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Coping with changing water resources: The case of the Syr Darya river basin in Central Asia

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ABSTRACT

This paper discusses how climatic-hydrological and socio-political developments will affect water allocation in the Syr Darya river basin and which adaptation measures will be needed to cope with changing water resources. In view of the geo-political complexity, climate-driven changes in water availability are of particular importance in this region. Water shortages during summer will become more frequent as precipitation is expected to further decrease and glacial meltwater releases will decrease in the long-term due to reduced glacier volume. Being the main valve to the entire Syr Darya river system, the Toktogul reservoir in Kyrgyzstan could take over, at least partly, the role of glaciers as seasonal water redistributors, thus allowing the generation of energy in winter – benefiting upstream countries – and irrigation for large-scale agriculture in summer – benefiting downstream countries. To date, however, there is no regional consensus on a balanced reservoir management, which currently favours irrigation according to past Soviet priorities. Moreover, the perception of water as a 'national concern' in Central Asia discourages efforts towards cooperation between states at the regional level. So far, climate change adaptation has focused on technical rather than institutional solutions. We suggest that policy-relevant adaptation measures should include consistent data collection and dissemination, cross-sectoral collaboration, promotion of national responsibility and initiative, and agreeing on a regional strategy.

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1. Introduction

1.1. Geographical, hydrological and climatic setting

Water takes on special importance in Central Asia: covering more than four million square kilometres, the post-Soviet states of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan make up an area that is larger in size than India, Pakistan, and Bangladesh combined, and is home to roughly 60 million people. The majority of water feeding the two main rivers of the region, the Amu Darya and the Syr Darya, is formed from glacier- and snowmelt in the high Pamir and Tien Shan ranges in Kyrgyzstan and Tajikistan (Fig. 1). The Syr Darya river is formed by two tributaries originating in Kyrgyzstan, the Naryn River and the Kara Darya river. As it flows towards the Aral Sea, the Syr Darya river provides freshwater and water for irrigation to Uzbekistan, Tajikistan and Kazakhstan (Barnett et al., 2005; Immerzeel et al., 2010; Kaser et al., 2010).

In view of its high complexity and interdependence, climate-driven changes in water availability are of particular importance for the Syr Darya basin. Substantial changes are expected to occur in the amount and seasonality of precipitation, with a likely increase in winter and decrease in summer (IPCC, 2007). This will put even more importance on the buffering effect of glaciers, which release additional water during dry summers and thus compensate for rain shortfalls. In the future, however, this buffering of glaciers will likely undergo a substantial change and reduced glacier volume will eventually result in a decrease of glacier-fed summer runoff (Braun and Hagg, 2009; Sorg et al., 2012). Water shortages during summer are thus likely to be caused by two exacerbating factors – less precipitation and less glacial meltwater. Implications are also expected for runoff from snowmelt, as snowcover duration is probably continuing to decrease (Aizen et al., 1997) and snowmelt will occur earlier in the year (Khalsa and Aizen, 2008). These expected changes call for appropriate adaptation measures (EDB, 2009; Perelet, 2010).

1.2. Complexities of the geo-political context

Historical legacies and the regional political context are of particular relevance in the Syr Darya basin. Agriculture was initially made possible by the Soviet administration in the early 20th century in Central Asia through the development of intensive irrigation systems to fuel larger-scale cotton cultivation. By the 1960s, the traditional belief in inexhaustible Central Asian water resources had diminished as river flows and ground water reserves were depleted and water and soil quality degraded (Klötzli, 1997).

In order for the Soviet Union to become self-sufficient, priority for water allocation was given to the cotton production in the Uzbek Soviet Socialist Republic (SSR) and to rice production in the Kazakh SSR, with the Kyrgyz SSR designated as water supplier. Major investments were made in the construction of dams, reservoirs, irrigation canals and other structures to promote and manage the transfer of water from its source in the Kyrgyz mountains to the main growing areas in the Uzbek and Kazakh SSRs. The administrative borders of the Central Asian Republics did not match the natural hydrological borders of the Syr Darya basin and were disregarded in the construction process of irrigation canals and dams. The costs of water management within the upstream SSRs were paid for or subsidised from Soviet central funds and the upstream republics received benefits such as the provision of cheap fuel, electricity and food supplies (Kemelova and Zhalkubaev, 2003; Klötzli, 1997; Hodgson, 2010; ICG, 2002).

