban forces killed Iranian diplomats in Mazar-e Sharif, which sparked an armed conflict, and "this led to the Taliban closing the Kajaki Dam's sluices, obstructing the water flow from Helmand River to Iran, which ultimately halted the water supply" (Dagress, 2023). In a recent example from 2023, at least two Iranians and one Afghan were killed amid tensions over the same river. "The two sides have wrangled for decades" (Al Jezeera Staff, 2023). The fighting over water supply is not unique to Iran-Taliban relations, or even to cross-border relations. As recently as July 2024, 11 people were reportedly hospitalized when "a clash took place near the Qosh Tepa Canal between ethnic Tajiks in Afghanistan and their Taliban rulers" after protests against the Qosh Tepa Canal's construction broke out (Goble, 2024). In their conclusion, Link et al. note that although past conflicts have been multidimensional, involving cultural, socioeconomic, and physical factors, they believe that climate change paired with rapidly growing populations will heighten the risk of water-related conflict (Link et al., 2016). Almost 10 years later, Qosh Tepa Canal promises to significantly heighten this preexisting risk.

1.4 Knowledge Gap & Research Questions:

While several publications seek to provide an overview of the Qosh Tepa Canal's construction and outline the implications, there is a distinct lack of comprehensive information that examines the pace of the QT Canal's construction and the canal's visible path. At the end of 2024, 3 years since the Taliban broke ground, this paper finds that 206 kilometers (approximately 70%) of the canal have been constructed. Researching the QT Canal, as a result, can be unnecessarily confusing. Information often conflicts, maps are incorrectly drawn, and the wide-ranging implications surrounding the degradation of a river present a web of potential directions for research. Therefore, analysts would benefit significantly from graphical data on its construction so far to draw additional conclusions from further research.

Through visual data, this paper seeks to definitively address a simple set of questions: (1) Can we characterize water diversion efforts through high-cadence satellite imagery? (2) Are there any significant visible problems with the canal? (3) What is the rate of construction?

1.5 Study Objectives & Approach

Despite the QT Canal's significant implications, there is little concrete data on the pace and scale of the construction. This paper seeks to fill the gap and provide a detailed timeline of the QT Canal's construction by using high cadence satellite imagery and examining its progress.

By providing a visual timeline and contextualizing the QT Canal's construction within both historical and modern regional issues, this paper seeks to contribute to the knowledge of the QT Canal's consequences. With 70% constructed in 3 years, as of the end of 2024, an informed response is crucial to curtail potential catastrophic damage to the region's fragile economic, ecological, and political stability.

2. METHODS

2.1 Data Collection:

This study utilizes the Harmonized Landsat and Sentinel-2 (HLS) merged dataset, provided by the National Aeronautics and Space Administration Land Processes Distributed Active Archive Center (NASA LP DAAC), and Google Earth Engine (GEE) as the primary tools for data collection. This project combines data from Sentinel-2 and US Landsat 8/9 to provide 2–3-day intervals of 30-meter resolution images through Google Earth Engine (GEE).

Sentinel-2 is a European Space Agency (ESA) network of two satellites launched in 2015 (Sentinel-2A) and 2017 (Sentinel-2B) that utilize a "Multi-Spectral Instrument" (MSI), which provides high-resolution satellite imagery at 10-20 and 60 meters per pixel to enable many types of surface monitoring. The MSI captures images in 13 spectral bands, such as RBG and Near-Infrared. The Sentinel-2 system passes over the same location on Earth every 5 days. Inserting the code below into Google Earth Engine has enabled close tracking of the progress of the canal since its start (EROS, 2020). Landsat 8 and 9 are the latest satellites of the Landsat series that utilize two Operational Land Imager (OLI) multispectral sensors on board. Landsat 8 and 9 have taken images of the Earth since 2013 and 2021, respectively. These sensors use "a false color combination of three bands: shortwave infrared, near-infrared, and red" (NASA LP DAAC, 2015). The sensors on board each satellite take photos with a 16-day cycle, creating a combined 8-day cycle and a special resolution of 30 meters. The data from these four satellites was run through the use of Google Earth Engine (GEE) cloud platform. "Scientists, researchers, and developers use Earth Engine to detect changes, map trends, and quantify differences on the Earth's surface" (Google, n/d).

The data is used to make a timeline, organized by the study area and three areas of interest. *Figure*

3 provides a general overview of the canal's progress from 2022 to the end of 2025 through a study area view. *Figures 4a to 6b* provide a pair of figures, one GIF and one set of four still images over time.

