Digging an ever-deeper hole: the response to climate change in the Helmand River Basin

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Acknowledgements

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Alcis designs and deploys online geospatial platforms, along with high-resolution imagery and geospatial analysis. Alcis provides world-class geographic information services (GIS) to enable better understanding, decisions and outcomes for its clients and beneficiaries. Alcis has worked continuously in Afghanistan since 2004, providing in-depth analysis and GIS to a wide range of donors, including the governments of the United Kingdom, United States, Australia, Denmark and Afghanistan, the Asian Development Bank, UN, academia, think tanks and NGOs. Over this period, it has patiently curated the most comprehensive and sophisticated geospatial database for Afghanistan, building a range of unique web-based geographic data visualization and analysis platforms for different clients with differing needs that enable the viewing, querying and annotation of bespoke geospatial data.

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About XCEPT

This publication is a product of the Cross-Border Conflict Evidence, Policy and Trends (XCEPT) research programme, funded by UK International Development from the UK government. XCEPT brings together leading experts to examine conflict-affected borderlands, how conflicts connect across borders, and the drivers of violent and peaceful behaviour, to inform policies and programmes that support peace. For more information, visit www.xcept-research.org or contact us at **info@xcept-research.org**.

Key findings

This report examines the impact of climate change across the Helmand River Basin. It documents the threat that both state and community responses to climate change and reductions in surface water pose to the livelihoods of an estimated 469,732 households in the Helmand River Basin – especially to the 3.65 million people on the Afghan side of the border, where the groundwater they have come to depend on is disappearing at an alarming rate.

This research is part of a wider project examining the conflict that broke out between Iranian and Taliban forces in May 2023. In contrast to media reports arguing that the fighting was the result of a historic dispute over transboundary water rights and a precursor of 'water wars' to come, this research offers a different explanation, one steeped in disagreements over territory and heightened tensions over border management following the Taliban takeover of Afghanistan in August 2021.

The details and implications of this conflict are documented in a separate report, 'Missing the Target: Examining the Causes of the Conflict on the Afghanistan-Iran Border in May 2023'.

Key findings regarding climate change impacts in the Helmand River Basin include the following:

- **Despite the evidence that the direct cause of the fighting lay with differences over how the border was managed and a breakdown in cross-border relations following the Taliban takeover, it is important not to completely dismiss the underlying frictions between the two governments over the flow of water from the Helmand River, and how it increases the potential for an outbreak of violence between the two states.** There is growing tension between Tehran and Kabul as they both jostle to divert and store more signicant amounts of water in a river basin impacted by climate change and reduced water flows. Some of the investments in infrastructural works made by Afghanistan and Iran have had dramatic effects on water flows to downstream populations on the other side of their respective borders, fuelling tensions between the two states and the war of words that erupted in the days before the fighting in May 2023.

- **Over the past 20 years, both Kabul and Tehran have built dams and reservoirs to divert surface water from the Helmand River Basin to the detriment of their neighbour, downstream populations, and the ecological balance of the river basin.** The current media focus is on Afghanistan and the completion of the Kamal Khan Dam, 80 kilometres upstream from the fork in the Helmand River and the intake to Iran. Completed in 2021, and now under the authority of a single administration, this dam gives Kabul signicant leverage, allowing it to control the volume of water and when it is released and divert it away from the Sistan River, from where Iran takes most of its water, via canal to the Afghan border districts of Kang and Zaranj. This has led to an increased area under agriculture and improved yields in 2024; further canals are being constructed to divert water flowing from Kamal Khan to other parts of Charburjak and Zaranj in Nimroz. This has been to the detriment of Iran and has led to a reduction in the size of the large reservoirs – the Chah Nimeh – that Tehran had constructed to provide potable water to the urban populations of Zabol and Zahedan. However, following Tehran's construction of the fourth and by far the largest of the Chah Nimeh reservoirs in 2008, the surface area of the natural wetlands in Kang contracted considerably. Consequently, while Tehran may complain about the diversion of water from Kamal Khan Dam, its construction of the Chah Nimeh some years earlier, as well as the two dams it built on the Sar-e-Shelah River, played a key role in denying water to the wetlands in Afghanistan further downstream.

- **This game of tit-for-tat by the Iranian and Afghan authorities is largely a response to dwindling water flows in the Helmand River Basin and a direct result of climate change.** The meteorological data for the period between 1990 and 2024 are concerning. Over this period, temperatures in the Helmand River Basin rose by 10 degrees Celsius; annual precipitation has declined from 225 millimetres to 200 millimetres; and considering rising and increasingly erratic temperatures, as well as declining precipitation, there has been a marginal decline in the amount of snow accumulating in the mountains. The cumulative effect is lower run-off in the Helmand River Basin, less water in the rivers, and increased frequency of drought. It is no coincidence that much of the rhetoric and sabre-rattling by Tehran and Kabul typically occur during drought years, and that soon after their investments in water diversion and storage infrastructure projects are implemented.

- **Since 2019, there has been a dramatic increase in groundwater extraction in both Afghanistan and Iran as a direct response to reduced surface water in the Helmand River Basin.** In Afghanistan, individual households have sunk groundwater wells in the Helmand River Basin, some of them up to 110 metres deep. Initially found mainly in former desert areas and using solar-powered water pumps, these groundwater wells have increasingly been sunk in surface irrigated areas in the middle and upper basin due to inadequate surface water in the summer (June to August), and now number almost 70,000. In Iran, groundwater exploitation has been led by the state, which has sunk three wells of between 1,000 and 3,000 metres in depth.

- **Available groundwater in the Helmand River Basin in Afghanistan is falling at an alarming rate, putting the livelihoods of 365,371 households – the equivalent of 3.65 million people – at risk over the next decade.** Solar-powered groundwater pumps are now ubiquitous across the Helmand River Basin, and even in surface irrigated areas, farmers are increasingly dependent on their wells to get sufficient water for a summer crop. Furthermore, the Taliban poppy ban has made the summer crop an increasingly important part of livelihood portfolios as farmers struggle to maintain a level of agricultural income that is commensurate with basic needs. This is further increasing the pressure for groundwater extraction and the risk that far more deep wells will be sunk. Currently, farmers in the Helmand River Basin consistently report annual drops in groundwater in their wells of between one and three metres, with rates of more than five metres in areas further from surface irrigated areas. Unchecked, this trend towards further groundwater extraction poses a major risk to the population across the Helmand River Basin in Afghanistan over the next decade.

Introduction

This report is an output emerging from a larger research initiative designed to interrogate the direct causes of the outbreak of violence on the Afghanistan-Iran border in May 2023, the role that climate change and state and community responses played in this, and the potential for further conflicts in the future. Lasting more than a week and leading to multiple deaths and injuries on both sides, this fighting attracted national, regional and international media coverage.[1] Ultimately, it took the authorities in Tehran and Kabul several days to bring a halt to the violence. At the time, most explanations attributed this cross-border conflict to long-standing disagreements between the Iranian and Afghan authorities over the distribution of water from the Helmand River [which had already surfaced in the summer of 2022, less than a year after the Taliban had taken power.][2] The escalation was viewed as a possible example of a climate change induced conflict and a potential precursor of further, perhaps more protracted violence in the sensitive tri-border area between Iran, Afghanistan and Pakistan,[3] a forewarning of what some have referred to as 'water wars'.[4]

The public argument that broke out between high-ranking Iranian and Afghan officials in the days preceding the outbreak appeared to suggest as much: the Iranian president and the foreign minister accused the Taliban of disregarding the water treaty between the two countries and withholding water from the population in Sistan and Baluchestan Province in Iran.[5] These allegations from Tehran, and the Taliban foreign minister and deputy foreign minister's responses,[6] alongside more provocative retorts of low-ranking Taliban officials on social media[7] took place against a backdrop of a worsening drought and indications that the Taliban would continue the Afghan Republic's plans to dam some of the major rivers that flow into Iran.[8]

However, empirical evidence challenges this accepted wisdom about the origins of the May 2023 violence. Rather, it documents a conflict that was more local in nature, steeped in disagreements over territory and how the border should be managed, which were heightened following the Taliban takeover in August 2021. Refuting the narrative that attributes the fighting directly to decisions taken in Tehran and Kabul, and historic disputes over transboundary water rights, a separate report, *Missing the Target: Examining the Causes of the Conflict on the Afghanistan-Iran Border in May 2023*, details how the conflict was the direct result of efforts to recalibrate cross-border relations, driven primarily by Taliban border officials less accepting of their counterparts' propensity to fire across the border than was the case during the Afghan Republic, but also Iranian Border Guard (IBG) frustration at the Taliban's tolerance, if not regulation, of the cross-border drug trade.

While *Missing the Target* documents the new equilibrium that has been reached between authorities on the border between Nimroz Province in Afghanistan and Sistan and Baluchestan Province in Iran,[9] this report dives deeper into the impacts that climate change has had on surface water across the Helmand River Basin, as well as the successive efforts of Afghan and Iranian governments to divert water flows in their favour, including through major infrastructural works, such as dams and canals. Drawing on substantial empirical data from fieldwork and satellite imagery, this research suggests that debates over the ongoing and deteriorating dispute between Kabul and Tehran over transboundary water rights is a distraction from what is likely to be a far more significant crisis: the dramatic increase in the exploitation of groundwater across south-west Afghanistan since 2019, reports of substantial yearly drops in the water table and the livelihoods of as many as 3.65 million people at risk. It is this pending crisis that can be directly attributed to the effects of climate change.

1. Al Jazeera, *Taliban fighters clash with Iranian border guards* [Video], YouTube, 28 May 2023, youtube.com.
2. Michael Scollon, 'Iran and Afghanistan's Taliban clash as water dispute boils over', *Radio Free Europe*, 30 May 2023 rferl.orgl.
3. Osama Ahmad, 'Water conflict between Iran and Afghan Taliban stirs sectarian tensions', *Terrorism Monitor,* Volume 21: 16, 8 Aug. 2023, jamestown.org.
4. Natasha Turak, 'Water wars: Afghanistan and Iran's deadly border flare-up spotlights scarcity crisis', *CNBC News*, 19 June 2023, www.nbcnews.com; Lynne O'Donnell, 'The water wars are coming to Central Asia', *Foreign Policy*, 2 Aug. 2023, foreignpolicy.com.
5. 'Raisi sternly warns Taliban over water rights', 19 May 2023, *Tehran Times*, www.tehrantimes.com; 'Iran's president warns Islamic emirate to take water issue seriously', *Tolo News*, 18 May 2023, tolonews.com; H. Amirabdollahian [@Amirabdolahian], در ماه های اخیر مکررا از ملامتقی سرپرست وزارت خارجه افغانستان خواستم طبق عهدنامه هیرمند،به تعهدات خودشان عمل کنند و امکان بازدید هیاتهای فنی و سنجش میزان آب را فراهم کنند، که نکردند, X, 18 May 2023, x.com/Amirabdolahian.
6. Mohammad Farshad Daryosh, 'Iran gives Afghanistan one month to resolve Iran's water rights issue', *Tolo News*, 20 May 2023, tolonews.com; x.com/AFIntlBrk.
7. General Mobin Khan Official, د ایران ولسمشر خبرو ته د جنرال مبین خان غبرگون [Video], YouThube, 18 May 2023, youtube.com.
8. 'Afghanistan: Construction of Bakhshabad dam on Helmand River resumes amid tensions over Iran's water rights', *Euronews,* 22 May 2023, parsi.euronews.com
9. David Mansfield and Alcis, 'Missing the target: examining the causes of the conflict on the Afghanistan-Iran border in May 2023, XCEPT (2025).

Methodology

This research was conducted as part of a larger project examining the cause of the conflict on the Afghanistan-Iran border in May 2023, which was designed to better understand underlying tensions and the risk of further, more protracted, outbreaks of violence in the future. The research adopts a genuinely mixed-methods approach and combines the results of geospatial, meteorological data and in-depth interviews to explore the causes of the conflict.

Each method employed offered valuable data, each with significant advantages. However, by combining these datasets, we could triangulate results and explore different lines of enquiry as they emerged. In particular, integrating geospatial analysis throughout the research process supported the verification of findings, the extrapolation of results over a larger geographic area than covered by in-depth interviews, and the mapping and quantification of the population impacted by phenomena or events. While more resource intensive, this mixed-methods approach offered a more robust assessment of the factors that led to this outbreak of violence, as well as the role that climate change and community and government responses to it might play in future conflicts.

The first report from this research focused on events on the Afghanistan-Iran border and drew on geospatial data and in-depth interviews from Nimroz Province (Afghanistan) and Sistan and Baluchestan Province. This second report takes a more comprehensive look at the Helmand River Basin; therefore, geospatial data and in-depth interviews cover a much wider geographic area and includes historic meteorological data.

Geospatial data consisted of multiple layers, including detailed data on agriculture and water, covering multiple years and supporting an analysis of changes over time across multiple datasets. The inclusion of a unique household compound dataset also allowed us to estimate the number of people impacted. To counter the inconsistency in the literature, high-resolution satellite imagery was also deployed to chart the sequencing of major infrastructural works in the Helmand River Basin and support analysis of the downstream effects of these programmes.

Meteorological data spanned 34 years and included temperature (average, minimum and maximum); precipitation; snow melt equivalent; evaporation; and Standardised Precipitation Index (SPI) for three, six and twelve months of drought. These data were then aggregated to a ten-kilometre hexagonal grid and mapped across the Helmand River Basin. The hex grid was then linked to the sub-basin dataset, enabling the project team to analyse time series climate information at basin and sub-basin scale for specific periods, and overlay it with other geospatial datasets available to the team.

The details of these datasets and how they were used are outlined in Annex A. Unless otherwise noted, all tables and figures are based on Alcis data and analysis.

A system uninterrupted: the Basin in its natural state

The Helmand River Basin covers a total area of 401,963 square kilometres, including parts of Iran (15 per cent of the basin) and Pakistan (3.6 per cent). As a closed river basin, it does not flow into the sea.[10] The Helmand River is the main river in the basin, and its size is such that it accounts for approximately 40 per cent of Afghanistan's total water resources. The river has two tributaries, the Arghandab River and Musa Qala River, which join at Qala Bost and Sangin, respectively (see Figure 1).

The sources of the Helmand River's water are primarily snow-melt in the mountains of the Hindu Kush and rain from the upper basin. Uninterrupted flows in the Helmand River are highest in March-May during snow-melt at higher elevations of the catchment area. After May, the flow in the river decreases, reaching its lowest ebb between August and November.[11]

From the mountains, the Helmand River travels through the middle of the river basin, where it is used extensively for large-scale formal irrigation, before entering the Sistan depression, most of which is in Iran. Here, it forms a series of terminal lakes and salt marshes, known in Iran as 'hamouns'; the Hamoun-e-Puzak and Hamoun-e-Saberi straddle the Afghanistan-Iran border (see Figure 2). Four more rivers flow from the north-west and the Provinces of Ghor and Farah into these hamouns: the Khash Rud, Farah River, Harut Rud and Kushpas Rud.

The surface area and level of water in the hamouns in the Sistan depression varies in response to inflows and evaporation.[12] During substantial and sustained discharge periods – typically flood conditions – water from the hamouns overflows via a gully, the Sar-e-Shelah River, and crosses the border into Afghanistan and the Gowd-e-Zirah. This is a further wetland that spans the Afghanistan-Pakistan border close to Pakistani Balochistan. This is the final lake in the system and the process of overflow rebalances any increasing salinity in the hamouns in Iran.[13]

Critical to Iranian interests is the area of Khwabjah, where the Helmand River makes first contact with the border of Iran and forks, forming the Sistan River and Nad-e-Ali River (see Figure 3).[14] The Sistan River crosses into Iran and discharges into the Hamoun-e-Saberi, also fed by the Farah River and Harut River. Overflow from the Hamoun-e-Saberi is then discharged into the Hamoun-e-Hilmand, which, when full, is then discharged into the Gowd-e-Zirah in Afghanistan.

The right fork of the Helmand River, the Nad-e-Ali, continues its path on the Afghan side of the border, where it eventually leads to Sar-e-Shela in Kang District, on the border with Zaranj District, and discharges into the marshes and Hamoun-e-Puzak. When full, this overflows into the Hamoun-e-Saberi and, thereby, the Hamoun-e-Helmand and Gowd-e-Zirah.[15]

As such, continued water flow from the Helmand River into the 'hamouns' is critical to life in Sistan and Baluchestan Province in Iran. At their peak, these wetlands covered an area of 5,346 square kilometres and sustained the population through livelihoods based on hunting, fishing and farming (see).[16] While subject to periodic droughts, where only the upper parts of the lakes remained flooded, the region would recover when the rains and the floodwaters of the Helmand River returned.

A drought that began in the region in 1998 continued until 2004. Its impact was so severe that by 2001, the 'hamouns' were completely dry: local fish and bird populations had all but disappeared, livestock

10. Ministry of Energy and Water, 'Helmand River Basin master plan, phase 2: technical report 1: progress on Helmand River Basin model and scenario development', Mott Macdonald (2012), p. 1.

11. United States Geological Survey (USGS), 'Water-balance simulations of runoff and reservoir storage for the upper Helmand watershed and Kajaki reservoir, central Afghanistan', Scientific Investigations Report 2007-5148, Afghanistan Project Product Number 165 (2007).

12. United Nations Environment Programme (UNEP), History of environmental change in the Sistan Basin: based on satellite image analysis 1976-2005, UNEP Post-Conflict Branch (Geneva, 2006); Abdul Tawab Assifi, An assessment of the Helmand valley water control systems, Final report prepared for the office of AID Representative for Afghanistan, US Embassy Islamabad (1991); Asian Development Bank (ADB), *F*easibility study, Chakhansur flood control and irrigation project, Afghanistan, Volume 1 – Report (July 1973); Ministry of Energy and Water, Helmand River Basin master plan, p. 19.

13. UNEP, *History of environmental change*.

14. Water and Power Authority, Republic of Afghanistan, 'Helmand Basin integrated irrigation and power development', Unpublished report (1975), pp. 1-9.

