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Climate Change in a Small Transboundary Tributary of the Syr Darya Calls for Effective Cooperation and Adaptation

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This article focuses on cooperative adaptation strategies at the community, water user association, district, and national levels along the Khojabakirgansai, a small transboundary tributary of the Syr Darya in Kyrgyzstan and Tajikistan. Data were collected in the basin through in-depth expert interviews, site visits, and household surveys, and were triangulated with climate change data from the available literature. Basin inhabitants cooperate on extreme events that are exacerbated by climate change, including water scarcity, droughts, and flash floods. Water demand and efficiency are key issues driven by population growth, expansion of croplands, and deteriorating canal infrastructure. Lessons learned can be considered in other small transboundary tributaries in the Ferghana Valley and Central Asia, which demonstrate how, despite the international level of tension on water issues in the region, local communities can find solutions. Cooperation, however, does not always improve the basin environment or living standards, and is likely to be strained in the coming decades by climate and population trends, among other issues.

Keywords: *Water management; transboundary; climate change; extreme events; cooperation; adaptation; water user association; Kyrgyzstan; Tajikistan; Syr Darya Basin.*

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Introduction

Since the collapse of the Soviet Union in 1991, interstate initiatives and research on water in Central Asia have focused on the shrinking Aral Sea and the main rivers, the Amu Darya and Syr Darya (see Sharma et al 2004 and De Martino et al 2005). Even though there are more than 20 small transboundary tributaries (STT) that flow into the Syr Darya in the Ferghana Valley, water sharing in these subcatchments is considered a local, bilateral issue (Wegerich et al 2012a; Wegerich et al 2012b). By addressing this gap in the research, our case study focused on one such STT and sought to inform other similar settings on possible actions and adaptation strategies in the face of emerging climate change threats.

Predicting climate change impacts, especially in Central Asia where regional models are less well developed than for other regions (Westphal 2008) remains difficult because of the inherent complexities and associated nonlinear responses of socioenvironmental systems. Although more regional data are required to unequivocally demonstrate the links between climate change and extreme events in the Syr Darya basin, a growing body of historical meteorological and hydrological evidence indicates that climate change is happening and impacting the water supply (Savoskul et al 2003; IPCC 2007; Kokorin 2008; Westphal 2008; Bernauer and Siegfried 2012).

In addition to factors that already complicate water management in Central Asia, such as deteriorated water infrastructure, degraded basin environments, population pressure, ongoing land reforms, and lack of cross-border cooperation (Weiss and Yakovlev 2012), experts expect climate impacts to become more severe over the next 20 (Westphal 2008) to 40 years (Bernauer and Siegfried 2012), but they also point out that people in the region are already being impacted. Indeed, there has been a significant increase in the number of droughts and floods in Central Asia in the past 20 years, and this trend is projected to continue (Fay et al 2010).

Although tensions about water exist at the international level, for example, between Uzbekistan and Tajikistan regarding the construction of the upstream Rogun hydroelectric dam or between Uzbekistan and Kyrgyzstan regarding exchanges of water and natural gas (see Allouche 2007), results of our research showed that cooperation on water management and sharing exists at the local level within and among water user associations (WUA), districts, and provinces, and across national and ethnic boundaries. Such cooperation is both threatened by and an essential foundation for coping with the basin-wide impacts of climate change.

FIGURE 1 Irrigated fields along the Khojabakirgansai in the Khozho-Bakyrgan WUA, Kyrgyzstan. The basin is arid, so the vast majority of crops are irrigated. (Photo by Dominic Stucker, 2011)

After introductions about the Syr Darya and Khojabakirgansai basins, our article provides insight into climate change and its local impacts, presents current cooperative adaptation strategies, assesses the long-term effectiveness of these strategies, and offers recommendations for consideration. Our core research questions were the following:

- What are the key climate change-related extreme events that are impacting the basin?
- How are local communities, WUAs, and district and province managers cooperating and adapting to these impacts?
- Do current adaptation strategies regenerate natural capital and improve living standards?