3. RESULTS

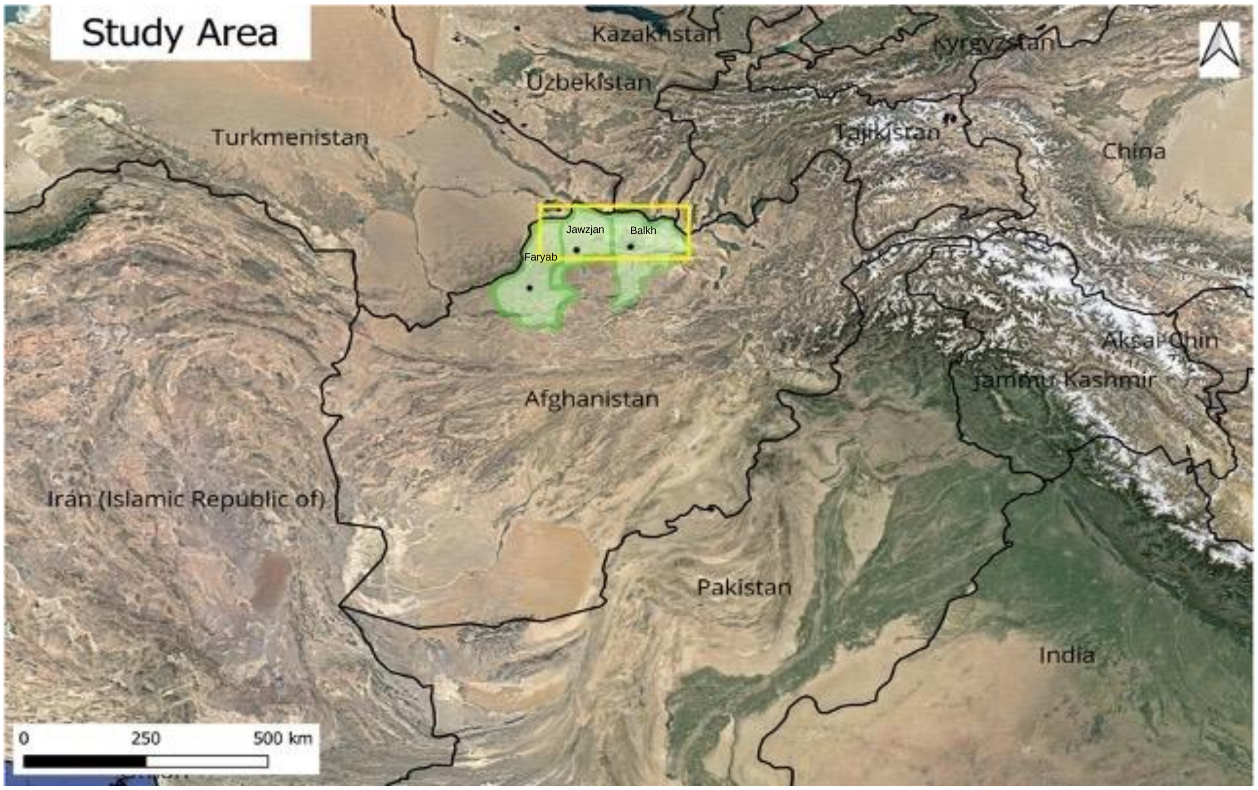


Figure 2a – Surrounding context of the study area with the involved Afghan provinces, Balkh, Jowzjan, and Faryab highlighted. Provincial capitals are marked with black dots.

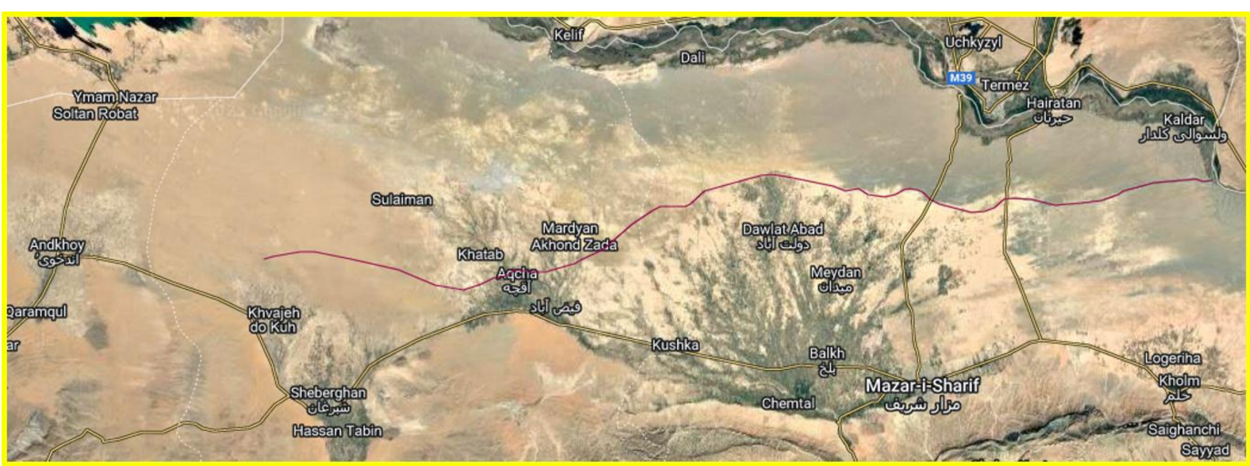


Figure 2b – Zoomed-in perspective on the Study Area Box from Figure 2a and an outline of the Qosh Tepa Canal as of December 2024 (206 km long). "Mazar-i-Sharif" and "Sheberghan" are the provincial capitals of Balkh and Jawzjan, respectively.

Figures 2a and 2b contextualize the area in which the Qosh Tepa Canal is being excavated to divert water from the Amu Darya. The Amu Darya originates in the Pamir Mountains of Tajikistan and parts of the Hindu Kush in the Northeastern provinces of Afghanistan. From where the river reaches the Study Area, it flows Northwest, along the borders of Tajikistan, Afghanistan, and Uzbekistan, and continues into the Turan Lowlands along Turkmenistan and Uzbekistan's borders and ends in the dwindling Aral Sea (*Figure 1)*. Thus, in the following figures, the Amu Darya and the Qosh Tepa Canal are shown as flowing from East to West. Any impact on the river within this study area will impact downstream river conditions to the Northwest.