15. UNEP, *History of environmental change*.

16. UNEP, *History of environmental change*.

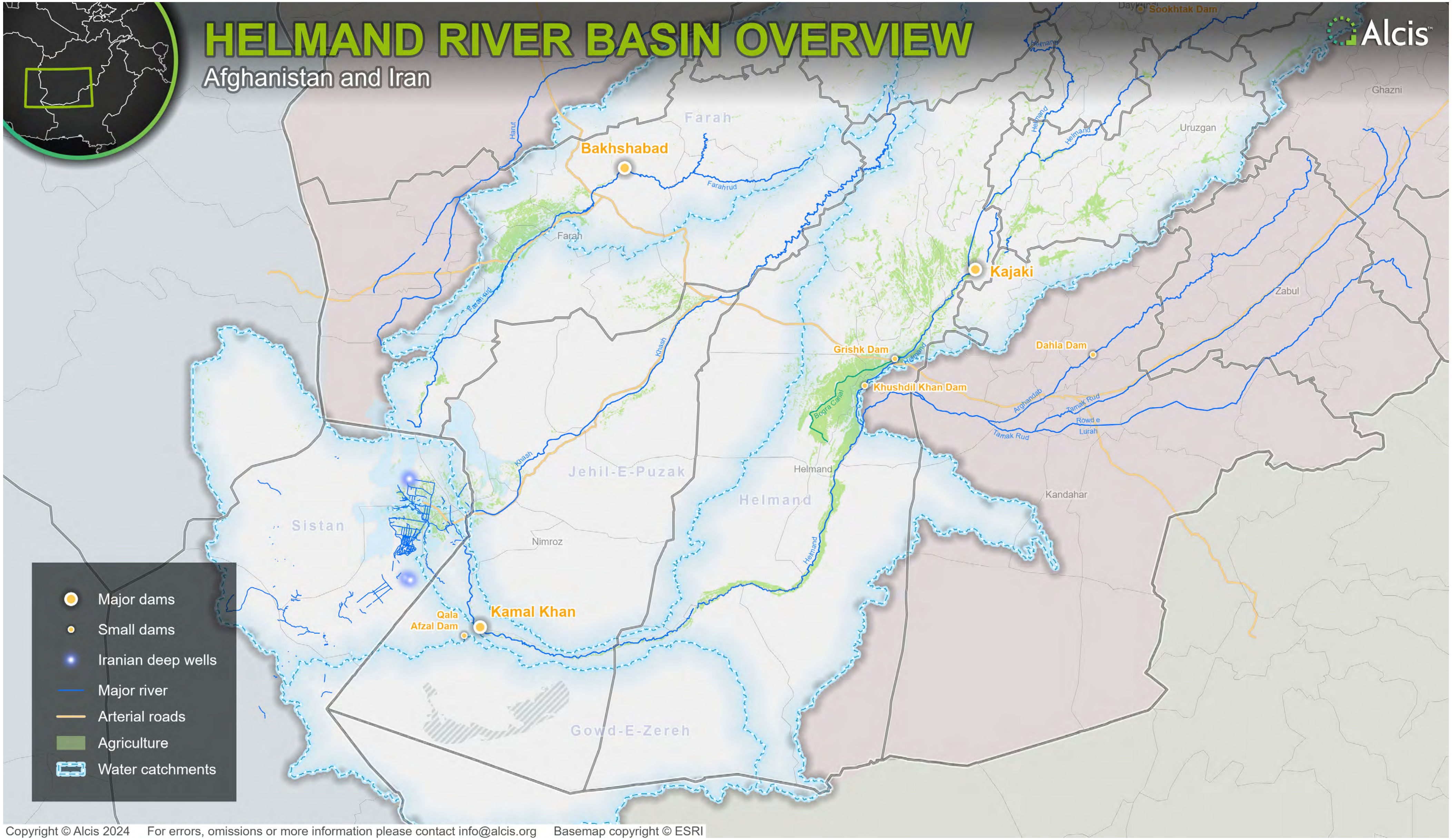

Figure 1: Helmand River Basin

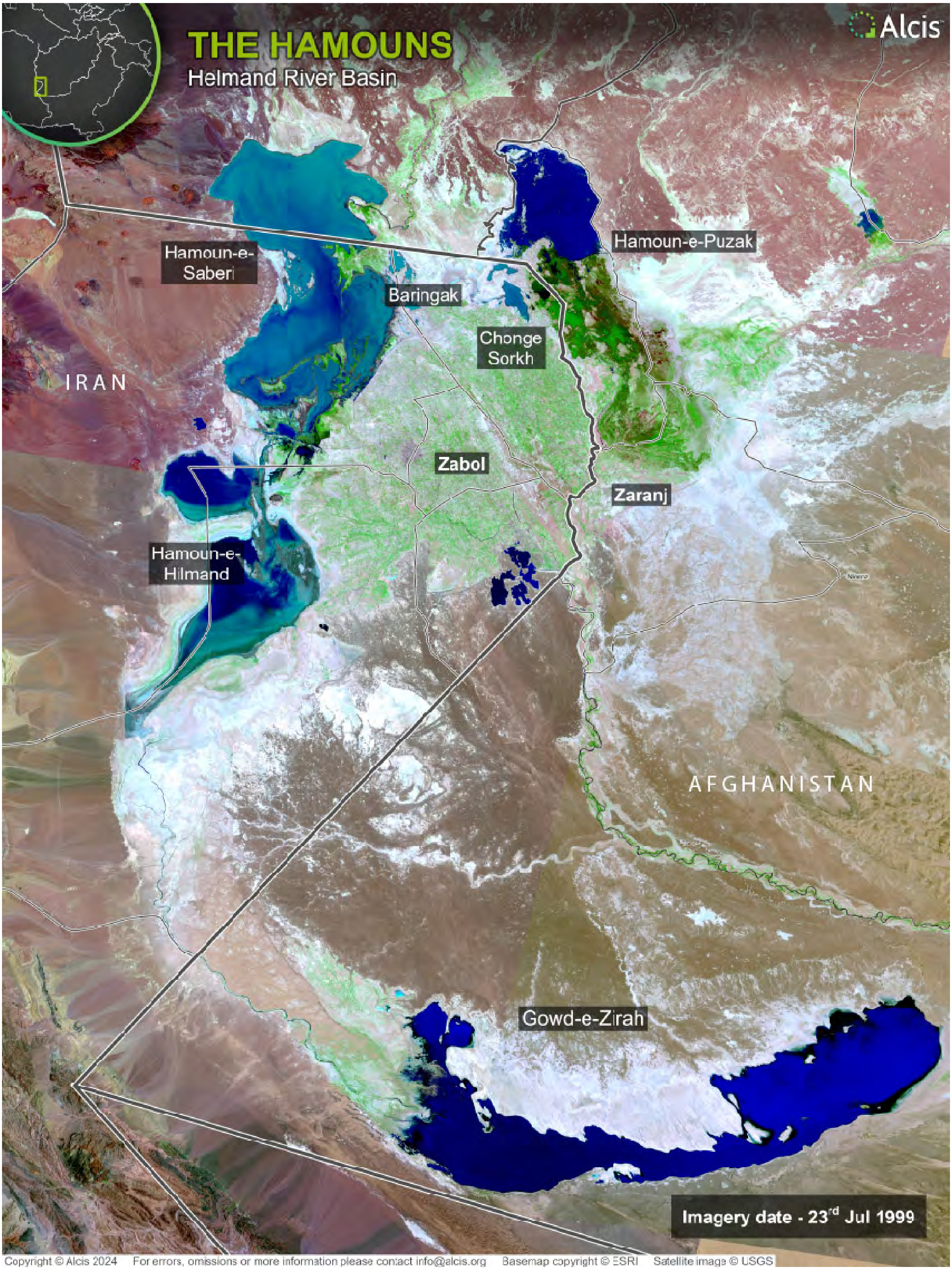

Figure 2: The Hamouns of the Sistan depression

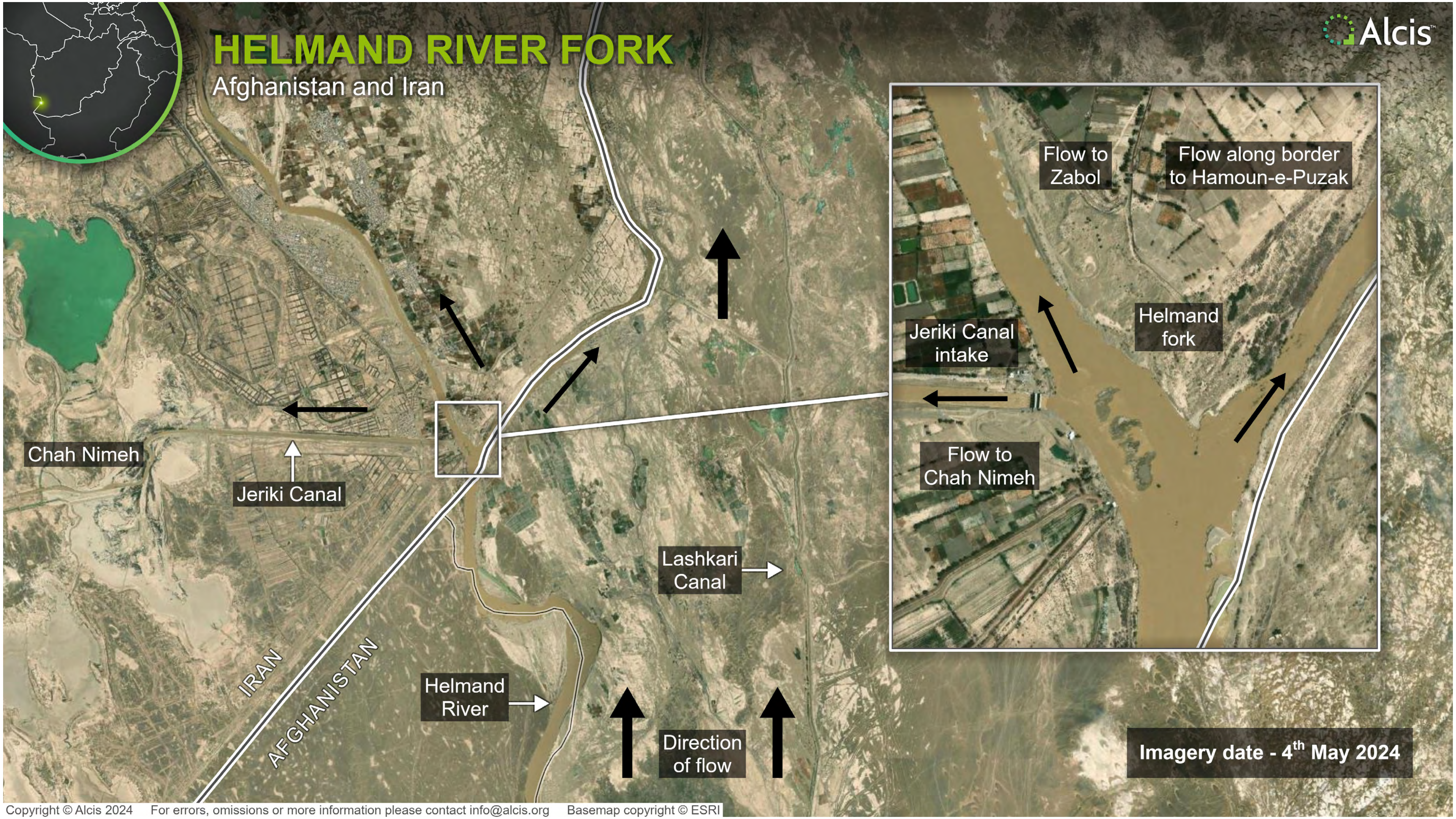

Figure 3: Helmand River fork

Table 1: Satellite-derived areas and volumes for the hamouns and Gowd-e-Zirah

Waterbody	Estimated depth (m2)	Area (km2)	Volume (million m^3)
Baringak	1	221.6	221.6
Chonge Sorkh	1	59.8	59.8
Hamoun-e-Hilmand	2	2,388.8	4,777.6
Hamoun-e-Puzak (Afghanistan)	3	1,453.4	4360.2
Hamoun-e-Puzak (Iran)	2	61.0	122.0
Hamoun-e-Saberi	3	1,161.5	3,484.5
Total hamouns		**5,346.1**	**13,025.7**
Gowd-e-Zirah	10	2,417.5	2,4175

Author's own based on data from UNEP (2006).[17]

numbers had plummeted, and many of the people of Sistan and Baluchestan migrated to look for work and to escape the dust and sand that swept through the area (see Figure 4).[18] While Tehran and Kabul have regularly argued about the flow of water from the Helmand River since the 1870s [particularly during drought years] the prolonged drought prompted both governments to expand t heir efforts to divert and store water, which exacerbated the conditions in the 'hamouns' and impacted the populations that depended on them for their livelihoods.[19]

Gaming the system: Water diversion and dams

There are several rich and detailed accounts of the various negotiations over the division of the waters from the Helmand River system, dating back to the 1870s and culminating in the 1973 Helmand Treaty.[20] Each documents the disputes, debates and challenges of reaching an agreement over water rights, made more complicated by the role of Britain as the colonial power that demarcated the border between Iran and Afghanistan, the shifting course of the Helmand River, and disputes over the actual percentage of the waters Iran was due (ranging from one-third to one-half).

Throughout these discussions and before the signing of the Helmand Treaty, the Helmand River Basin was altered significantly through infrastructural works, most of which were completed in the 1950s and 1970s, before the outbreak of the civil war in 1978 and subsequent Soviet invasion. During this period, the most consequential project for neighbouring Iran and its water rights was the Kajaki Dam and reservoir, completed in 1953. With a capacity of 1,844 million cubic metres of water at its peak,[21] the dam gave Kabul greater control over the flow of water in the Helmand River and the timing of its release. Following in quick succession from the completion of another large dam and reservoir at Dahla on the Arghandab tributary, the Kajaki Dam helped consolidate Kabul's control over the waters in the upper basin.

17. UNEP, *History of environmental change*.
18. NASA Earth Observatory, *From wetland to wasteland: the destruction of the Hamoun oasis* (Dec. 2002).
19. NASA Earth Observatory, *From wetland to wasteland.*
20. Ministry of Energy and Water, Helmand River Basin master plan; Mohammad Assem Mayar, The long winding river: unravelling the water dispute between Afghanistan and Iran, Afghan Analysts Network, (2023), https://www.afghanistan-analysts.org/en/themed-reports/economy-development-environment-themed-reports/the-long-winding-river-unravelling-the-water-dispute-between-afghanistan-and-iran/; Vincent Thomas, Mujib Ahmad Azizi and Khalid Behzadl, Developing transboundary water resources: what perspectives for cooperation between Afghanistan, Iran and Pakistan? Afghanistan Research and Evaluation Unit (2016).
21. Ministry of Energy and Water, *Helmand River Basin master plan*, p. 13.

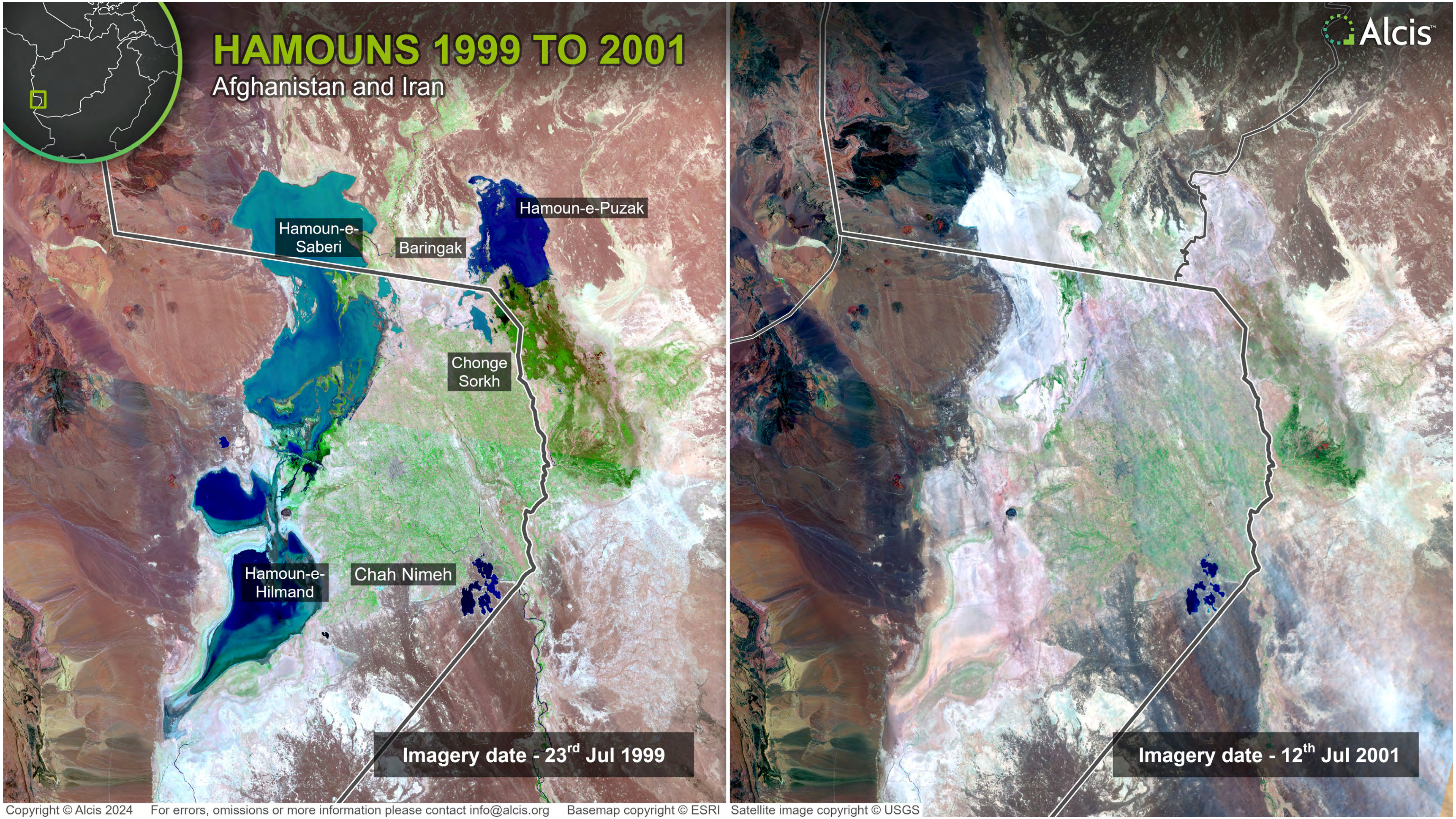

Figure 4: Hamouns fully inundated (1999) and dry (2001)

The hamouns of the Helmand River Basin

The Hamoun-e-Puzak wetland is located on the Afghanistan-Iran border, with 96 per cent in Afghanistan and four per cent in Iran, the latter designated a Ramsar wetland[22]. It is fed by several rivers, including the Helmand and Farah River, and is characterised by reed beds and submerged vegetation, all of which have been significantly impacted by fluctuations in water levels. Detailed mapping undertaken by the United Nations Environment Programme shows a steady decline in vegetation cover from the mid-1970s to 2002.

Chonge Sorkh is a small wetland covering approximately 60 square kilometres, with a maximum depth of one metre, located directly adjacent to Hamoun-e-Puzak and Baringak. It does not receive water from major rivers but depends upon neighbouring wetlands for inflow. It has significant restoration potential through water control measures, only drying out completely twice between 1985 and 1999. Despite maintaining at least 60 per cent water coverage even in low periods, it too saw a decline in vegetation cover from 1985-95, peaking at only 30 per cent, down from 47 per cent in the mid-1970s, despite sufficient water availability.

Baringak is approximately four times larger than Chonge Sorkh, at 222 square kilometres and a maximum depth of one metre, and connects Hamoun-e-Puzak and Hamoun-e-Saberi. Known for its dynamic water levels during medium and high periods, it fills quickly but dries out more often than Chonge Sorkh, making it highly vulnerable. From 1985 to 1999, vegetation cover, which had always been lower than in Chonge Sorkh, noticeably declined. By 2000, only a small amount of vegetation remained.

Hamoun-e-Saberi, a wetland of 1,162 square kilometres with an average depth of three metres, receives water primarily from the Adrashkan (Harut) River and partly from the Farah River. The northern Sistan River also contributes, especially during high-water periods when Hamoun-e-Puzak overflows into it. Satellite imagery indicates lighter water tones due to differences in water quality and limited submerged vegetation. The water regime in Hamoun Saberi varies, filling rapidly during low-water periods but remaining relatively stable during high-water periods. In early 2002, only 25 per cent of the wetland was filled, marking the only inundation during a drought. Vegetation cover, which was about 10 per cent in the mid-1970s, declined significantly, leading to the abandonment of over 100 nearby villages by 2005.

Hamoun-e-Hilmand is the largest lake in its system, covering 2,389 square kilometres, with an average depth of two metres. It receives water from Hamoun-e-Saberi and the Sistan River, while excess water flows out through the Shile River. The lake has a short water residency time, often exhibiting reduced water cover, especially during low-water phases. Although it maintained at least 60 per cent of its capacity during high-water periods, it dried out during medium-water phases and dropped below 20 per cent capacity after the 2005 floods. This trend has also contributed to a decrease in vegetation cover.

Gowd-e-Zirah is in the very south of Nimroz Province on the Afghanistan-Pakistan border. It is a hyper-saline lake fed by the overflow from the hamouns in the north during periods of substantial and sustained discharge, typically flood conditions. When this happens, the waters of the hamouns are pushed south from Hamoun-e-Hilmand via the Shile River to Gowd-e-Zirah. The process rebalances any increasing salinity in the hamouns. Under rare and extreme flood conditions, it also receives water directly from the Helmand River. As one of the most arid regions on earth, this region of Afghanistan receives as little as 50 millimetres of precipitation a year, but experiences over 3,000 millimetres of evaporation due to persistently high temperatures, strong winds and low humidity.

22. 1971 Ramsar Convention, www.ramsar.org

Built alongside the Kajaki Dam and Dahla Dam, a multitude of much smaller diversion dams and canals were constructed as part of the Helmand and Arghandab Valley Authority's efforts to manage the flow of water in the Helmand River Basin and increase the amount of land under agriculture. Established in 1952 and expanded in 1965 under the Ministry of Agriculture, Irrigation and Livestock, the Authority received considerable financial and technical support from the United States government between 1949 and 1979, and subsequently during the Afghan Republic (2003 to 2021).[23]

While Tehran consistently voiced its concerns about the impact the Kajaki Dam and the smaller diversion dams and canals had on the water Iran received [particularly during drought] the Helmand Treaty was signed in 1973, codifying Tehran's right to water from the Helmand River.[24] However, despite having this agreement in place – complete with provisions for lower water flows during drought years – both Tehran and Kabul have repeatedly sought to game the system, constructing several infrastructure projects designed to divert and store water in their favour.

Typically, such efforts have been designed to gain as much advantage from the water flows from the Helmand River as possible, even if it is to the detriment of their neighbour, downstream populations and the ecological balance of the river basin. Charting the chronology of some of the most notable interventions and their impact on the downstream populations is critical to better understanding the causes of cross-border tensions between Afghanistan and Iran, often attributed solely to climate change and reduced water flows.

Lashkari Canal

One of the earliest attempts to directly divert water away from its neighbour was Afghanistan's construction of the Lashkari Canal in the 1970s.[25] The intake for the canal is located 30 kilometres upstream from the Iranian border and 47 kilometres from the Kamal Khan Dam, after which the Helmand River opens into a delta. It is the last canal in the Helmand River system, and therefore represents Kabul's last opportunity to divert water away from the Helmand fork and the Sistan River which flows into Iran (see Figure 5). From the Helmand River, the Lashkari Canal runs north through the district of Zaranj and to the west of the city before terminating at Sar-e-Shela. Here, the water from the Lashkari Canal discharges into the Sekhsar Canal, which runs north on the Afghan side of the border and irrigates agricultural lands in Kang.[26]

Although the Soviet invasion (1979) and Afghan civil war (1989 to 1982) put a halt to any significant infrastructure investments in this lower part of the Helmand River Basin in Afghanistan until the subsequent construction of Kamal Khan Dam in the final years of the Republic, the inlet to the Lashkari Canal remained a priority for more informal works. For example, local residents report that in the late 1990s, the Taliban provincial leadership ordered several shipping containers to be positioned in the dry riverbed at the inlet for the Lashkari Canal in an attempt to direct waters to the canal and the populations in Kang and Zaranj; and in 2016, the governor of Nimroz, Amir Mohammed Akhundzade, constructed an intake to direct water to the Lashkari Canal in what was a particularly dry year.

Chah Nimeh reservoirs

In Afghanistan, investments in large formal infrastructural works were not a priority during the war. Tehran, however, engaged in major infrastructural works, building four artificial and interconnected reservoirs known as 'Chah Nimeh', located to the west of the Helmand fork at Khwabjah; the nearest – Chah Nimeh 1 – is only six kilometres from the Afghan border.[27] Imagery analysis shows that these four reservoirs have had a significant impact on the flow of the Helmand River and the livelihoods of the downstream populations on the borders of Afghanistan and Iran.

Each of the four reservoirs, known as Chah Nimeh 1, 2, 3 and 4, were constructed from natural basins, enhanced with berms and dam walls, and canals which connect the reservoirs in sequence. Chah Nimeh 1 takes its water from the Jeriki Canal, which has an intake from the Sistan River 290 metres from the Iranian border wall and 620 metres from the

23. Ministry of Energy and Water, *Helmand River Basin master plan*, p. 13.
24. Mayar, *The long winding river.*
25. ADB, *Feasibility study.*
26. ADB, *Feasibility study.*
27. Fazel Amiri, Vahid Rahdari, Saeideh Maleki Najafabadi, Biswajeet Pradhan and Tayebeh Tabatabaei, Multitemporal landsat images based in eco-environmental change analysis in and around Chai Nimeh reservoir, Baluchestan, *Environmental Earth Sciences*, Aug. 2014.