Fig. 1 – Hydro-political map of Central Asia.

The demise of the USSR in 1991 brought about dramatic geopolitical changes in Central Asia; both Syr Darya and Amu Darya became international river basins covering territories of newly independent states. It also caused a sudden power vacuum and the breakdown of the state-controlled subsidised provision system. The most difficult Soviet legacy, however, was the mismatch between the regional water management systems and the newly established political borders. At the same time, the cotton-oriented economic development of Soviet planners had produced environmental depletion and degradation (Klötzli, 1997), which now needed to be resolved by independent countries. Furthermore, the introduction of private land holding, and the decentralisation of water allocation, led to a multiplication of water users and responsibilities concerning water allocation and infrastructure maintenance (Bichsel et al., 2009). This situation was further complicated as each riparian state declared state ownership over natural resources (Sehring, 2009).

The combination of Soviet central planning and fractious Central Asian states after the collapse of the Soviet Union has therefore created numerous challenges (Mosello, 2008). The distribution of water in the Syr Darya basin continues to be aimed at increasing the output of water-intensive cotton and rice production (ICG, 2002; World Bank, 2011a). The recipients of the benefits have become the newly independent downstream states, which makes them in favour of maintaining the status quo and transforms any development of water resources management in upstream countries into a situation with a high conflict potential (Allouche, 2004; Shalpykova, 2002).

1.3. Aims and objectives of this study

Changing water availability in mountain regions has a strong impact on water-dependent economic sectors such as energy and agriculture. The Syr Darya river basin figured as a non-European case study within the EU-FP7 ACQWA project (www.acqwa.ch), which aimed at identifying how climate change might impact rivalries among these sectors in mountain environments and adjacent lowlands (Beniston et al., 2011).

So far, most studies on water related challenges in Central Asia have focused either on climato-hydrological or on socio-political aspects. In this paper, we bring these two perspectives together for the case of the Syr Darya river basin in order to identify issues which are likely to be exacerbated by both climatic-hydrological and socio-political developments. The goal of this paper is thus to present the impact of future climatic trends on the water regime (chapter 2), to assess current challenges of water governance (chapter 3), and to discuss adaptation challenges and options for water governance and management in the Syr Darya river basin (chapter 4).

2. Future water availability and -demand in the context of climate change

2.1. Climatic trends

Central Asia is characterised by a continental and semi-arid to arid climate with hot summers and cold winters. Precipitation rates are low, especially during summer, when precipitation occurs almost exclusively in the mountainous regions. Over the past decades, temperatures have increased in all parts of Central Asia, whereas precipitation rates have increased at low altitudes and decreased at higher elevations (IPCC, 2007; Giese et al., 2007; Sorg et al., 2012). In the future, substantial climatic changes are expected to occur in the amount and seasonality of precipitation and in a continuous increase of temperatures, which exerts feedback mechanisms on the hydrological cycle: Precipitation is likely to increase in winter (4–8% by 2050), whereas summer precipitation is expected to decrease by an equal amount (4–7%).[6] This will probably result in more extreme events such as drought-prone summers and flooding in winter and spring. Temperatures are likely to further increase in all seasons: summer and winter air temperatures are expected to increase by +3.1 to +4.4 °C and by +2.6 to +3.9 °C until 2050, respectively. Although these projections reflect the current state of knowledge, changes in precipitation and snow remain highly uncertain, and the level of temperature increase, especially at high altitudes and during summer, suffers from considerable disagreement between existing data (Sorg et al., 2012).

As a result of higher temperatures and a prolonged melting season, glaciers in the Tien Shan mountains have already lost much of their volume in the past decades–probably around 0.9% per year (Dikikh, 2004; Vilesov and Uvarov, 2001). The estimated glacier volume in the Syr Darya catchment has been reduced from approximately 121 km^3 in the 1960s/1970s to 101 km^3 in 2000 (UNDP, 2009). However, these numbers have to be treated with caution, as they are only rough estimates. Gravimetric measurements (GRACE) revealed a glacier mass loss for the entire Tien Shan of around 5 ± 6 Gt (0.32 ± 0.39 m water equivalent) per year in the period 2003–2010 (Jacob et al., 2012). Snowcover is also affected by climate change, as increasing temperatures reduce the proportion of solid precipitation and lead to earlier and more intense snowmelt. Thus, snowcover duration is likely to decrease further (Aizen et al., 1997) and snowmelt will occur earlier in the year (Khalsa and Aizen, 2008).

