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The Three Blind Spots of Afghanistan: Water Flow, Irrigation Development, and the Impact of Climate Change

*David W. Rycroft and Kai Wegerich**

ABSTRACT
The article discusses the three blind spots of northern Afghanistan: water flow, irrigation development, and the impact of climate change. Consideration is given to the different data sets for the current irrigated areas, water resources, and future potentials according to identified projects in northern Afghanistan. The water accounting programme WEAP (Water Evaluation and Planning System) has then been applied to estimate the current demands for water as well as the increased demands resulting from climate change.

Keywords • Northern Afghanistan • Water Flow • Irrigation Development • Climate Change

Introduction – The Blind Spot of Afghanistan

So far in all the literature on the Amu Darya, Afghanistan has either been a blind spot in terms of its current and future irrigated area and water demands or, depending on the author, estimated water demands vary enormously. Generally, authors only consider the increase of irrigated areas and ignore the effects of climate change. Given the uncertainties, it is difficult to provide accurate estimates of future demand. A similar blind spot applies to the amount of water which originates in Afghanistan and which is then utilized in the Amu Darya basin.

In this paper the different data sets for current irrigated areas, water flow, and future potentials are reviewed. The water accounting

* David W. Rycroft is based at the School of Civil Engineering and the Environment, University of Southampton, UK. Kai Wegerich is based at the Irrigation and Water Engineering Group, Wageningen University, The Netherlands.

programme WEAP (Water Evaluation and Planning System) has then been applied to estimate both the current demand for water from a representative irrigated area as well as the increased demand expected to arise due to climate change.

The first section of this paper provides a short introduction to the Amu Darya basin and the different sub-basins contributing flow from within Afghanistan. The second section considers the different data sets for flow at an individual gauging station. The third section considers the different perceptions concerning the current irrigated areas in Afghanistan, the driving forces for expansion, as well as the different assumptions on the potential increases in irrigated area. The fourth section considers the impact of climate change on demand, taking as a case study 111,600 ha of irrigated land surrounding the town of Emam Saheb in northern Afghanistan.

Background

The Amu Darya is the largest river in Central Asia, formed by the confluence of its main headwater tributaries, the rivers Vaksh and Pyanj. The total length from the head of the Pyanj to the Aral Sea is about 2,540 km, although the length from the confluence with the Vaksh to the Aral Sea is 1,415 km.[1] The catchment comprises 309,000 km^2 and is shared between Afghanistan, Iran, and the four Central Asian Republics: Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. The most important river, the Pyanj, originates at the glacier in the Vakjdjir Pass and forms the border between Afghanistan and Tajikistan.

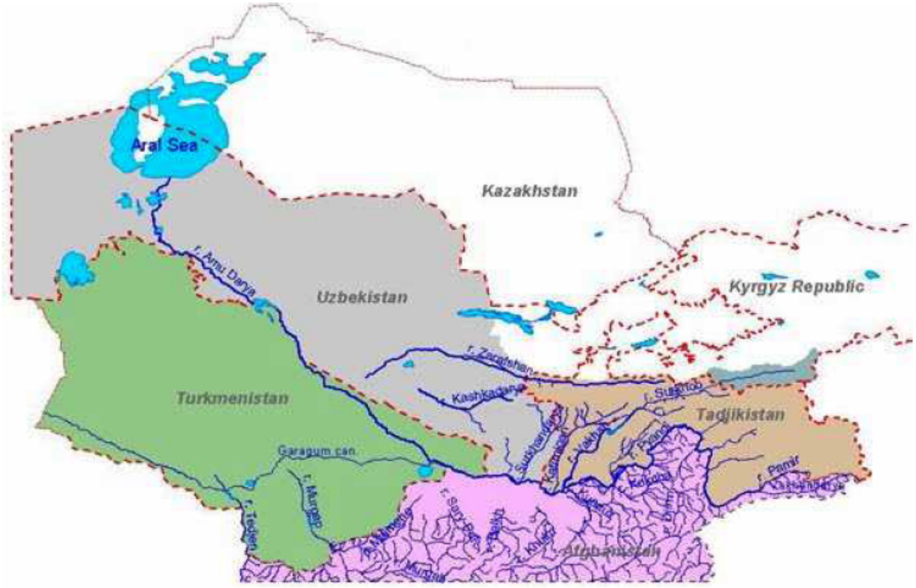
Ahmad and Wasiq identify three sub-basins within northern Afghanistan.[2] The first includes minor rivers which are adjacent to the Amu Darya but only contribute rarely to the flow in the Amu Darya: these are the Khulm, Balkh, Sar-e-Pul, and Sherintagau rivers. The second sub-basin includes the Harrirud and Murghab rivers, but their links to the Amu Darya have been discontinued (Map 1). The Harrirud joins the Tijen river, which originates in Iran before entering Turkmenistan. These rivers are, however, interlinked with the Amu Darya system by their contribution to the flow in the Kara Kum Canal. This is believed to be the longest canal in the world, with a maximum capacity at its inlet from the Amu Darya of 600 m^3/s. The third sub-basin contains rivers which continue to contribute flow to the Amu Darya: the

[1] J. Froebrich J and O. Kayumov, "Water management aspects of Amu Darya," in J. C. J. Nihoul and al. (eds.) *Dying and Dead Seas - Climatic Versus Anthropic Causes*, Nato Science Series: IV, Earth and Environmental Sciences, Volume 36 (Kluwer Academic Publishers, Dordrecht, 2004), pp. 49-76.