Methodology

In addition to conducting a literature review on regional climate change for the first question, we addressed all 3 questions through field research in the basin, including 20 in-depth structured interviews with water experts at the provincial, district, and WUA levels, site visits to 3 upstream and 3 downstream WUAs (Kyrk-Bulak, Khozho-Bakyrgan, and Kulunda-Razzakov upstream, and Obi Ravoni Ovchi Kalacha, Madaniyat, and Gulakandoz downstream), and 49 household surveys in the same WUAs. We ensured participation of women and men at all levels. Our interview questions focused on trends in population, water resources quality and quantity, water decision-making and cooperation, and extreme events and climate change, whereas our household surveys focused on household demographics and livelihoods and on extreme events and climate change. To validate initial findings, we presented our research at a stakeholder workshop that involved 31 participants from throughout the basin and integrated the feedback we received.

Our approach is based on the assumption that the future is not negatively determined and that there is potential for change through development. Paraphrasing Allan and Karshenas (1996), 3 future scenarios are possible: conventional, precautionary, and regenerative. Although the conventional scenario raises living standards in the short term, it is predicated on natural capital depletion; the precautionary scenario first reduces natural capital but then stabilizes it, maintaining living standards; and the regenerative scenario, taking a longer view, improves natural capital and living standards. In an arid, agrarian context such as our case study (Figure 1), the Khojabakirgansai basin, where water and land are essential for livelihoods, Allan and Karshenas' framework applies well. At the end of our article, we apply it to assess the effectiveness of adaptive strategies.

The Syr Darya Basin

The Syr Darya, at 2212 km, is the longest river in Central Asia, starting at the confluence of the Kara Darya and Naryn rivers in the Ferghana Valley in Uzbekistan (when including the Naryn, its length is 3019 km). The Khojabakirgansai is one of more than 20 STTs of the Syr Darya in the valley. The sources of these tributaries are glaciers in Kyrgyzstan. Before flowing out of the Ferghana Valley, the Syr Darya enters Tajikistan and fills the

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BOX 1: Water user associations in the Khojabakirgansai Basin

Water user associations (WUA) emerged recently in the basin to manage water in the territories of former collective and state farms, dismantled as a result of agricultural restructuring reforms in Central Asia. Land reforms and formation of WUAs were promoted by external donors and international organizations, based on models applied previously in developing countries. WUAs are supposed to be noncommercial and nonprofit member organizations, formed by water users (in our case, farmers) to manage and deliver water equitably, efficiently, and in a timely manner.

WUAs in the Kyrgyz part of the basin were established starting in 1998 as part of a World Bank–financed project, whereas, in the Tajik part of the basin, the International Water Management Institute (IWMI) started to promote them in 2005. All WUAs are now operating similarly, as the IWMI continued to work in the basin through their Integrated Water Resource Management in the Ferghana Valley project.

Members of WUAs are supposed to meet annually to make key governance decisions on operations, development plans, and strategy. Elected at the annual meeting, each WUA has a council that gives operational guidance to the directorate, audits accounts, and resolves conflicts, usually meeting on a monthly basis. The directorate, consisting of a director, head *mirob*, accountant, and other technical staff, carries out daily maintenance and water distribution. Members pay for their share of water to cover staff and infrastructure maintenance costs.

The question of an uneven level of development and sustainability (organizational and financial) of WUAs in the basin is still open and related to the welfare of farmers and the effectiveness of relevant agricultural reforms. These are not complete downstream, with WUAs covering approximately 75% of irrigated lands in 2010. At that time, there were 14 WUAs in the Tajik part of the basin and 3 in the Kyrgyz part (Figure 3).

(Sources: Schaap and Pavey 2003; Narain 2004; Kazbekov and Yakubov 2010)

Kairakkum Reservoir. Tajikistan lifts water from the reservoir and the river for supplying agriculture in Sughd Province. These lift stations and canals interact with the STTs that come from the Kyrgyz mountains (Wegerich et al 2012c). Thereafter, the river flows again into Uzbekistan and across southern Kazakhstan, before reaching the Aral Sea.