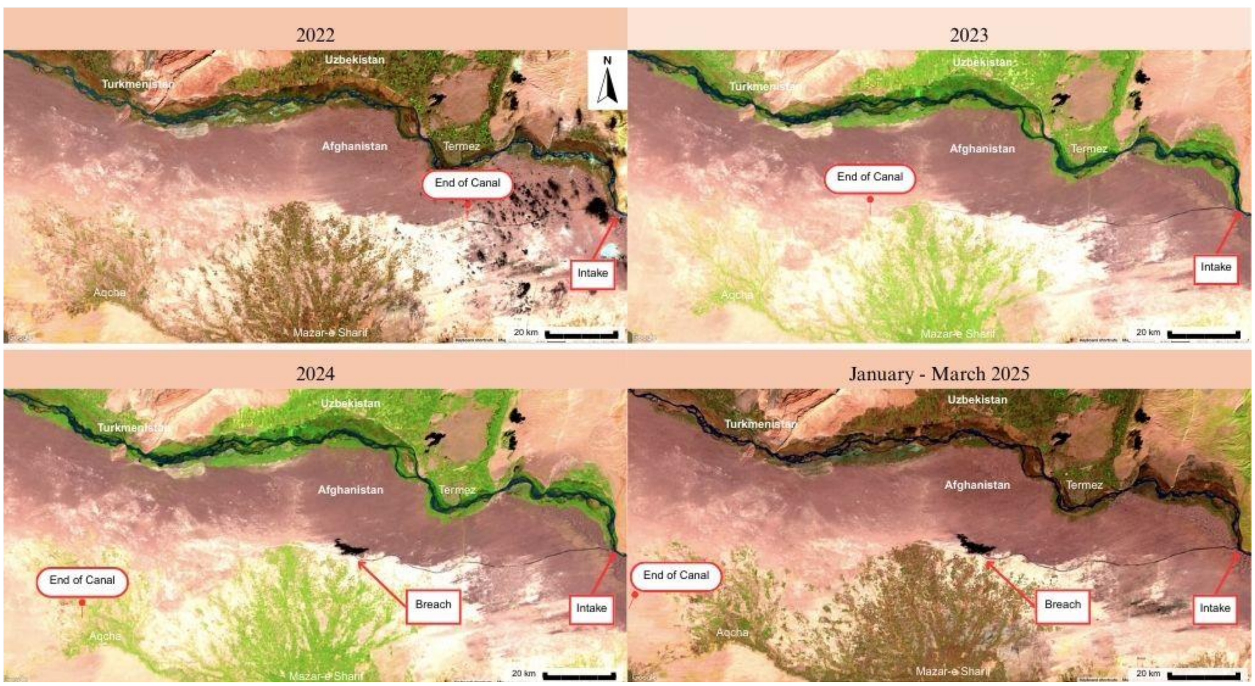


Figure 3 – Study Area: Annual Westward progress of the QT Canal excavation across Northern Afghanistan (0-220 km)

The Study Area perspective in *Figure 3* offers a general view of the pace of the first 220 kilometers of the canal that has been excavated from January 2022 to March 2025. Afghanistan is shown on the South side of the river, while Turkmenistan, Uzbekistan, and the Uzbek city of Termez are shown on the North side of the river. Developed cropland, highlighted in green, around the river is significantly less prominent on Afghanistan's side of the Amu Darya, showing Afghanistan's relatively low water consumption.

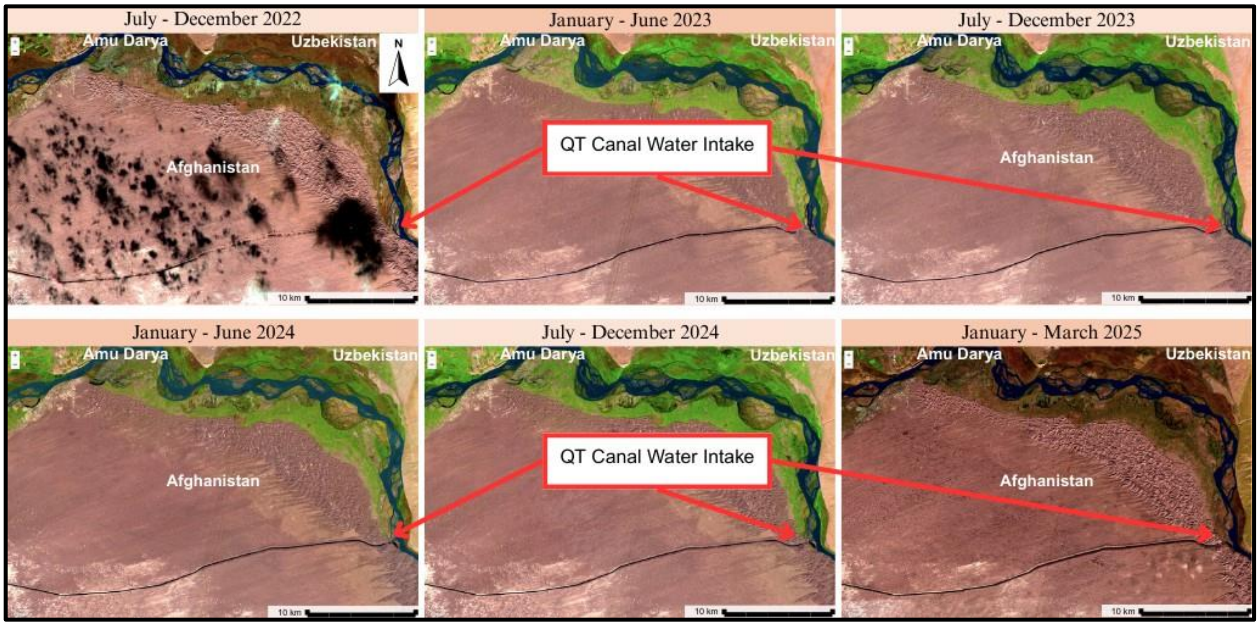


Figure 4a – Area of Interest 1: Timeline of QT Canal Westward construction leveraging Sentinel-2 (0-40 km West)

Figure 4b (GIF, Jan 2022-Jan 2025) – Area of Interest 1: Timeline of QT Canal Westward construction leveraging Sentinel-2 (0-40 km West)

Area of Interest 1 in *Figures 4a and 4b* provides a view of the QT Canal's intake and early development. The black splotches in *Figure 4a, July – December 2022,* are clouds interfering with the image. The canal also appears to have filled with groundwater in late 2022 before it was connected to the Amu Darya. The GIF's dynamic perspective shows how the area around the mouth of the canal has been altered over time, as well as showing seasonal changes in the river's volume.