[2] M. Ahmad, M. Wasiq, *Water Resource Development in Northern Afghanistan and its implication for Amu Darya Basin,* Working Paper no. 36 (Washington, DC: World Bank, 2004), p. 3.

Wakhan and Pamir as well as other rivers of Badakhshan, the Kokcha, and Kunduz. The emphasis here is mainly on sub-basin three, but consideration is also given to aspects of sub-basin one, particularly because, according to former Soviet plans, irrigation in these sub-basins depended on diversions from sub-basin three.

Map 1: Amu Darya Basin



Source: NeWater.

Trends

There are no agreements between the former Soviet Union and Afghanistan on water sharing for the Pyanj and Amu Darya. Nevertheless, Ahmad and Wasiq make reference to different protocols and agreements between Afghanistan and the Soviet Union signed before 1965.[3] They state, "these documents provide a treaty basis for prohibiting any construction work on Pyanj and Amu Darya whether by Afghanistan or by the other Central Asian republics (Tajikistan, Turkmenistan, and Uzbekistan) without consultation, although Afghanistan may, without consultation, use and regulate water on tributaries of the Pyanj and Amu Darya." It appears that the Soviet Union did not consult Afghanistan when it constructed pump stations serving the major canals: the Amu-Bukhara, the Amuzang, or the Karshi/Kashkardarya); or even the huge Kara Kum canal, or further down the Amudarya at the head of the Aral Sea delta the Tuyamuyun reservoir complex.

In 1977 Afghanistan sent a delegation to Tashkent to prepare a water sharing agreement for their claim to 9 km^3 from the Amu Darya; the Soviet

[3] *Ibid.*, pp. 38-39.

Union only offered 6 km^3, however, so no agreement was reached.[4] In September 1987, the Scientific-Technical Council of the Soviet Ministry of Land Reclamation and Water Management decided on annual water-distribution limits for the Union Republics of the Amu Darya Basin and at the same time created River Basin Organizations (*Basseynoe Vodnoe Ob'edinenie*, BVOs), which were responsible for managing the water according to the set limits. Afghanistan did not participate in this decision-making process. Hence, the limits established in 1987 ignored claims by Afghanistan, and simply assumed a utilization of 2.1 km^3; this was actually less than Afghanistan was already using in 1965, namely 3.85 km^3.[5]

Even to the present day, there is no agreement about how much of the flow in the Amu Darya originates in Afghanistan, with estimates indicating that some 8–21 km^3 of the mean flow of the Amu-Darya originates in the country.

Table 1. Different Data Sets for the Amu Darya Basin

Amu Darya basin (km^3/year)				
State	ICWC data[6] on river runoff	International data[7] on river runoff	Set limits[8, 9]	Officially used water (1993 - 1999)
Afghanistan and Iran	8.06	21.6		
Kyrgyzstan	1.5	1.6	0.4	0.2
Tajikistan	42.6	49.6	9.5	7.3
Turkmenistan	1.549	1.5	22	21.5[10]
Uzbekistan	1.2	5.1	29.6	21.6
Aral Sea				6.1
Total				56.7

[4] Personal conversation, Dukhovny, 2008.

[5] M. Qaseem Naimi, "Conflict Prevention and the Politics of Central Asia Water Co-operation from the Point of View of Afghanistan," Paper presented at a workshop (University of Peace: Central Asia Programme, Almaty, 2005).

[6] Source: Dukhovny (without date).

[7] Source: Diagnostic Study, November 2001, SPECA.

[8] Figures agreed by Protocol 566 of the Scientific-Technical Council of Ministry of Land Reclamation and Water Management of the USSR on September 10, 1987.

[9] Dukhovny and Sokolov (no date (b): 13) highlight the temporary nature of the set water allocation, by arguing "The principles of water allocation that existed in Soviet times have been retained for the purpose of annual planning until new regional and national water management strategies can be developed and adopted"

[10] Stanchin and Lerman (2006) show that Turkmenistan's agricultural area increased from 1,329,000 ha in 1990 to 1,843,000 ha in 2003. At the same time the total water use increased from 22.435 cu km to 27.958 cu km. Even though the paper does not state directly that the overall increase comes from the Amu Dar'ya, it is very doubtful that this increase could be achieved only from the smaller rivers (Murgan, Tedjen, and Atrek) and that no additional water was taken from the Amu Dar'ya.

Notwithstanding this uncertainty, there is conflicting flow data even for the same measuring stations (e.g., Freenet and Kunduz River Basin Program).

Table 2. Different Data Sets for the Kunduz River at Pulikumri

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Freenet - Mean (1951-67)	37.1	35.2	33.8	32.2	31	30.6	39.7	98.8	233	149	60.3	38.6
KRBP - Mean (1968-79)	21.8	21.1	19.3	18.1	17.4	18	21.8	51.3	95.2	53.6	26.6	22.1

Irrigation Development in Afghanistan

By the mid-1970s some 3.3 million ha had been brought under irrigation in the whole of Afghanistan. Currently, approximately 1.8 million ha are irrigated.[11] Based on Development Alternatives Inc's (DAI) 1993 analysis of satellite imagery, Ahmad and Wasiq concluded that 385,000 ha of this are within sub-basin 3, where rivers continue to contribute flow to the Amu Darya.[12] The data indicates that 21,000 ha are inactive. The same value (385,000 ha) is reported by Qaseem Naimi.[13] Other reports, however, provide different estimates which are considered to be less reliable. For example, Uzvod reports a current irrigated area in sub-basin 3 of 148,000 ha (and a further 250,000 ha in sub-basin one).[14] Uzvod provide as source of this information "the *State and Prospects of Irrigation Development in Northern Afghanistan*, drawn up by the Sredazgiprovodkhlopok Institute." However, it is unclear how this information was derived. According to Pasquet, after the decrease of irrigation during the Russian war and the Mudjaheddin period, the irrigated area in the third sub-basin has increased once again.[15]

