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Climate change and international water conflict in Central Asia

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Abstract

We engage in a critical assessment of the neo-malthusian claim that climatic changes can be an important source of international tensions, in the extreme even militarized interstate disputes. The most likely scenario is conflict over water allocation in international catchments shared by poorer, less democratic, and politically less stable countries, governed by weak international water management institutions, and exposed to severe climatic changes. The Syr Darya corresponds quite well to all these characteristics. If the neo-malthusian specter of conflict over water is empirically relevant, we should see signs of this in the Syr Darya. The riparian countries of the Aral Sea basin have experienced international disputes over water allocation ever since the USSR collapsed and, with it, existing water management institutions and funding. The worst such dispute concerns the Syr Darya, one of the two largest rivers in Central Asia. Based on hydrological data and other information we find that the only existing international water management institution in the Syr Darya has failed. Based on a coupled climate, land-ice and rainfall-runoff model for the Syr Darya, we then examine whether, in the absence of an effective international water allocation mechanism, climate change is likely to make existing international tensions over water allocation worse. We find that climate change-induced shifts in river runoff, to which the Uzbek part of the Syr Darya catchment is particularly vulnerable, and which could contribute to a deterioration of already strained Kyrgyz–Uzbek relations, are likely to set in only in the medium to long term. This leaves some time for the riparian countries to set up an effective international framework for water allocation and prevention of climate-induced geohazards. By implication, our findings suggest that a climate change-induced militarized interstate dispute over water resources in Central Asia is unlikely.

Keywords

Central Asia, climate change, conflict, international river, Syr Darya, water

Introduction

Existing research shows that one of the most important social and political risks associated with climate change pertains to water availability. It also shows, in this context, that the greatest risk of international disputes and perhaps even militarized interstate conflict is likely to materialize in international water systems located in poor and politically unstable parts of the world (Bernauer & Kalbhenn, 2010; Dinar & Dinar, 2003; Wolf, Yoffe & Giordano, 2003).

In this article we focus on one of the potentially most problematic cases in this respect, the Syr Darya river basin in Central Asia. As noted by Smith: ‘Nowhere in

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the world is the potential for conflict over the use of natural resources as strong as in Central Asia' (Smith, 1995).[1] We engage in a critical assessment of this claim, both by studying, ex post, international water allocation problems in the Syr Darya, and by examining, ex ante, whether climatic changes are likely to make existing international tensions worse in future. The underlying logic is that, if the neo-malthusian claim of international water wars is empirically relevant, we should see signs of this in the Syr Darya.

Large-N statistical research on international river basins is very useful for identifying general patterns, for instance whether greater water scarcity is associated with more political or even armed conflict (Brochmann & Hensel, 2009; Dombrowsky, 2007; Gleditsch et al., 2006). Nonetheless, studies of individual international river systems, though weaker in terms of their ability to produce highly generalizable results, offer more detailed insights into dynamic processes that evolve between changing environmental conditions and human efforts to cope with those changes (Bernauer, 2002; Dinar & Dinar, 2003; Wolf, 1998) – hence our focus on a single and, arguably, critical case.

No existing event dataset on international river basin conflict and cooperation (Wolf et al. 2003; Bernauer & Kalbhenn, 2010) records an armed international conflict over water resources in Central Asia. In fact, the standard datasets on war, notably the UCDP/PRIO and Correlates of War datasets, do not record any international armed conflict, more broadly defined, in this region – though there have been several internal armed conflicts (not apparently water-related) in Central Asia over the past two decades.

We should, however, not jump too quickly from such conflict data to the conclusion that the neo-malthusian water wars claim is empirically irrelevant. The absence of international armed conflict among the Syr Darya countries could reflect successful institutionalized solutions to international water allocation problems. It could also reflect geophysical processes that have mitigated water scarcity and thus the potential for international water conflict. Moreover, data on conflict in the past may not tell us much about what the future holds, particularly in cases where climatic changes could have strong negative impacts on water availability. In-depth analysis of the neo-malthusian water conflict claim thus requires both an analysis of water allocation policy and institutions, and an analysis of hydro-climatological processes. This is the research agenda we pursue in this article.

Specifically, we are interested in studying two important propositions that are widely shared by observers of water problems in Central Asia (Swarup, 2009; Hodgson, 2010; Maplecroft, 2010; Perelet, 2007): first, that the water allocation problem in the Syr Darya basin is highly conflict-prone and attempts to solve the problem have thus far failed; second, that climate change will exacerbate the problem.

Our results show that the answer to the first question is: Yes. The answer to the second is, perhaps surprisingly: probably not as much as most observers think, at least in the short to medium term. The latter finding offers some room for optimism that policymakers of the riparian countries can set up an effective international water management system before the most severe climate change-related problems (primarily significant changes in the seasonality of runoff and geohazards) hit the region.

The next section describes the water allocation problem. We then examine the existing international water allocation system in the Syr Darya and assess its effectiveness. The following section looks at the implications of climate change.

Water–energy–food nexus and its history in Central Asia

The two major rivers of Central Asia, the Amu Darya and Syr Darya (Figure 1), were domestic rivers in the USSR until the latter broke down and disappeared in 1991. The two rivers thus turned from domestic into international water systems virtually over night.

The Syr Darya river, on which we focus in this article, originates as the Naryn river in the mountains of Kyrgyzstan. It then flows through Uzbekistan, Tajikistan and Kazakhstan where it drains into the Aral Sea. Its total length is around 2,800 km. Around 20 million people inhabit this river catchment, which covers an area of around 400,000 km^2. More than 75% of total runoff is generated in the upstream mountainous terrain on Kyrgyz territory, as the river is mainly fed by glacier- and snowmelt. The natural runoff pattern, with annual flows of 23.5–51 km^3 (around 40 km^3 in the past decade), is characterized by a spring/summer flood that usually starts in April and peaks in June or July. Around 90% of the Syr Darya's mean annual flow is regulated by reservoirs.

[1] Most studies of this kind use the word 'conflict' without defining it clearly. Most of them appear to refer to a large spectrum of conflictual interactions between states that may range from mutual accusations and diplomatic tensions all the way to what popular quantitative datasets define as militarized interstate disputes. We use words such as 'dispute', 'tension', and 'conflict' when referring to non-militarized conflicts between states, and the term 'militarized interstate dispute' or 'international armed conflict' when armed violence between state actors is involved.