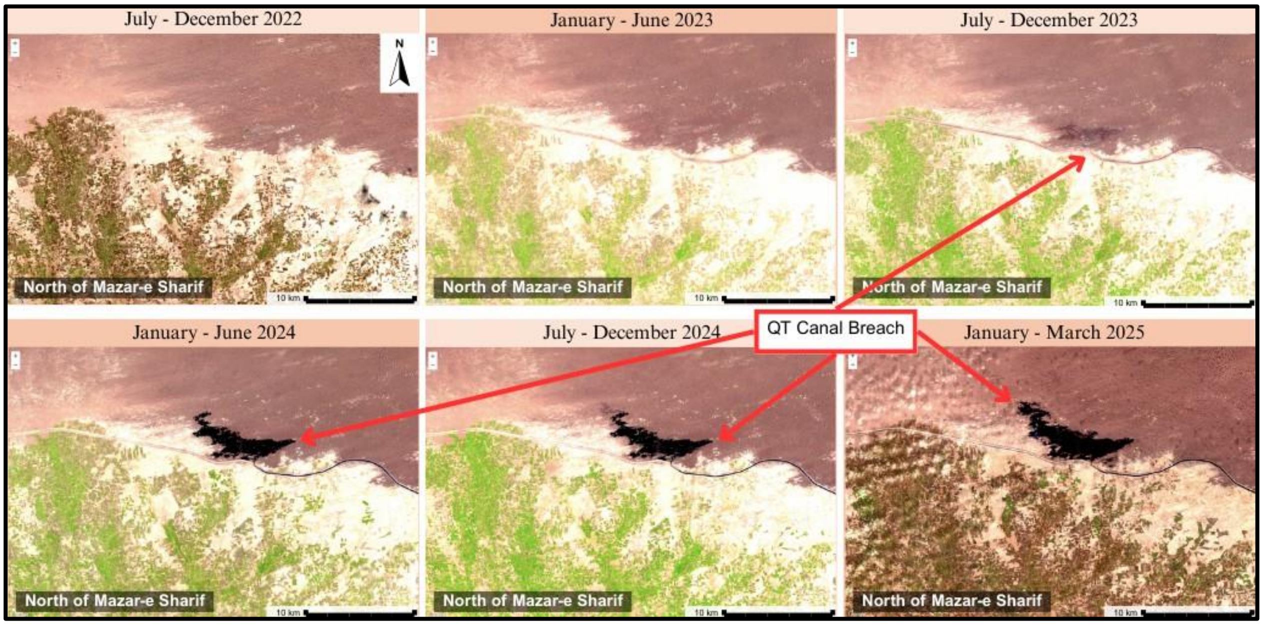


Figure 5a – Area of Interest 2: Outskirts of Afghan city Mazar-e Sharif, agricultural land (60-100 km West)

Figure 5b (GIF, Jan 2022-Jan 2025) – Area of Interest 2: Outskirts of Afghan city Mazar-e Sharif, agricultural land (60-100 km West)

Area of Interest 2 in *Figures 5a and 5b* provides a view of the QT Canal's path on the outskirts of a major Afghan city, Mazar-e Sharif, and a view of a canal wall breach which resulted in a significant volume of lost water accumulating in the desert. Excavations reached the 60-100 km mark one year after they began, and the spill appeared in the second half of 2023. The spill has continued to grow as of March 2025.