During Soviet times, there was a preference for crops in the downstream plains and more limited crops and animal husbandry in the upstream mountains. Although an extensive network of water management infrastructure exists downstream, there is little water management control in most upstream parts of STTs. The large upstream dams that are found in a half dozen STTs are often poorly maintained, because their primary purpose was usually to provide water for downstream agriculture (De Martino et al 2005).

Agriculture is essential for the economy in the Syr Darya basin and is almost entirely dependent on irrigation (De Martino et al 2005). Yet nearly 79% of water is lost due to infrastructure deterioration compared with an average of 60% in developing countries (Sharma et al 2004). Such water losses have led to a higher water table, with significant increases in waterlogging and salinization of arable lands (Savoskul et al 2003).

The Khojabakirgansai Basin

The Khojabakirgansai is approximately 117 km long and has a catchment area of 1740 km^2, the vast majority of which lies in the upstream Leylek District of Kyrgyzstan (Kazbekov and Yakubov 2010). The upper reaches of the basin are at 5000 m and the lower reaches are at 300 m. Upon flowing into Tajikistan, the river encounters the largest structure on its course, the Plotina Dam. The dam is used from March through October to divert almost all water into the large Khojabakirgan Canal for irrigation in the B. Gafurov and J. Rasulov Districts (Figure 2).

In 1992, the 5 newly independent Central Asian states (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan; a riparian of the Amu Darya, Afghanistan, was not included) formed the Interstate Commission for Water Coordination for the Aral Sea basin, and reaffirmed all Soviet-era water agreements. The Khojabakirgansai agreement, signed in 1962, stipulates that the annual flow of the river be divided 79% for the Tajik and 21% for the Kyrgyz part of the basin.

The basin is arid, with 5427 ha of land dedicated to irrigated crops upstream and 14,205 ha downstream (Kazbekov and Yakubov 2010). A large reservoir at Ak Took, Kyrgyzstan, has been discussed since the 1970s but lacks funding. Data about the dam is hard to obtain, but plans apparently exist and, if implemented, would reportedly more than double irrigated lands upstream (interview with district-level water managers, Kulundu, Kyrgyzstan, 19 May 2011).

The steadily increasing population of the basin is overwhelmingly rural, with approximately 34,000 people living in the Kyrgyz part and 114,000 in the Tajik part (Kazbekov and Yakubov 2010). A mix of ethnicities coexists in the basin, predominantly Kyrgyz, Tajiks, and Uzbeks. Any mention, therefore, to the "Tajik" or "Kyrgyz" part of the basin refers to political, not ethnic boundaries.

Families who live in the basin are dependent on agriculture as a source of sustenance and income, with every household surveyed having cropland and/or a home garden. Orchards are also prevalent, and animal husbandry, especially upstream, is widely practiced. A reliance on agrarian livelihoods makes basin inhabitants especially susceptible to water variability. Learn more about basin WUAs in Box 1 and Figure 3.

Climate change impacts in Central Asia

Data from official Tajik and Kyrgyz government reports show that increases in temperature range from 0.3–1.2°C

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FIGURE 2 Khojabakirgansai Basin. (Map by Alexander Platonov, 2011; courtesy of The International Water Management Institute)

from 1950 to 2005, depending on the weather station. Given the higher temperatures, glaciers have been melting in Central Asia at a rate of 0.2–1% per year since the late 1950s. This has resulted in an overall 15% decrease in glacier volume in Tajikistan and Kyrgyzstan (Tajikistan 2008; Kyrgyzstan 2009). Modeling projects that glaciers will continue to retreat at least through the middle of the century, and will leave unstable terminal moraines filled with meltwater that have the potential to burst and cause catastrophic flooding (Bernauer and Siegfried 2012). Snow cover has decreased by as much as 15% in the past 20 years and reduced seasonal water storage (ZEN 2009).

Based on climate and water modeling in the Syr Darya basin, changes in river flow patterns are expected, with the flow pattern peaking more sharply, higher, and earlier in the year, before tapering off below baseline levels (Figure 4) (Savoskul et al 2003) or peaking lower and earlier in the year before tapering off below baseline levels for most of the growing season (Bernauer and Siegfried 2012). Models concur on an increase of precipitation intensity, but a decrease in overall runoff, estimated at a loss of 20% over the next 50 years (Westphal 2008; Kokorin 2008).