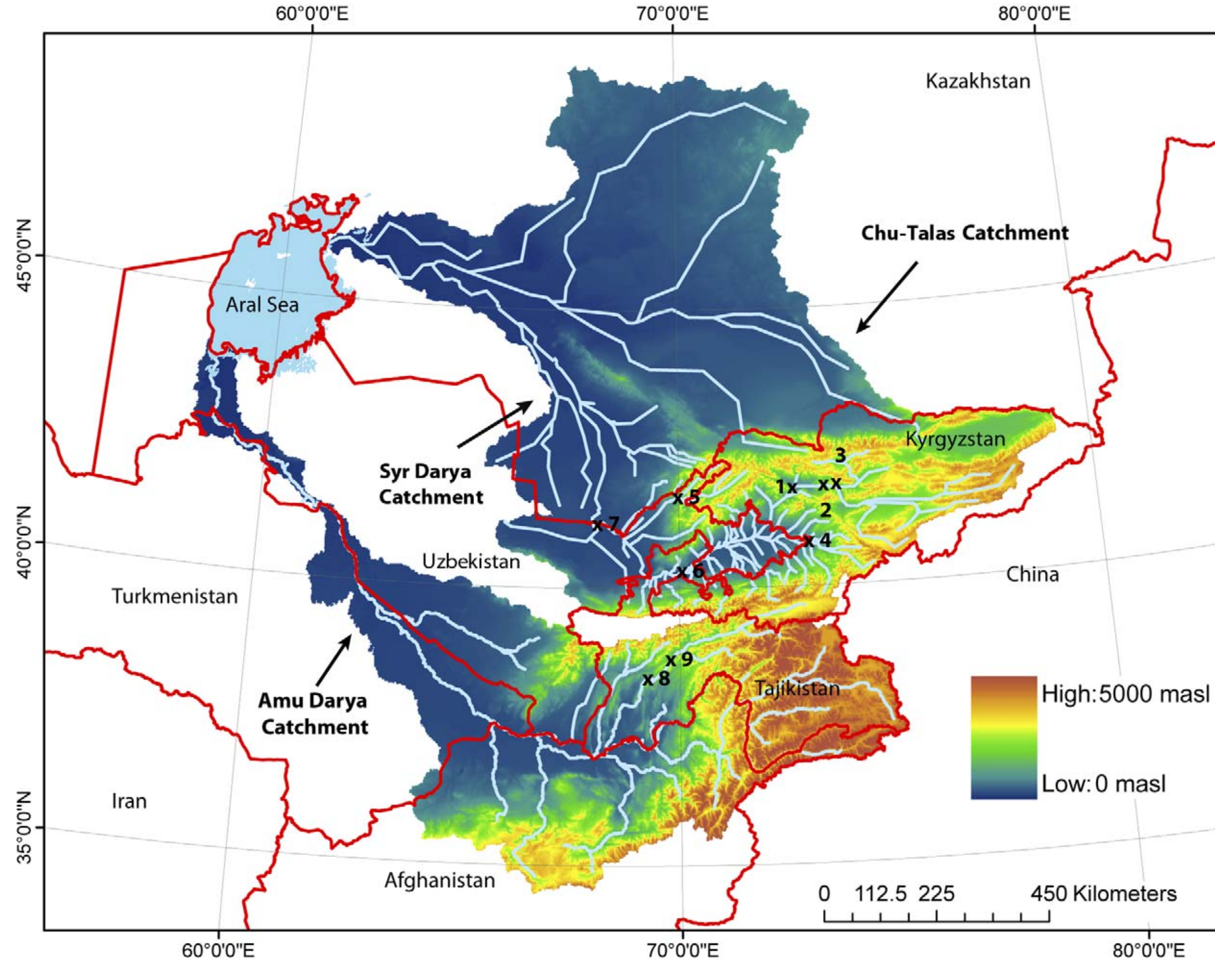

Figure 1. Map of Central Asia with major river catchments. Amu Darya, Syr Darya, and Chu-Talas are shown together with basin topographies

Locations of major dams are indicated with crosses. 1: Toktogul, 2: Kambarata II (construction completed), 3: Kambarata I (planned), 4: Andijan, 5: Charvak, 6: Kayrakum, 7: Chardara, 8: Nurek, 9: Rogun (planned). A color version of this Figure is shown in online Appendix Figure A.1, available at http://www.prio.no/jpr/datasets.

Decisionmakers in the USSR realized that the abundant water resources of Kyrgyzstan, together with a favorable topography, make the country exceptionally rich in water storage and hydropower potential. At the same time, the vast low-lying steppes in the midstream and downstream reaches of the Syr Darya (nowadays Uzbekistan and Kazakhstan) could be turned into centers of irrigated agricultural production (Dukhovny & Sokolov, 2003; Savoskul et al., 2003). Hence the USSR began to develop large-scale irrigated agriculture, particularly cotton and wheat production, in the Stalinist period and under Khrushchev in the mid-1950s. The major irrigated agricultural areas at present are the densely populated and ethno-politically unstable Fergana Valley in Uzbekistan and the Kyzylorda and South Kazakhstan oblasts in the Syr Darya catchment in Kazakhstan. The policy of turning Central Asia into a major irrigation economy ultimately led to the desiccation of the Aral Sea, with highly adverse social, economic and environmental consequences in the region (Micklin, 1988).[2]

[2] Both Uzbekistan and Kazakhstan are experiencing major problems with soil fertility due to negative effects of chronic salinization of heavily irrigated lands in places with insufficient and/or defunct drainage systems (personal communication: Yakovlev, Dronin, 5 January 2011. A list of all stakeholders interviewed for this article is shown in Appendix Table A.I, available at http://www.prio.no/jpr/datasets). The environmental disaster of the Aral Sea is imposing a heavy burden on Kazakhstan, notwithstanding concerted international and regional aid and the recent restoration of water levels in the north-eastern part of the Aral Sea basin after construction of the Kok-Aral dam (Burton, 2006; Micklin, 1988).