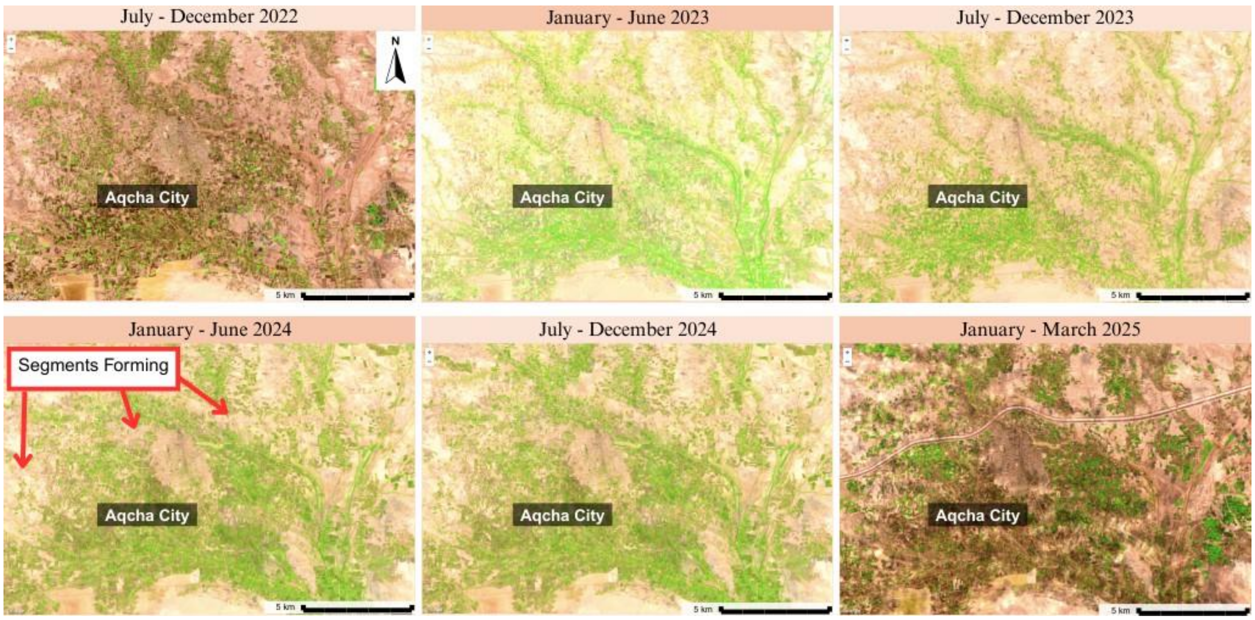


Figure 6a – Area of Interest 3: Aqcha district surrounded by agricultural land (150 – 170 km West)

Figure 6b (GIF, Jan 2024-Jan 2025 – Area of Interest 3: Aqcha district surrounded by agricultural land (150 – 170 km West)

Area of Interest 3 in *Figures 6a and 6b* provides a view of the Afghan city of Aqcha and its surrounding cropland. The city lies approximately 160 kilometers downstream from the canal's intake, and signs of excavation appear in early 2024. As of October 2024, the canal through the area appears complete. The extreme brightness of the images is a consequence of the extremely dry area, likely causing the brightness through interference, such as dust clouds.

4. DISCUSSION

4.1 Interpreting the High-Cadence Satellite Imagery

This method of analysis provided an effective monitoring tool for the Qosh Tepa Canal's construction progress. In a region with limited data availability, geospatial imagery provided an alternative analysis method. In December 2024, approximately 206 kilometers, 70% of the canal, was excavated, and the rate of construction was far faster than expected, as the predicted completion is in 2026, 2 years ahead of schedule. This finding has significant implications, signaling to regional actors to prepare for the possibility of canal activation before the original deadline of 2028.

The arid environment in Northern Afghanistan creates minimal cloud cover and consistent contrast between land, excavated earth, and water, which enhances the clarity of the images. Thus, the region was an ideal target for the methods of this study. In more humid areas, these methods could face severe visibility limitations.

4.2 The Qosh Tepa Canal's Integrity Challenges

A key finding of this study was the details surrounding a structural breach appearing in late 2023 near Mazar-e Sharif in *Figure 5a* & *Figure 5b*. The resulting lake, over 10 kilometers long, highlights compromised structural integrity, resulting in major loss of precious water resources. Additionally, the walls of the canal are formed by piling displaced sediment from canal excavation, and less dramatic amounts of erosion can be seen along other sections, too. The absence of

additional structural reinforcement causes questions about its reliability and safety.
These observations lend strength to the potential costs of rapid, underdeveloped infrastructure projects in sensitive environments. Past water diversion projects along the Amu Darya, such as the Soviet-era canal projects, have experienced similar issues, leading to outcomes such as the Aral Sea's destruction. These failures, if repeated in the Qosh Tepa Canal's construction, carry an enormous number of risks, from the efficacy of the canal to the broader stability of ecosystems and geopolitics of the downstream regions.

4.3 Downstream Water Security Implications

The Qosh Tepa Canal's imminent completion will significantly impact the regional balance of water, especially for downstream Uzbekistan and Turkmenistan, which use a combined 80% of the Amu Darya's total allocated withdrawals under Soviet-era agreements. Previous studies have pointed out that large ecological and economic impacts will follow even a moderate decrease in the Amu Darya's flow. The observed spell reflects supply diverted away from vital cropland and populations downstream and lost to the desert.

Considering the research by Wang et al. (2022), the Qosh Tepa Canal's diversion of up to 17% of the river's flow will result in substantial ecological damage downstream, counteracting the long process of ecological stabilization since the construction of Soviet-era canals. There will also be an economic impact. As Busch et al. (2023) estimate, around 250,000 agriculture-related jobs in Uzbekistan would be put at risk, and though Turkmenistan's figures are unknown, the dominance of agriculture and heavy reliance on the Amu Darya's flow imply similarly dramatic, if not worse, impacts on people's livelihoods.

The QT Canal also heightens geopolitical risks. Historically, water insecurity has caused internal and external disputes across Central Asia. Former Uzbek President Islam Karimov once warned that "water-related problems could spark wars." Disputes over water in the region are not rare, as people in countries are often reliant on water, a declining resource, flowing from outside of their own borders. For example, the Taliban's 1998 conflict with Iran saw them use the flow of water as leverage over Iran; they illustrated how water can be used as a justification as well as a weapon for armed conflict. The findings of this study show that construction is taking place at an accelerated pace, which risks escalating tensions more dramatically and sooner than expected.

4.4 Broader Uses and Limitations of High-Cadence Satellite Monitoring

The methods of monitoring used in this study could be generalized to other regions with similar climates to track the progress of similar infrastructure developments. The contrasting colors between desert, water, empty canal, and cropland make this approach especially effective in arid regions. There are limitations, however. In regions with frequent cloud cover, visual data would be exceedingly difficult to obtain. Future monitoring efforts on the QT Canal could continue using these methods. The accessibility of Google Earth Engine facilitates much-needed, easy, and quick access to insightful and up-to-date data to monitor the rapidly progressing canal.