Climate change impacts in the Khojabakirgansai Basin

In paralleling some of the runoff factors described in Kohler and Maselli (2009), our field research on local stakeholder perception of climate phenomena and their impact on seasonal water supply, droughts, and flash floods in the Khojabakirgansai basin is summarized in Table 1. We found that such processes and impacts are

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FIGURE 3 Water User Associations and Farmers' Associations in Khojabakirgansai Basin in 2010. (Map by Alexander Platonov, 2011; courtesy of The International Water Management Institute)

FIGURE 4 River flow projections from 2 models for the Charvak Basin, 2010–2039 and 2070–2099, compared with 1961–1990 baseline average. (Redrawn based on Savoskul et al 2003, with kind permission from the publisher)

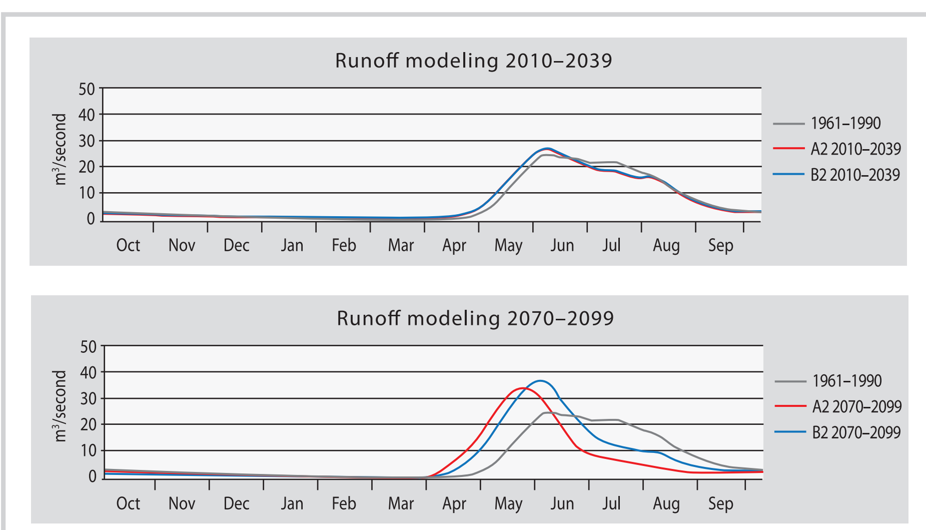


TABLE 1 Local stakeholders' perception of climate change-related phenomena and impacts.

Season	Climate change phenomena	Impacts
Winter	Warmer; decreased snowfall and snowpack	Decreased river flow in growing season; decreased water for crops
Spring	Warmer; precipitation that used to fall as snow falls as rain; increased intense rainfall; peak number of flash floods and increased number of flash floods	Increased variability of beginning of growing season; flash floods erode streambed and cause siltation, damage canal infrastructure, bridges, and home gardens, and sweep away livestock; fear of damage to homes and Plotina Dam; delays in ability to repair canals and access water; decreased water for crops
Summer	Warmer; continued flash floods; decreased and more variable rainfall; decreased and more variable river volume; highest temperatures and lowest monthly rainfall; increased frequency of droughts; increased evapotranspiration from water bodies and soil	Continued damage from flash floods to canal infrastructure, bridges, and home gardens; livestock swept away; fear of damage to homes and Plotina Dam; delays in ability to repair canals and access water; increased frequency of droughts; parched earth no longer absorbs rains well, increasing severity of flash floods but decreasing soil moisture; decreased water for crops
Autumn	Warmer; decreased runoff; high temperatures and low rainfall	Low river flow; continued evapotranspiration; decreased water for crops

most commonly attributed to the weather, water supply, water accessibility, and/or Allah's will, but rarely to "climate change" as such.

Concurring with the modeling in the section above, data collected upstream at Andarkhan, Kyrgyzstan, indicates that average annual river volume of the Khojabakirgansai decreased from 340 million m^3 in 1945 to less than 300 million m^3 in 1995 (Figure 5, blue trend line). If this trend continued, then the 2012 annual volume would be approximately 286 million m^3, more than a 15% loss since 1945.