By 1960, the irrigated land area in the Syr Darya basin had reached around 2 million hectares (ha) and grew to about 3.3 million ha by 1990. With slightly more than 300 persons/km^2, Kazakhstan has a significantly lower labor intensity per permanently cropped area on its territory in the Syr Darya catchment, as compared to more than 600 persons/km^2 in Uzbekistan. From 1996 onwards, total agricultural output in the Kazakh part of the Syr Darya catchment increased to 2–3 million tons in 2009, whereas total agricultural production has been stagnating on the Uzbek side at around 8–9 million tons.[3]

Kazakhstan, like Uzbekistan, is a major hydrocarbon producer in the region. However, only a small fraction of Kazakhstan's GDP is generated in the agricultural sector, that is, 6% or USD 10.9 billion (2009 prices, PPP), as compared to 22% or USD 17.1 billion in Uzbekistan (CIA, 2011). In the Syr Darya catchment in the vicinity of the Fergana Valley, approximately 50% of the total Uzbek population live on 8.7% of the total national territory (39,000 km^2 out of 447,000 km^2). There, more than 40% of the total land area is irrigated. On the Kazakh side of the Syr Darya catchment, in the oblasts Kyzylorda and South Kazakhstan, 20% of the total Kazakh population live on 12.6% of its national territory (344,600 km^2 of 2,724,900 km^2) of which about 2% is irrigated.[4] Thus, unlike Uzbekistan, where the rural population is expected to increase by 60% from 1991 to 2020, Kazakhstan faces no population pressure in the agricultural sector as its agricultural population is expected to decline by approximately 16% over the next 10 years (FAO, 2011).

These differences between the two main downstream countries in the Syr Darya are crucial with respect to international water allocation: Uzbekistan is much more sensitive to changes in water availability than Kazakhstan. Not surprisingly then, the most severe international allocation disputes in the Syr Darya basin have materialized between Kyrgyzstan and Uzbekistan.

The management history of the Syr Darya is, at least in part, visible in the hydrological data (Siegfried & Bernauer, 2007). Runoff at the Uch Kurgan gauge station, which is located at the foot of the Naryn/Syr Darya cascade shortly after the river enters Uzbekistan from Kyrgyzstan, fluctuates strongly over time. It is characterized by four distinct periods, that is, natural runoff and Periods 1–3 as shown in Figure 2.

Until 1974, the runoff was largely natural, that is, determined by seasonal and climatic variability, with a high interannual variability in summer runoff and a mean flow of around 390 m^3/s. A major change in flow patterns set in with the commissioning of the Toktogul reservoir in 1974. This event marks the beginning of what one could label the first river management period (1974–90). This period was characterized by centralized management by the USSR of the Naryn/Syr Darya cascade and the river basin as a whole. The Toktogul dam is by far the largest water storage facility in the Aral Sea basin, with a total volume of ca. 19.5 km^3. It accounts for more than half of the total usable reservoir capacity in the entire Naryn/Syr Darya Basin. The reservoir area is around 280 km^2, its length around 65 km. The capacity of the Toktogul hydropower plant is 1,200 MW, that is, the second biggest in the Aral Sea basin (Antipova et al., 2002). After the commissioning of the dam, a general attenuation of peak downstream flows can be observed and an overall decline of monthly flow variability set in due to targeted releases (Figure 2).

From 1974 to 1990, the management system for the Syr Darya was primarily oriented towards water provision for irrigated agriculture (above all, cotton and wheat production) in Uzbekistan and Kazakhstan. Consequently, the timing of winter and summer flow releases did not change substantially compared to the natural runoff pattern, where peak flows also occur in the agricultural growing season. This water allocation pattern is visible in the hydrograph, where the in- and outflows to and from the Toktogul reservoir are in phase (Siegfried & Bernauer, 2007).

After a severe drought in the early 1980s, the USSR set up a river basin organization for the Naryn/Syr Darya, with headquarters in Tashkent, Uzbekistan. Its mandate was to operate and maintain all head water structures with a discharge of more than 10 m^3/s. This management system and its infrastructure were funded from the federal budget of the USSR. In consultation with the governments of the riparian Soviet republics and based on forecasts by the Central Asia Gidromet Service, the ministry of water resources (Minvodkhoz) in Moscow defined annually (based on a multi-year master plan) how much water was to be released for irrigation during the growing season (April to September). On top of that, overall annual water use from the Syr Darya was limited to 10 km^3 for Uzbekistan, 10 km^3 for

[3] Statistics for the Uzbek part of the Syr Darya catchment cover the oblasts Syrdarya, Tashkent, Namangan, Andijan, and Fergana. Population and agricultural data for Kazakhstan and Uzbekistan are taken from http://www.cawater-info.net/data_ca/.

[4] See footnote 3.