Given the decline of irrigation during the last 40 years and the considerable potential for irrigation, it is not surprising that the Afghan

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[11] WSS *Islamic Republic of Afghanistan, Afghanistan National Development Strategy (ANDS) Draft Water Sector Strategy 2008 – 2013, February 2008,* p. 24.
[12] M. Ahmad, M. Wasiq *Water Resource Development in Northern Afghanistan and its implication for Amu Darya Basin, op. cit.*, p. 3.
[13] M. Qaseem Naimi, "Conflict Prevention and the Politics of Central Asia Water Co-operation from the Point of View of Afghanistan," *op. cit.*
[14] SANIIRI/UZVOD Afghanistan: Water consumption, demand and forecast Contractor: SANIIRI Subcontractor: UZVOD ECC Co. European Community Commission. General Investigations Directorate; Integration and Reinforcement of European Science; JAYHUN; Interstate water resource risk management: towards a sustainable future for the Aral basin; International Cooperation – INCO; Contract 516761, 2008.
[15] J. Pasquet, Farming systems research – Final Report, PMIS/URD, (Plaisians, France, 2007).

Water Sector Strategy (WSS) is driven by ambitious plans to improve and/or to rehabilitate and re-establish irrigated areas.

The Draft WSS places its emphasis on poverty reduction, and the strategy to achieve this relies on irrigated agriculture.[16] The draft provides detailed information about major infrastructure projects which have been identified for implementation, some having already been started. It provides as justification for these 27 projects "the needs of the population and the growth in the economy of Afghanistan requiring continued and accelerated implementation of projects." However, it is unclear whether these projects are based on old or new pre-feasibility studies. An earlier Draft WWS (July 2007) was itself highly critical about water management projects which were mentioned in the same 2008 WSS report.

The Draft WSS states "Sociological and environmental considerations tend to nullify much of the planning study selection criteria upon which most of these former studies have been based."[17] Sociological considerations are, for example, the return of refugees who are now living in areas that were previously considered for water developments. These constraints are not restated in the Draft WSS of February 2008. Hence, it is highly doubtful whether all these 27 projects are feasible or as beneficial in terms of irrigated area or hydro-power production, or whether they might even have some negative consequences or cannot be implemented.

There are not only considerations for the local communities living in these identified areas. Afghanistan is very well aware that any irrigation development in the country has implications for downstream riparian states, and the transboundary concerns raised:

> Afghanistan has been extremely reluctant in facing these pending confrontations, as the country has been in a total state of disarray with respect to evaluating its current and future needs. Afghanistan attention has been focused upon national reconstruction and the underlying problems of poverty alleviation. No resources have been made available to ascertain its physical position on determining its own requirements.[18]
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> Because of Afghanistan's innate land locked setting, virtually all of its major rivers drain into riparian neighbouring states. Transboundary concerns are intensifying along all of

[16] WSS (Draft February 2008) *Islamic Republic of Afghanistan, Afghanistan National Development Strategy (ANDS)*, p. 3.
[17] WSS *Islamic Republic of Afghanistan, Afghanistan National Development Strategy (ANDS) Draft Water Sector Strategy 2008 – 2013*, July 2007, p. 20.
[18] *Ibid*., p. 44.

> Afghanistan's borders, and with the added impetus of climate change and diminishing glaciers, can no longer be avoided. Afghanistan has been preoccupied with so many other problems, that it has not had either adequate resources or sufficient time to thoroughly address the issues. Afghanistan requires solid support from the donor/financing community to study and add dimensions to both its current and future water requirements. Based on more clearly defined facts, Afghanistan can approach its neighbours on an equal footing, and can then participate in achieving optimal efficiency in regional development of these water resources.[19]

Different estimates exist concerning the potential total area of land suitable for irrigation in sub-basin three. Ahmad and Wasiq claim that "a 15–20 percent expansion would be feasible purely on technical grounds," and state that it should be possible to expand the area to 443,000 ha. They consider, however, that this will only be achieved over the next 20 years. Similarly, they refer to Soviet, French, and World Bank surveys. According to Ahmad and Wasiq:

> In 1971, the State Planning Committee of the Soviet Union concluded that: Though most of the proposed waterworks would be effective, construction of a big waterworks with hydropower stations, generation, and capacity of which considerably exceeds current needs of Afghanistan, requires great investments. In this context, as well as taking into account construction of a large scale hydraulic works on waterways of Central Asia, the USSR only could be interested in developing these water and power resources not earlier than 20 years from now.[20]

Uzvod identifies a potential increase of 142,700–152,900 ha to a total of 290,500– 300,800 ha in sub-basin three. According to it, work has not progressed because of the deteriorating security situation, and not because of prioritization of the Central Asian Soviet Socialist Republics (SSRs).

An extreme estimate by Zonn identifies the potential for sub-basin three as being 840,000 ha by 2020. He argues that:

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[19] WSS (Draft October 2007) *Islamic Republic of Afghanistan, Afghanistan National Development Strategy (ANDS) Draft Water Sector Strategy 2008 – 2013*, October 2007, p. 9.

[20] M. Ahmad, M. Wasiq *Water Resource Development in Northern Afghanistan and its implication for Amu Darya Basin . op. cit.*, p. 22.