Upon closer examination of decadal averages, the river volume did decrease steadily from 1946–1985, with the lowest period being 1976–1985, at 300 million m^3. For 1986–1995, however, it increased to 311 million m^3. Given the lack of hydrological and meteorological data from the mid 1990s onward, we can only conjecture that this change may be due to accelerated glacial melt and/or changes in precipitation patterns.

What is clear from the historical hydrological data is that the variability of annual river volume has been increasing, with the 2 highest and 2 lowest years all within the final recorded decade, 1986–1995. High-volume years are as much as 29% above the average flow of 315 million m^3 and low-volume years as much as 39% below average, representing a potential range of 213 million m^3 in any

FIGURE 5 Trends in Khojabakirgansai annual volume, 1945–1995. (Graph based on data from Rysbekov 2008)

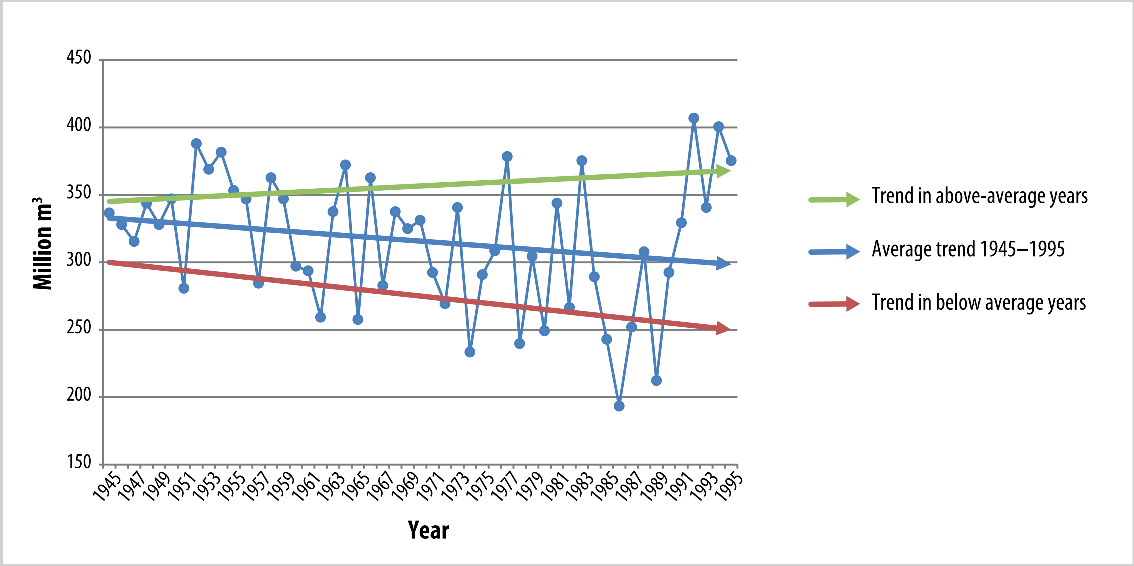
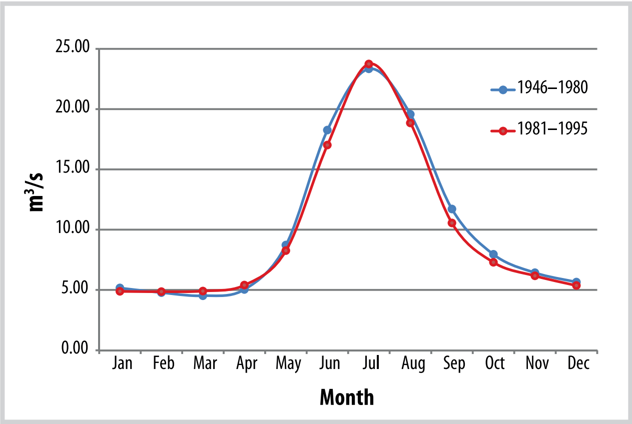


FIGURE 6 Changes in monthly Khojabakirgan river flow. (Graph based on data from Rysbekov 2008)



given year. The green line in Figure 5 shows the trend in above-average volume years and the red line shows the trend in below-average years. According to our household surveys, variability has continued to increase from the early 1990s to the present.