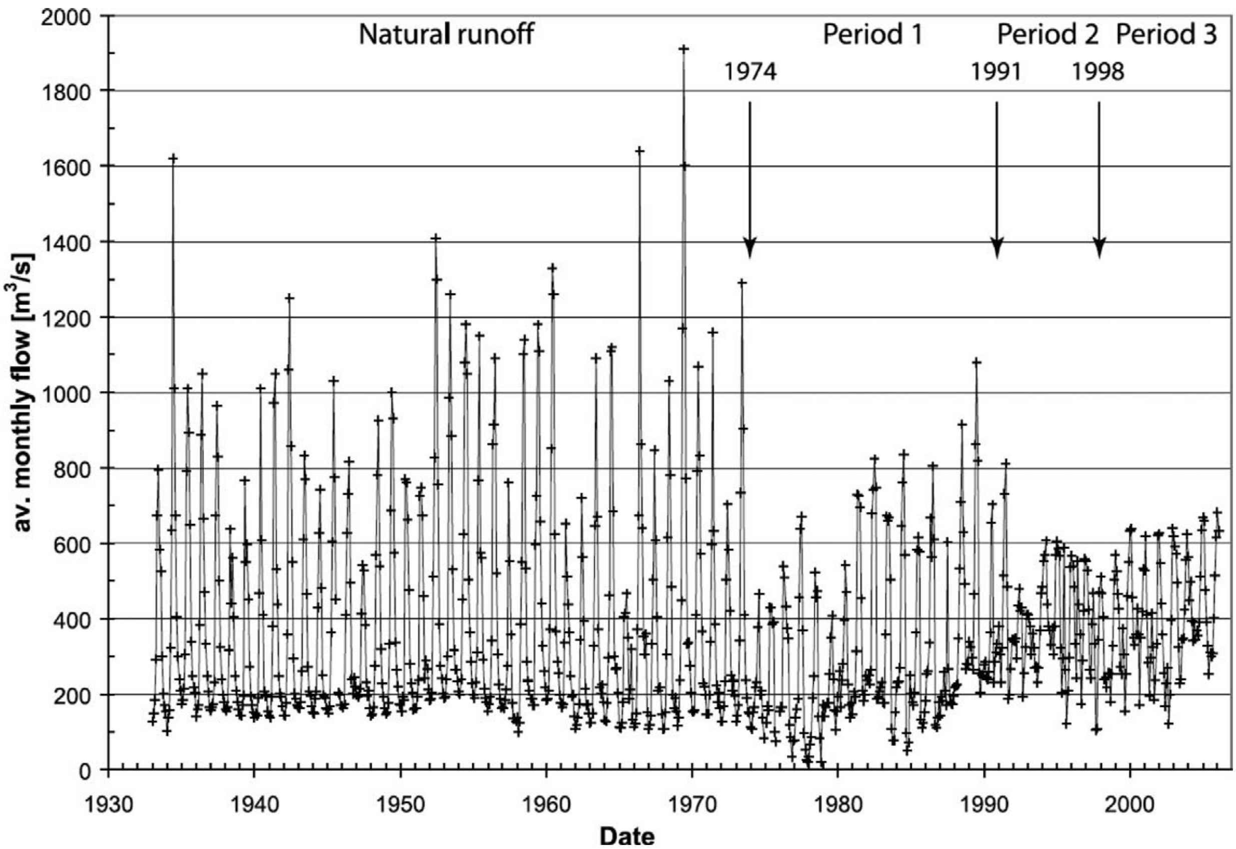

Figure 2. Mean monthly flow of the Naryn/Syr Darya river at the Uch Kurgan gauge
Period 1: USSR period. Period 2: Post-independence period. Period 3: Post-1998 agreement period. Data Sources: Uzbek Hydrometeorological Service (Gidromet) and Portal of Knowledge for Water and Environmental Issues in Central Asia (http://www.cawater-info.net/index_e.htm).

Kazakhstan, 0.4 km^3 for Kyrgyzstan, and 1.8 km^3 for Tajikistan, that is, 22 km^3 in total (Protocol no. 413, issued by the USSR in February 1984). The river basin organization also had the authority to increase or reduce allocations to each Soviet republic by up to 10%, depending on anticipated climatic conditions, reservoir levels, and other factors. The electricity produced at Toktogul during that period went into the Central Asian Energy Pool and was shared among the riparian republics. The neighboring republics supplied coal, oil, and gas to Kyrgyzstan in winter to cover increased Kyrgyz energy demand for heating during the colder months (Antipova et al., 2002; McKinney, 2004; McKinney & Kenshimov, 2000; Weinthal, 2002).

The collapse of the USSR led to a breakdown of this centralized water and energy resources management and sharing system. Coal, oil, gas, and electricity supplies from the downstream countries to Kyrgyzstan declined dramatically from 1991 onwards (Wegerich, 2004). As a consequence, thermal and electric power output of Kyrgyz thermal power plants,[5] which had hitherto operated largely with low-cost or even free fossil fuels imported from Uzbekistan and Kazakhstan, fell dramatically.[6] To compensate for the drastic loss in imported primary and secondary energy, Kyrgyzstan changed the operation of the Toktogul reservoir from an irrigation to an electric power production mode (see Period 2 in Figure 2). The hydropower share in the total energy

[5] The main thermal power plants in Kyrgyzstan are located in Bishkek and Osh. The capacities of the Bishkek plant and the Osh plant are around 660 MW and 50 MW, respectively, though both plants have been running well below that capacity in the past decade (personal communication: Nazarov, Aliev; see also Table A.I).

[6] The electricity output dropped from 4,108 GWh in 1988 to 1,631 and then to 982 GWh in 1998 and 1999, respectively. The thermal power output dropped from 5,145 thousand Gcal to 2,716 and then 2,054 Gcal in those years (Antipova et al., 2002).

supply of Kyrgyzstan grew to around 90%. This change, in turn, has led to severe upstream–downstream conflict.

Upstream interests deriving from seasonal water demands are diametrically opposed to downstream water demands and interests. Kyrgyzstan has, since 1991, sought to store water in spring to autumn and release this water in winter to spring for hydropower production when demand for electricity is highest. Conversely, downstream Uzbekistan and Kazakhstan, by far the largest consumers of irrigation water in the basin, are interested in obtaining sufficient amounts of water during the growing season from April to September. A second priority for them is to obtain minimal winter runoff due to the threat of catastrophic flooding caused by collapsing ice dams in the often frozen river and its tributaries (Savoskul et al., 2003).

The principal challenge in the Syr Darya therefore pertains to coordinating the management of the Naryn/Syr Darya cascade of reservoirs, which are located entirely in Kyrgyzstan, and in particular the handling of trade-offs between consumptive water use for downstream irrigation in summer and non-consumptive use for upstream energy production in Kyrgyzstan in winter.

The Syr Darya water–energy–food nexus is viewed by the riparian countries also in terms of an important national security issue (Gleick, 1993; Hodgson, 2010; Weinthal, 2002). From the Uzbek perspective, people and agriculture in the Fergana Valley are almost entirely dependent on the Syr Darya's water entering the country from Kyrgyzstan; and this water supply is not only controlled by natural variability, but also by a large Soviet-area hydraulic infrastructure whose operation is almost entirely in the hands of the upstream country. This hydro-political setting has been causing great anxiety, particularly among Uzbek policymakers, ever since the country became independent. These concerns have grown further since Kyrgyzstan revived Soviet-era plans to develop two additional reservoir and hydropower production sites, Kambarata I and II, a few kilometers upstream of the Naryn's inflow into the Toktogul reservoir.[7]

Kazakhstan too, being the most downstream country in the Syr Darya, faces several inter-related water challenges. Similarly to mid-stream Uzbekistan, it is primarily concerned with ensuring access to sufficient amounts of river water for irrigation in the summer, and with controlled low-flow in the winter months for effective flood control. Moreover, Kazakhstan is very concerned with river water quality since a large fraction of its population in the catchment uses the river water for household purposes. As the river accumulates total dissolved solids and pesticides and herbicides from irrigation drainage return flows (mainly from the cotton fields in Uzbekistan), and as its waters have become ever more allocated along the flow path, maintaining river water quality targets has become increasingly difficult for Kazakhstan in recent years (Shalpykova, 2002).