> Irrigation of the whole free land stock of Northern Afghanistan (more than 1.5 million ha) is possible without the construction of waterworks, it will be enough to construct a damless water intake with water pumping in three places: near the confluence of the Pyanj and Vakhsh Rivers; near the Geshtepe outpost (opposite the mouth of the Kafirnigan River); near the Kelif gap. In all cases water should be pumped to a height of no more than 20 to 30 m.[21]

However, it seems that Zonn did not consider the operational costs of pumping. If these projects need "only" to lift water by 20 to 30 m, they may actually be more economically feasible then the existing canal systems located downstream which rely on high pumped lifts: e.g., the ABMK Canal serving Bukhara (discharge: 270 m^3/s, lift 57 m) or the KMK Canal serving Karshi/Kashkardarya (discharge: 350 m^3/s, lift 170 m). In the past such high lift pumping was possible because of the distorted economics of the Soviet Union, but in any new developments this will no longer apply.

Considering abstractions, Ahmad and Wasiq (2004) argue that there will be a total water diversion of about 5.8 km^3, or at the most 6 km^3, by 2020. According to Zonn the demand for water within the direct tributaries of the Amu Darya in sub-basin three will increase to 3.9 km^3: including 1.2 to 2.5 km^3 from the Kunduz; 0.3 to 0.7 km^3 from the Kokcha, and 0.4 to 0.7 km^3 from the Pyanj.

Given the current deteriorating security situation, even in northern Afghanistan, it is very doubtful whether such large-scale projects, some relying on dams, can be implemented. Nevertheless, one EU funded project, "The Kunduz River Basin Project" (KRBP), is currently rehabilitating and constructing new intakes and water diversions in the Kunduz basin. Another EU funded project, "the Amu Darya Basin Programme" (ADBP), is surveying the Pyanj river. Hence, small-scale projects are already underway. Since the long-term objective of the Afghan WSS is poverty alleviation, and also cost recovery of the water delivery services, it is highly doubtful if such costly projects will ever be implemented. Hence, even though it might be technically feasible to construct pumping stations, as proposed by Zonn (and mentioned by Ahmad and Wasiq), it appears that the costs of lifting water to 20–30 m will impose an unacceptable burden on agricultural water users.[22]

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[21] I. Zonn, "Water Resources of Northern Afghanistan and their Future Use," Paper presented at workshop on water, climate and development issues in the Amu-Dar'ya basin, Philadelphia, PA, 2002.

[22] It is doubtful whether lifting the water 20-30 meters will be sufficient to allow the projects to proceed. A 20-30 km wide strip of land between the river and the potential irrigated areas is occupied by sand dunes (Barkhan sands) which will require an expensive

Taking the data of Ahmad and Wasiq as being the most reliable, and bearing in mind that the KRBP has already begun rehabilitating weirs and intakes, it is likely that the canals in their study of the Lower Kokcha and Gawhargan-Chardara areas will go ahead.[23] From an economic standpoint, it is unlikely that pump stations will be constructed and from a social stability perspective, it is highly unlikely that dams will be constructed when resettlement is the priority. According to Landell Mills Ltd., in 2006 only 6 percent (about 600,000 Euros) of the total budget (11.6 million Euros) had actually been spent on irrigation scheme rehabilitation, although 17 scheme rehabilitation works had been contracted. The Participatory Management of Irrigation Systems (PMIS) project also drew attention to the increased rice production after the KRBP rehabilitation. This is mainly the result of the collapse of the established agricultural industries (cotton and sugar beet factories in Taloqan and Baghlan provinces).

Therefore, one can assume that from the projects identified by Ahmad and Wasiq for the Kokcha basin that 29,420 ha could be newly irrigated and 33,140 ha be provided with improved access to water. In the Kunduz basin, 3,450 ha could be newly irrigated and 24,860 ha have improved access to water. Finally in the Pyanj basin 41,500 ha could be provided with improved access to water. Hence, there would only be a marginal increase of newly irrigated areas, equivalent to 32,870 ha, and improved access to water for a further 99,500 ha. Given the current activities of the KRBP and the assumed activities by the ADBP, the areas with improved access to water are likely to increase even more. Bearing in mind that the preferred crop in the Kunduz basin is the cash crop rice, it is highly likely that at least in the Kunduz basin, rice production might dominate.

If the dam projects are established in the future, given the high costs of pumping, and the current need for electrification for urban and rural areas in Kunduz, it is considered much more likely that the generated electricity would be used either for domestic or industrial supply, rather than for agriculture. In addition, with the expansion of the current electricity grid from Tajikistan to the south and north, it is likely that any surplus electricity would be sold to Afghanistan's neighbors.

Taking the figures mentioned by Ahmad and Wasiq and confirmed by Qaseem Naimi, of the 385,000 ha currently irrigated area in sub-basin

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lined canal to be provided. It would also be difficult to prevent this from becoming blocked by wind blown sand leading to high maintenance costs.

[23] Landell Mills Limited (2006) 4th Progress Report (January – June 2006); TA to the Ministry of Energy and Water for the Implementation of the Food Security/Water Management Project in Kunduz, Baghlan and Takhar Provinces, <http://www.krbp.net/eng_reports/4th%20KRBP%20Progress%20Report%20Jan-June%2006%2010.11.06.pdf> (August 25 2008).

three, it could be argued that the irrigated area might increase to 417,870 ha. The rehabilitation projects might also lead to a change of cropping patterns which might further increase the demands for water.