Changes in monthly river-flow averages are not statistically significant for the period 1946–1995. The direction of changes, however, is consistent with a sharpening of the seasonal river-flow pattern in the basin (Figure 6). For similar results regarding the neighboring Zeravshan basin, see Olsson et al (2010).

Our basin household surveys, consistent with the regional meteorological data and model projections, pointed to greater precipitation intensity and variability, with increases in both dry periods and heavy rains. Households reported that snowfall has been decreasing over the past 20 years, whereas rainfall has been increasing during the winter months and into the early spring.

Expert interviewees unequivocally identified heavy rains as the primary cause of flash floods, with severe ones reported over the past 20 years in 1992, 1993, 1998, 2003–2005, and 2007–2011. By reinforcing models and household observations, data collected in the parallel Isfana river from 1987–2010 demonstrate that the annual number of flash floods is steadily increasing, particularly in March, April, and May (Solijonov and Karimov 2011). Mismanagement of upstream pastures and deforestation may also be contributing factors to increased severity of flash floods and erosion.

In addition to increases in floods, all interviewees reported severe droughts across the basin over the past 20 years, in 2000, 2001, and 2008. Interviewees also reported droughts in 2003, 2007, and 2011. These droughts tend to be felt most acutely during the growing season, with June, July, and August as the hottest months and July, August, and September as the driest. In addition to the lack of rainfall, an increase in temperature leads to greater evapotranspiration from the river, canals, and soil.

Increasing water demand

In addition to the “natural” impacts of climate change on the water supply, several important social and technical processes cause an increase in demand for water in the basin combined with inefficient water usage and decreased accessibility. Our household surveys and expert interviews show that, over the past 20 years, demand for water has increased due to population growth and expansion of croplands upstream. Interviewees indicated that water losses occur due to increased subdivision of existing croplands and related inefficiencies across the basin, including more earthen canals and increased numbers of inexperienced farmers. The area of irrigated lands in the Tajik part of the basin has remained constant since independence, at approximately 14,205 ha, whereas, in the Kyrgyz part of the basin, it has increased from 4732 to 5031 ha.

Although flash floods may bring a lot of water down the riverbed, it is of little use to farmers, because they cannot channel it to their fields. On the contrary, canals that are built to divert water directly from the river, especially in upstream Kyrgyzstan, are susceptible to being damaged and often remain in a state of disrepair due to a lack of funding. Diversions during maintenance work are not possible. Furthermore, livestock can be swept away and fields near the river damaged. Canals that rely on a pump are susceptible to technical malfunction and electricity outages.

The situation is a bit different at the Plotina Dam, where the river enters Tajik territory. If Tajik personnel are warned, then the dam is opened to allow flash floods to flow through instead of damaging the water infrastructure. With little water in the lower reaches of the river, however, flash floods that are let through have washed out the riverbed and destroyed bridges. In sum, trends show a decreasing and more variable supply of water, increased occurrence of flash floods, an increasing demand for water, and significant water losses, which results in mounting pressures on agriculture, basin inhabitants, and the environment.

Adaptation through cropping and orchard choices

Due to land reforms and the cessation of the state order of crops in Kyrgyzstan and recently to some extent in Tajikistan, farmers have a greater say in what they plant, which has contributed to changes in cropping patterns (Schaap and Pavey 2003). Our household surveys suggest that cotton, wheat, corn, and onions are currently the main crops downstream and that wheat, corn, sunflowers, and potatoes are the main ones upstream.

In the households we surveyed in Tajikistan, there was a drop over the past 20 years in the planting of cotton and an increase in onions. In the households in Kyrgyzstan, sunflowers decreased, whereas wheat increased;

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TABLE 2 Overview of cooperative climate change adaptation strategies.