The Syr Darya setting is in fact quite unique in comparison to other prominent international water catchments that appear conflict prone. In the Nile, for instance, there is a rather strong downstream hegemony. The downstream country (Egypt) is the militarily and economically most powerful country in the system, and it also controls the main water storage capacity (Aswan dam) (Howell & Allan, 1994; Zeitoun & Warner, 2006). In the Euphrates-Tigris, the upstream country (Turkey) is also the most powerful country in the system and in control of the main reservoirs (Daoudy, 2009; Kibaroğlu, 2002). The Syr Darya setting is arguably less hegemonic and thus potentially more unstable politically; the dominant economic and military powers (Uzbekistan and Kazakhstan), which also face the most severe water security risks, are located downstream, whereas the upstream country is in almost total physical control of the catchment's runoff.[8]

At the most general level, many game theoretic and also empirical studies have shown that upstream–downstream conflicts such as the one in the Syr Darya are difficult to solve (Ambec & Ehlers, 2008; Ambec & Sprumont, 2002; Bernauer, 2002; Bernauer & Kalbhenn, 2010). The Syr Darya situation is particularly complex for the reasons outlined above. Such upstream–downstream conflicts can, in principle, be solved by installing adequate compensation mechanisms (Abbink, Moller & O'Hara, 2005; Bernauer, 1995; Dinar, 2006; Kilgour & Dinar, 1995; Moller, 2004). However, the transactions costs of reaching such deals can be very high. They usually increase

[7] Personal communication: Dukhovny, Maag; see also Figure 1 for the location of the new dams.

[8] The Composite Index of National Capability (CINC), a popular index in political science for measuring the material capabilities of countries for projecting power, has Kazakhstan as the most powerful country in the Syr Darya basin using 1991–2007 averages. If we set the value of this variable for Kazakhstan to 100%, the capabilities of Uzbekistan are 73%, and those of Kyrgyzstan and Tajikistan 11% each (Sarkees & Wayman, 2010). Moreover, Kyrgyzstan's water storage capacity (approximately 24.81 km^3 in total) is almost equivalent to the Syr Darya's total long-term average annual runoff measured at the inflow to the Aral Sea, not accounting for consumptive upstream allocation (approximately 30 km^3 per annum).

Table I. Water release schedule in the 1998 Agreement

Month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
q [m^3/s]	495	490	300	230	270	500	650	600	190	185	395	460
q [km^3/month]	1.33	1.23	0.8	0.6	0.72	1.3	1.74	1.61	0.49	0.5	1.02	1.23

Sources: http://ocid.nacse.org/tfdd/treaties.php?BCODE=ARAL&GET=tfdd and information obtained from water management authorities in Uzbekistan and Kyrgyzstan (Zyrianov, Yakovlev, Chub, and Dukhovny).
Total water releases during the vegetation season amount to 6.32 km^3 (April–September) as compared to 6.03 km^3 during the non-vegetation season (October–December and January–March).

when general political relations between the riparian countries are poor. The main reasons are that poor relations are associated with low levels of trust, and low levels of trust normally lead to more acrimonious distributional bargaining and exacerbate time-inconsistency problems in implementing agreements. All these problems are clearly visible in the Syr Darya case.

Multilateral arrangements versus unilateral action

International negotiations on managing the Syr Darya began shortly after the demise of the USSR. In February 1992, the newly independent riparian countries of the Syr Darya basin set up the Inter-State Commission for Water Coordination (ICWC). They agreed to keep the water allocation principles of the former USSR in place until a new system could be established, albeit without the funding for the infrastructure that had formerly come from Moscow. The most important hydraulic structures, and in particular the biggest reservoirs in the basin (including Toktogul), were not put under the control of the ICWC. That is, they were de facto nationalized by the riparian countries.

From 1995 the riparian countries negotiated, annually, bilateral agreements on water releases and energy exchanges. In March 1998, under the aegis of the Executive Committee of the Central Asian Economic Community, Kazakhstan, Kyrgyzstan, and Uzbekistan signed a trilateral agreement. This agreement marks the beginning of Period 3, as defined in Figure 2. In 1999 Tajikistan joined this agreement. The 1998 agreement follows the approach of earlier bilateral agreements. It includes quantitative targets for monthly water releases from the Toktogul reservoir (Table I).

Moreover, the agreement holds that in the growing season (April–October), Kyrgyzstan will supply 2,200 million kWh of hydropower electricity to Kazakhstan and Uzbekistan (1,100 million kWh each). Kazakhstan and Uzbekistan, in exchange, agree to deliver specific amounts of electricity, gas, fuel oil, and coal to Kyrgyzstan in certain months under conditions set forth in earlier bilateral agreements. A framework agreement, also concluded in March 1998, holds that these exchanges will subsequently be specified each year through negotiations.

The reasoning behind this exchange is the following. Kyrgyzstan needs to release around 3.5 km^3 from Toktogul to meet its energy requirements in April to September, and around 8.5 km^3 in October to March. The downstream countries, in turn, need around 6 km^3 in April to September, but no water in winter. Natural constraints limit possible water releases from Toktogul to a total of around 12 km^3 per year. To meet downstream needs, a shift, compared to what Kyrgyzstan would prefer, of around 2.5 km^3 from the October to March period to the April to September period is required. Total releases of around 2.5 km^3 can generate electricity in the order of 2,200 million kWh. This implies that Kyrgyzstan can export around 2,200 million kWh in excess electricity in the form of cheap hydropower to the downstream countries in the growing season and get compensated for this amount in the winter season.[9]

The implementation of the 1998 agreement can be evaluated based on hydrological data, energy trade data, and expert interviews. Our analysis of this information strongly suggests that the 1998 agreement has, thus far, failed to solve the problem of effective water and energy resources sharing.