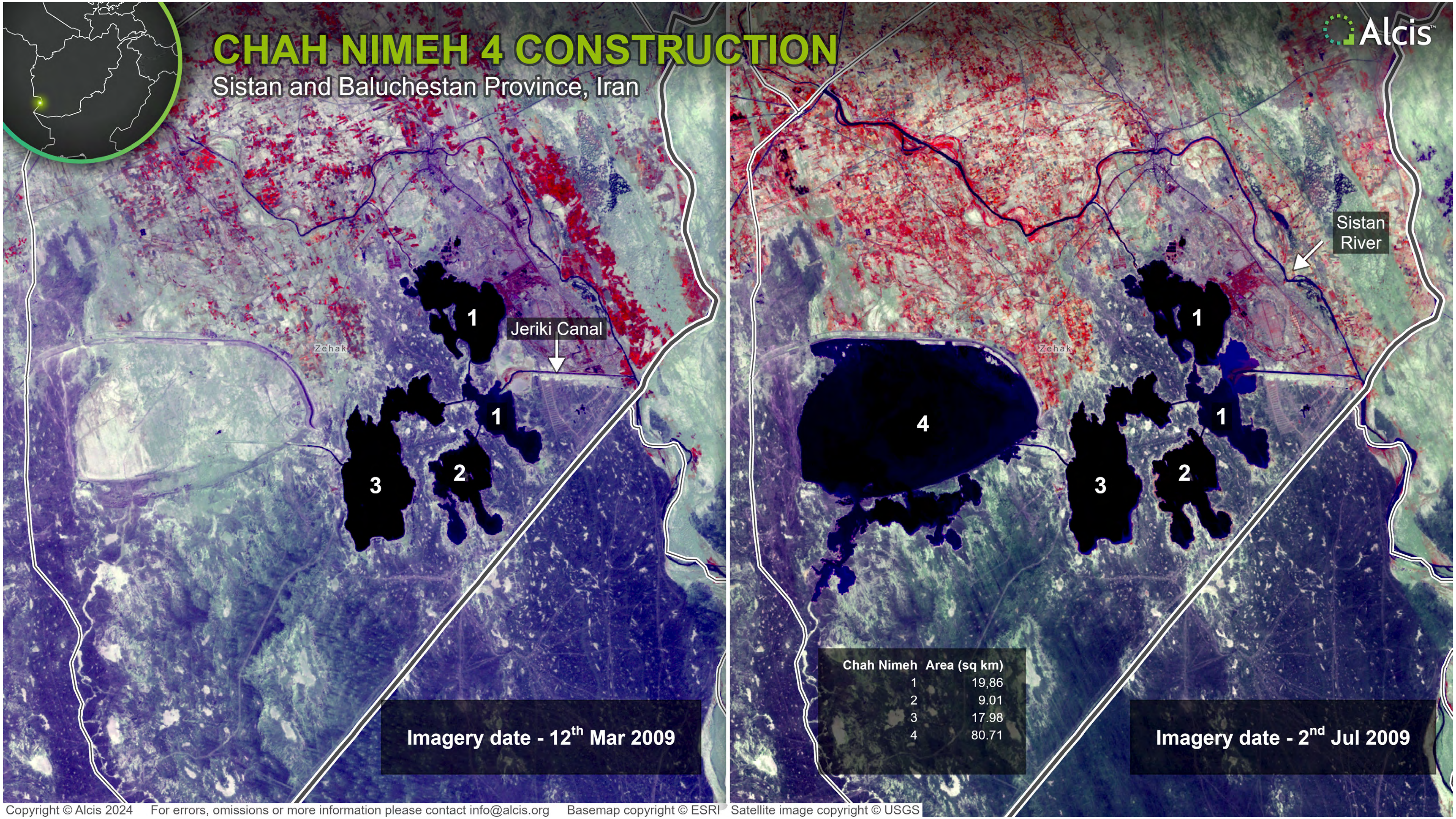

Figure 5: Development of Chah Nimeh 4, Sistan and Baluchestan (2009)

official Afghan border. From Chah Nimeh 1, water flows to 2 and 3; from Chah Nimeh 3, water runs to Chah Nimeh 4 to the west.

Reference to the plans to construct these artificial lakes can be found in documents from 1973.[28] The first three reservoirs, covering a combined area of 46.85 square kilometres and with an estimated storage of 630 million cubic metres, were finished in 1982. The construction of the fourth began after the prolonged drought. Imagery shows that it was completed in 2008, covering an area of 80.71 square kilometres, with an estimated storage capacity of 900 million cubic metres.

The Chah Nimeh reservoirs were primarily built to provide potable water to the urban populations of Zabol and Zahedan, the last of which (Chah Nimeh 4) was connected by an underground pipe.[29] After allocating water to the cities, the Iranian government determines the water distribution and directs any residual to agricultural production on the Sistan plains, a prioritisation farmers in the area verified.

Consequently, maintaining the flow from the Helmand River to the Sistan River, and subsequently the Jeriki Canal, is critical to Tehran's efforts to secure sufficient water for the growing urban population of Sistan and Baluchestan Province.

Khwabjah and the Helmand fork

This has made the area at Khwabjah and the Helmand fork particularly contentious during drought years. For example, in the summer (June to August) of 2019, the IBG is reported to have walked onto the largely dry riverbed without first approaching the Afghan Border Police (ABP) and begun digging a channel to divert water from the Helmand River to the Sistan River and the Jeriki Canal.[30] Believing the area to be Afghan territory, the ABP fired on them, resulting in cross-border fire and at least one death (see Figure 7, showing ongoing works to direct water into Jeriki Canal). That same summer, a similar incident happened 17.5 kilometres downstream at Hajji Abdul Hamid, where there is another intake on the Iranian border, highlighting the increased risk of conflict during drought years.[31]

Perhaps ironically, Khwabjah, the Helmand fork, and the Jeriki Canal have gained even greater importance because of the direct impact the Chah Nimeh has had in diverting water away from the Nad-e-Ali River northwards to Sar-e-Shela and the Hamoun-e-Puzak. In fact, imagery shows that since Chah Nimeh 4 was completed in 2008, the surface area of Hamoun-e-Puzak has contracted considerably, and often contains only a small amount of water to the north in an area fed by the Farah River in those years when there is more precipitation (see Figure 8). In constructing the Chah Nimeh, the Iranians have played a part in draining the cross-border natural wetlands to the north of Kang and Hirmand, and created far smaller artificial reservoirs further upstream, exclusively in Iran and close to the city of Zabol.

Kamal Khan Dam

Iran's almost sole reliance on the Sistan River for surface water from the Helmand River Basin and the importance of the Chah Nimeh for its potable water supply made Afghanistan's most recent infrastructure addition to the Helmand River – the Kamal Khan Dam – perhaps the most contentious, and a source of growing tension following the Taliban takeover. Located 72 kilometres upstream from Khwabjah and the Iranian border, the dam was inaugurated only a few months before the collapse of the Afghan Republic (see Figure 8).[32] Such was Tehran's opposition to the construction of the Dam that during the insurgency, Iran is alleged to have funded the Taliban to repeatedly attack the area to prevent it from being built.[33]

It has, however, become increasingly evident that with the completion of the Kamal Khan Dam and the subsequent Taliban takeover, Kabul has consolidated its control over the water flow to Iran, and thereby gained significant leverage over Tehran.

For example, historically, once water was released from the dam at Kajaki, there was little to prevent it from flowing into Iran, especially since the construction of the Chah Nimeh. While water is diverted through major canals such as the Boghra, the Darwishan and even the Lashkari, and used in

28. ADB, *Feasibility study*, pp. 3-5.
29. Mayar, *The long winding river*.
30. Mansfield and Alcis, *Missing the target*.
31. Mansfield and Alcis, *Missing the target*.
32. 'Afghanistan finally gets the Kamal Khan Dam, to provide much-needed water to Nimroz', *South Asia Monitor,* 25 Mar. 2021, www.southasiamonitor.org
33. Cited in Thomas et al., *Developing transboundary water resources*.

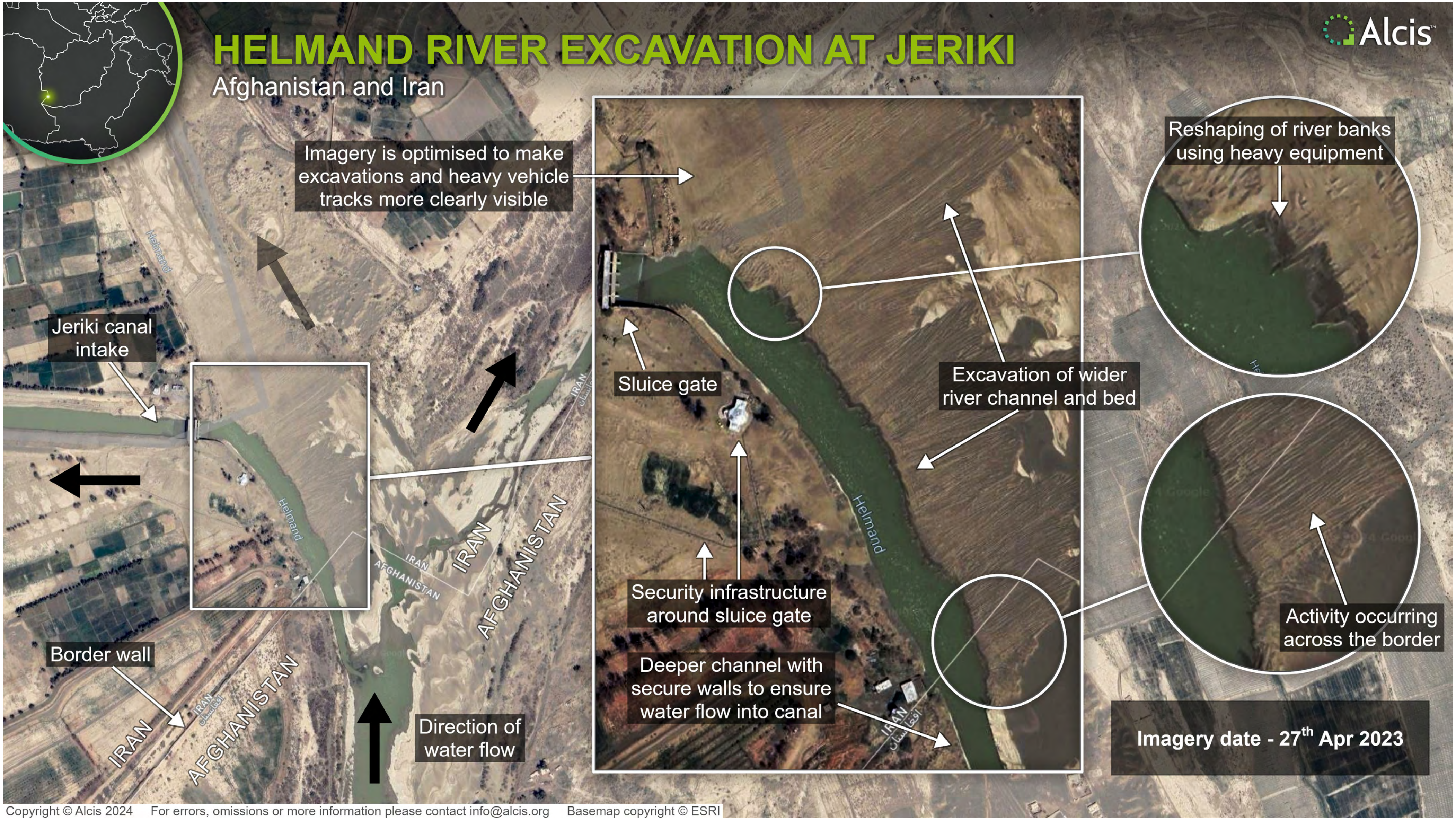

Figure 6: Jeriki Canal – Sistan River (2023)

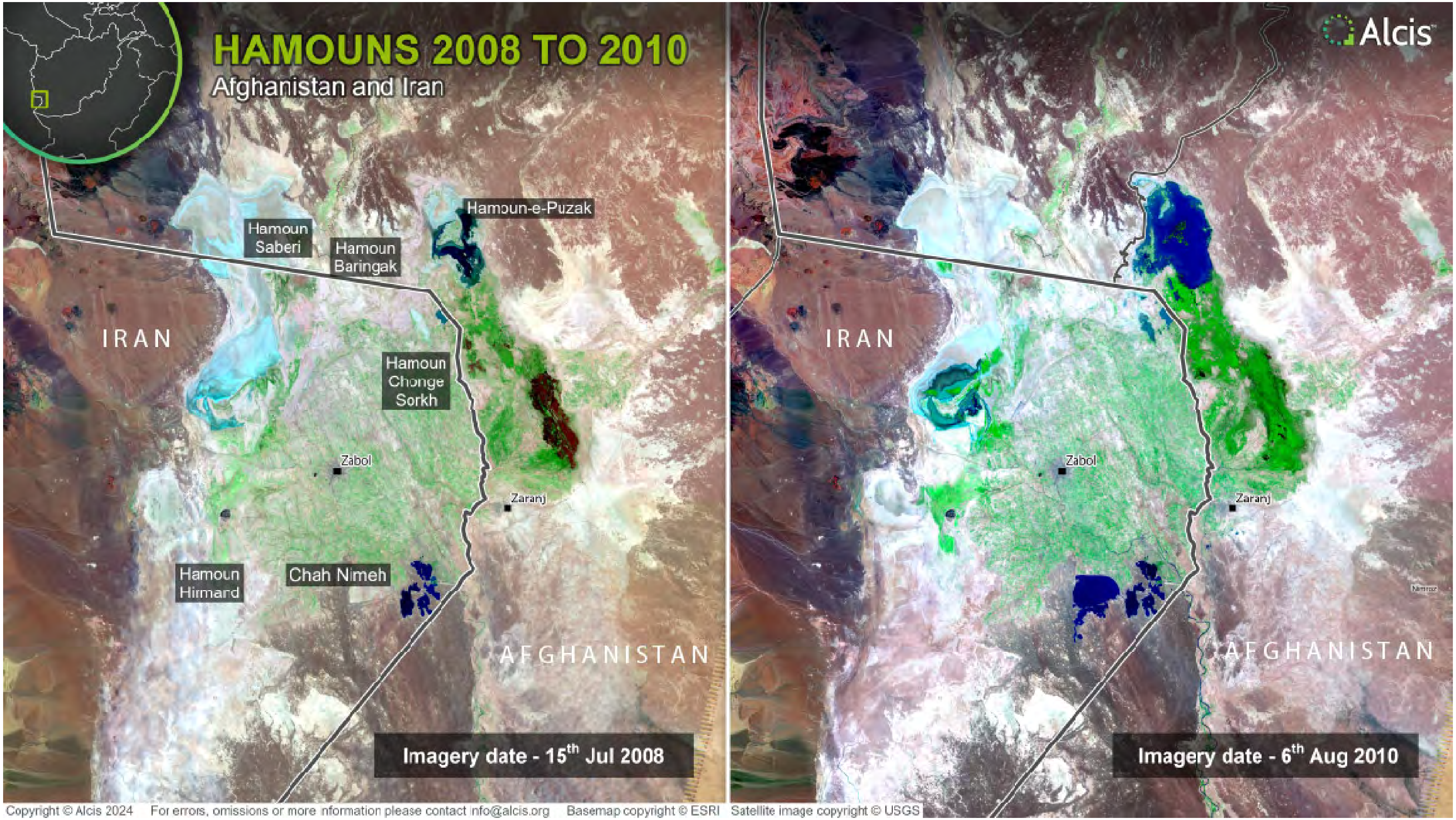

Figure 7: Impact of construction of Chah Nimeh 4 on the hamouns (2008–10)

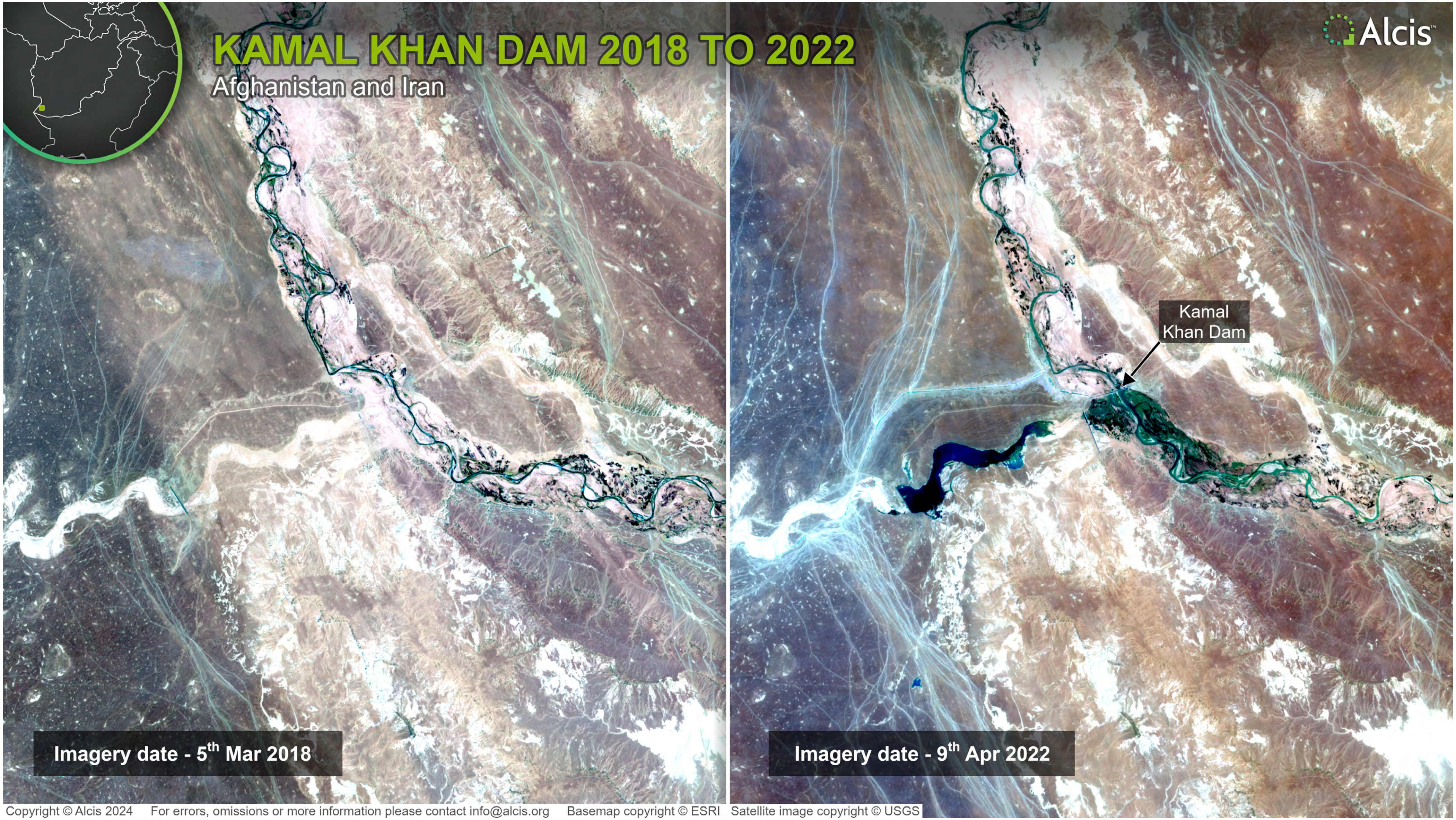

Figure 8: Impact of Kamal Khan Dam on river discharge (2018–22)

Farmers note the contrast with the Republic where even though the provincial authorities were under the same government, personal rivalries and no clear chain of command over line departments meant dysfunction and delays.

large-scale formal irrigation systems, once water is released, there is little to prevent any unused water being drawn off at Khwabjah and discharged into the Chah Nimeh. With the completion of Kamal Khan, much of this unused water can be retained and directed to the advantage of Afghan farmers and away from the Helmand fork, Sistan, Chah Nimeh and the urban populations of Zabol and Zahedan.[34] This is a significant blow to Iranian interests.

It is even more the case now that a single authority exists in Kabul. In fact, farmers in Kang in 2024 reported much improved water flows to their lands since the Taliban takeover, an increased area under irrigation, and improved yields, a claim supported by imagery analysis (see Figure 9). Now managed under a unified authority rather than the more fractious and competing administration that prevailed during the Republic, they reference cooperation and communication between the provincial authorities of Helmand and Nimroz and the line departments they manage. Farmers talk of a coordinated campaign to time the release of waters from Kajaki to the Kamal Khan Dam and subsequently divert water from the dam via the strategic opening of sluice gates to the Lashkari Canal, and from there into the Sekhsar Canal, so that farmers in Kang have sufficient irrigation for what is a single cropping season.

Farmers note the contrast with the Republic where even though the provincial authorities were under the same government, personal rivalries and no clear chain of command over line departments meant dysfunction and delays. Even when water was released from the Kajaki Dam, farmers complained that the canal system did not function effectively, and that water was often diverted by communities upstream, particularly in the upper Helmand River basin, where the insurgency held sway. The result was insufficient and inconsistent irrigation water for those at the very end of the system: farmers in Kang.

High-resolution imagery and analysis highlight the impact of the Kamal Khan Dam's completion on the Chah Nimeh, and the reason for Tehran's concerns. For instance, between 2016 and 2020, Chah Nimeh 4, the largest reservoir, covered an area of 60-80 square kilometres, which was typical for this water body since its inauguration in 2008. However, since 2020, there has been a dramatic reduction in its size, shrinking from 80 square kilometres to zero by 2024, despite an increase in rainfall and floodwaters in 2024 (see Figure 11 and Figure 12 from 2022, mid-decline).