5. CONCLUSION

5.1 Can we characterize water diversion efforts through high-cadence satellite imagery?

The methods used proved effective at granting unique visual perspectives in various areas of construction. The arid climate and barren landscape proved an ideal target for this imagery because of minimal atmospheric interference. Through high-cadence satellite imagery, this study achieved a highly accurate and intuitive examination of the rate of construction and three areas of interest.

5.2 Visible Issues with the Qosh Tepa Canal:

The breach in the canal wall in *Figure 5a & Figure 5b*, which appeared in late 2023, rapidly pooled and grew into a lake spanning over 10 kilometers East-West. The rapid pace of its growth in the desert shows the power of even a small proportion of the Amu Darya’s flow and its potential for damage if not carefully handled. The lost water also negatively impacts downstream communities in Turkmenistan and Uzbekistan, who face severe water shortages.

The water-filled portion of the Qosh Tepa Canal possesses walls of displaced sediment from the canal's excavation, and the integrity of the wall was compromised because of the hasty construction. If the entirety of the 285-kilometer canal were to operate under the same conditions as seen in *Figures 4a & 4b*, additional spills may occur. The region also consistently experiences natural disasters, increasing the risk of additional spills. In 2017, it was reported that "Afghanistan is highly prone to intense and reoccurring natural hazards, including earthquakes, floods, flash floods [and] landslides" (World Bank). This poses additional risks to the hastily constructed canal walls.

5.3 The Qosh Tepa Canal's rate of construction:

It is possible to extrapolate two expected rates of construction from the stated 2028 completion date, depending on whether the canal is completed at the beginning or the end of the year. For a target of early 2028, the rate of construction necessitates 47.5 km/year since the start of 2022. For a target of late 2028, the rate of construction necessitates 40.71 km/year since 2022. A rate of construction within a range of either of these numbers would indicate that Afghans and downstream populations in Uzbekistan and Turkmenistan should have until 2028 to make preparations for changes to the water supply. This study finds that the actual rate of construction, based on the length of the canal at the end of 2024, is about 68.67 km/year, 45% faster than the fastest rate estimate needed for canal completion in early 2028. With 79 km of unconstructed canal remaining at the end of 2024, the Qosh Tepa Canal could be complete and capable of diverting up to 17% of the Amu Darya's total flow in less than two years, as early as 2026.

As of March 2025, the Qosh Tepa Canal reached a length of 230 kilometers. However, attempts to calculate an annual excavation rate including data from 2025 were not made. Incorporating data from the spring of 2025 would likely bias this study's result to exaggerate the construction's speed because each month does not show a uniform amount of progress, likely influenced by harsh weather conditions during certain months. Excavation imagery from *Figure 5a, 5b, 6a* and *6b* shows that the most rapid progress is consistently made in the early months of the year, and *Figure 6a and 6b,* in particular, shows how canal construction around Aqcha formed in early 2024, remained static in late 2024, and then rapidly expanded in early 2025. This could be explained partially by the regional climate, in which spring and fall pose the most work-friendly temperatures, while harsh winter cold and summer heat are avoided. Due to these findings, the visible rate of the Qosh Tepa Canal's expansion is calculated only by taking the average annual expansion until the end of 2024 to avoid the false impression of an exaggeratedly fast rate of progress.

5.4 Future uses for this code:

Finally, this monitoring method could also be applied to other water-related monitoring projects in similar climates without precipitation. The imagery of Northern Afghanistan produced by this study was able to clearly differentiate between cropland, water, and desert landscapes by leaving much of the desert naturally colored, while the water and cropland were well highlighted. This method is not feasible, however, if there is much cloud cover, as seen in July-December 2022 in *Figure 4a*.

While this study focuses on the rate of canal excavation and aspects of the spill, many additional insights could be gained about the QT Canal through the use of high-cadence satellite imagery. Studies could focus on smaller areas such as the intake, spill area, or the process of excavation to gain a detailed understanding of specific aspects of the canal. Progress in the coming years of the QT Canal could also continue to be monitored.

BIBLIOGRAPHY

"Balkh Climate." *Nomad Season*, Nomadseason, 18 Jan. 2025, nomadseason.com/climate/afghanistan/balkh.html#:~:text=Balkh%2C%20Afghanistan%20experiences%20a%20continental,June%2C%20July%2C%20and%20August.

Dagres, Holly. "Iran and Afghanistan Are Feuding over the Helmand River. the Water Wars Have No End in Sight." *Atlantic Council*, atlanticcouncil.org, 7 July 2023, www.atlanticcouncil.org/blogs/iransource/iran-afghanistan-taliban-water-helmand/.

Earth Resources Observation and Science (EROS) Center. (2020). Landsat 8-9 Operational Land Imager / Thermal Infrared Sensor Level-1, Collection 2 [dataset]. U.S. Geological Survey. https://doi.org/10.5066/P975CC9B

Asia-Plus. (2023, October 31). *With what money the Taliban are building the Qosh Tepa Canal*. AsiaPlusTJ. https://old.asiaplustj.info/en/news/world/20231031/with-what-money-the-taliban-are-building-the-qosh-tepa-canal

Busch, C., Gafurov, A., Bobojonov, I., & Bekchanov, M. (2023, June). Impact of the Qush-Tepa canal on the agricultural sector in Uzbekistan - Summary of results -. german-economic-team.com/wpcontent/uploads/2022/02/GET_UZB_PB_05_2021_EN.pdf

Byrd, W. (2022). *One year later, Taliban unable to reverse Afghanistan's economic decline | United States Institute of Peace*. USIP. https://www.usip.org/publications/2022/08/one-year-later-taliban-unable-reverse-afghanistans-economic-decline

Faizee, M., & Schmeier, S. (2023, August 18). *Charting complex currents: The qush tepa canal and Central Asia's water*. New Security Beat. newsecuritybeat.org/2023/08/charting- complex-currents-qush-tepa-canal-central-asias-water/

European Parliament. "Water Disputes in Central Asia Rising Tension Threatens Regional Stability." *Europarl.Europa.Eu*, Oct. 2015, europarl.europa.eu/RegData/etudes/BRIE/2015/571303/EPRS_BRI(2015)571303_EN.pdf.