Table A.II in the online Appendix presents seasonal outflows of the Toktogul reservoir as well as deviations from the 1998 agreement. The summer releases have closely followed the levels agreed prior to 2008. In this year though, there was a strong negative precipitation anomaly, most probably related to the strong warm phase of the El Niño-Southern Oscillation (ENSO) at that time (Cane, 2010).[10] After that, compliance has remained very low as seasonal releases became more and more skewed towards the winter in favor of hydroelectric

[9] Personal communication: Zyrianov, Yakovlev, Chub, Dukhovny.
[10] ENSO is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales.

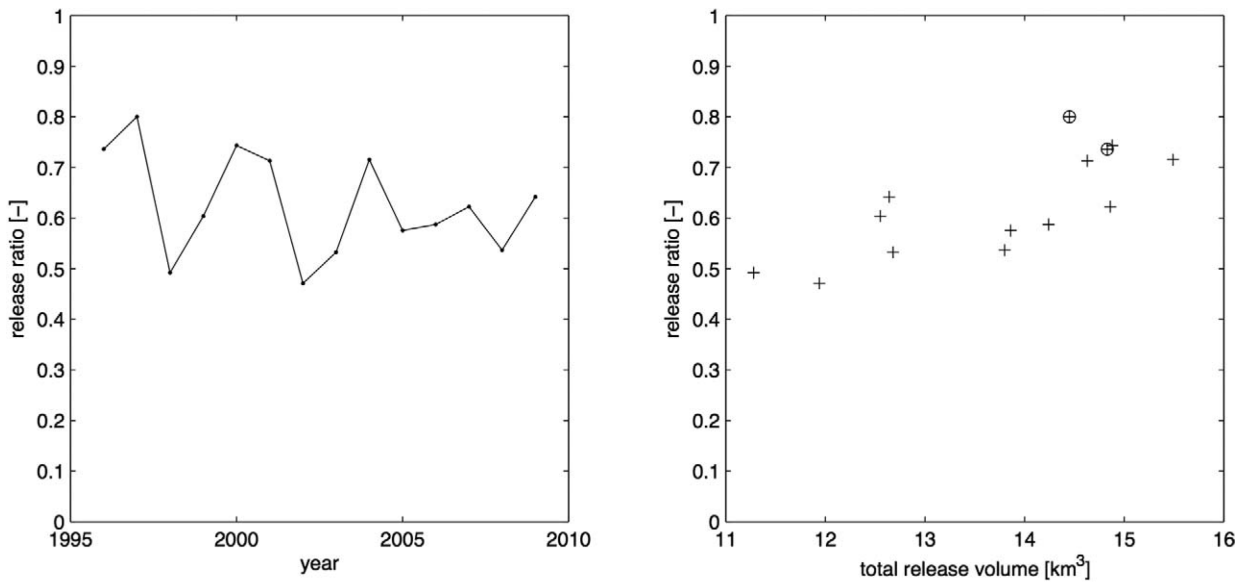

Figure 3. Left panel: release ratios of summer releases versus prior season winter releases in 1996–2009. Right panel: scatterplot of total annual release volumes versus release ratios as shown in the left panel (circles indicate 1996 and 1997 data)

production for Kyrgyzstan.[11] As shown in Figure 3, the high interannual variability of releases points to the fact that the multi-year storage at Toktogul is ineffectively managed. In addition, Figure 3 shows that there is a strong positive correlation between summer releases as a fraction of previous season non-vegetation period releases and total release volume. Hence, when unfavorable hydrological conditions force a reduction in annual release volumes, the downstream suffers disproportionally. This effect is certainly among the reasons why downstream stakeholders have in recent years become increasingly worried about the overall system's management.[12]

Data on electricity exports from Kyrgyzstan to Uzbekistan point in the same direction. Table II shows that these exports dropped to 523 million kWh in 2002 and to zero in 2004–06. After a short recovery in 2007 they again dropped to zero and have not picked up again since.[13] Fossil fuel trade data between the riparian states is harder to track than electricity trade. Table A.III in the Appendix shows Kyrgyz energy imports and exports from/to Uzbekistan and Kazakhstan from 1991 to 1999. This information suggests that compliance with bilateral targets before the 1998 agreement and during the starting phase of this agreement has been incomplete at best. No systematic information exists for the period after 1999. Our interviews with decisionmakers in Bishkek and Tashkent in June 2009 strongly suggest, however, that in most years since 1999, negotiations did not take place, failed to produce specific targets, or set targets that were not met.

These hydrocarbon trade data are important because the 1998 agreement has been conceptualized primarily as an energy-for-energy, rather than a water-for-energy exchange. The reason is that, despite repeated requests by Kyrgyzstan that Uzbekistan pay for upstream water releases, Uzbekistan insists that it is, according to international conventions dealing with transboundary freshwater catchments,[14] entitled to receive a fair share of the Syr Darya's waters. Hence it refuses to pay for water per se.

Kazakhstan has followed a more conciliatory policy with respect to water–energy exchanges with Kyrgyzstan. The principal reason, as noted further above, is that Kazakhstan's economy and population are less sensitive to Kyrgyzstan's dam operations than Uzbekistan's.

[11] Elsewhere, we have developed a methodology for assessing the performance of international institutions and have applied this methodology to the Syr Darya (Siegfried & Bernauer, 2007). The results of this assessment show that the 1998 agreement has been ineffective in dealing with the water allocation conflict.

[12] Based on interviews with the persons listed in online Appendix Table A.I.

[13] Whether these data are accurate is, like in the case of any energy trade data from Central Asian countries, not entirely clear. For instance, there are rumors that considerable amounts of energy trade occur outside the official accounts. In fact, one recent initiative of the new Kyrgyz government seeks to establish more transparency and accountability in the energy sector (http://www.eurasianet.org/node/61653).

[14] See, for example, the 1966 Helsinki Rules: http://www.internationalwaterlaw.org/documents/intldocs/helsinki_rules.html.