Moreover, in completing the Kamal Khan Dam and improving water management, the Taliban has not just increased its ability to divert the waters of the Helmand River to Kang via the Lashkari Canal. Water can also now be channelled from Kamal Khan to a smaller retaining dam to the east at Qala Afzal, and then diverted directly to the Gowd-e-Zirah; a belated retort to Tehran's decision to construct dams on the Sar-e-Shelah River in Iran, and limit any overflow from the Hamoun-e-Helmand into the Gowd-e-Zirah (see Figure 13). High-resolution satellite imagery also reveals a wide range of other infrastructural works around Kamal Khan, including extensive canal works to the east towards Rami Rud, as well as northwards to Qala Farah, reinforcing Tehran's concerns that further projects are planned that will have a detrimental effect on the water flows to Sistan and Baluchestan (see Figure 14).

34. A report on modelling of water flows in the Helmand River Basin by Mott Macdonald in 2012 stated: 'The Kamal Khan Flood Control and Power Project will have no impact on existing water users upstream. The project would have an impact on the river flows downstream, and consequently the inflow of water into the Hamouns' (Ministry of Energy and Water, Helmand River Basin master plan, p. 60).

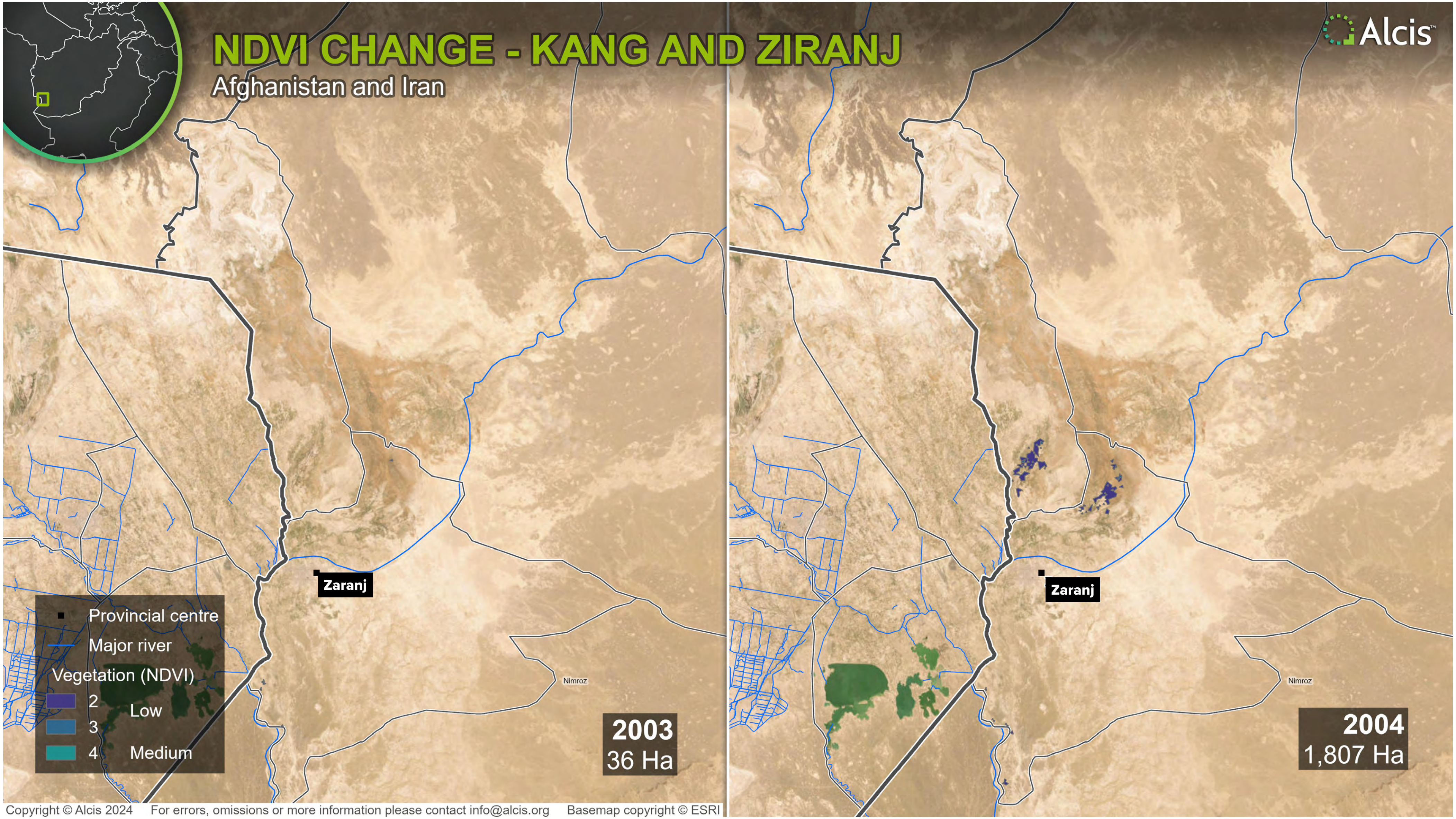

Figure 9: Area under agriculture in Kang and Zaranj (2003 and 2004)

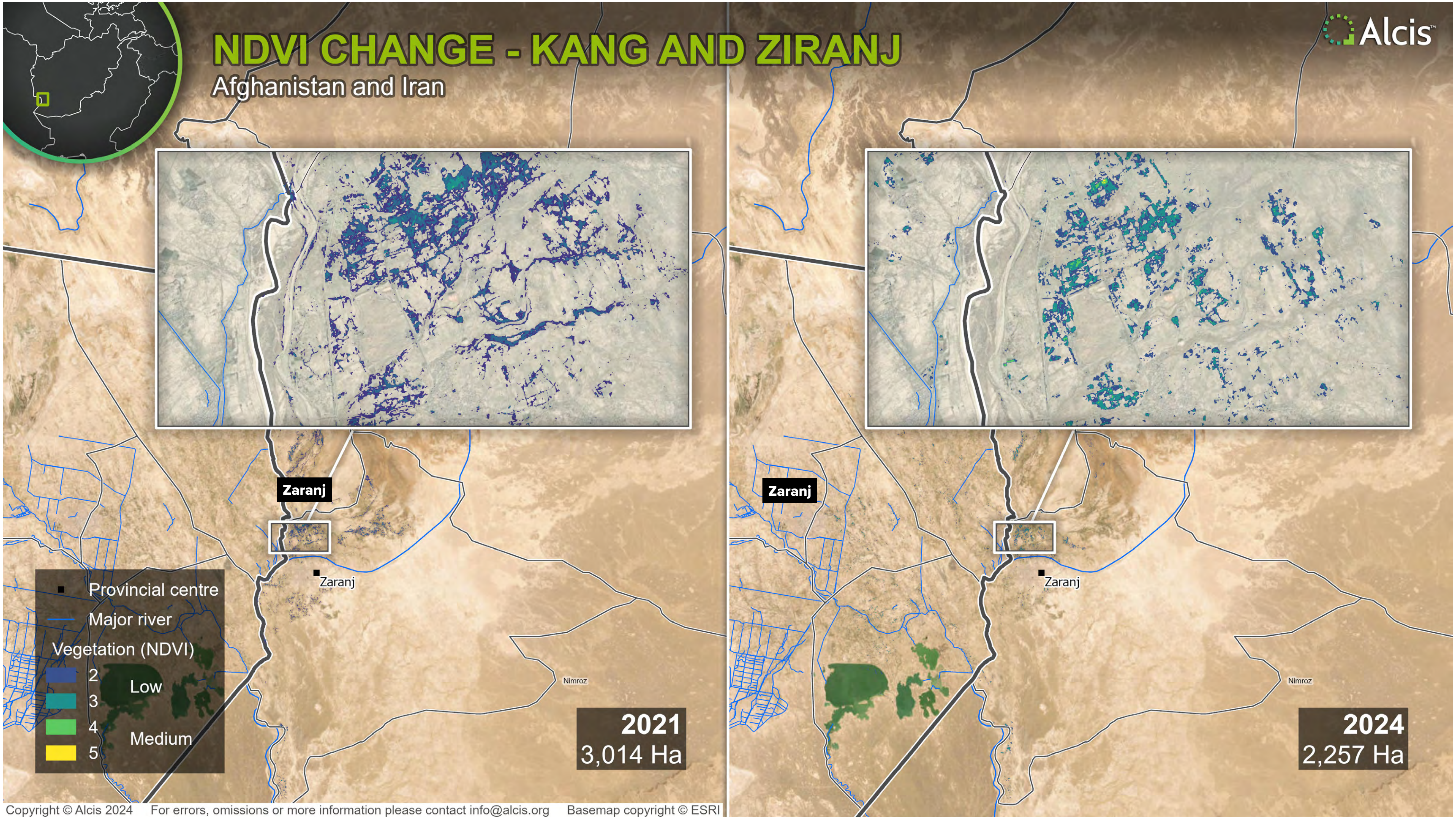

Figure 10: Area under agriculture in Kang and Zaranj before and after Taliban takeover (2021 and 2024)

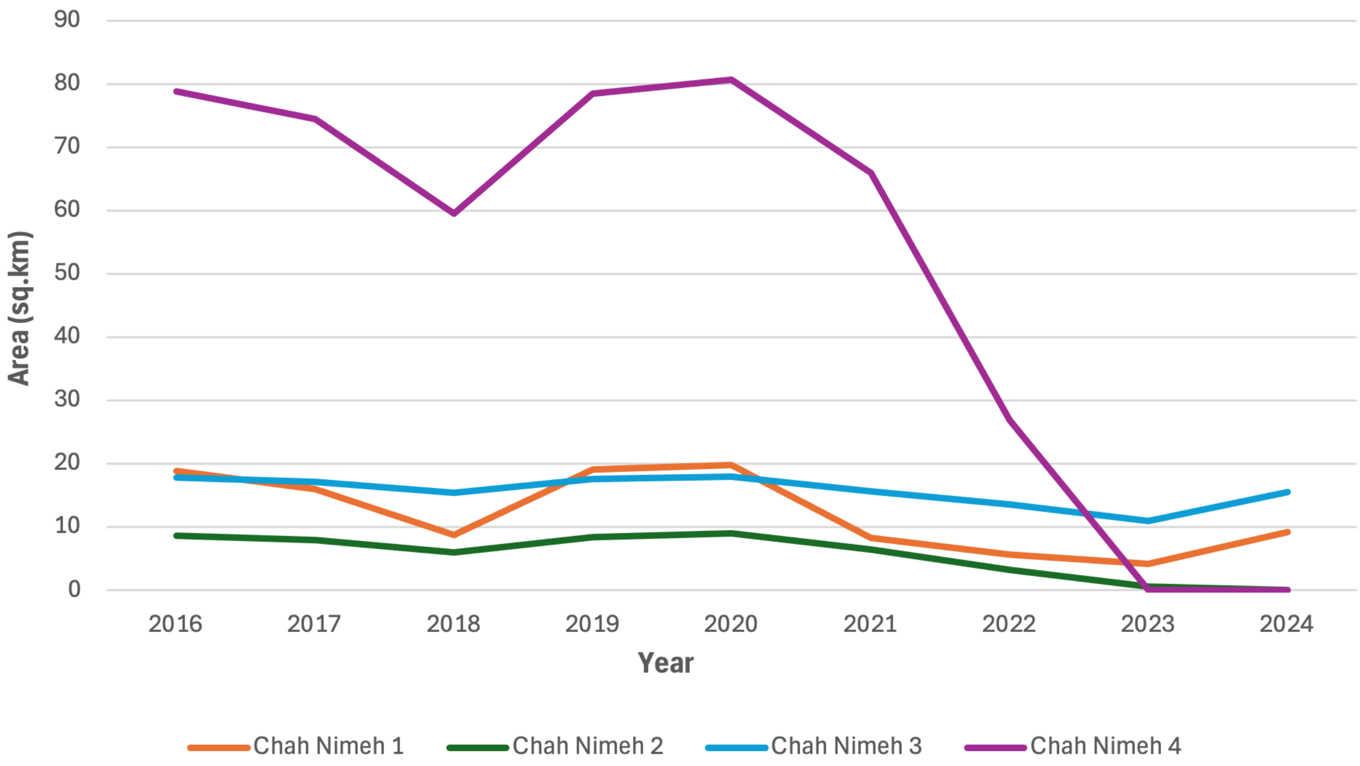

Figure 11: Surface area of Chah Nimeh before and after the commissioning of Kamal Khan Dam (2016–24)

Adapting to a system under stress: state and community responses

This game of tit-for-tat by the Iranian and Afghan authorities is in large part a response to dwindling water flows in the Helmand River Basin, and a direct result of climate change. It is no coincidence that much of the rhetoric and sabre-rattling by Tehran and Kabul typically occur during drought years; and that soon after, their investments in water diversion and storage infrastructure projects are implemented.

Meteorological, satellite and household data highlight the growing challenges communities face in the Helmand River Basin because of climate change. The meteorological data between 1990 and 2024 are stark. Over this period, average maximum temperatures in the Helmand River Basin rose by one degree Celsius (see Figure 15); precipitation declined from 225 millimetres (mm) to 200 mm (see Figure 16); and in light of rising and increasingly erratic temperatures, as well as declining precipitation, there was a marginal decline in the amount of snow accumulating in the mountains (see Figure 17). The cumulative result has been lower run-off in the Helmand River Basin, less water in the rivers, and increased frequency of drought (see Data source: ESA Copernicus ERA5-L (2024) Figure 18).

High-resolution imagery also shows the dramatic decline in the waters upstream of the Kajaki Dam between 1994 and 2024 (see Figure 20) and in the reservoir surface area between 2016 and 2024 (see Figure 19). For example, in the upper area to the north of the dam, in the district of Ghorak in Kandahar, communities experienced a significant reduction in water coverage. This was initially to their benefit when the water resided and created new agricultural lands. However, as the run-off reduced further, and the Helmand River meandered to the east, away from the surface irrigated land, these communities had to shift to solar-powered water pumps to extract enough water during the summer months, then, in some cases, abandoned surface irrigation altogether and drilled groundwater wells (see Figure 21).

Impact on farmers

Across the Helmand River Basin there are growing concerns over extreme temperatures, increased frequency of drought and overall reductions in surface water.

In the upper basin, in Uruzgan, northern Helmand, and Ghorak in Kandahar, many complain of the challenges of frequent flooding; of living in

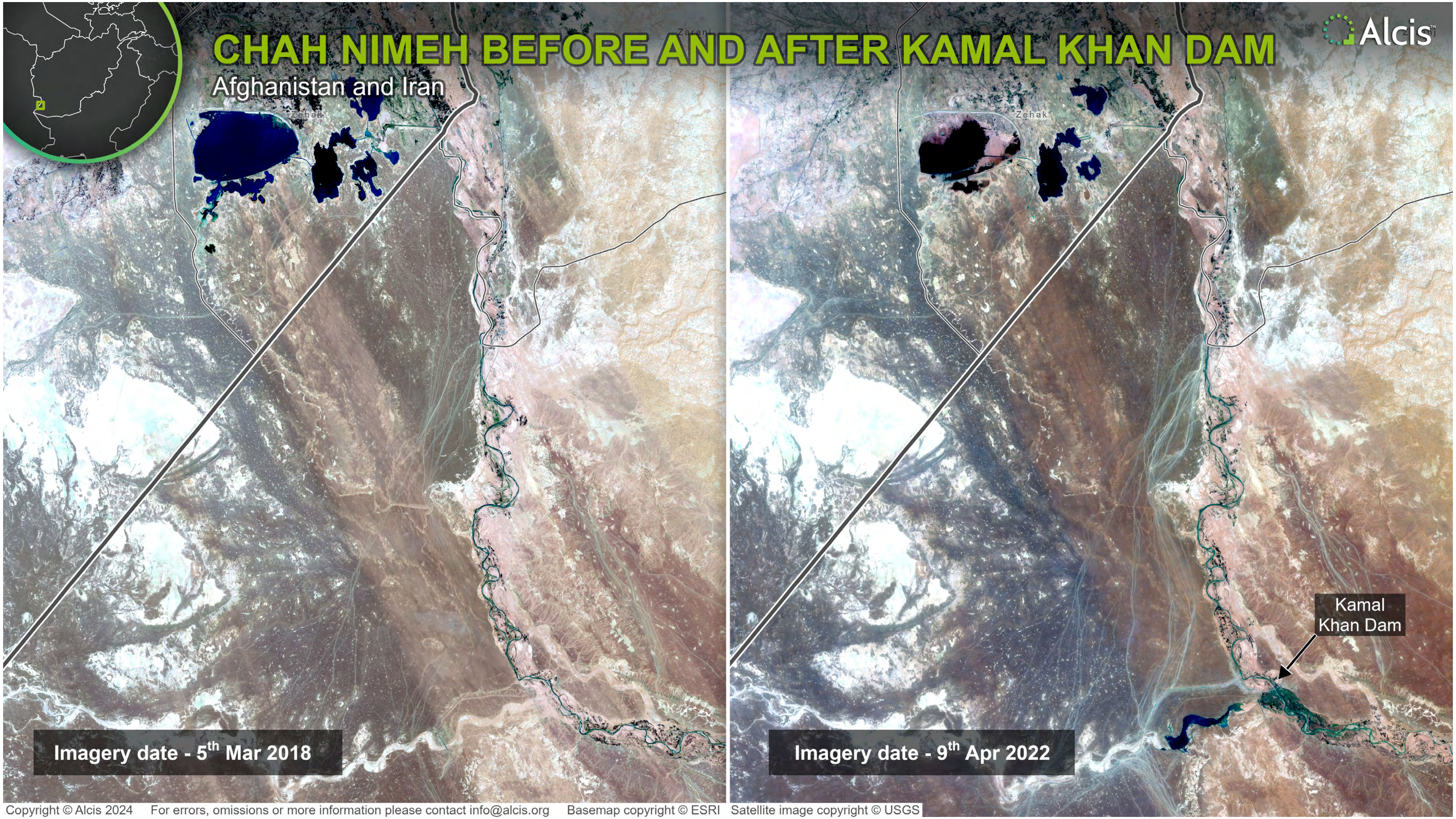

Figure 12: Chah Nimeh before (2018) and after (2022) commissioning of Kamal Khan Dam

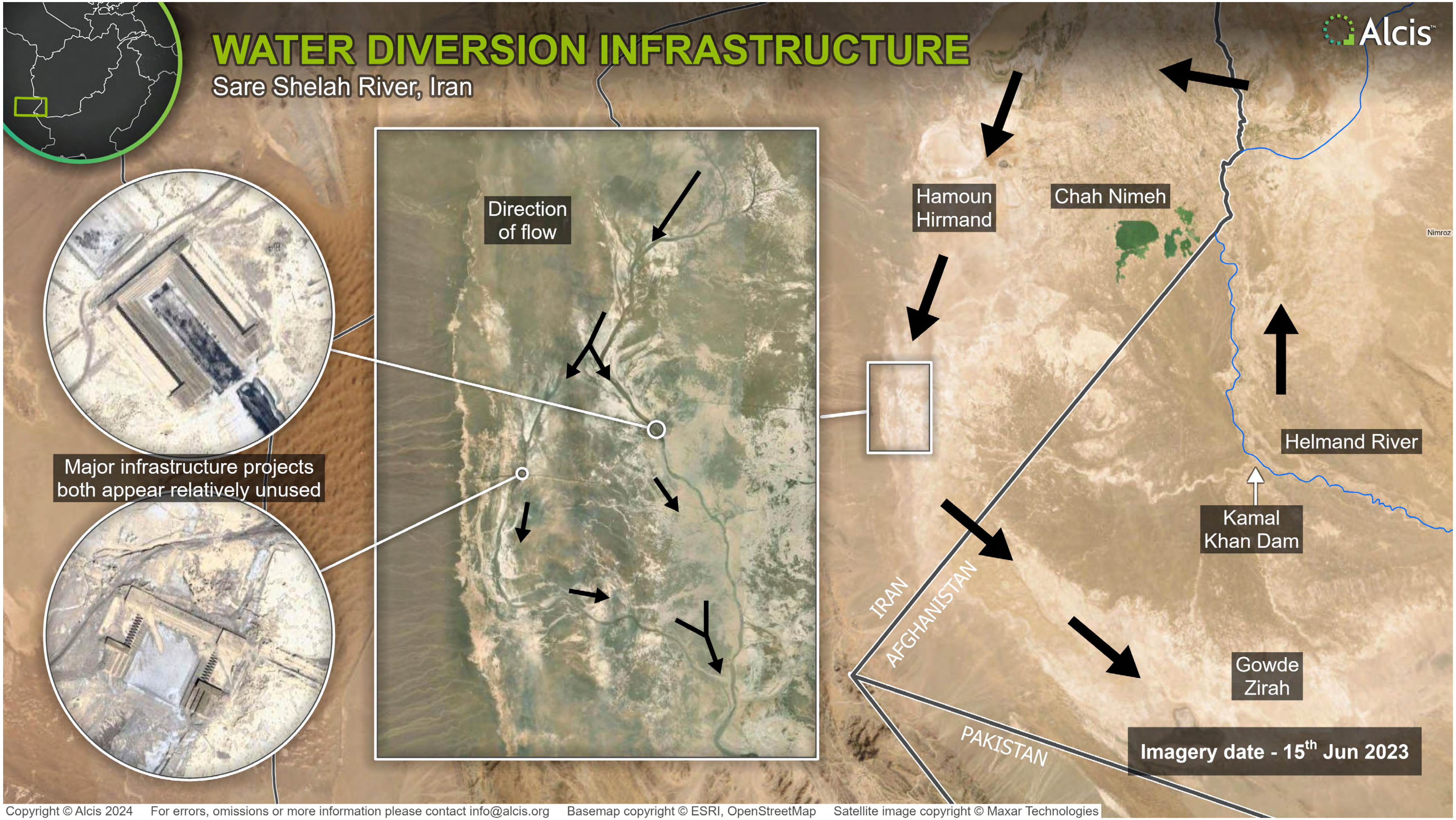

Figure 13: Dams on Sar-e-Shelah River constructed circa 2001, redirecting water from flowing towards Gowd-e-Zirah(2023)