2.2. Impacts on water availability

These changes will put even more importance on the buffering effect of glaciers, which release additional water during dry summers and thus compensate for rain shortfalls. In the future, however, this buffering of glaciers will likely undergo a substantial change and reduced glacier volume will eventually result in a decrease of glacier-fed summer runoff (Fig. 2; Braun and Hagg, 2009; Sorg et al., 2012). At first, shrinking glaciers supply ample quantities of water in the form of increased glacial runoff (phase 1), thus providing surface runoff surpluses over a number of decades that might seem to represent a potential opportunity to develop hydropower infrastructure and produce more energy (Beniston et al., 2011). However, this water supply is far from sustainable and inevitably results in a tipping point ("peak water", Baraer et al., 2012; Gleick and Palaniappan, 2010), as glacial

[6] Numbers are based on the lower and higher bound IPCC SRES B1 and A1F1 (IPCC, 2007).

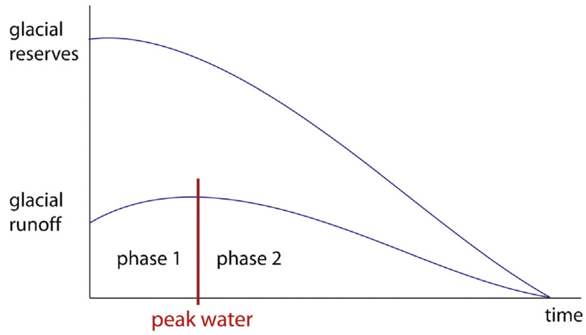

Fig. 2 – Tipping point ("peak water") in glacial runoff.

contributions diminish. Thus, reduced glacier volume will eventually result in a decrease of summer runoff (phase 2), if no other sources can offset water deficiency from reduced glacier melt (Braun and Hagg, 2009). The volume of summertime glacier meltwater may then no longer be sufficient to feed water into river catchments at a time of the year when precipitation amounts are low and the snowpack has already melted (Beniston et al., 2011). Moreover, the year-to-year variability of surface runoff tends to increase when glaciers lose some of their buffering capacity and runoff will thus respond more directly to inter-annually variable precipitation (Braun and Hagg, 2009).

It remains uncertain as to when the Syr Darya or its tributaries will cross this tipping point, though some of them may even have already done so. It appears that catchments with a higher fraction of glacierised area showed mainly increasing runoff trends in the past, while river basins with less or no glacierisation exhibited large variations in the observed runoff changes (Unger-Shayesteh et al., 2013). The increase in long-term average annual runoff of Syr Darya at the confluence of Naryn and Kara Darya from 29.1 km^3 (average 1947–1972) to 30.4 km^3 (average 1973–2000; Mamatkanov et al., 2006; Yakimov and Kostenko, 2003) could be a result of increased glacier melting, but could have also been caused by increasing precipitation amounts. Numerical modelling of runoff components in the headwater catchment of Syr Darya is needed to shed light on past and future changes in glacial runoff and on dating the tipping point. Considerable uncertainties regarding the future evolution of precipitation amounts and impact on water availability, however, will remain.

2.3. *Growing demand for water*

The Central Asian economies are dominated by irrigated agriculture practices (Granit et al., 2010) and water consumption has been mounting to unsustainable levels (ICG, 2002). More than 90% of water in the region goes to irrigated agriculture, which produces about 30% of the regional GDP and provides employment for more than 60% of the region's population (ICG, 2002; Rakhimov, 2009). Agriculture in the region is dominated by cotton production with an increasing shift towards wheat. Uzbekistan, for instance, is currently the second largest exporter of cotton in the world, selling over 800,000 metric tonnes every year (Granit et al., 2010). In Tajikistan, two-thirds of agricultural production is irrigated, but many farmers still have to make a living from rain-fed land, which is even more vulnerable to drought and climate change (Oxfam, 2010). In addition to climate change impacts, the potential for conflict in the region is exacerbated by the current high population growth rate of between 2.5% and 3.4% per year (Lutz, 2010). As living standards improve and demand for resources increase, pressures on scarce water resources heighten.