Table II. Electricity exports from Kyrgyzstan to Uzbekistan

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Exports(million kWh)	1,926	1,038	523	258	0	0	0	2,380	543	864

Sources: Ministry of Industry, Energy and Fuel Resources, Bishkek and interviews with authorities in Kyrgyzstan and Uzbekistan (see Table A.I) and presentation by A. Kalmambetov, Deputy Minister, Kyrgyzstan (available at: http://www.carecinstitute.org/uploads/events/2010/ESCC-Sep/Day1-KGZ-Energy-Sector.pdf). These data may also include some electricity exports outside the 1998 agreement, so higher amounts do not necessarily mean that the exchange is more effective. Conversely, however, no exports means that no electricity exports have taken place under the 1998 agreement and that, therefore, this agreement is non-operational.

Kazakhstan has usually paid Kyrgyzstan in cash and with hydrocarbon equivalents for summer irrigation water. However, on occasion, Uzbek and Kazakh decision-makers have clashed over Kazakh accusations that Uzbekistan does not route agreed-upon water volumes through its territory but uses some of the Kazakh quota for covering its own irrigation water demand.[15]

The 1998 agreement is, furthermore, suffering from a major design flaw that pertains to energy exchange prices. The energy-for-energy exchange was originally defined in terms of a kWh-for-kWh exchange. In the year 2000, a pricing mechanism was added. While Kyrgyzstan received around 2–3 cents per kWh from the downstream countries for its electricity deliveries, compensation deliveries by the downstream countries were priced in the order of USD 20–22 per ton of coal and USD 45–65 per 1,000 m^3 of gas. This exchange unraveled when energy prices of electricity and fossil fuels diverged. Whereas hydropower prices have remained at 2–3 cents per kWh, the downstream countries have, with increasing world market prices for fossil fuels, raised coal prices to around USD 40/ton and gas prices to more than USD 200/m^3.[16]

The implications are quite obvious: diverging prices have made it impossible for Kyrgyzstan to turn the additional water release of 2.5 km^3 in the months from April–September into income from hydropower exports that could buy the equivalent (in terms of energy value) amount of energy from the downstream countries in the winter period. As shown in Table II, this has virtually stopped Kyrgyz electricity exports to the downstream countries.

In summary, the institutional arrangements for water allocation in the Syr Darya have, thus far, failed to solve the problem. The reasons are multifaceted and at least in part due to the flawed design of the 1998 agreement, which clearly lacks robustness against hydrological variability and commodity price volatility. As climatic changes in Central Asia become more pronounced and, as a consequence, also greater hydrological uncertainty, it is widely feared that the current, dysfunctional approach to water- and energy-sharing will unravel completely and international disputes over water will escalate (Swarup, 2009; Hodgson, 2010; Maplecroft, 2010; Perelet, 2007). In the next section we thus examine how climate change could affect water availability in the Syr Darya.

Climate change impacts

We assess the implications of climate change for the Syr Darya catchment until 2050 using an integrated systems model approach that couples climate and land surface hydrology including snow- and ice-storage (details of the coupled climate, land ice, and hydrological model can be found in Pereira Cardenal et al., 2011; Siegfried et al., 2011). A baseline scenario (BL) with the current climate trend assumed to continue into the future is contrasted with the IPCC SRES A2 scenario that assumes a 2.9°C warming until the mid-21st century in the region.[17] Uncertainty is accounted for in an ensemble Monte Carlo approach.

Three important modeling results emerge. First, the most important impacts of climate change in the Syr Darya basin result from significant changes in the seasonality of runoff. Weekly runoff contributions from unregulated catchments that dewater directly into the Fergana valley are shown in the upper left plate of Figure 4. Historic contributions from 2000–09 are compared with the runoff regime for 2040–49 under the A2 scenario. The other plates in Figure 4 show weekly runoff contributions into the major surface reservoirs in the Syr Darya catchment under the assumption of unregulated flow and zero consumptive upstream use, that is, no human interference with the natural runoff regime.[18] In all instances, the runoff peak under the A2 scenario is shifted in time from the current spring/

[15] Based on interviews, cf. Table A.I.

[16] Based on interviews, cf. Table A.I.

[17] The temperature trend is a model ensemble average over 18 GCM models under the IPCC SRES A2 run (see Siegfried et al., 2011 for a detailed list of the utilized GCMs).

[18] See Figure 1 for the locations of the surface reservoirs.