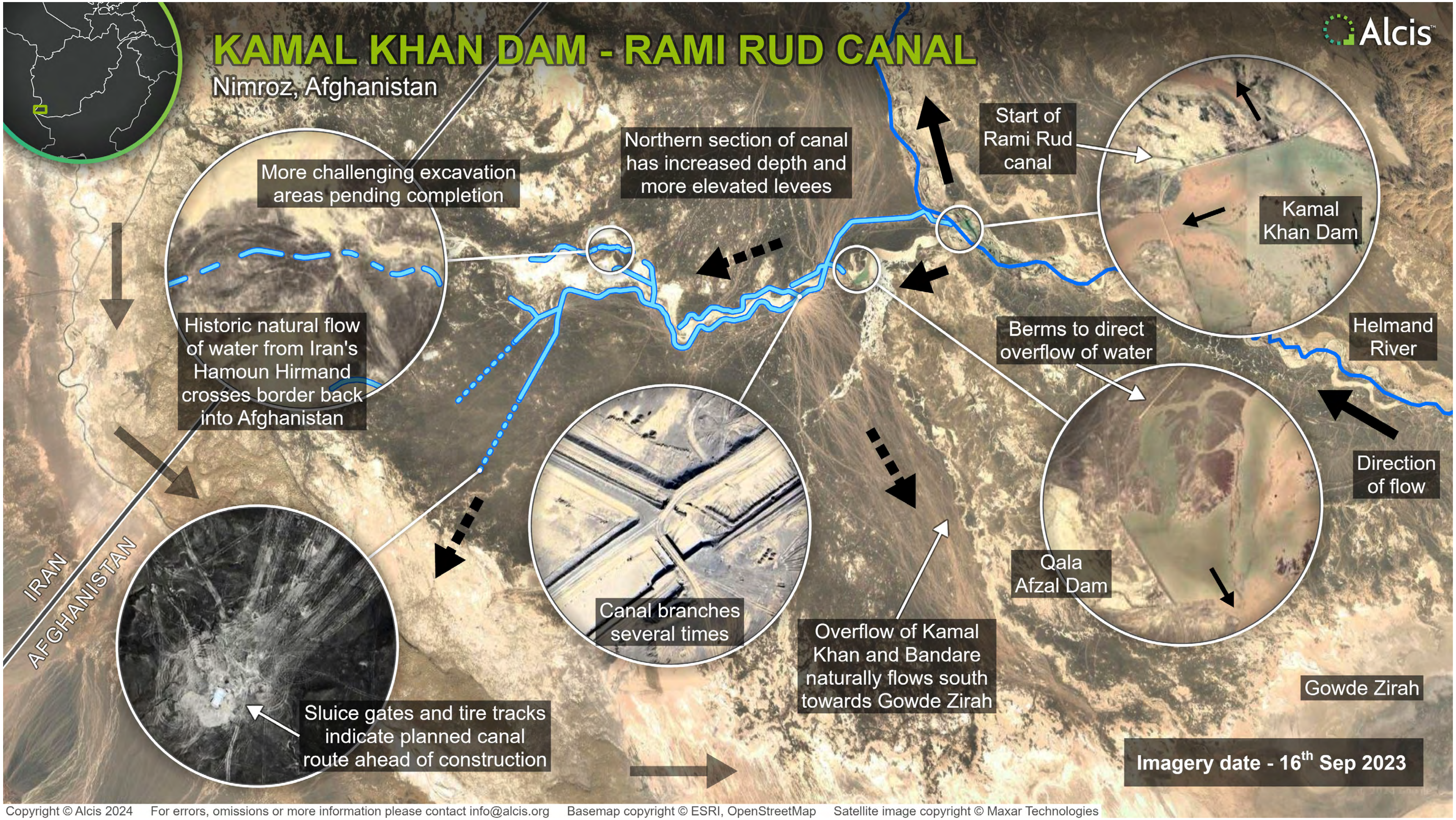

Figure 14: Canals directing water from Kamal Khan Dam to Gowd-e-Zirah (2023)

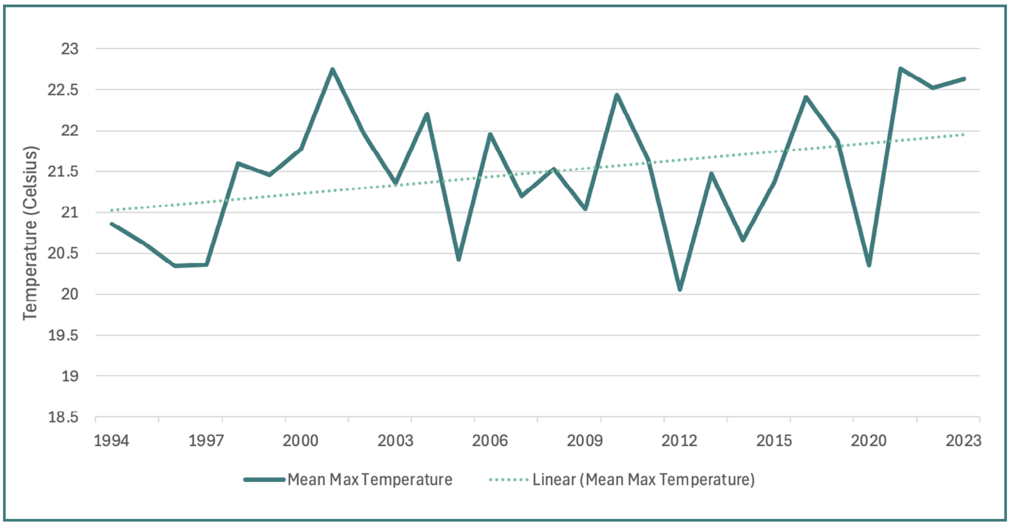

Figure 15: Average maximum temperature in the Helmand River Basin (1994-2023)

Data source: ESA Copernicus ERA5-L (2024)[35]

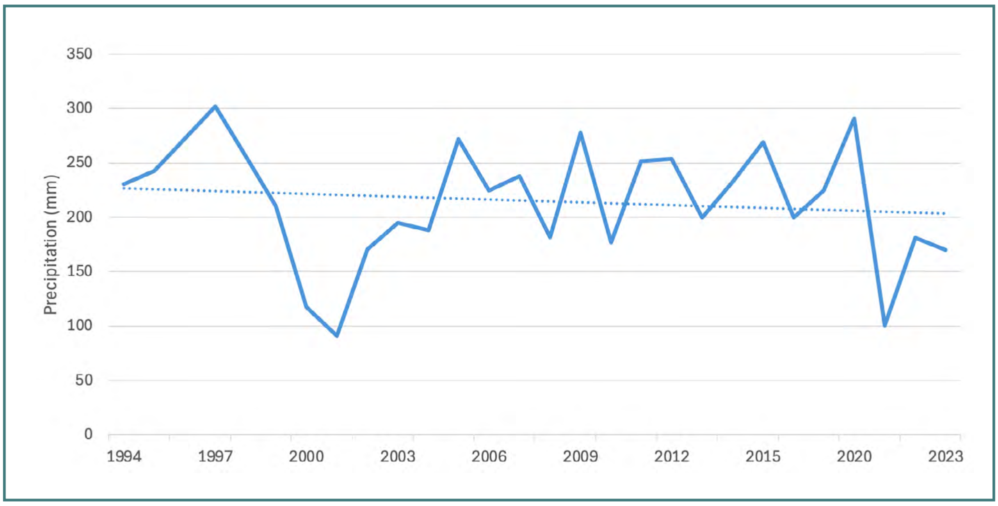

Figure 16: Average annual precipitation in the Helmand River Basin (1994-2023)

Data source: ESA Copernicus ERA5-L (2024)[36]

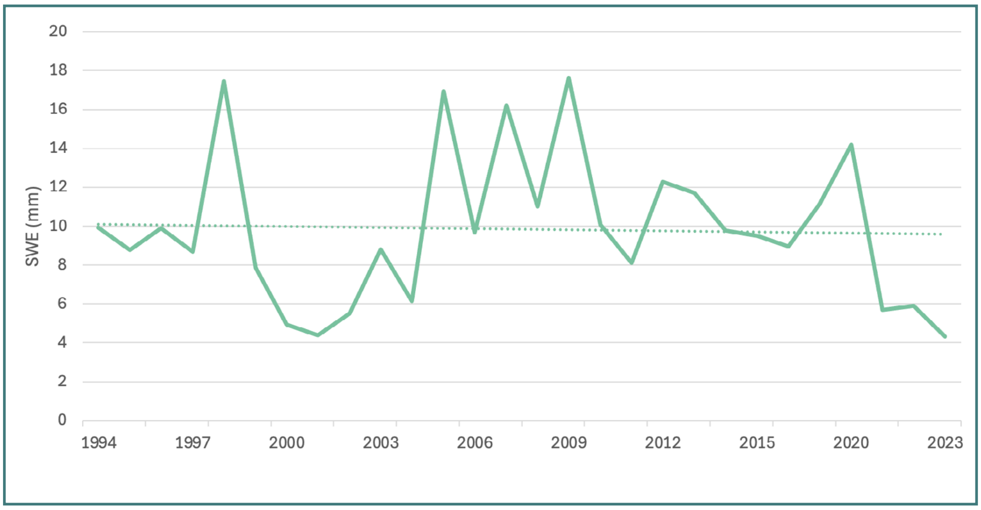

Figure 17: Average snow water equivalent in the Helmand River Basin (1994-2023)

Data source: ESA Copernicus ERA5-L (2024)[37]s/b 37

35. J. Muñoz-Sabater et al, ERA5-Land: a state-of-the-art global reanalysis dataset for land applications, *Earth Syst. Sci.* Data,13, 2021, 4349–4383, https://doi.org
36. Ibid. *Earth Syst. Sci.* Data,13, 2021, 4349–4383, doi.org
37. Ibid. *Earth Syst. Sci.* Data,13, 2021, 4349–4383, doi.org

temperatures that can vary from minus ten degrees Celsius in the winter to 45 degrees Celsius in the summer; of increasingly frequent summer illness affecting children, including diarrhoea, and the failure of the traditional irrigation system [known locally as karez] which has been used to transport groundwater to their lands. In the lower part of the basin, many have been driven to leave the area by lower Helmand and Nimroz, extremely high temperatures in the summer (up to 50 degrees Celsius), dust that sweeps through the villages and silts up canals during the '120-day wind',[38] and the shortage of surface water (see Figure 24).

Despite these worsening conditions, there is little evidence of farmers adapting their cropping patterns and shifting to more drought-resistant crop varieties. Moreover, in contrast to farmers across the border in Sistan and Baluchestan in Iran, only a small minority in Afghanistan (and only wealthier families growing commercial orchards in the upper basin) have shifted to more water-efficient drip irrigation. Instead, farmers on the Afghan side of the border along the Helmand River mostly continue to flood irrigate the same crops they have grown for decades: wheat and poppy in the winter, followed by summer crops of maize, mung bean, and cotton.

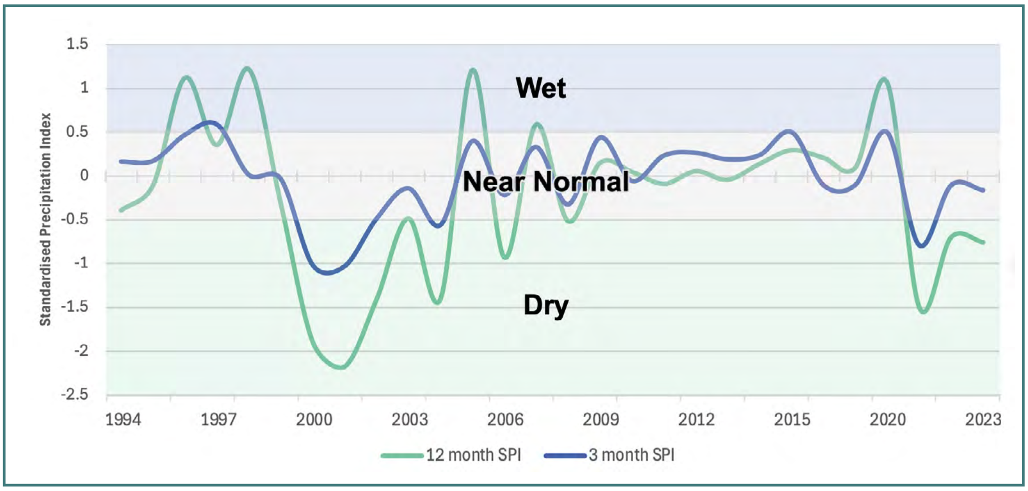

Figure 18: SPI as indicator of drought in the Helmand River Basin (1994-2023)

Data source: ESA Copernicus ERA5-L (2024)[39]

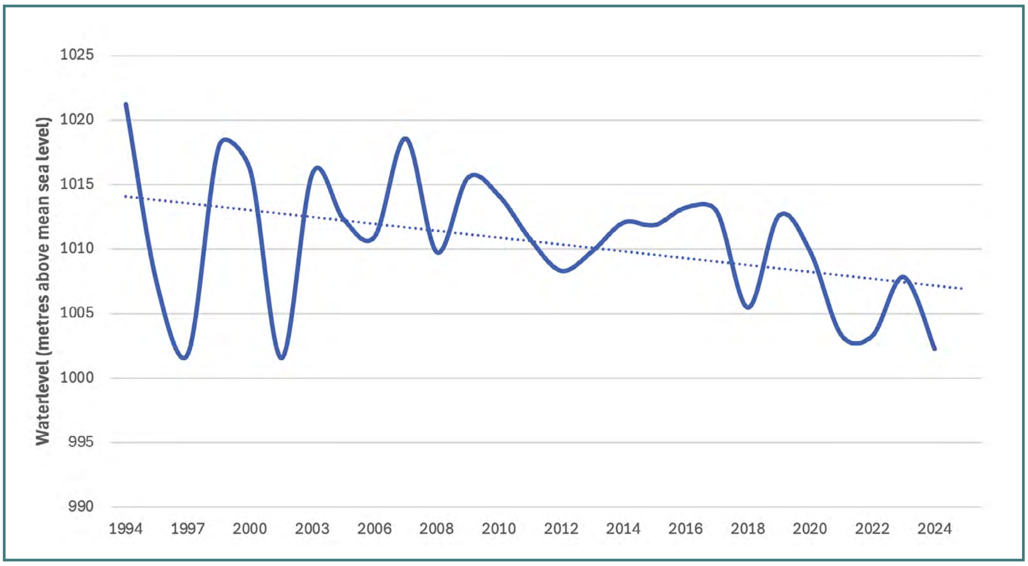

Figure 19: Reduction of water levels at Kajaki Dam (1994-2024) metres above mean sea-level.

Source: Alcis (2024)
Data source: Database for Hydrological Time Series of Inland Waters (DAHITI; 2024).[40]

38 'The 120-day wind' is a strong summer wind that hits the eastern Iranian plateau, and particularly the Sistan River Basin. It strikes between late May to late Sept., Wind speeds of 30-40 kilometres per hour are typical, although can exceed 100-110 kilometres per hour.

39. J. Muñoz-Sabater et al, ERA5-Land: a state-of-the-art global reanalysis dataset for land applications, *Earth Syst. Sci.* Data,13, 2021, 4349–4383, https://doi.org

40. 'Database for Hydrological Time Series of Inland Waters' (DAHITI; 2024): Kajaki Reservoir. dahiti.dgfi.tum.de.

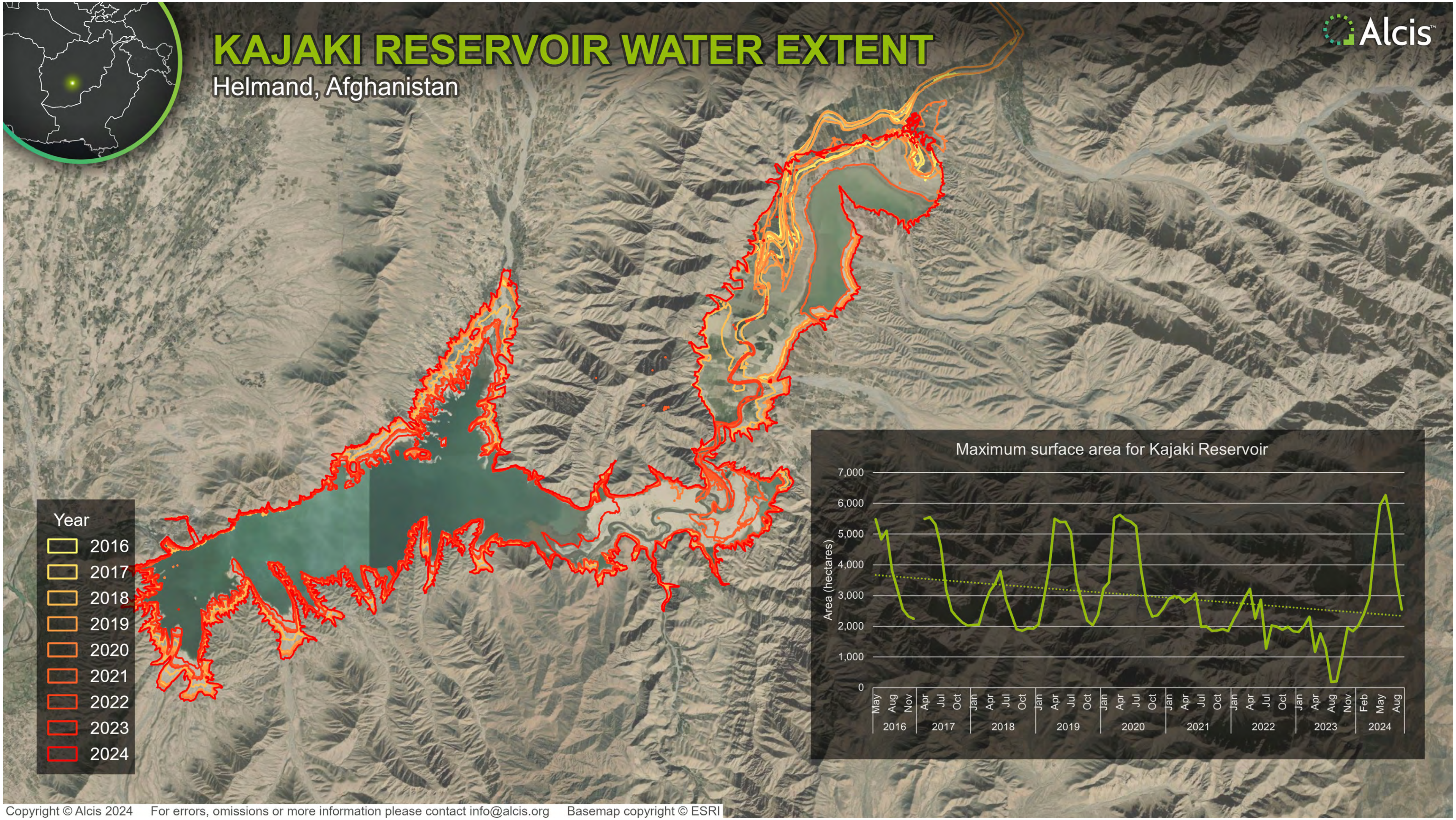

Figure 20: Reduction in Kajaki reservoir surface area (1994-2024)

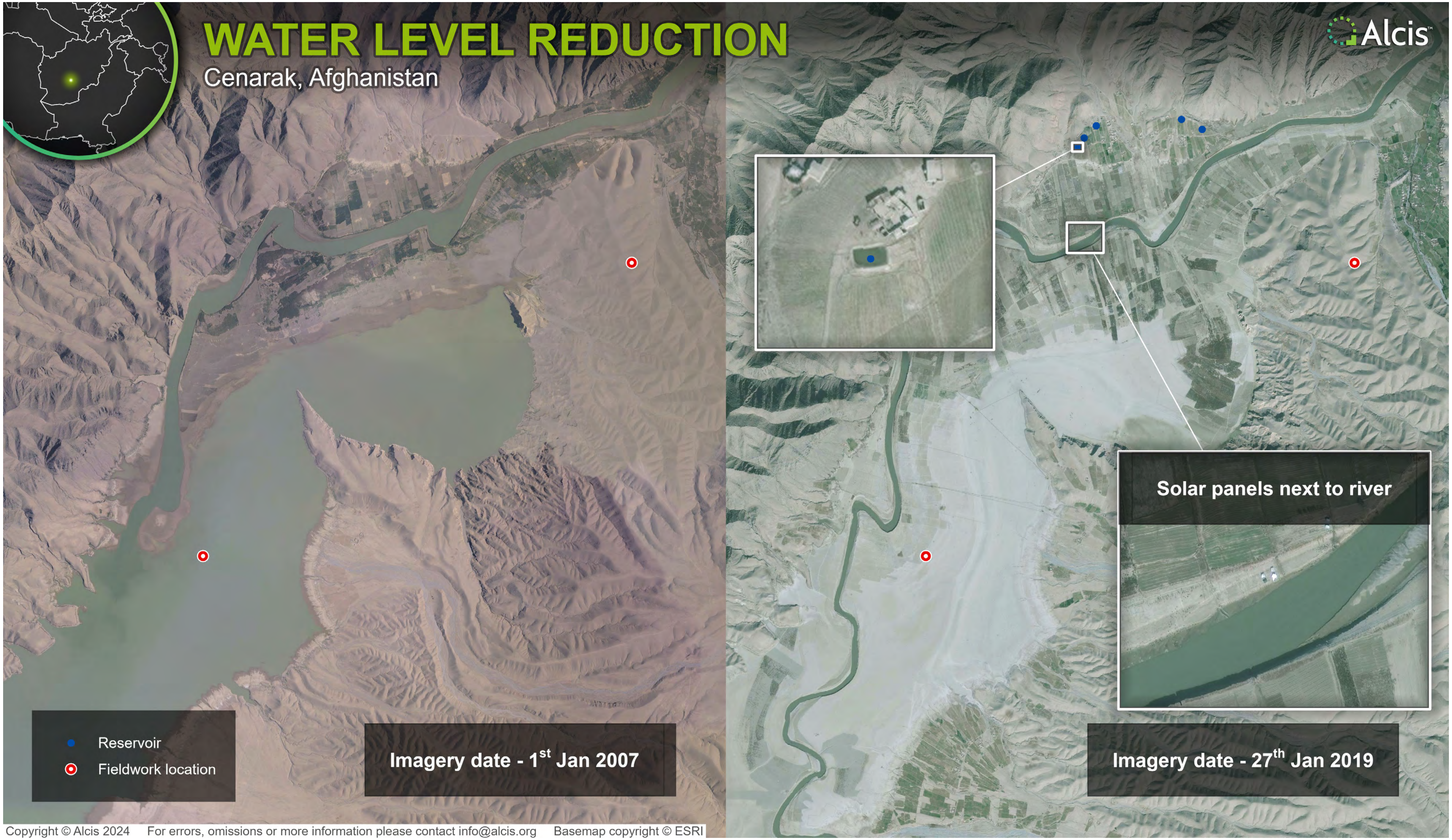

Figure 21: Irrigated agriculture upstream of Kajaki Dam at Cenarak (2007 and 2019)