Influence of Climate on Water Demand

So far, only the expansion of the irrigated area has been considered. Another uncertain issue is the impact of climate change on crop water requirements and the demand for irrigation. The analysis here considers the demands for water for a representative area located in sub-basin three which is irrigated with water from the Pyandj. The area occupies 111,600 ha around the town of Emam Saheb in northern Afghanistan.

The procedures used to determine crop water requirements and the demand for water are described in further detail in the annex to this paper.

The analysis considers firstly the crop water requirements (potential evapotranspiration) for the existing climate (1961–1990), using downscaled climatic data derived by the Climate Research Unit of the University of East Anglia (CRU data). Secondly, the demands in 2070–2099, using temperature rise data derived from the most recent 4th assessment report of the Inter-Governmental Panel on Climate Change (the IPCC). The monthly temperature anomalies (increases in temperatures) are the means of seven global circulation models included in the IPCC 4th assessment for the climate change scenario judged to most closely correspond to recent patterns of climate change in Central Asia, the A2 climate change scenario. This assumes a very heterogeneous world, with high population growth and slower economic growth than other climate change scenarios. The time interval 1961–1990 is a period used by the IPCC to represent the existing climate, whilst the future time interval of 2070–2099 represents a period which today's young children can expect to experience in their lifetime.

Table 3. Potential Evapotranspiration (Crop Water Requirements) for the Emam Salieb Area for 1961-1990 and 2070-2099

	Monthly Potential Evapotranspiration, million cubic metres												
	Climate 1960-1991												
Crop	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
Barley	0.52	1.81	3.36	2.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	8.83
Cotton	0.00	0.00	0.00	0.00	2.87	5.53	8.57	8.68	5.46	2.86	1.03	0.00	35.01
Fodder	0.78	2.42	4.50	6.13	0.00	0.00	0.00	0.00	0.00	0.00	1.40	0.84	16.06
Fruits	0.00	0.00	0.00	1.43	3.64	7.01	7.60	6.69	3.81	2.04	0.00	0.00	32.21
Maize	0.00	0.00	0.00	0.00	0.00	15.81	22.86	24.15	16.03	7.62	0.00	0.00	86.46
Oil Crops	0.00	0.00	0.43	1.13	3.16	3.56	2.57	0.00	0.00	0.00	0.00	0.00	10.85
Pulses	0.00	0.00	0.00	0.00	0.00	0.79	2.00	2.77	2.00	0.36	0.00	0.00	7.92
Rice	0.00	0.00	0.00	0.00	0.00	20.29	23.00	21.13	15.30	5.83	0.00	0.00	85.55
Vegetables	0.00	0.00	0.00	0.00	0.00	5.93	8.57	8.68	6.28	2.86	0.00	0.00	32.32
Winter Whea	12.93	26.16	58.93	90.24	59.89	0.00	0.00	0.00	0.00	0.00	14.31	8.56	271.03
Sum	14.23	30.39	67.23	101.50	69.57	58.92	75.18	72.08	48.88	21.55	16.74	9.96	586.23
	Monthly Potential Evapotranspiration, million cubic metres												
	Climate 2070-2099												
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
Barley	0.62	2.04	3.81	2.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	10.03
Cotton	0.00	0.00	0.00	0.00	3.20	6.16	9.41	9.63	6.10	3.22	1.20	0.00	38.93
Fodder	0.92	2.73	5.10	6.99	0.00	0.00	0.00	0.00	0.00	0.00	1.62	0.92	18.30
Fruits	0.00	0.00	0.00	1.63	4.06	7.81	8.34	7.42	4.25	2.30	0.00	0.00	35.81
Maize	0.00	0.00	0.00	0.00	0.00	9.67	17.83	24.64	17.90	7.56	0.00	0.00	77.60
Oil Crops	0.00	0.00	0.49	1.29	3.52	3.96	2.82	0.00	0.00	0.00	0.00	0.00	12.09
Pulses	0.00	0.00	0.00	0.00	0.00	0.88	2.20	3.07	2.24	0.40	0.00	0.00	8.79
Rice	0.00	0.00	0.00	0.00	0.00	22.59	25.25	23.45	17.08	6.58	0.00	0.00	94.96
Vegetables	0.00	0.00	0.00	0.00	0.00	6.60	9.41	9.63	7.02	3.22	0.00	0.00	35.88
Winter Whea	15.36	29.55	66.82	102.97	66.76	0.00	0.00	0.00	0.00	0.00	16.65	9.48	307.58
Sum	16.91	34.32	76.23	115.82	77.54	57.68	75.27	77.84	54.59	23.29	19.47	11.02	639.97

The annual potential crop evapotranspiration for the existing climate for the 111,600 ha equates to 586 million m^3 (Table 3). Specifically, crops such as rice occupying 7,812 ha consume 85.6 million m^3 (1.1 m); cotton occupying 3,348 ha consumes 39.9 million m^3 (1.05 m), whereas winter wheat occupying 69,750 ha only consumes 308 million m^3 (0.44 m).

The overall demand for water (Table 4) includes more water than is consumed by the crops to allow for irrigation efficiencies, assumed in this case to be 50 percent.[24] Thus the equivalent total demand for the existing climate is 844 million m^3. Part of the crop water requirements is supplied by precipitation (80 percent of the P_{50} values in Table 5 is considered to be effective) but most is provided by irrigation. Specifically rice requires 170.6 million m^3 to be provided (2.2 m equivalent depth), cotton requires 67.5 million m^3 (2 m equivalent depth), whilst winter wheat only requires 263 million m^3 (0.38 m equivalent depth) reflecting both the low

[24] J. Berkof, "Irrigation in the Balkh Basin. A Preliminary Assessment," 2004.

evaporation rates during the winter-spring period as well as the contribution of rainfall.