3. Current governance challenges in the Syr Darya river basin

3.1. *International aspects of water governance*

In view of the geo-political complexity, water governance is particularly challenging in the Syr Darya river basin. Customary international law allows riparian states an equal right to the equitable and reasonable share of international watercourses (McCaffrey, 1991, 2007; Rieu-Clarke, 2005). The Syr Darya downstream states have acceded to the *Helsinki Convention* (UNECE, 1992), but as of today, neither Kyrgyzstan nor Tajikistan have done so. Of the riparian countries, only Uzbekistan has ratified the *Convention on the non-navigational uses of international watercourses* (UN, 1997). Both of these instruments actively require cooperation by states over shared waters to ensure that the standards required by international law are upheld. While Kazakhstan and Kyrgyzstan have acceded to the *Espoo Convention* (UNECE, 1991) – though not to the strategic environmental assessment protocol – Uzbekistan, potentially a beneficiary under the convention, has not. The *Aarhus Convention* (UNECE, 1998) is in force in the Syr Darya basin, again with the exception of Uzbekistan. Uzbekistan also has yet to sign the *Framework Convention for the Protection of the environment for sustainable development in Central Asia* (UNEP, 2006).

The patchy application of relevant international agreements is exacerbated by implementation challenges related to transposing international law to national frameworks. Thus, Uzbekistan has yet to put a Water Code in place and Kyrgyzstan has not yet implemented its own 2005 Water Code (Djayloobaev et al., 2009) or the practical aspects of the *Aarhus Convention* (UNECE, 2010a,b). In addition, the lack of financial capacity, difficulties in enforcement and compliance, and sparse data gathering and monitoring networks render the application of international law difficult.

3.2. *The dilemma of water allocation at the regional and basin level*

A fundamental driver of tensions in the Syr Darya basin derives from the operating regime of the basin's largest reservoir, the Toktogul (Antipova et al., 2002). With a total volume of 19 billion m^3, Toktogul is the main valve to the entire river system and accounts for 91% of electricity production in Kyrgyzstan (World Bank, 2004). Whereas downstream Uzbekistan requires water discharges in summer to irrigate its cotton fields, upstream Kyrgyzstan prefers water discharge in winter when demands for electricity are highest. Although the series of dams that form the Toktogul cascade were intended to be dual purpose, thus for both irrigation and hydropower generation, most of the water was conveyed by canals to the downstream republics to irrigate their fields (Hodgson, 2010). The failure of downstream republics to deliver required agricultural and energy supplies (ICG, 2002) has "led the upstream republics to withhold irrigation water during summer months for release in winter in order to meet internal needs for electricity" (UNDP, 2003).

Interestingly, downstream countries are seen to have greater material and non-material power than upstream countries, thus producing asymmetrical power relationships (Votrin, 2003; Zeitoun and Warner, 2006). Water is perceived as a 'national concern' in Central Asia and the five republics have brought it into their national security agenda (ICG, 2002; Mosello, 2008). This securitisation of the water discourse discourages efforts towards cooperation between states at the regional level, despite a number of attempts that have been made in this direction (Mosello, 2008). For example, the *Almaty Treaty on Cooperation in the Field of Joint Water Resources Management and Conservation of Interstate Sources* (1992) reaffirmed the Soviet-era water sharing provisions that were set in 1984 and are still in force today (*Scheme for Complex Use and Protection of Water Resources of the Syrdarya River Basin*, 1984; Table 1). The 1992 *Almaty Treaty* sets offtake limits for each riparian country with respect to surface and groundwater, and in relation to irrigation and non-irrigation uses. It also led to the establishment of the *Inter-state Commission for Water Coordination* (ICWC), which was charged with the allocation of water in respect of canals and structures controlled by the Soviet-era *Basin Valley Organisations* (BVOs), which are still in place today (Allouche, 2007). Other regional agreements have followed, with the goal of establishing a common coordinated policy for energy and water resources (*Agreement on the Use of Water and Energy Resources in the Syr Darya Basin*, 1996) and to provide for compensation of upstream countries with coal, gas or money for energy loss when releasing water in winter, and for the implementation of joint hydropower projects (*Agreement on the Use of the Syr Darya Water Resources*, 1997, and *Agreement over the use of the Naryn – Syr Darya Cascade*, 1998; Allouche, 2007; Hodgson, 2010). The abstention of Uzbekistan from recent agreements has, however, greatly undermined this approach (Hodgson, 2010; Libert et al., 2008).