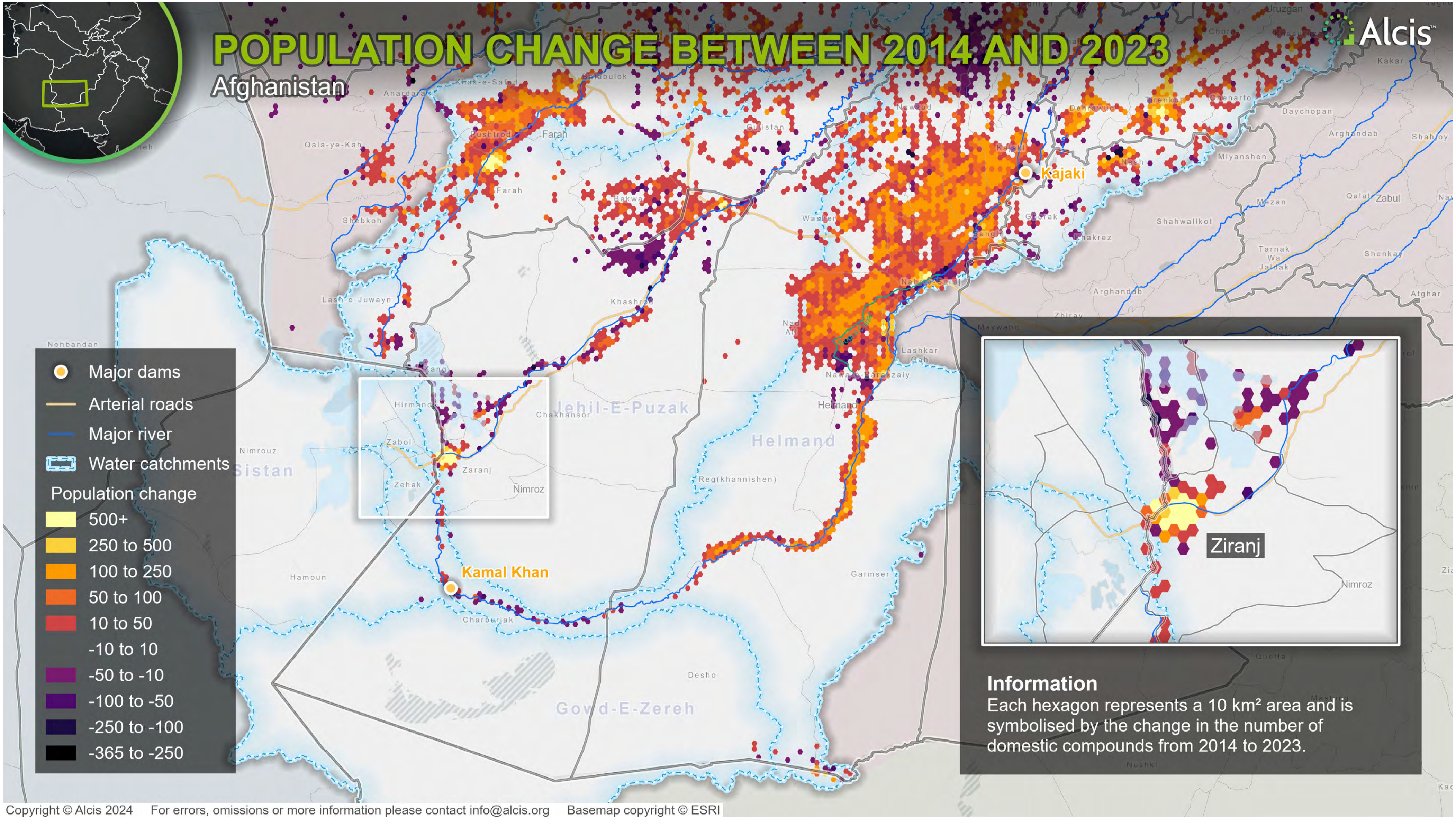

Figure 22: Changing population in Helmand River Basin (2014 to 2023)

Ban on poppy cultivation

Although household data show increases in crops such as cumin and basil since 2022 in response to increasing market demand, as well as recent increases in the cultivation of a spring crop of cotton, the most significant change in cropping patterns that has occurred in recent years is not a function of climate change, but of the Taliban leader's April 2022 decision to ban poppy cultivation, and its effective implementation in 2023 and 2024 (see Figure 23).

The loss of the poppy crop is having a significant impact on household annual income and represents the most immediate concern for farmers, far more so for the land poor who typically do not have opium stored from the years before the imposition of the ban. However, for most landed farmers across the Helmand River Basin, the poppy ban has been welcomed, as the majority hold inventory, and they have gained financially from a dramatic rise in the opium price, and the subsequent increase in their purchasing power and capital.[41]

Detailed livelihoods analysis quantifies the significant shortfall in annual household income for farmers in the Helmand River Basin who do not grow poppy. For example, Table 2 shows that landed farmers would need to cultivate at least two hectares in surface irrigated areas during both winter and summer cropping seasons, and four hectares in the former desert areas where yields are lower, to earn the equivalent of US$2.15 per person per day and meet

> **The loss of the poppy crop is having a significant impact on household annual income and represents the most immediate concern for farmers,**

the international poverty line.[42] The situation is more acute in the upper and lower parts of the Helmand River Basin, where crop yields and prices are often much lower. In these areas, even those farmers who own and cultivate up to five hectares of land cannot meet their households' basic needs with current cropping patterns. Landless people, employed on the farms of others, receive only a share of the total yield – one-quarter of the summer crop and one-fifth of the winter – and fall well below the international poverty line.

For people with land, any shortfall in agricultural earnings can typically be supplemented with earnings from local businesses and trade or from the sale of opium stocks. For land-poor or landless people, the economic situation is more acute. With no inventory and few wage labour opportunities in situ – especially with the loss of as many as 23.7 million labour days in the Helmand River Basin during the poppy harvest following the Taliban ban – increasing numbers of young males are migrating from their villages in search of work, either to other parts of Afghanistan, most notably Kandahar, or on to Iran.

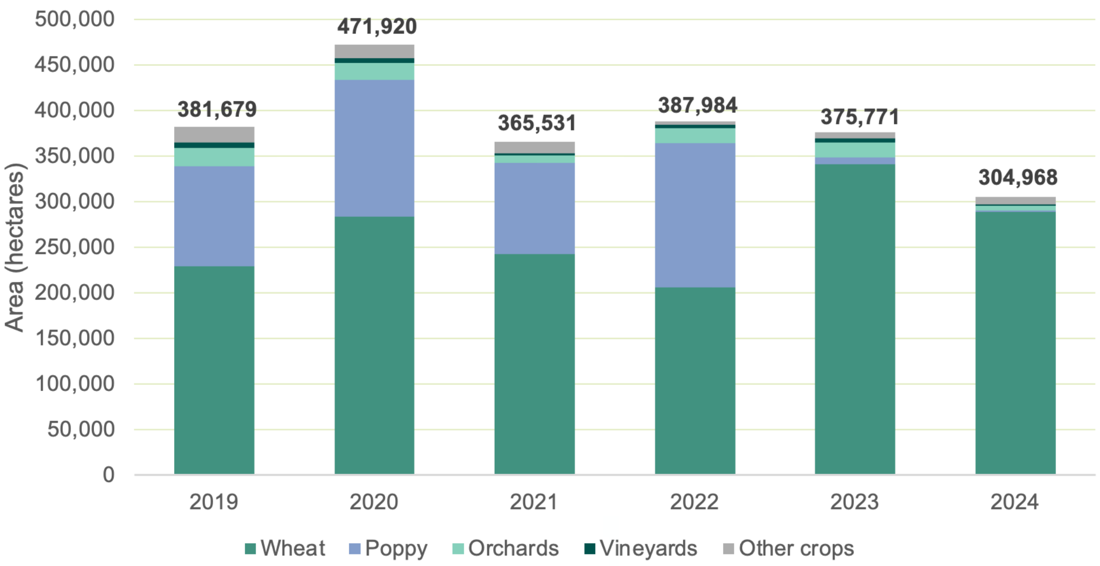

Figure 23: Changes in crops in Afghan portion of Helmand River Basin

41. David Mansfield, 'Gold never gets old': opium stores are critical to understanding the effects of the current Taliban drug ban' (Alcis, 18 Apr. 2024), alcis.org

42. World Bank Group, 'Measuring poverty' (15 Oct. 2024), worldbank.org.

Table 2: Net returns on agricultural investments (US$).

hectares (ha)				Landowner						Sharecropper					
				Winter		Summer		Total		Winter		Summer		Total	
				Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1 ha	Canal	1 wheat	1 cotton	1,217	2,378	1,119	1,869	2,336	4,247	314	546	368	556	683	1,102
	Canal	1 wheat	0.5 okra/ 0.5 tomato	1,217	2,378	2,168	2,736	3,385	5,114	314	546	675	817	989	1,363
2 ha	Desert	2 wheat	1 maize/1 cotton	2,435	2,570	592	1,847	3,026	4,417	629	656	325	1,458	954	2,114
	Canal	1 wheat/1 cotton	1 maize/1 mung bean	2,738	5,417	1,863	3,711	4,601	9,128	689	1,225	643	2,636	1,332	3,861
	Canal	2 wheat	1 tomato/1 okra	2,435	4,756	2,968	5,472	5,402	10,228	629	1,093	1,008	3,000	1,636	4,092
	Canal	2 wheat	1 cotton/1 ground nut	2,435	4,756	3,738	7,595	6,173	12,351	629	1,093	1,112	3,442	1,740	4,535
3 ha	Desert	3 wheat	1 maize/2 cotton	1,477	3,855	1,238	3,084	2,714	6,939	508	984	575	2,266	1,083	3,250
	Canal	2 wheat/1 cotton	2 maize/1 mung bean	3,955	7,795	2,902	5,607	6,857	13,402	1,004	1,771	991	3,882	1,995	5,653
	Canal	3 wheat	1 maize/ 1 cotton/ 1 ground nut	3,652	7,134	4,375	8,321	8,027	15,455	943	1,639	1,359	4,395	2,302	6,034
4 ha	Desert	4 wheat	1 maize/3 cotton	1,969	5,140	1,883	4,321	3,852	9,461	677	1,311	825	3,074	1,502	4,385
	Desert	3 wheat/1 cotton	2 maize/2 cotton	2,123	5,092	1,183	3,694	3,306	8,786	708	1,302	650	2,905	1,358	4,207
5ha	Desert	5 wheat	3 maize/2 cotton	2,461	6,426	1,129	4,304	3,590	10,730	846	1,639	725	3,568	1,571	5,207
	Desert	4 wheat/1 cotton	2 maize/3 cotton	2,740	7,331	1,829	4,931	4,569	12,262	902	1,820	900	3,951	1,802	5,771

Increasing numbers of wells

While household interviews reveal that the most pressing concern is the potential duration of the poppy ban and the amount of residual opium farmers' have stored, there is also widespread recognition of a pending water crisis. However, this is not a crisis over surface water and reduced discharge from upstream. Farmers in the middle and lower parts of the basin have become accustomed to reduced water flows for almost two decades and have made efforts to adapt, sinking groundwater wells in increasing numbers.

In fact, it is this very response and its widespread uptake across the Helmand River Basin that is now causing farmers concern; with reports of groundwater falling by more the five metres per year in some areas, farmers worry about how sustainable this strategy is and about the risks to their livelihoods over the next five to ten years.

Dug with percussion drills at a cost of up to US$3.50 a metre and lined with plastic pipe, groundwater wells vary in depth from 40 to over 110 metres, depending on the area and the distance from a river (see Figure 26). Geospatial analysis shows how prevalent these groundwater wells have become across the entire Helmand River Basin, rising more than five-fold from at least 12,160 in 2016 to at least 68,160 in 2023.[43] This analysis, combined with household data, also shows the geographic spread of groundwater wells from the former deserts in the central basin to the lower and upper reaches of the Helmand River (see Figure 26).

The initial uptake of groundwater wells was concentrated in the former desert areas of Helmand, Farah and Nimroz, and was closely associated with rising poppy cultivation in south-west Afghanistan.

Earlier research in these areas documents the encroachment on these former desert lands from as early as 2005 and shows how a combination of increasing population pressure, the complicity of elites in the Afghan Republic, access to new technology (percussion drills, and at that time, diesel-powered generators) and increased poppy cultivation supported a growing population.[44] Following the success of this initial settlement of these former desert lands, the population increased more rapidly: first in response to the Afghan Republic's efforts to ban poppy cultivation in the surface irrigated areas of central Helmand between 2008 and 2012, and then following the uptake of solar technology in 2014, when farmers perceived that 'water became free'.[45]

Solar-powered wells

The advent of solar technology proved a game changer, eliminating the need for expensive diesel and the maintenance costs associated with running water pumps and generators using heavily adulterated fuel. While the initial costs of a solar-powered deep well were higher than a diesel one, with an outlay of US$3,500-5,500 for the entire system, a farmer could secure access to consistent irrigation from groundwater with almost no recurrent costs. The move to solar-powered deep wells was rapid. For example, in 2013, of 170 farmers interviewed in twelve villages in Bakwa, only four pumped water from their deep wells using solar technology; the rest used diesel-powered generators, incurring fuel costs of up to US$720 per hectare.[46] Five years later, in 2018, only two farmers were still using diesel, while 175 had installed solar-powered systems.

Figure 29 shows the expansion of solar-powered deep wells across the Helmand River Basin between 2016 and 2019, and the shift beyond the former desert areas into the surface irrigated areas of upper and central Helmand, Farah and Nimroz. Farmers in these surface irrigated areas argue that this shift was a direct result of reduced flows of water in the Helmand River, and the desire to ensure consistent irrigation during the summer months (June to August). Between 2019 and 2023, there was an even more rapid expansion, this time with the widespread uptake of solar technology and groundwater wells, even in areas upstream of Kajaki Dam, including Uruzgan (see Figure 27).

43. This figure is based on a count of the reservoirs that are used to store water after it is pumped from solar-powered groundwater wells. These reservoirs are easily identified from imagery. Fieldwork indicates that rather than pump groundwater directly on to their fields, farmers prefer store to first store it in a reservoir. However, where a farmer has insufficient land, and where the soil is sandy and water infiltrates quickly, a reservoir will not be built and the water will be used directly on the land. This is particularly prevalent in in the lower parts of the Helmand river basin, in districts such as Khanishin, and Deshu in Helmand and Charburjak in Nimroz. This means that the number of deep wells in the Helmand river basin may in fact exceed the number of reservoirs counted.

44. David Mansfield, 'When the water runs out: the rise (and inevitable fall) of the deserts of southwest Afghanistan and its impact on migration, poppy and stability,' Synthesis report, Afghanistan Research and Evaluation Unit (2024), areu.org.af

45. Mansfield, When the water runs out.

46. Bakwa livelihoods fieldwork (2013).

By combining meteorological and geospatial data, it is possible to show how important the move to solar-powered groundwater wells has been to Afghan farmers in the Helmand River Basin. Figure 31 indicates that while precipitation has been in long-term decline, vegetation, as measured by the Normalised Difference Vegetation Index (NDVI) has increased. What is of particular note is how these two measures largely tracked one another between 2004 and 2010, but where precipitation continued its downward trajectory, the NDVI deviated upwards around 2012, when there was a shift to solar-powered groundwater wells. It has continued to follow an upward trend as the number of these wells has grown. It is likely that if it were not for the uptake of this new technology, significantly more livelihoods would be at immediate risk in the Helmand River Basin.

Impact on the water table

The consequences of this extensive move to groundwater extraction are unclear, as little is known about the aquifers that farmers draw on and how they are recharged.[59] Household data indicate widespread concern about how long groundwater might last, particularly if its use continues unchecked by Afghan authorities. For example, while there is some variance between areas, farmers closer to the river and surface irrigation report annual reductions in groundwater levels in wells of between one and two metres; further away, the drop in the water table can be between three and five metres.

Farmers know that this cannot continue, and while they report the water levels in their wells being unchanged in 2024 due to substantial rain over the spring, many fear a time when their groundwater wells will run dry. Farmers who once irrigated their land using the more traditional groundwater management system, known locally as karez, note the irony. Reporting that they first sank their groundwater wells in response to reduced water flow in the karez, they also recognise that when more farmers in their village did the same, the karez went completely dry. Now, they note the rapid decline in water in their groundwater wells and are concerned about the long-term effects.[60]

It is also argued that this dramatic shift to groundwater extraction is having a direct impact on water flows in surface irrigated areas. For example, while farmers argue that wells were initially sunk in response to reduced water flows in the canals, over time and with the individualisation of water extraction from the ground, community interest in the maintenance of these canals and streams can deteriorate, resulting in increased siltation and even further reductions in discharge (see Figure 30 and Figure 32). This, in turn, is increasing farmers' reliance on their deep wells.

> **"The advent of solar technology proved a game changer, eliminating the need for expensive diesel and the maintenance costs associated with running water pumps and generators using heavily adulterated fuel.**

Most farmers call for the Afghan authorities to restrict any further exploitation of groundwater and to invest in check dams upstream, but in the absence of any state intervention, they recognise that further groundwater wells will be sunk, and groundwater levels will continue to fall, perhaps at an even faster rate. A review of household data from the 34 research sites suggests that if the groundwater continues to fall at current rates, the deep wells in 30 per cent of the research sites could be dry within one decade and 76 per cent within two decades (see Figure 27). Given the likelihood that there will be further increases in the number of deep wells sunk in the Helmand River Basin in the coming years, there is every likelihood that this is an optimistic assessment and that there is a risk that the groundwater levels will fall even faster, putting the livelihoods of many of the 365,371 households in the Helmand River Basin at risk, an estimated total of 3.65 million people.

50. This figure is based on a count of the reservoirs that are used to store water after it is pumped from solar-powered groundwater wells. These reservoirs are easily identified from imagery. Fieldwork indicates that rather than pump groundwater directly on to their fields, farmers prefer store to first store it in a reservoir. However, where a farmer has insufficient land, and where the soil is sandy and water infiltrates quickly, a reservoir will not be built and the water will be used directly on the land. This is particularly prevalent in in the lower parts of the Helmand river basin, in districts such as Khanishin, and Deshu in Helmand and Charburjak in Nimroz. This means that the number of deep wells in the Helmand river basin may in fact exceed the number of reservoirs counted.

51. David Mansfield, 'When the water runs out: the rise (and inevitable fall) of the deserts of southwest Afghanistan and its impact on migration, poppy and stability,' Synthesis report, Afghanistan Research and Evaluation Unit (2024), areu.org.af

52. Mansfield, *When the water runs out.*

These measures are estimates of groundwater sustainability based on field observations and discussions with farmers and calculated based on the current rate of reduction.