Goble, Paul. "Afghan Canal Project Affecting Not Only Central Asia but China and Russia Too." *Jamestown*, jamestown.org, 11 July 2024, jamestown.org/program/afghan-canal-project-affecting-not-only-central-asia-but-china-and-russia-too/.

Google. (n.d.). Google Earth engine. https://earthengine.google.com/

Huseynli, O. (2024, May 14). *Explainer: What happened to the Aral Sea?*. Earth.Org. https://earth.org/the-aral-sea-catastrophe-understanding-one-of-the-worst-ecological-calamities-of-the-last-century/

Ilkhamov, A. (2023, November 14). *Implications for Uzbekistan's water supply of Qosh Tepa Canal Construction in Afghanistan*. ResearchGate. researchgate.net/publication/376602329_Implications_for_Uzbekistan's_Water_Supply_of_Qosh_Tepa_Canal_Construction_in_Afghanistan

ITA. (2023, December 1). *Uzbekistan - agricultural sectors*. International Trade Administration Trade.gov. https://www.trade.gov/country-commercial-guides/uzbekistan-agricultural-sectors

Kamil, Ikramuddin. "Afghanistan, the Amu Darya Basin and Regional ..." *Hpacenter.Org*, Chinese Journal of Environmental Law, 8 July 2021, hpacenter.org/en/article/1627/afghanistan_the_amu_darya_basin_and_regional_treaties.

Khalid, A. (2021). *Central Asia: A new history from the imperial conquests to the present*. Princeton University Press.

Kuchins, A. C., Aidarkhanova, E., Sadid, N., & Barakzai, Z. (2024, November). *Report launch: Afghanistan's Qoshtepa Canal and water security in Central Asia*. Center for the National Interest. https://cftni.org/recent-events/report-launch-afghanistans-qoshtepa-canal-and- water-security-in-central-asia/

Link, P. M., Scheffran, J., & Ide, T. (2016). Conflict and cooperation in the water-Security Nexus: A global comparative analysis of river basins under climate change. *WIREs Water*, *3*(4), 495–515. https://doi.org/10.1002/wat2.1151

NASA LP DAAC. (2015, November). *HLSS30: HLS sentinel-2 multi-spectral instrument surface reflectance daily global 30m | Earth Engine Data catalog | google for developers*.Google. https://developers.google.com/earth-engine/datasets/catalog/NASA_HLS_HLSS30_v002#description

Safi, L., Mujeeb, M., Sahak, K., Mushwani, H., & Hashmi, S. K. (2024). Climate change impacts and threats on basic livelihood resources, food security and social stability in Afghanistan. *GeoJournal*, *89*(2). https://doi.org/10.1007/s10708-024-11077-8

Trilling, D. (2022, November 10). *Uzbekistan: Where the amu darya goes to die*. Eurasianet.

https://eurasianet.org/uzbekistan-where-the-amu-darya-goes-to-die#:~:text=While%20the%20sea%20is%20gone,change%20make%20western%20Uzbe kistan%20uninhabitable.

UNWFP. (2024). *Afghanistan: World Food Programme*. UN World Food Programme. https://www.wfp.org/emergencies/afghanistan-emergency

USAID. (2018, December 10). *Feasibility Study for khush tepa irrigation canal ceremony held [en/dari] - Afghanistan*. ReliefWeb. https://reliefweb.int/report/afghanistan/feasibility-study-khush-tepa-irrigation-canal-ceremony-held-endari

Wang, Z., Huang, Y., Liu, T., Zan, C., Ling, Y., & Guo, C. (2022). Analysis of the water demand- supply gap and scarcity index in Lower Amu Darya River Basin, Central Asia. *International Journal of Environmental Research and Public Health*, *19*(2), 743. https://doi.org/10.3390/ijerph19020743

World Bank. (2021). *Internal Climate Migration in Eastern Europe and Central Asia*. World Bank . https://openknowledge.worldbank.org/server/api/core/bitstreams/1dbab8f5-881d-517c-af10-5315e02f4d44/content

Al Jezeera Staff, "What Caused Deadly Afghan-Iran Border Clashes? What Happens Next?" *Al Jazeera*, Al Jazeera, 31 May 2023, www.aljazeera.com/news/2023/5/30/what-caused-deadly-afghan-iran-border-clashes-what-happens-next.

World Bank, Washington, D.C., 2017, pp. 2–2, *DISASTER RISK PROFILE AFGHANISTAN*.