In general, therefore, non-cooperation tends to prevail as a consequence of a number of reasons. First of all, existing agreements do neither incorporate adequate provisions for data exchange nor notification of planned measures at the regional level, which increases mistrust amongst the Central Asian governments as far as water resources are concerned. In each country, water, agriculture and energy decision-making continue to occur in a separate way, which renders the governance structure for water resources management sectorial, fragmented and confused – a situation that is further complicated by the presence and action of international organisations. If integration does not occur at the national level, it is unlikely to happen at the regional level either. Therefore, the political, economic and social context of water resources management has resulted in the Central Asian states perceiving water resources as a zero-sum game, one in which one's gain is achieved at the expense of another's loss (Mosello, 2008).

While the BVOs as well as the ICWC are still operational, they cease to play significant roles in terms of water allocation (Hodgson, 2010). The rights claimed by upstream countries to be compensated for storage and supply of irrigation water as well as for the operation and maintenance of the water infrastructure have been persistently opposed by downstream governments (Hodgson, 2010; Slay, 2011) stating their entitlement to the free use of naturally flowing water (Shalpykova, 2002). Tensions started surfacing particularly from 2001 onwards, when the Kyrgyz government made an attempt to introduce water-pricing by supplying water to downstream countries only on a 'paid' basis and operation and maintenance costs of the water infrastructure should be shared (*Law On Interstate Use of Water Units, Water Resources and Water Facilities of the Kyrgyz Republic*, 2001; Tarlock and Wouters, 2007; Votrin, 2003). The 2001 law was based on principle 4 of the *Dublin Statement on Water and Sustainable Development* (1992), according to which "*water has an economic value in all its competing uses and should be recognised as an economic good*". Given that the largest part of water usage of the Syr Darya waters is not for drinking, sanitation or subsistence agriculture, but for cash crops such as cotton (Khamrayev, 2009), a monetary compensation for Kyrgyzstan's energy losses and costs for the maintenance of water infrastructure would have only seemed reasonable. However, the 2001 law was severely criticised in Kazakhstan and

Table 1 – Water offtake quotas in the Syr Darya river basin according to Resolution No. 413 (07.02.1984).

Republic	Offtake Quotas (km^3)				
	Total	Including		Including for irrigation	
		Surface sources	Underground and return waters[a]	Total	Underground and return waters
Uzbekistan	25.49	19.69	5.80	21.36	4.21
Kazakhstan	15.29	12.29	3.00	10.40	2.26
Kyrgyzstan	4.88	4.03	0.85	4.38	0.51
Tajikistan	3.66	2.46	1.20	3.17	0.75
Total	49.32	38.47	10.85	39.31	7.73

[a] Return flows from irrigation drainage canals – i.e. water that has gone into canals and not leaked, evaporated or been used consumptively by crop uptake.

Uzbekistan. The Kazakh leader, Nazarbaev, claimed that the law "does not have any legal foundation [...] it is impossible to set a price for irrigation water [...] it contradicts international standards [...] it is unacceptable for Kazakhstan" (Usubaliev, 2002). Uzbekistan's President Karimov supported his colleague by saying "Water belongs to God" (Uzbekistan National News Agency, 2001). As of today, Kyrgyzstan's Ministry of Foreign Affairs has not yet implemented the 2001 law (UNDP, 2003).

4. Implications for adaptation

4.1. Equitable water allocation

The agreements currently framing water governance and management in the Syr Darya basin do not address the question of equitable water allocation at the basin level, which still favours irrigation according to past Soviet priorities. Furthermore, the system suffers from considerable technical losses, because the infrastructure dates from before independence and little or no investments have been made since then (Murphy et al., 2011) as a consequence of commercial losses (OECD, 2011) and corruption. These dual governance issues are exacerbated by climate change impacts such as water shortages during summer, when water is pivotal for irrigation. Thus, the Central Asian states face at the same time significant challenges and impetus to develop coherent and effective strategies to guarantee an equitable and sustainable allocation of water resources. Currently, water resources management in the region focuses on infrastructural projects (e.g., dams, canal repairs, groundwater wells, irrigation), and pays less attention to increasing the adaptiveness of governance processes. Accordingly, infrastructure improvements are the most common adaptation measure prioritised by the Central Asian States' National Communications to the United Nations Framework Convention on Climate Change (CAREC, 2011, 38). However, while relatively adequate attention is also posed upon the development of effective regulatory transboundary water agreements and the implementation of Integrated Water Resources Management (IWRM), none of these efforts explicitly target adaptation to climate change, mostly as a result of lacking national adaptation policy frameworks (CAREC, 2011, 38).