The existing demand, 844 million m^3 (averaging 7,564 m^3/ha or 0.75 m/ha), is relatively low because of the high proportion of winter wheat grown (62.5 percent of the area); this only requires 3,775 m^3/ha compared to cotton (3 percent of the area) which requires 20,158 m^3/ha (2.0 m) or rice (7 percent of the area) which requires 21,834 m^3/ha (2.1 m).

Table 4. The Demand for Water (Supplied by Irrigation):- Emam Salieb, 1961-1990 and 2070-2099

	Monthly Demand for Water per Crop, Million Cubic Metres												
	Climate 1960-1991												
Crop	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
Barley	0.00	0.07	1.54	1.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.06
Cotton	0.00	0.00	0.00	0.00	4.34	11.06	17.14	17.35	10.93	5.49	1.16	0.00	67.49
Fodder	0.00	0.00	1.29	6.74	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00	9.01
Fruits	0.00	0.00	0.00	0.00	5.50	14.01	15.20	13.38	7.61	3.79	0.00	0.00	59.50
Maize	0.00	0.00	0.00	0.00	0.00	31.60	45.72	48.29	32.06	14.65	0.00	0.00	172.31
Oil Crops	0.00	0.00	0.00	0.90	5.62	7.11	5.14	0.00	0.00	0.00	0.00	0.00	18.78
Pulses	0.00	0.00	0.00	0.00	0.00	1.58	4.00	5.53	4.01	0.64	0.00	0.00	15.76
Rice	0.00	0.00	0.00	0.00	0.00	40.56	46.01	42.25	30.60	11.15	0.00	0.00	170.57
Vegetables	0.00	0.00	0.00	0.00	0.00	11.85	17.14	17.35	12.57	5.49	0.00	0.00	64.41
Winter Wheat	0.00	0.00	38.88	124.00	90.47	0.00	0.00	0.00	0.00	0.00	9.94	0.00	263.30
Sum	0.00	0.07	41.72	133.09	105.94	117.77	150.36	144.17	97.77	41.21	12.08	0.00	844.17

	Monthly Demand for Water per Crop, Million Cubic Metres												
	Climate 1960-1991												
Crop	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Sum
Barley	0.00	0.54	2.44	2.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15
Cotton	0.00	0.00	0.00	0.00	5.00	12.32	18.82	19.26	12.20	6.23	1.50	0.00	75.33
Fodder	0.00	0.21	2.50	8.47	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00	12.61
Fruits	0.00	0.00	0.00	0.00	6.33	15.60	16.69	14.85	8.50	4.31	0.00	0.00	66.29
Maize	0.00	0.00	0.00	0.00	0.00	19.33	35.66	49.28	35.79	14.53	0.00	0.00	154.59
Oil Crops	0.00	0.00	0.00	1.22	6.35	7.92	5.65	0.00	0.00	0.00	0.00	0.00	21.13
Pulses	0.00	0.00	0.00	0.00	0.00	1.76	4.39	6.14	4.47	0.73	0.00	0.00	17.50
Rice	0.00	0.00	0.00	0.00	0.00	45.17	50.50	46.89	34.17	12.65	0.00	0.00	189.38
Vegetables	0.00	0.00	0.00	0.00	0.00	13.20	18.82	19.26	14.03	6.23	0.00	0.00	71.54
Winter Wheat	0.00	5.19	54.67	149.45	104.19	0.00	0.00	0.00	0.00	0.00	14.61	0.00	328.11
Sum	0.00	5.95	59.61	161.31	121.88	115.29	150.53	155.68	109.17	44.68	17.54	0.00	941.64

By 2085 the crop water requirements are predicted to rise by 9.2 percent, from 586.2 to 643 million m^3. The overall demand, taking into account the contribution of precipitation, is expected to rise by 11.6 percent, from 844 to 942 million m^3.

Estimates of demand are of course quite specific to the particular range of irrigated crops adopted; other cropping patterns would clearly result in quite different values. Nevertheless, the importance of these findings is in revealing that demand is likely to rise by approximately 12 percent by 2070–2099, and this could rise even further if cultivation of either rice of cotton were to expand.

For example, if the irrigated area in sub-basin three were to increase to e.g., 417,870 ha, then the demand for water for the existing climate would be 3.16 km^3 rising by the period 2070–2099 to 3.52 km^3. If half of the newly irrigated area (16,435 ha) and half of the area having improved access to water (49,750 ha) were to be used to cultivate rice instead of winter wheat, the total demand for the existing climate would rise to 4.37 km^3, increasing even further with climate change to 4.84 km^3 by 2070–2099.

Conclusion

Flow data

Until now there has been no consensus on the mean flow in the Amu Darya which originates in Afghanistan. Estimates vary between 8.06 and 21.1 km^3 for Afghanistan as well as Iran (including all three sub-basins). Given that in 1977 the Afghan delegation demanded an allocation of 9 km^3 and the Soviet Union offered 6 km^3, it seems that the debate concerning the contribution of Afghanistan to the flow in the river is not new and has not yet been resolved. Even existing data sets provided by Freenet or KRBP for the same gauging station (but for different time periods) vary so much as to call into question whether these apply to the same river.