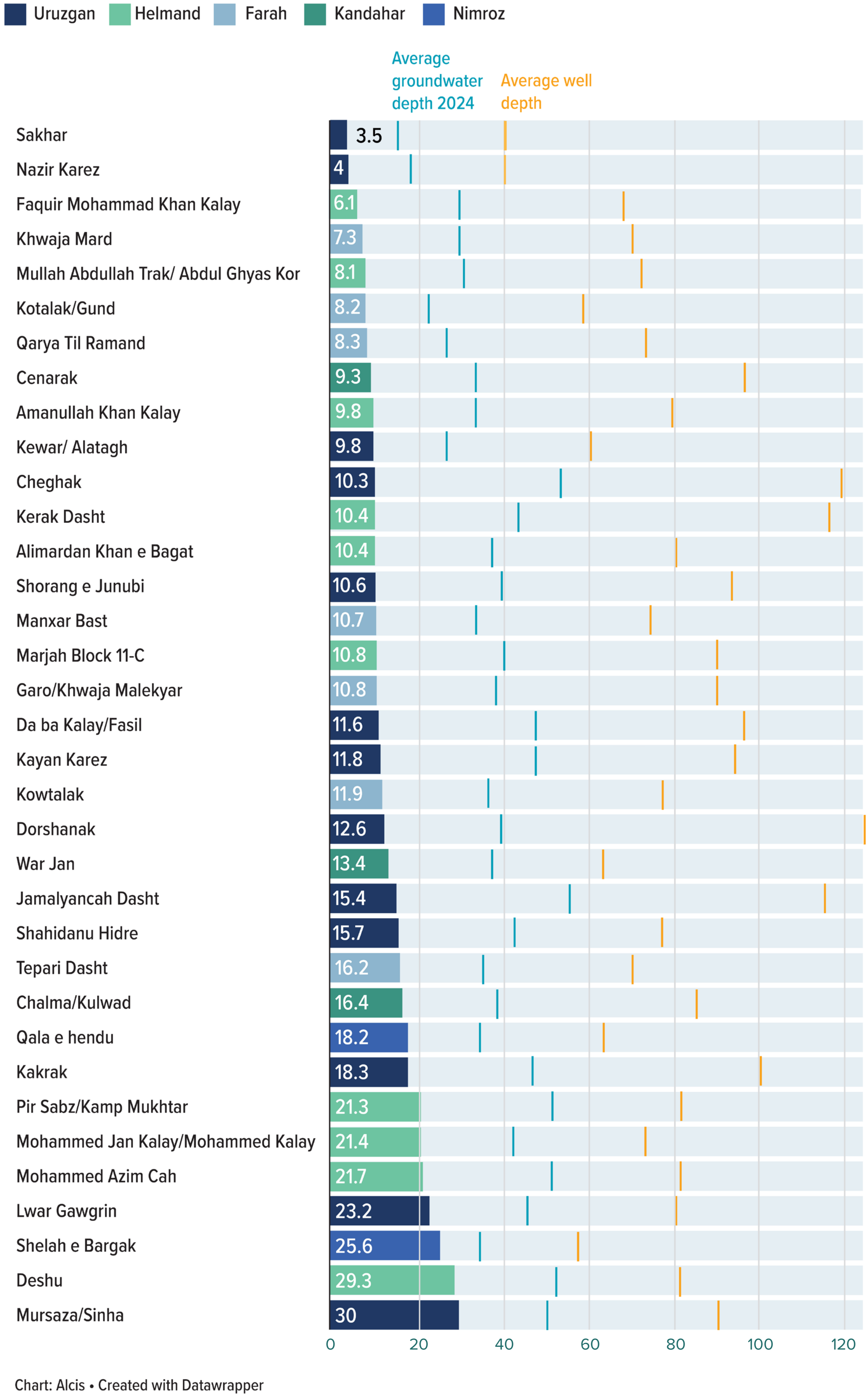

Figure 24: Estimated groundwater projections for 2024 onwards, based on field observations.

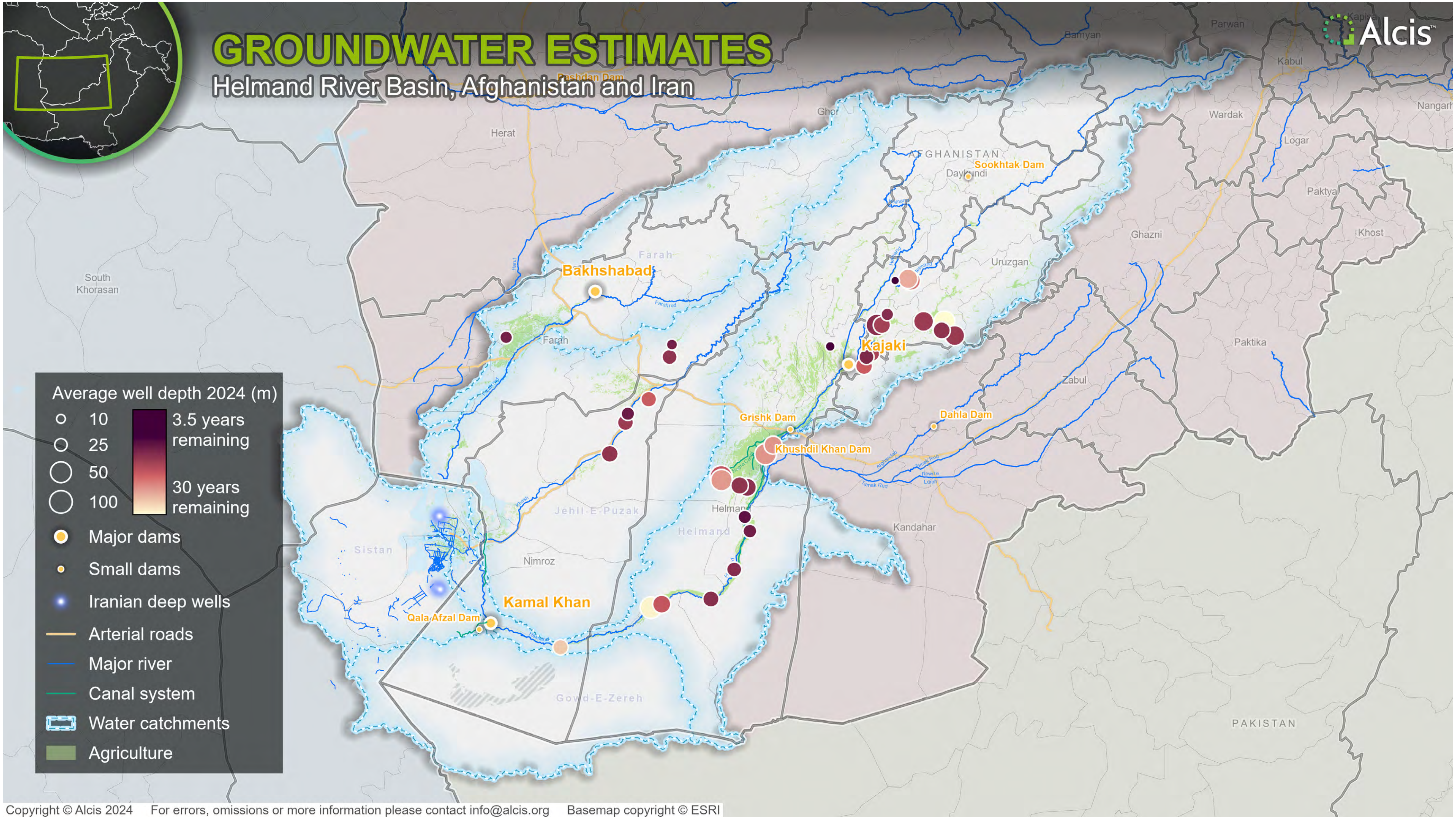

Figure 25: Estimated groundwater projections for 2024 onwards, based on field observations

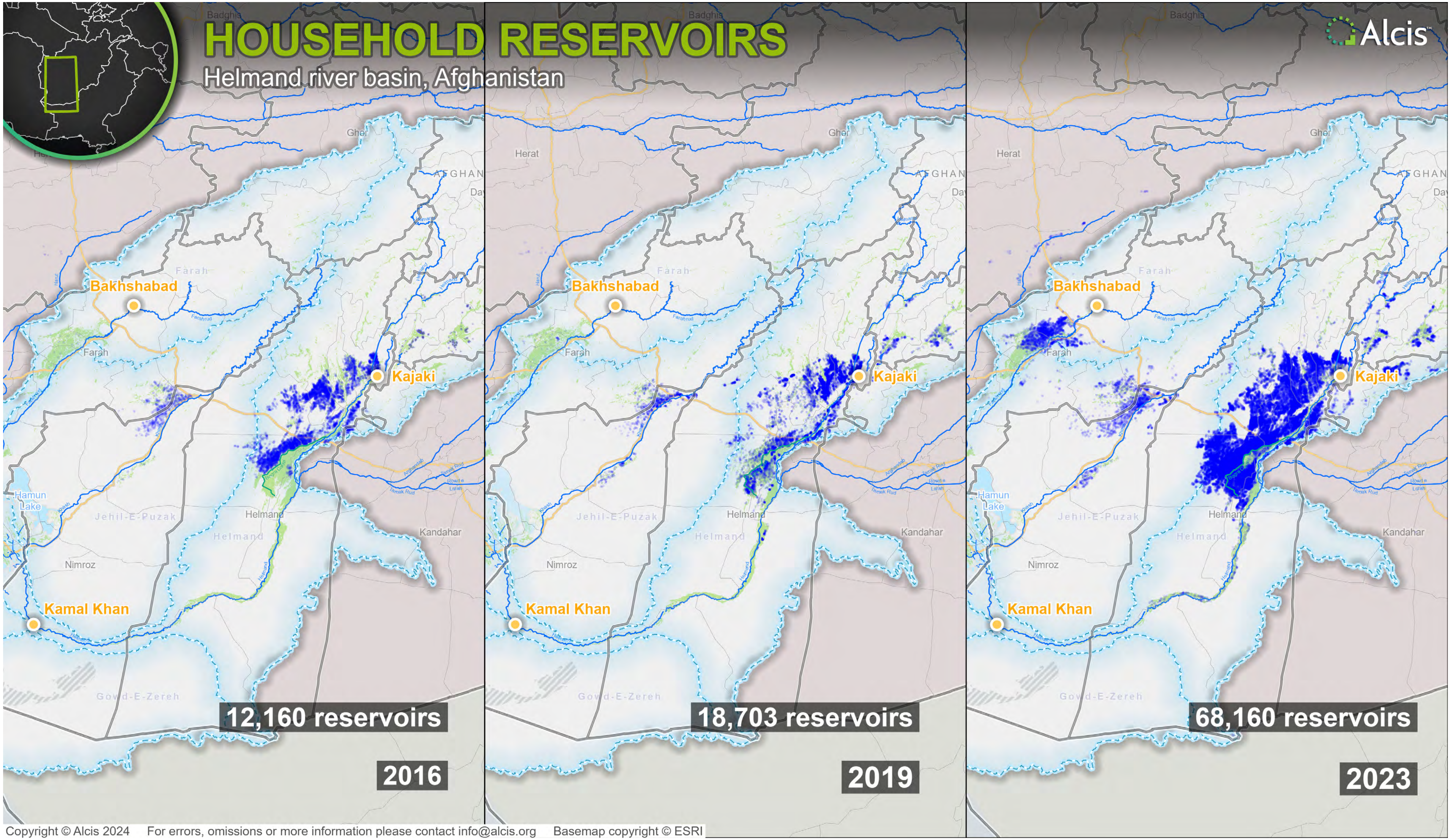

Figure 26: Household reservoirs (2016, 2019, and 2023)

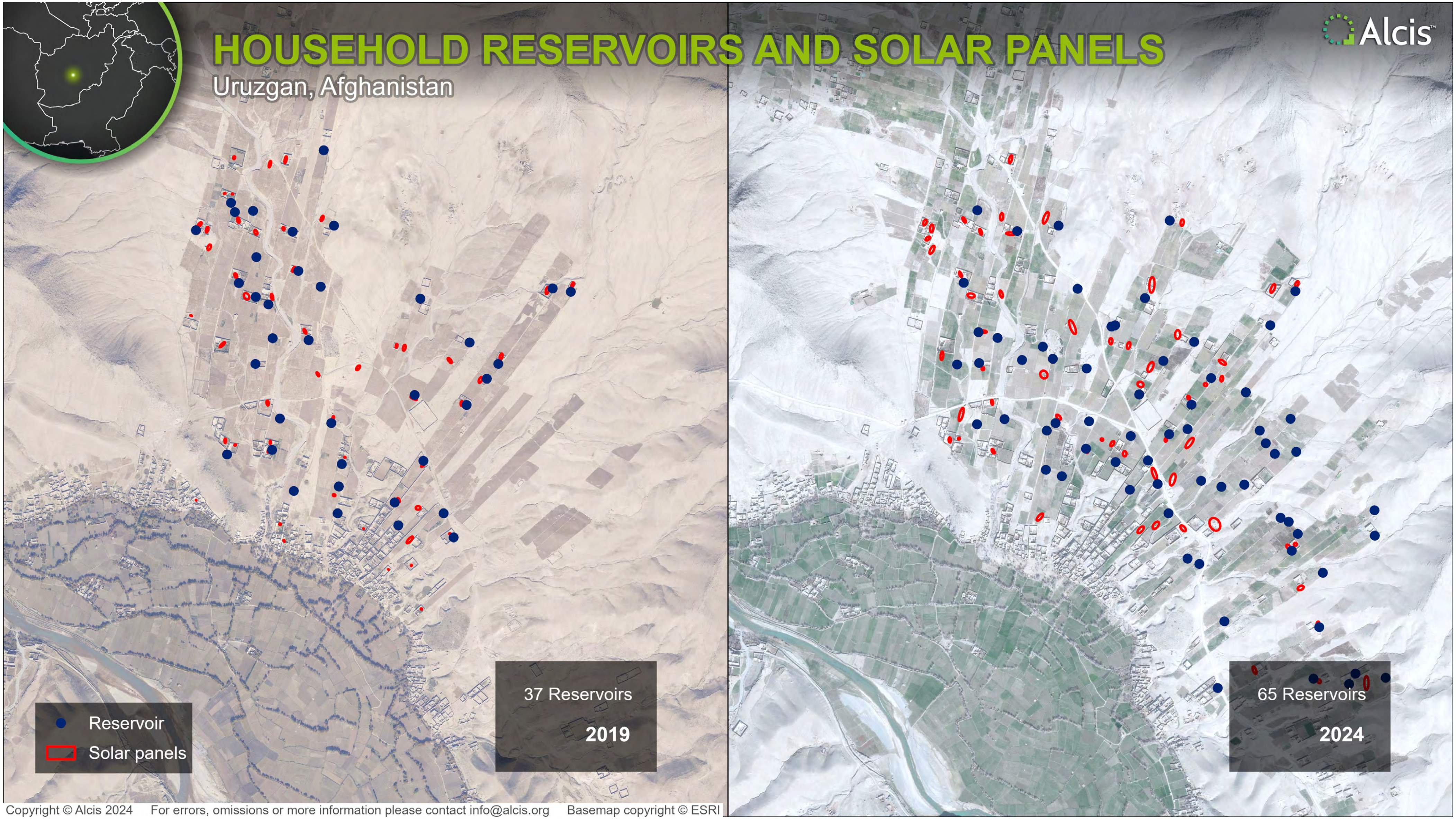

Figure 27: Groundwater wells in Uruzgan (2019 and 2024)

Moreover, it is not just in Afghanistan that we see a move to groundwater extraction in response to reducing water flows in surface irrigated areas. However, in contrast to Afghanistan, where groundwater extraction has become an unregulated and private endeavour, in Iran the state has made significant investments in sinking three wells between 1,000 and 3,000 metres in depth only a short distance across the border in Sistan and Baluchestan Province (see Figure 29). Tehran estimates that these wells can extract thousands of cubic metres per day and provide drinking water for around 30,000 people, a project that began in 2019 in response to the pending completion of the Kamal Khan Dam.

Ultimately, these rapid developments in groundwater extraction in Afghanistan and Iran reflect how responsive both states and communities can be to the effects of climate change, particularly where it is at its most extreme, such as in the Helmand River Basin. Afghan farmers have responded to reductions in precipitation, increased temperatures, and reduced surface water flows in irrigated areas with a widespread shift to groundwater extraction, which has, in turn, led to increased vegetation levels. The Iranian state has used the same means, albeit on a much larger scale, to secure drinking water for its urban population. Both objectives are important for the well-being of the population of the Helmand River Basin.

However, we know little of how sustainable such widespread private groundwater extraction will be. The potential volumes of water drawn from these aquifers are extraordinary, but we know little about how they are recharged. Evidence from Afghanistan suggests that the shallower aquifers on which Afghan farmers have relied for a decade are already under threat, with the water table dropping at an alarming rate each year. We can only guess at the effects of extracting such large volumes of water from the much deeper aquifer Iran is exploiting. While both individuals and states have pursued these actions in response to the direct effects of climate change and reduced water flows, there is every likelihood that they are merely delaying the inevitable and that substantial numbers of people in this region will be facing significant water shortages in the next decade.

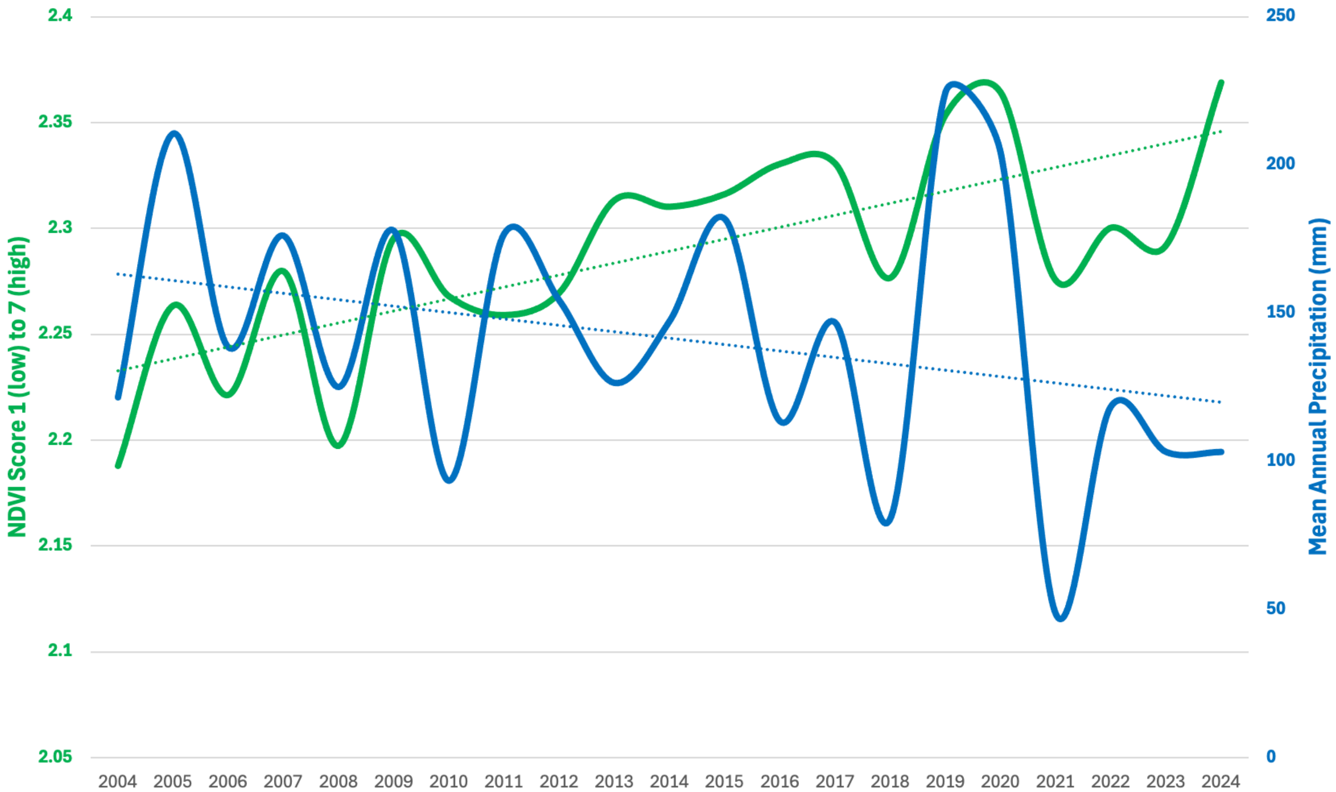

Figure 28: NDVI vs precipitation for the Helmand River Basin (2004 to 2024)
Data sources: ESA Copernicus ERA5-L (2024)[47] /MODIS 16-day global vegetation indices.[48]

47. J. Muñoz-Sabater et al, ERA5-Land: a state-of-the-art global reanalysis dataset for land applications, Earth Syst. Sci. Data, 13, 2021, 4349–4383, https://doi.org
48. Ibid. *Earth Syst. Sci.* Data,13, 2021, 4349–4383, doi.org

Groundwater recharge and exploitation in the Helmand River Basin and western Afghanistan

As established in this report, groundwater is a critical resource in the Helmand River Basin. United States Agency for International Development (USAID) funded groundwater assessment initiatives focusing on Afghanistan in 2003 (Uhl 2003)[57] and 2009 (USAID 2009)[58] reviewed earlier assessments from the 1970s by the US Army Corps of Engineers alongside the Food and Agriculture Organisation (FAO) national groundwater recharge assessment in 1996.

Uhl et al. (2003) established estimates for groundwater recharge within the consolidated and unconsolidated sedimentary geological units of the Western Helmand River Basin. At that time, groundwater extraction relied primarily on springs, karez, and open wells, as diesel-powered pumping from deeper aquifers was generally too expensive for most farmers to irrigate sustainably. The assessment in the Helmand River Basin focused exclusively on the upper Helmand River Basin, as the lower area experiences very little rainfall and, consequently, significantly lower groundwater recharge. The upper basin comprises a blend of consolidated (37,000 square kilometres) and unconsolidated and carbonate (25,000 square kilometres) aquifer systems. Assuming precipitation recharge rates of 5 per cent for consolidated aquifers and 10 per cent for unconsolidated and carbonate aquifers, and based on an average annual rainfall of 300 millimetres, Uhl et al. (2003) estimated the annual recharge to be 1,310 cubic millimetres per year. With groundwater usage estimated at 750 cubic millimetres per year, they identified considerable potential for further groundwater exploitation, based on an estimated area irrigated by groundwater of 100,000 hectares.

In 2009, the same team conducted further assessments of groundwater exploitation potential in Bakwa district, Farah Province (still within the Helmand River Basin; USAID, 2009). This work included a review of results from a 1975 project by the Government of Afghanistan and FAO, along with additional desktop analyses and field data collection. Firstly, they noted an estimated drop in groundwater levels of 0–2 metres from measurements taken 34 years earlier. They also observed that by 2009, all previously productive karez in the area had dried up, with the primary sources of irrigation and drinking water coming from groundwater wells equipped with in-line diesel-powered pumps, these wells numbering 'in the hundreds to a thousand' (USAID 2009). Based on more detailed investigations and physical modelling, they identified considerable groundwater storage capacity with healthy recharge, establishing the basis for significant agricultural groundwater exploitation potential.