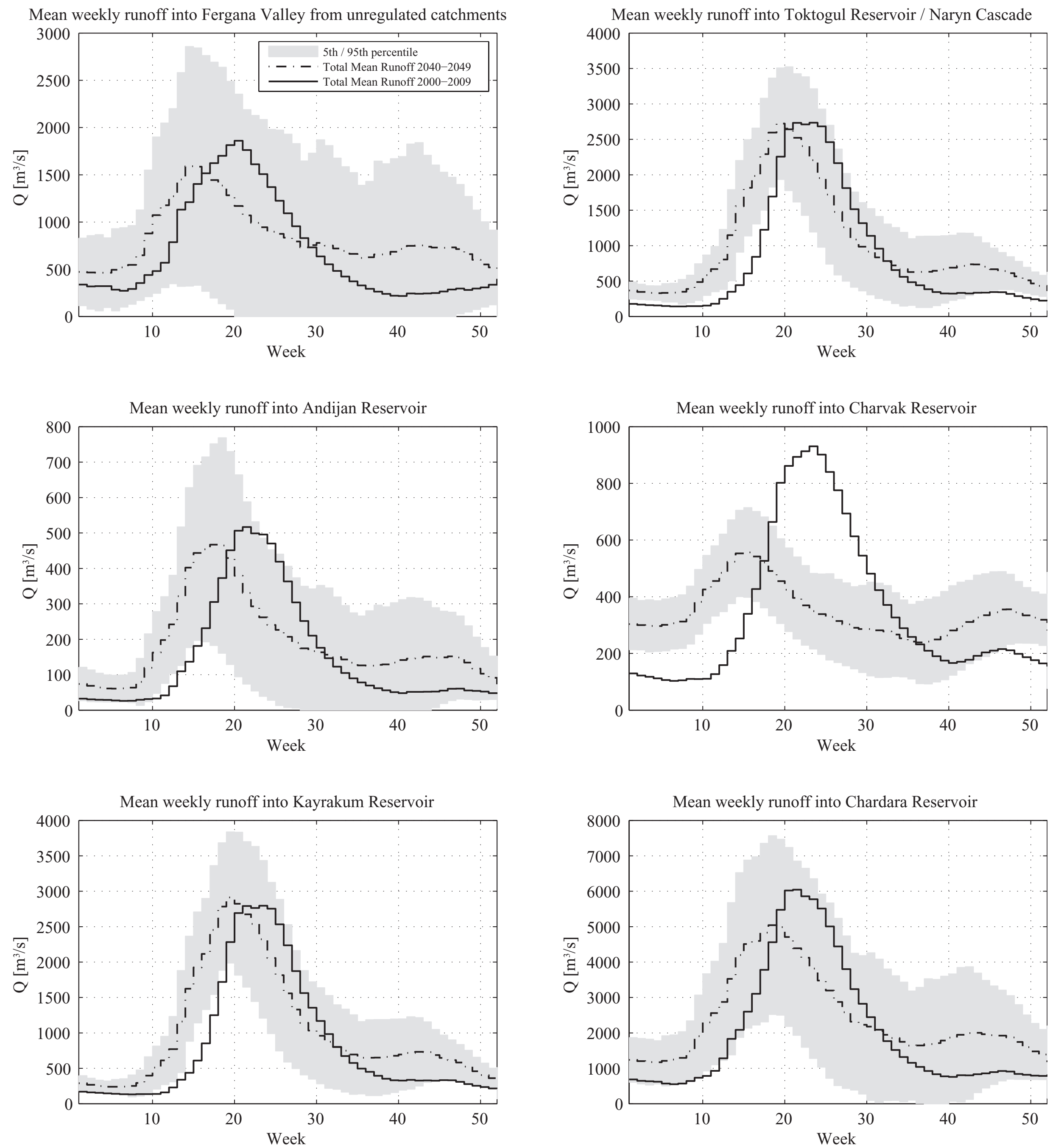

Figure 4. Seasonality of runoff (mean weekly runoff in m3/s) for selected locations in the Syr Darya catchment
Figures for the first decade of the 21st century and for 2040-49 are shown for the A2 scenario (see also Siegfried et al., 2011). The upper left plate shows total unregulated flows into the Fergana Valley, i.e. runoff from catchments that have no or only insignificant man-made surface water storage. The other plates show mean weekly runoffs into the major reservoirs in the basin (see Figure 1 for the location of these dams). Mean runoff for 2000–09 is the solid black line, expected mean runoff in 2040–49 is the dotted black line, with corresponding uncertainty bands (2 standard deviations).

early summer regime towards a late winter/early spring runoff regime. This change has important repercussions for reservoir management since a pronounced deficit of summer runoff as compared to the present regime starts to emerge. It translates into less direct water availability during the vegetation period when more than 90% of total average annual consumptive water use for irrigation purposes occurs (see also Figures A.2 and A.3 and the discussion in the following section).

Second, depending on the emissions scenario, glacier melt will continue to contribute to runoff during the first half of the 21st century. Even under the rather extreme emissions scenario IPCC SRES A2, only approximately one-third of present total land ice volume (approximately 200 km^3) will melt over this period. With an average expected mean annual runoff of 50 m^3/s under the A2 scenario, annual runoff contributions from 2010 to 2050 will stay roughly constant over the assessment period and are approximately double the contribution under the BL scenario. Expressed as a fraction of total natural basin runoff, this corresponds to around 2.7% or approximately one-third of present average inflow into the Aral Sea for the A2 runs, after all upstream consumptive use has been accounted for. Basin-wide glacier melt contributions to river flow are thus small compared to the natural runoff regime.

The third observation is that glacier lengths will experience a significant decline across all size categories as land ice continues to melt. As these glaciers retreat they leave behind unstable terminal moraines behind which significant volumes of meltwater can get trapped. If these moraines collapse, glacier lake outbursts can occur that can potentially cause catastrophic flooding in the downstream (see also Nayar, 2009 for a related discussion on the Himalayas). The Fergana Valley region will be particularly exposed to these geohazards because glaciers surround the valley floor in the south, the east, and the north.

In summary, climate change will impact the Central Asia region mainly through temperature effects on the snow and ice cover in the Tien Shan mountains. Whereas the frequently voiced concern about aridization of Central Asia over the near term (Malone, 2010; Swarup, 2009) is not supported by our model results, the distribution of water within the year could change quite dramatically. This development will have important implications for the management of surface water storage in the region, and also for the design of international water sharing mechanisms.

Conclusions

In this article we have engaged in a critical assessment of the neo-malthusian claim that climatic changes can be an important source of international tensions, in the extreme even militarized interstate disputes. The most likely scenarios are international disputes over transboundary waters. Existing event datasets on international river basin conflict and cooperation indicate that international disputes over water issues are quite common. But none of these disputes has thus far escalated into a militarized interstate dispute in a form that would, according to common definitions, qualify as a war. Nonetheless, many observers expect that the outbreak of future militarized interstate disputes remains a strong possibility.

The strongest ‘candidates’ in this respect are international catchments shared by poorer, less democratic, and politically less stable countries, governed by weak international water management institutions and exposed to severe climatic changes. Since the Syr Darya corresponds quite well to these characteristics, it is a critical test case. If the neo-malthusian specter of militarized interstate disputes over water is empirically relevant, we should see signs of it in the Syr Darya. Hence we have studied, ex post, international water allocation problems and institutions in the Syr Darya and, ex ante, whether climatic changes are likely to make existing international tensions worse in future.

Based on hydrological data and other information, we have found that the currently existing international water management institution in the Syr Darya has failed. Using a coupled climate, land-ice, and rainfall-runoff model for the Syr Darya, we have then examined whether, in the absence of an effective water allocation mechanism in this international catchment, climate change is likely to make existing international tensions worse. The biggest concern in this respect is Kyrgyz–Uzbek relations, which could deteriorate further because the Uzbek population and agriculture in the Syr Darya catchment are particularly vulnerable to climate change-induced shifts in runoff. We conclude, however, that such shifts are likely to occur only in the medium to long term. This leaves some time for the riparian countries to set up an effective international framework for water allocation and prevention of climate change-induced geohazards. By implication, our findings suggest that a climate change-induced militarized interstate dispute over water resources in Central Asia is unlikely.

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