In the study we have not considered the issue of decreasing river flows. Despite all the uncertainties, there is general consensus among relevant scientists that the flows in the rivers will diminish.[25] The reductions will be caused by a combination of factors: the shrinkage of the glaciers which are important for maintaining flow during summer; the rising snowline which will free up land on which plants will grow, and more significantly will consume water due to evapotranspiration; the changing patterns of flow as snow, with its slow release during melting, increasingly falls as rainfall encouraging rapid runoff. Estimates of flow reduction across the Amu Darya basin, including the Pyanj, indicate that these are anticipated to be within the range 10–30 percent. The implied

[25] V.G. Konovalov, "Past and prospective Change in State of Central Asian," in *Glaciers in Watershed and Global Hydrology*, International Commission on Snow and Ice Workshop (Austria, August 2007), p. 47-52; D. P. Bedford, *Climate Sensitivity and Water Management In The Upper Amu Darya Basin* (PhD Thesis, the University of Colorado, Boulder, 1997); *The First National Communication of the Republic of Tajikistan to the United Nations Framework Convention on Climate Change* (Dushanbe, 2002): Chapter 4. Projected Impacts and Vulnerability Assessment (National Project Manager Begmurod Makhmadaliev).

shortage of water is certain to have a dramatic effect on plans for the expansion of irrigation in Afghanistan.

Irrigation development

The evaluation of the different projects referred to suggests that water use in Afghanistan is likely to increase in the future. However, most of these projects were based on old Soviet plans, which also reflected the rationale at that time, low electricity prices, and an emphasis of expansion of irrigation at any cost. Hence, only the capital costs of construction were considered. The modern rationale, cost recovery of provided services, and assumed realistic energy costs make it highly unlikely that most of the former identified projects will ever be implemented.

The current deterioration of the security situation in northern Afghanistan also makes it unlikely that the identified dam projects will be implemented. As stated, returnees might have settled in the former surveyed areas. Therefore, it is considered that the irrigated area is unlikely to increase beyond about 420,000 ha, much less than the figure suggested by Zonn, and less than that suggested by Ahmad and Wasiq.

The current water use of 3.07 km^3 estimated by Ahmad and Wasiq is likely to increase with the ongoing rehabilitation of existing projects. With improved access to water, farmers might change from the crops identified by Berkhof and FAO (see Annex for more details) to the cash crop rice, as observed by Thomas and Wegerich. Hence, there is already a likely increase of demand for water from the 99,000 ha of rehabilitated land. With the increase in the number of smaller rehabilitation projects, demand will continue to increase. Taking into consideration the current national focus of the Afghan Water Sector Strategy, it is evident that these projects will affect the total water availability of water for downstream states.

Climate change impacts

The SRA2 climate change scenario considered is only one of several possible climate change scenarios; others predict that temperatures could rise even more, whilst the generality of climate change models suggests that precipitation will, if anything, be less. Based on the SRA2 scenario, our estimates of the grossed up water requirements for the likely increased irrigated area of 417,870 ha will rise for the assumed cropping pattern (based on Berkhof/FAO, see also Table 8) by 0.36 km^3, from 3.16 km^3 to 3.52 km^3 by 2070–2099.

Changing cropping patterns

The likely increase in demand for changing cropping patterns was considered. This assumed that half of the newly irrigated area (16,435 ha) and half of the area having improved access to water (49,750 ha), equating to 66,185 ha, might be used to cultivate rice rather than winter wheat. The analysis indicated that the demand for the existing climate would rise from 3.16 km^3 to 4.37 km^3 and would increase even further with climate change to 4.84 km^3 (by 2070–2099). This indicates that changing cropping patterns could be of potentially more significance than climate change.

Annex: Procedure Used to Determine the Future Demands for Water

The demand for water was established for a representative area in northern Afghanistan (Emam Salieb) with the help of routines available within the software package WEAP (Water Evaluation and Planning System) developed by the Boston Centre of the Stockholm Environment Institute (http://www.weap21.org). WEAP is a water balance accounting programme, but in this case it was only used to facilitate the estimation of the demand for water for irrigation. Demands were determined for the climate in: 1961–1990, a period used by the International Panel on Climate Change (IPCC) as a reference for the existing climate as well as the climate predicted to exist in the period 2070–2099. The future time period was chosen as being a time which those born today can expect to experience in their lifetime.

WEAP uses the FAO Cropwat routines to determine crop water requirements (FAO, 1998). Input data includes the mean monthly reference crop (grass) potential evapotranspiration, the mean monthly precipitation, the range and distribution of crops, as well as the crop growth factors.

Table 5. Climatic Data for Emam Salieb (1961-1990):- Source IWMI Climate Summary Service

Emam Saheb-Afghanistan (Lat 37 є 11 ' 13 " N Long 68 є 53 ' 54 " E)

	P50 (Mm/month)	Rainfall (P75) (mm/month)	Temp (mean) (deg. C)	(DTR) (deg. C)	Ref Humid (%)	Sunshine (% of Hrs)	Wind Run (m/s)	Penman ETo (mm/day)
Jan	37.81	23.19	2.10	9.10	76.00	38.00	1.70	0.81
Feb	48.36	32.08	4.90	9.70	73.00	40.00	1.90	1.28
Mar	70.77	49.15	10.70	10.50	70.00	44.00	2.10	2.21
Apr	50.61	32.79	17.10	11.90	66.00	52.00	2.00	3.54
May	26.27	13.47	22.20	14.10	53.00	65.00	2.00	5.30
Jun	0.13	0.01	27.80	16.40	34.00	77.00	2.40	7.69
Jul	0.02	0.00	29.70	16.10	31.00	78.00	2.50	8.09
Aug	0.00	0.00	27.70	16.20	32.00	78.00	2.40	7.12
Sep	0.00	0.00	22.80	14.90	35.00	78.00	2.20	5.36
Oct	4.11	0.92	16.80	14.90	46.00	66.00	2.00	3.21
Nov	16.74	7.16	10.00	12.70	61.00	57.00	1.60	1.54
Dec	25.09	12.86	4.90	10.00	72.00	40.00	1.50	0.88

Data from IWMI Water& Climate Atlas (www.iwmi.org)

The climatic data for the period 1961–1990 was derived for the Emam Salieb area from the IWMI Digital World Water Atlas (IWMI, 2007: see

Table 5). Values for the reference potential evapotranspiration (shown as ET_o in Table 5) were then re-calculated using the Penman procedure (Penman, 1963) within the FAO "CropWat for Windows" programme (FAO, 1998 and Clarke et al, 2000), to ensure consistency between the values applicable to the existing climate and those in 2070–2099.