4.2. Infrastructure and technology

Despite the uncertainty over the extent of the changes induced by climate, projections suggest that the Syr Darya basin will experience reduced summer runoff and seasonal water shortages. For upstream countries, technical and infrastructural adaptation measures could include the construction and maintenance of hydropower dams that replicate glaciers by storing water resources in the winter season and releasing them during summer. Just as glaciers have in the past and at present acted as intra- and inter-annual buffers in the hydrological cycle, hydropower dams might have to take over this role of seasonal redistributors in the upper Syr Darya catchment. If the proposed construction of the Verkhnenarynsky hydropower cascade upstream of Toktogul reservoir will be realised,[7] Kyrgyzstan will be able to generate sufficient electricity in winter, and to run the Toktogul reservoir in irrigation mode (Abbink et al., 2010). This development underscores the need for mutually accepted rules on releases and compensations between upstream and downstream stakeholders. To prevent any misuse, minimum runoff has to assured in summer and flooding releases have to be prevented in winter. In return, downstream users will have to compensate for shortfalls in hydropower generation when upstream countries release water upon request during summer.

For downstream countries, adaptation of the irrigation system will require efficiency improvements and changes in crop choice. This is particularly complex in the context of planned economies like Uzbekistan and in local processing monopolies (OECD, 2011), and the interpretation of "vegetation" and "non-vegetation" seasons in the 1998 Agreement makes irrigation scheduling more appropriate for some crops than others. Downstream countries are also likely to invest in additional backup-reservoirs, which change the seasonal distribution of water availability for any given release by the upstream country (Abbink et al., 2010). Such reservoirs have already been constructed in Uzbekistan (e.g. Arnasai, Kenkulsai, Rezaksai reservoirs) and in Kazakhstan (e.g. Koksarai reservoir; CAWATER, 2013).

4.3. Governance and policy

More comprehensive approaches are also required to direct investments from being focused on infrastructure only to also taking into account environmental sustainability, capacity building and participatory management. Adaptive governance will need to involve "the evolution of new governance institutions capable of generating long-term, sustainable policy solutions to wicked problems through coordinated efforts involving previously independent systems of users, knowledge, authorities, and organised interests" (Scholz and Stiftel, 2005). Thus, policy-relevant adaptation measures should include consistent data collection and dissemination, cross-sectoral collaboration, promotion of national responsibility and initiative, and agreeing on a regional strategy. For Central Asia, this will mean that, in order to respond to climate-induced and socio-economic challenges to water resources management, the following issues need to be addressed:

(a) Consistent data collection and dissemination: Existing agreements do not provide adequately for data exchange or notification of planned measures. Although this is not mandatory under the current *1992 Almaty Treaty*, managing compliance with international agreements will be impossible without monitoring networks. In particular, a need exists to expand data collection and processing on surface and

[7] In September 2012, the Russian state-controlled hydropower company RusHydro and Kyrgyzstan's Electric Stations have set up a joint venture for the construction of the Verkhnenarynsky hydropower cascade. Kyrgyzstan will manage water resources and set tariffs for power export (Uznews, 2012), while Russia will take on the role of mediator in Kyrgyzstan's dispute with downstream countries (HydroWorld, 2012).

Table 2 – Suggested policy measures to address climate change impacts in the Syr Darya basin.

Governance and policy barriers to adaptation		Suggested policy measure
a	No adequate provisions for data exchange or notification of planned measures	- Intensified data collection, processing and sharing on surface and groundwater - Monitoring of climate change, including the continuation and re-establishment of hydro-meteorological measurements and in situ measurements of snow and glaciers - Monitoring of impacts on agriculture and energy - Enhanced quality and scope of climate change vulnerability assessments, including economic assessments
b	Sectoral separation of water from agriculture and energy, as well as from disaster risk and land management	- Integrated water resources management with improved communication between competent decision-making authorities across sectors to allow a balanced operational regime of hydropower dams and to assure the flexibility to react to future water supply and demand - Improved connections between economic actors in the river basin - Identification of solutions to invest in hard and natural infrastructure
c	Risk that national authorities do not assume responsibility and initiative	- Development of national adaptation plans to improve water use efficiency and agricultural crop diversification
d	Lack of regional cooperation	- Enhanced data communication and trainings on climate change impacts and adaptation options on various levels

ground-water, to monitor climate change impacts on water, agriculture and energy and to enhance the quality and scope of climate change vulnerability assessments, including economic assessments. Monitoring networks and cadastre development are critical for both short- and long-term planning and management of resources, but financial limitations have thus far fatally compromised these elements (Djayloobaev et al., 2009; UNECE, 2009, 2010a,b; World Bank, 2009, 2011b) with financial corruption further eroding implementation in some cases (EBL, 2011).