Appendix:

Google Earth Engine Imported Code (To establish coordinates and import sensor data for data collection specific to AOIs and the Study Area)

```
var Study_area =
  /* color: #d63000 */
  /* shown: false */
  /* displayProperties: [
    {
      "type": "rectangle"
    }
  ] */
  ee.Geometry.Polygon(
      [[[65.3554041604422, 37.48579040372005],
        [65.3554041604422, 36.743320789191166],
        [67.8328211526297, 36.743320789191166],
        [67.8328211526297, 37.48579040372005]]], null, false), AOI_1
  =
  /* color: #98ff00 */
  /* shown: false */
  /* displayProperties: [
    {
      "type": "rectangle"
    }
  ] */
  ee.Geometry.Polygon(
      [[[67.27526500028596, 37.301402166583834],
        [67.27526500028596, 36.96528960998766],
        [67.8218348245047, 36.96528960998766],
        [67.8218348245047, 37.301402166583834]]], null, false), AOI_2
  =
  /* color: #0b4a8b */
  /* shown: false */
  /* displayProperties: [
    {
      "type": "rectangle"
    }
  ] */
  ee.Geometry.Polygon(
      [[[66.59548594755158, 37.199193785753174],
        [66.59548594755158, 36.85383634226728],
        [67.15853526395783, 36.85383634226728],
        [67.15853526395783, 37.199193785753174]]], null, false),
```

```
AOI_3 =
/* color: #ffc82d */
/* shown: false */
/* displayProperties: [
 {
  "type": "rectangle"
 }
] */
ee.Geometry.Polygon(
   [[[66.06149567254157, 36.95036295360874],
     [66.06149567254157, 36.814154599238044],
     [66.31315125115485, 36.814154599238044],
     [66.31315125115485, 36.95036295360874]]], null, false),
imageVisParam = {"opacity":1,"bands":["B11","B8","B4"],"min":0.2,"max":0.3,"gamma":1};
```

Study-Area-Specific Code

```
var collection = ee.ImageCollection("NASA/HLS/HLSS30/v002")
                .filterBounds(Study_area)
                .filter(ee.Filter.lt('CLOUD_COVERAGE', 30));

var visParams = {
  bands: ['B11', 'B8', 'B4'],
  min:0.1,
  max:0.4,
};

Map.centerObject(Study_area, 8)

//---Study Area

var img_2022 = collection.filter(ee.Filter.date('2022-01-01', '2022-12-30')).median() var
img_2023 = collection.filter(ee.Filter.date('2023-01-01', '2023-12-28')).median() var img_2024 =
collection.filter(ee.Filter.date('2024-01-01', '2024-12-28')).median() var img_2025 =
collection.filter(ee.Filter.date('2025-01-01', '2025-12-28')).median()

Map.addLayer(img_2022.clip(Study_area), visParams, '2022');
Map.addLayer(img_2023.clip(Study_area), visParams, '2023');
Map.addLayer(img_2024.clip(Study_area), visParams, '2024');
Map.addLayer(img_2025.clip(Study_area), visParams, '2025');
```

```
// Filter for each AOI
var img_2022_1 = collection.filter(ee.Filter.date('2022-01-01', '2022-06-30')).median() var
img_2022_2 = collection.filter(ee.Filter.date('2022-07-01', '2022-12-31')).median() var img_2023_1
= collection.filter(ee.Filter.date('2023-01-01', '2023-06-30')).mean() var img_2023_2 =
collection.filter(ee.Filter.date('2023-07-01', '2023-12-31')).mean() var img_2024_1 =
collection.filter(ee.Filter.date('2024-01-01', '2024-06-30')).mean() var img_2024_2 =
collection.filter(ee.Filter.date('2024-07-01', '2024-12-31')).mean() var img_2025_1 =
collection.filter(ee.Filter.date('2025-01-01', '2025-02-26')).mean()

//---AOI 1
Map.addLayer(img_2022_1.clip(AOI_1), visParams, 'AOI_1_2022_1');
Map.addLayer(img_2022_2.clip(AOI_1), visParams, 'AOI_1_2022_2');
Map.addLayer(img_2023_1.clip(AOI_1), visParams, 'AOI_1_2023_1');
Map.addLayer(img_2023_2.clip(AOI_1), visParams, 'AOI_1_2023_2');
Map.addLayer(img_2024_1.clip(AOI_1), visParams, 'AOI_1_2024_1');
Map.addLayer(img_2024_2.clip(AOI_1), visParams, 'AOI_1_2024_2');
Map.addLayer(img_2025_1.clip(AOI_1), visParams, 'AOI_1_2025_1');

//---AOI 2
Map.addLayer(img_2022_1.clip(AOI_2), visParams, 'AOI_2_2022_1');
Map.addLayer(img_2022_2.clip(AOI_2), visParams, 'AOI_2_2022_2');
Map.addLayer(img_2023_1.clip(AOI_2), visParams, 'AOI_2_2023_1');
Map.addLayer(img_2023_2.clip(AOI_2), visParams, 'AOI_2_2023_2');
Map.addLayer(img_2024_1.clip(AOI_2), visParams, 'AOI_2_2024_1');
Map.addLayer(img_2024_2.clip(AOI_2), visParams, 'AOI_2_2024_2');
Map.addLayer(img_2025_1.clip(AOI_2), visParams, 'AOI_2_2025_1');

//---AOI 3
Map.addLayer(img_2022_1.clip(AOI_3), visParams, 'AOI_3_2022_1');
Map.addLayer(img_2022_2.clip(AOI_3), visParams, 'AOI_3_2022_2');
Map.addLayer(img_2023_1.clip(AOI_3), visParams, 'AOI_3_2023_1');
Map.addLayer(img_2023_2.clip(AOI_3), visParams, 'AOI_3_2023_2');
Map.addLayer(img_2024_1.clip(AOI_3), visParams, 'AOI_3_2024_1');
Map.addLayer(img_2024_2.clip(AOI_3), visParams, 'AOI_3_2024_2');
Map.addLayer(img_2025_1.clip(AOI_3), visParams, 'AOI_3_2025_1');
```