While these studies identified opportunities for groundwater exploitation for agricultural and domestic purposes based on recharge estimates calculated using recognised methodologies, the recommendations were made in the context of minimal diesel-powered groundwater extraction, implying that the price of diesel influenced and, to some degree, suppressed the expansion of groundwater exploitation beyond hand-dug wells and karez. In 2009 and 2010, with the introduction of solar-powered groundwater pumps, circumstances changed dramatically. Once the costs of drilling, solar panels and pumps were recouped almost overnight, subsistence farmers gained access to free water. This led to extensive and, more recently, unrestricted groundwater well drilling. This surge in groundwater use occurred without any formal groundwater exploitation or management planning and without ongoing monitoring of groundwater levels or quality, meaning that the only measure for groundwater sustainability was the predictable drying-up of wells, which followed the hand-dug wells and karez that Uhl et al. (2003) had already documented.

Remarkably, the physical expression of this shift from diesel to solar-powered 'free water' is visible in a long-term comparison of precipitation in the Helmand River Basin with NDVI scores. As shown in Figure 31, NDVI historically followed water availability from rainfall and snow-melt. However, by 2009, with the advent of affordable solar pump technology, NDVI decoupled from precipitation and began to increase steadily, even as average annual precipitation dwindled by about 50

57. V. W. Uhl, 'Afghanistan: an overview of groundwater resources and challenges, Uhl, Baron, Rana Associates', Inc. Washington Crossing, PA, USA (2003).

58. United States Agency for International Development (USAID), 'Bakwa district, groundwater study', Uhl, Baron, Rana & Associates, Inc. of Lambertville, New Jersey, and Basic Afghanistan Services of Kabul, Afghanistan (2009).

millimetres over 15 years. This means that vegetation performance, which should be dropping with lower rainfall, is increasing in productivity based on the increased availability of water from groundwater wells.

Focusing again on Bakwa, we can see the impact of the dwindling groundwater resources, as illustrated in the following chart and map. The map combines information collected during the 2009 study (USAID 2009) with in-house Mansfield/Alcis data from the Bakwa area gathered during other prior research and NDVI time series data already discussed above. Here, we see two related trends unfolding. Firstly, the groundwater level data shows the depth to groundwater in each period, showing that the water table is falling. Typically, this is due to over-extraction and limited recharge. Secondly, following the proliferation of solar technology from 2009 to 2013, we see an increase not only in the area under agriculture but also in an increased NDVI response over that period. This is related to improved vegetation performance, likely due to increased irrigation. Then, in 2018, the area under agriculture again reduced, and the NDVI values fell to close to 2009 conditions. Recognising that these integrated datasets do not constitute a continuous monitoring programme and serve as snapshots in time, they offer insights to support the narrative of potentially unsustainable groundwater exploitation in the late 2000s, with shallower wells already drying up. This was followed by a rapid increase in solar-powered groundwater pumps, leading to higher NDVI values and further declines in the water table, which were subsequently accompanied by reductions in agricultural land, declining NDVI values, and additional drops in the water table.

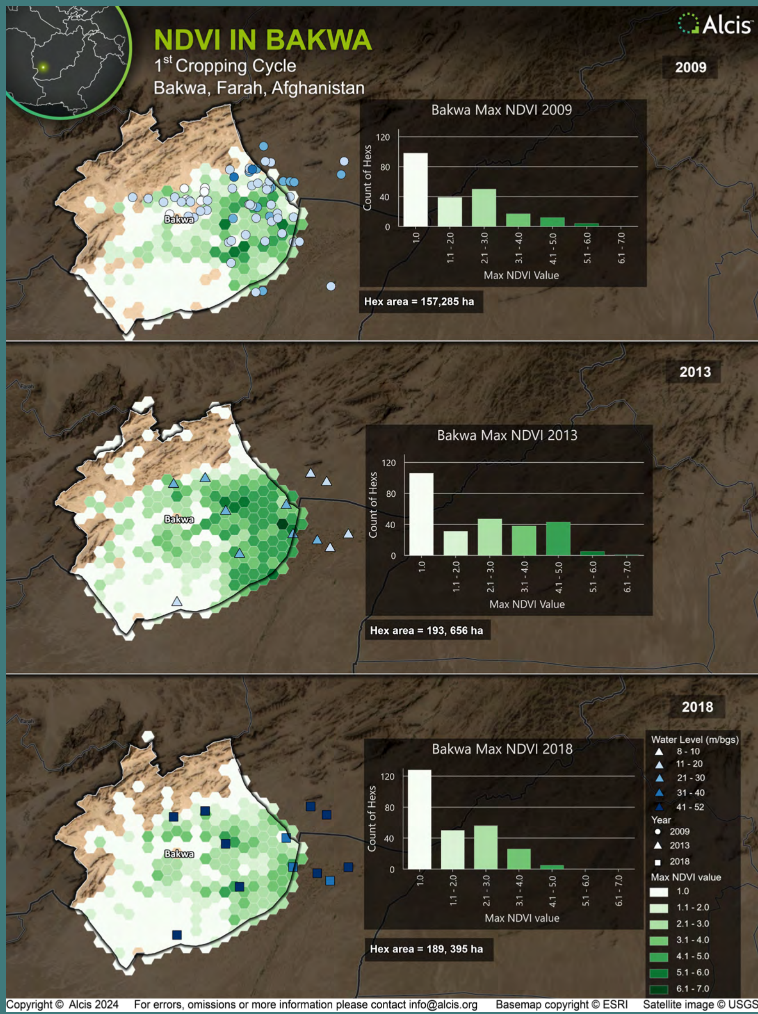

Figure 29: NDVI in Bakwa (2009, 2013, and 2018)

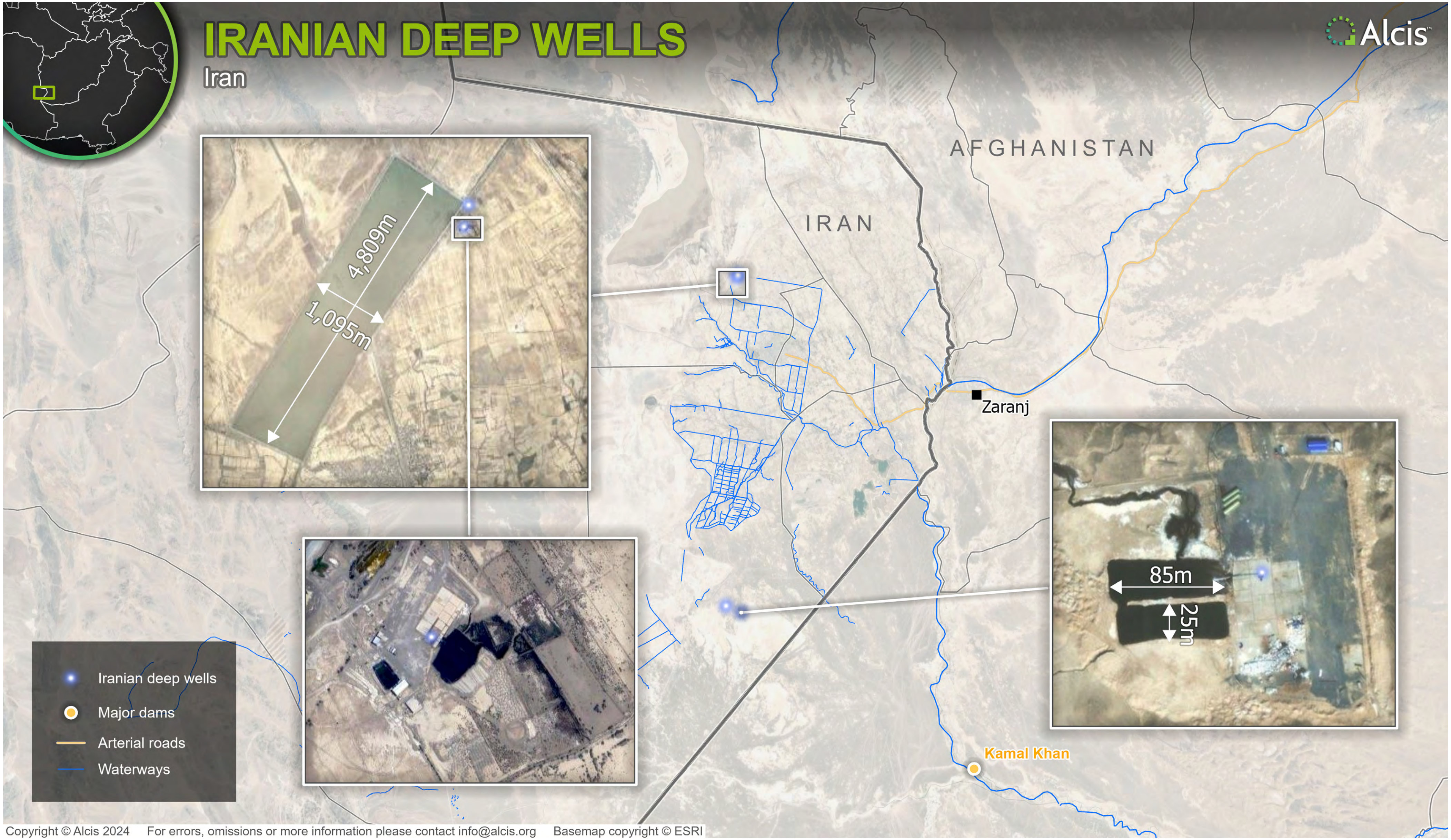

Figure 30: Location and extent of Iranian deep well drilling operations and water storage (2024)

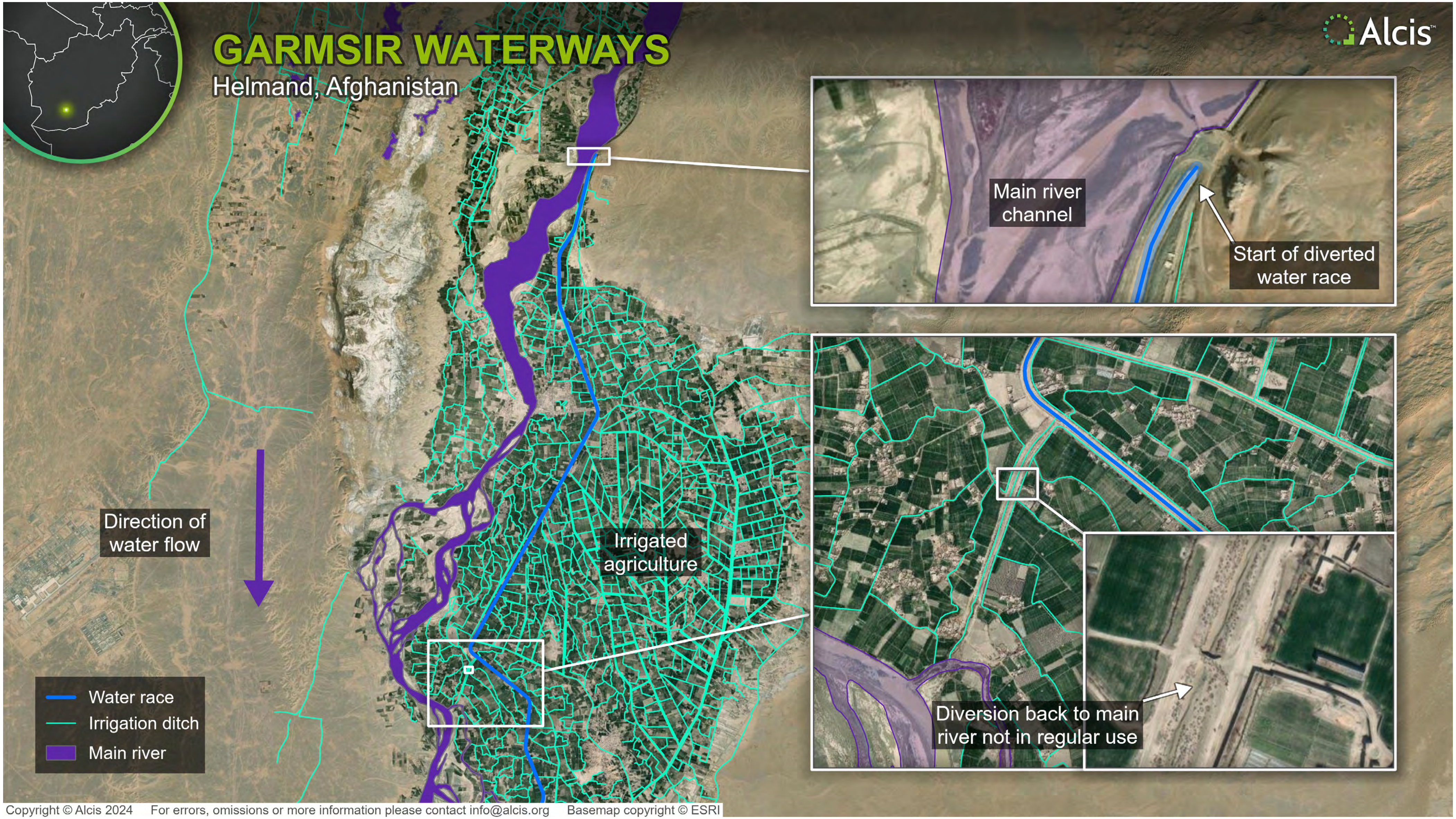

Figure 31: Silting of canals and increase in solar-powered groundwater pumps in Garmsir, Helmand Province (2024)

Conclusion: digging an ever-deeper hole

This research project was designed to examine the causes of the heavy fighting that broke out between Iranian and Taliban forces on the border between Nimroz Province in Afghanistan and Sistan and Baluchestan Province in Iran in May 2023. Following immediately after senior Iranian and Afghan officials had traded barbs over each country's obligations under the Helmand Water Treaty (1973), many assumed that the border conflict was a direct result of this dispute and a precursor of future 'water wars' to come.

However, as the first report from this research project detailed,[52] the events that led to the conflict in May 2023 related to how the border was managed and the challenges of recalibrating cross-border relations following the August 2021 collapse of the Afghan Republic and the Taliban takeover. In fact, this research showed that reduced water flows from the Helmand River to Iran played only an indirect role in the violence. Deprived of sufficient water for their lands due to reduced surface water in the Helmand River Basin, border communities have seen their income from hunting, fishing, livestock and agriculture disrupted over the past two decades and have increasingly turned to cross-border smuggling. The differences in the way the Iranian and Afghan forces policed the border, and in particular the Taliban's tolerance and regulation of the drugs trade following its takeover, increased border tensions and led to the outbreak of violence.

Findings of the second report

This second report from the research project has focused on the Helmand River Basin and the effects of large-scale infrastructural works and climate change on downstream populations. It has entailed using high-resolution imagery to inventory the most significant infrastructural works along the Helmand River in Afghanistan and Iran, and their chronology and effects. It has also involved detailed household interviews with those living along the Helmand River and parts of the Farah River, examining how communities have adapted to the effects of climate change. The research has raised several salient points critical to better understanding the impact of climate change on the Helmand River Basin and its potential outcomes, including the risk of a border conflict between Iran and Afghanistan.

Firstly, the research has helped better understand how the dispute over transboundary water rights in the Helmand River Basin is described by the main protagonists – the authorities in Tehran and Kabul – and the accuracy of these accounts. Typically, the dispute begins with the Iranian government accusing whichever authorities are in Kabul at the time of withholding water from the Helmand River and failing to comply with their treaty obligations. The repeated response from Kabul is to assert that any reduction in water flow is a function of drought and that Iran's complaints often coincide with drought years noting that there is a provision in the Helmand Treaty to reduce water flows under such conditions.

A critical part of Tehran's complaint is Afghanistan's ability to store and divert water through infrastructure projects such as the Kajaki Dam, constructed in the 1950s, and more recently with the completion of the Kamal Khan Dam in 2021, arguing that Kabul has not allowed sufficient water to discharge from these structures into Iran for use by the population of Sistan and Baluchestan.

There is, of course, some truth to this complaint, much more so since the completion of the Kamal Khan Dam. As this research has shown, this latest dam, constructed in the lower part of the Helmand River Basin and just upstream from the Helmand fork, now allows Kabul to release water from the Kajaki Dam in the upper basin to be used by communities downstream in Afghanistan, while retaining any remaining discharge at Kamal Khan, and preventing it from flowing to Iran. However, this was not an option until the Kamal Khan Dam was completed in 2021.

Importantly, this research has shown that any efforts by the Afghan authorities to retain and divert water have been mirrored on the Iranian side of the border and often some years earlier. For instance, the Jeriki Canal and Chah Nimeh reservoirs, located close to the Helmand fork, where the Helmand River first meets the Iranian border, were initiated in the 1970s and 1980s, respectively, designed to divert and then store water mainly for the urban populations of Zabol and Zahedan. Before the construction of the Kamal Khan Dam inIran, these reservoirs captured the water once released from the Kajaki Dam, and following the construction of Chah Nimeh 4 in 2008, which more than doubled

61. Mansfield and Alcis, Missing the target.

storage capacity, significantly reduced the water flow into the Nad-e-Ali River and Hamoun-e-Puzhak in Afghanistan, and the Hamoun-e-Saberi in Iran.

Consequently, while historically Tehran has argued that it is Kabul's failure to release water from Kajaki that limited the water flow to the hamouns, a series of terminal lakes and salt marshes, and Sistan and Baluchestan Provinces, its own infrastructure efforts at the Helmand fork were more consequential on the rural livelihoods of the downstream populations in both Afghanistan and Iran. This is particularly the case when we consider that the Iranian authorities prioritise the populations of Zabol and Zahedan, and that water is only released from the Chah Nimeh reservoirs to farmers in Sistan and Baluchestan for irrigation once the needs of the urban population have been met.

It is important to note that Tehran also sought to stem the flow of water from the Hamoun-e-Hirmand to the through a series of dams on the Sar-e-Shelah River in the district of Hamoun in Sistan and Baluchestan Province. As such, while Tehran accuses Kabul of seeking to retain and divert water to its advantage and to the detriment of downstream populations in Iran, Tehran has been doing the same for longer, and until the completion of the Kamal Khan Dam, perhaps more effectively. While Tehran's complaints have reached a higher pitch since the completion of the Kamal Khan Dam, and with the threat of further dams to come, it is inaccurate for Tehran to portray itself as the sole victim in this dispute and Kabul as the perpetrator.

Secondly, this research has raised the issue of the dramatic shift to groundwater extraction across the Helmand River Basin. This has been in direct response to reduced water flows in the river basin, partly due to climate change and the infrastructural works of both the Afghan and Iranian authorities. In south-west Afghanistan, farmers are increasingly reliant on their deep wells for irrigation and drinking water, even neglecting the maintenance of surface irrigated systems that are collectively managed. This move towards seeing water as a privately owned asset will not end well, and will make the problem of water management even more intractable.

Access to affordable solar-powered systems led to even greater numbers of Afghan farmers installing deep wells; by 2023, there were at least 68,160 deep wells in the Helmand River Basin, five times more than in 2016. Once only used by farmers looking to settle remote former desert lands in the south-west Provinces of Helmand and Farah, often for the purpose of growing poppy, deep wells have become ubiquitous, commonly used even in surface irrigated areas where water flows have become increasingly unreliable because of the effects of climate change.

“ In south-west Afghanistan, farmers are increasingly reliant on their deep wells for irrigation and drinking water, even neglecting the maintenance of surface irrigated systems that are collectively managed.

In areas formerly irrigated using traditional irrigation systems (known as 'karez'), increased temperatures and reduced precipitation in the Helmand River Basin resulted in reduced water flows and a move to deep wells. As the number of deep wells increased, the karez dried up completely. Now, with many more deep wells installed, groundwater levels are falling at an alarming rate, in some cases by as much as five metres per year. Some of the earlier, shallower wells that were dug in the initial years of settling the former desert lands of the south-west have failed, resulting in ever-deeper wells being installed in ever-increasing numbers.

Farmers in Afghanistan note the threat this increase in groundwater extraction poses to their ability to continue to draw water, grow crops and sustain their livelihoods into the future, but see no other option. After all, without groundwater exploitation, many households in the Helmand River Basin would already be without water and would have had to migrate. With the authorities in Kabul unable or unwilling to act to regulate groundwater extraction, build the necessary infrastructure (such as check dams) and create non-farm income opportunities that would reduce the need to extract large volumes of groundwater, there are no obvious solutions. The result is a race to the bottom, perhaps best captured by the government of Iran's installation of three wells between 1,000 and 3,000 metres in depth in Sistan and Baluchestan. Developing a much better understanding of the impact this shift to large-scale groundwater extraction is having on the aquifers in Afghanistan and Iran is a critical first step to establishing the implications of

61. Mansfield and Alcis, Missing the target.

> **The risk is that the groundwater level will fall even faster, putting the livelihoods of many of the 365,371 households in the Helmand River Basin at risk, an estimated total of 3.65 million people.**

these developments, and what it means for the lives and livelihoods of those in the Helmand River Basin. This can only be done with access to groundwater data, including groundwater level and water quality monitoring across large areas like the Helmand River Basin, which is also conducted over a longer period. Without such information, policymakers and national authorities are guessing about this critical resource's long-term sustainability.

Ultimately, this research finds that if groundwater levels continue to fall at current rates, the deep wells in 30 per cent of the research sites could be dry within a decade and 76 per cent within two decades. However, given the likelihood there will be further increases in the number of deep wells sunk in the Helmand River Basin in the coming years, there is every likelihood that this is an optimistic assessment, and the risk is that the groundwater level will fall even faster. This will put the livelihoods of many of the 365,371 households in the Helmand River Basin at risk, an estimated total of 3.65 million people. This should be of considerable concern to those in the region and further downstream in Europe. Without the means to sustain themselves in situ, there is every likelihood that many of these people will leave Afghanistan in search of a life in other countries, as many Afghans before them have done over the past few decades.

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