Impact	Category[a)]	Adaptation strategy
Water scarcity	Conventional	Allocate water according to 1962 basin water-sharing agreement
		Rotate water between districts, WUAs
		Ration water within WUAs
		Clean and repair canals
	Precautionary	Plant less water-intensive crops
	Regenerative	Expand orchards
		Integrate IWRM principles into institutions, practices
Drought	Conventional	Use drought-resistant seed varieties
		Plant less water-intensive crops
		Do not plant a second crop
Flash floods	Conventional	Clean and repair canals
		Early warning calls

[a)]Allan and Karshenas (1996).

furthermore, upstream interviewees reported that rice production decreased significantly since its peak in 1999. Although multiple factors contribute to planting decisions, these initial findings suggest a shift away from water-intensive crops. Reasons for these changes may include market prices for crops, preference for subsistence crops, and/or adaptation to reduced availability and access to water.

The most widespread orchard tree varieties in surveyed downstream households are apricot, cherry, apple, and persimmon and, in upstream households, are apricot, apple, cherry, and walnut. Orchard yields seem to be faring better than crop yields over the past 20 years, with 45% of households reporting increases (compared with 30% for crops), and 21% of households reporting decreases (compared with 38% for crops). Orchards themselves appear to be expanding, with a 6% increase in the number of trees downstream and 17% upstream; the latter likely in part due to expansion of irrigated upstream lands. Given their deeper root system and their capacity to regenerate the soil, fruit trees may have a better capacity to withstand water scarcity and processes that would otherwise decrease soil fertility. On one farm we visited downstream, a half hectare of land had been reportedly reclaimed from the washed-out riverbed by methodically planting advancing rows of trees over a 50-year period.

Cooperation strategies for adaptation to extreme events in the Khojabakirgansai Basin

We heard consistent reports in both Tajikistan and Kyrgyzstan of good cooperation on water management within and between communities, WUAs, districts, and nations, including across ethnic identities. What appears to be a clear upstream–downstream riparian relationship, however, is actually more nuanced. There is a small portion of downstream Kyrgyz territory that receives water from the Khojabakirgan Canal (after it has passed through Tajikistan), and another that receives water from the Kairakkum Reservoir in Tajikistan. This might already create an incentive for cooperation across the national boundary, as tit-for-tat measures are reportedly taken. This situation also occurs in other STTs in the Ferghana Valley, but more research and comparative studies are necessary to improve understanding.

Although it is important to acknowledge and build on cooperation, it will likely be put to the test in the coming decades by the population growth and climate change trends described above. We must also not take for granted that cooperation always leads to regenerative or even precautionary adaptive strategies. This section, therefore, assesses cooperative strategies according to Allan and Karshenas' framework (1996) of whether they take a conventional, precautionary, or regenerative approach. An overview is provided in Table 2.

At the transnational level, working groups of the respective Ministry-appointed National Water Commissions meet each winter and make water allocation decisions that seek to uphold the 1962 water-sharing agreement. This agreement is inherently conventional, which leaves little to no water for the environment during the cropping season (21% for the Kyrgyz part of the basin and 79% for the Tajik part annually). In periods of extended water scarcity, especially during March, April, May, and the rest of the cropping season, water managers from the Tajik part of the basin go across the border to

FIGURE 7 In the upper part of the watershed, stonewalls have been constructed to protect homes close to the riverbank from flash floods. Khozho-Bakyrgan WUA, Kyrgyzstan. (Photo by Dominic Stucker, 2011)

their Kyrgyz counterparts and request that more water be allowed to flow to their fields for 3 days at a time. Although their counterparts have reportedly always complied with downstream demand, this type of water use ensures that as much water as possible is directed toward agriculture.

Similarly, water rotation occurs among the 3 WUAs in Kyrgyzstan as well as between the B. Gafurov and J. Rasulov districts in Tajikistan, alternating every 3 days during the cropping season. A water rotation agreement also exists between the densely populated Gulakandoz WUA and those further up the Khojabakirgan Canal, in which half of the water flows to Gulakandoz. Within WUAs, irrigation water is carefully rationed, with *mirobs* (water masters) enforcing agreements.