The range of crops was developed from reports by Berkof (2004) and FAO (FAO AQUASTAT) for Afghanistan. Crop growth factors, k_c factors, needed to convert the reference crop potential evapotranspiration into the individual crop water requirements were also derived from FAO guidelines (FAO, 1998). Both sets of values are detailed in the following two Tables:-

Table 6. The Range and Distribution of Crops Adopted for Emam Salieb

	Assumed Area Distribution of Crops for Emam Salieb, % 111,600 ha									
Crop	Cotton	Winter Wheat	Fruits	Fodder	Veg	Maize	Barley	Pulses	Rice	Oil Crops
% Area	3	62.5	3.8	6.1	3	8	4.1	1	7	1.5

Table 7. The Crop Growth Factors (k_c) Used to Determine Crop Water Requirements (k_c Factors Based on FAO Guidelines FAO, 1998)

Kc (monthly)	Crop Growth Factors (k_c)to convert Reference Crop (grass) Evapotranspiration into the Evapotranspiration by the Crops											
Crop	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
W Wheat	0.65	0.95	1.15	1.15	0.5	0	0	0	0	0	0.4	0.4
Maize	0	0	0	0	0	0.4	0.7	1.1	1.1	0.7	0	0
Barley	0.4	1	1	0.5	0	0	0	0	0	0	0	0.4
Pulses	0	0	0	0	0	0.3	0.7	1.1	0.8	0.3	0	0
Vegetables	0	0	0	0	0	0.75	1	1.15	1	0.7	0	0
Cotton	0	0	0	0	0.5	0.7	0.9	1.15	1	0.8	0.6	0
Fodder	0.4	0.9	0.9	0.8	0	0	0	0	0	0	0.4	0.4
Rice	0	0	0	0	0	1.1	1.15	1.2	1.2	0.6	0	0
Oil Crops	0	0	0.35	0.6	1.1	0.9	0.6	0	0	0	0	0
Citrus	0	0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0	0
Grapes	0	0	0	0.3	0.5	0.7	0.7	0.7	0.6	0.45	0	0
Orchards	0	0	0	0.3	0.7	0.9	0.95	0.95	0.85	0.7	0	0

The impact of climate change was confined to considering the impact of rising temperatures. No attempt was made to consider changes of precipitation, partly because such predictions are generally considered unreliable; whilst in addition precipitation is low and its contribution to crop water requirements minimal, particularly in relation to the water needing to be provided by irrigation. In the calculations, eighty percent of the monthly precipitation (80 percent of the P_{50} values in Table 5) has been considered to be effective in meeting crop water requirements.

The increases in monthly temperatures due to climate change (1961–1990 to 2070–2099) have been derived from the most recent 4th Assessment Report of the IPCC, for the scenario judged to correspond most closely to recent patterns of climate change in Central Asia (the A2 storyline). The increases, termed anomalies, are the means of the monthly values based on seven global circulation models[26] included in the IPCC 4th Assessment for the Emam Salieb area (see Table 8).

Table 8. IPCC 4th Assessment: Mean Monthly Temperature Anomalies for the SRA2 Climate Change Scenario: 1961–1990 to 2070–2099 for the Emam Salieb Area; Means Based on 7 Global Circulation Models

Grid Centre: **37.50°N, 67.50°E**	
	30 Year 2m Mean Surface Temperature (TAS) Anomalies 1961-1990 to 2070-2099, for the SRA2 Climate Change Scenario, means based on 7 National Gobal Circulation Models °C
January	4.64
February	4.04
March	4.40
April	4.58
May	4.82
June	5.81
July	5.03
August	5.35
September	5.21
October	4.51
November	4.30
December	4.04

These values were then used to amend the temperatures within the IWMI climate file (Table 5) before being processed using the CropWat for Windows programme to determine revised values of reference crop potential evapotranspiration applicable to 2070–2099 (Table 9).

[26] CCSM3; NRM-CM3; CSIRO-MK3; ECHAM5; GFDL-CM2; HadCM3; MIROC3.2

Table 9. Reference Crop (Grass) Mean Monthly Potential Evapotranspiration Rates:- Climate in 1961–1990 and 2070–2099

	Mean Reference Crop (grass) Potential Evapotranspiration (ETo), mm/month Emam Salieb	
	1961-1990	2070-2099
January	28.52	34.1
February	39.48	44.8
March	73.47	83.7
April	112.5	129
May	171.74	192.2
June	236.1	264
July	256.06	282.1
August	225.37	251.1
September	163.2	183
October	106.64	120.9
November	51.3	60
December	30.69	34.1

The potential evapotranspiration (the crop water requirements) for the individual crops grown was then determined using WEAP (Table 4). The demand for irrigation (Table 5) was then established by summating the individual elements of crop water requirement and increasing them (in this case by the factor 2) to allow for the reported irrigation efficiency of 50 percent.