(b) Cross-sectoral collaboration: In all Central Asian countries, the separation of water from agriculture and energy decision-making, as well as disaster risk and land management is a critical issue. One prominent example in this sense is the state-owned power company Electric Stations operating the Toktogul reservoir, which is instructed by both the Ministry of Energy and the State Committee for Water Resources. The former requires water discharges to produce sufficient electricity for domestic demand and exports, while the latter aims at satisfying irrigation demands and attends the negotiations of the ICWC. These instructions are frequently conflicting and certainly do not help Kyrgyzstan's negotiating position vis-à-vis its neighbours. Incentivising better connections between economic actors in the river basin might also open the doors for identifying solutions to invest in both hard and natural infrastructure, which in turn would increase the adaptive capacity of water systems in the Central Asian region.

(c) Promotion of national responsibility and initiative: So far, most of the adaptation actions in the region have been funded and encouraged by external donors and international organisations (e.g. World Bank, International Monetary Fund, international NGOs). While their interventions can be considered as positive first steps, the risk is that national authorities do not step in and leave the responsibility to the international community only (O'Hara, 2004). Central Asian countries should therefore develop national adaptation plans that are free from the economic interest of increasing productivity at all costs, and focus instead on improving water use efficiency and agricultural crop diversification.

(d) Regional strategy: For all Central Asian countries, their capacity to adapt to the prospected impacts of climate change would be greatly enhanced by improving the diplomatic relations with their neighbours. Given the interconnected nature of the hydrological system and legacy management system in place, institutions can only become and remain adaptive if a mutually-agreed and shared regional strategy is in place. There is a recognised need to enhance data communication and educational systems and trainings on climate change impacts and adaptation options on various levels, for example by developing a comprehensive and freely accessible water web-portal for Central Asia (Table 2).[8]

5. Conclusion

The post-Soviet history of Central Asia has introduced immense social, political and economic changes. This article has discussed how current challenges in the water operating regime are likely to be exacerbated by climate change impacts. Substantial changes are expected for precipitation, with a likely increase in winter and a decrease in summer, and for glacial meltwater releases, with a short-term increase and a long-term decrease. The difficulty for the Central Asian states is to apply the principles of equitable and reasonable use by revising the Syr Darya water allocation scheme as well as to agree on a balanced reservoir management, which would allow the generation of energy in winter – benefiting upstream

[8] Existing web-portals such as CAREWIB (CAWater-Info, www.cawater-info.net) or CAWSCI (Central Asia Water Sector Coordination Initiative, http://waterwiki.net/index.php/CAWSCI; not regularly updated) seem to be predominantly used by international actors and less by regional and local decision-makers.

countries – and irrigation for large-scale agriculture in summer – benefiting downstream countries.

To date, climate change adaptation has focused on technical rather than institutional solutions. We present adaptation options relating to both these significant areas of adaptation. Technical and infrastructural adaptation measures include a reconsideration of operating regimes as hydropower dams will have to take over the role of glaciers as seasonal redistributors in the upper Syr Darya catchment. To prevent any misuse, mutually accepted rules have to be effectuated to assure minimum runoff in summer and to prevent flooding releases in winter. In return, downstream users will have to share operation and maintenance costs and compensate for shortfalls in hydropower generation when upstream countries release water upon request during summer. The core challenge related to the governance of regional water resources will be to agree on how much water should be discharged, at what time and for which purpose. While the new role of reservoirs both in upstream and downstream countries will play a crucial role in adaptation to climate changes, our analysis suggests that the following governance related adaptation measures are key: ensuring consistent data collection and dissemination, fostering cross-sectoral collaboration, promoting national responsibility and initiative, and agreeing on a regional strategy. Given the interconnected nature of the hydrological system, as well as the Soviet legacy in the definition of a common water management paradigm, institutions can only become and remain adaptive if a mutually agreed and shared regional strategy is in place.

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