Both upstream and downstream at the WUA level, community members prepare for water scarcity by cleaning out and repairing canals through *hashar* (community volunteer projects). Maintenance work is rarely sufficient, however, partly due to the long conveyance canals from the river to the fields. If properly maintained, benefits would include more efficient water delivery to crops and avoidance of waterlogging, which decreases soil fertility and can cause salinization. Whereas maintenance would otherwise be a precautionary approach, under the current paradigm the irrigation infrastructure is meant to channel as much water as possible to agriculture, which leaves little to help regenerate the basin's environment.

In drought years, farmers in the basin often plant less water-intensive crops, such as clover or wheat, in addition to using drought-resistant seed varieties. When a drought is severe, the farmers often refrain from planting a second crop, which usually consists of vegetables, after they harvest their main crops. Farmers then have to rely more heavily on their livestock and orchards for sustenance. Under other circumstances, these strategies could be considered precautionary, but, during times of drought,

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households are focused on survival, not regenerating natural capital.

Flash floods occur most frequently in the basin in April, May, and June. As above, preparation for flash floods in both Tajikistan and Kyrgyzstan includes using *hashar* in the months of November–March, when the canals are empty to clean and repair them. In this case, repair is meant to fortify the canals from damage that they may incur from stones and debris carried by the next floodwaters. Repair also includes clearing and repairing existing offtakes. Sometimes, it is possible to borrow machinery from other WUAs and private individuals to reinforce the riverbanks and to dig runoff canals.

When heavy rains start, transboundary early warning calls are made from water managers in the Kyrgyz part of the basin to colleagues, mayors, farm managers, and/or friends downstream. Local governments have provided some phones for this purpose. The early warning calls give downstream WUAs approximately 2–4 hours to prepare by opening side or parallel canals and by opening the Plotina Dam. The early warning calls allow disaster support groups, especially in the upstream Khozho-Bakyrgan WUA to warn households near the river.

After the intensity of a flash flood subsides, it is sometimes possible to borrow machinery and/or get financial support from individuals, the local government, international aid agencies or the respective Ministry of Emergency Situations to help clean out and repair canals. Tajiks have responded to requests to come upstream with their machinery to help clean out and repair nearby canals and numerous micro dams after flash floods. On the Kyrgyz side of the basin, one WUA reported that they have set aside a reserve fund for these situations, which can help cover fuel and driver costs. Also, the Ministry of Emergency Situations and the French Agency for Technical Cooperation and Development have provided 1-m^2 wire cages that are filled with river stones and are used to reinforce weak riverbanks and protect nearby homes (Figure 7). On the Tajik side, the Gulakandoz WUA reported that Mercy Corps helped them restore damaged canals after a 2005 flood.

Discussion and conclusions

Given climate change and population trends, the conventional approach is untenable, demonstrating little adaptive capacity. The focus is on survival from year to year, an understandable preference for ensuring short-term human wellbeing over long-term regeneration of the environment. A precautionary approach espouses behavioral change and/or technical fixes to improve water-usage efficiency, seeking to bring consumption and supply into balance. A precautionary strategy that we identified is planting less water-intensive crops when there is no drought. If adopted widely, then this could decrease agricultural demand for water. As mentioned above, canal repair and maintenance also has the goal of improved water usage efficiency, but, if not accompanied by a paradigm shift in how water should be used, then this remains a conventional approach.

A regenerative approach goes beyond adaptation, mitigating some of the impacts on the basin through, for example, expanding orchards and applying integrated water resources management principles in water institutions. The former increases soil fertility, decreases erosion, and, if adopted widely, could improve the basin's environment. The latter promotes bottom-up participation of water users in governance and management, which can lead to more efficient and equitable water use, and improve system performance (Uphoff and Wijayaratna 2000). Unless a paradigm shift from conventional to regenerative, or at least precautionary, approaches is achieved, natural capital, especially water and land, will degrade, living standards will decrease, and/or people will have to leave agriculture, often migrating for work (Stucker 2009). For long-term sustainability, this paradigm shift needs to happen at the local and global levels by ensuring both adaptation to and mitigation of climate change.

In the Khojabakirgansai basin, climate change contributes to a decreasing and more variable water supply, subdivision of agricultural lands and deteriorating infrastructure have increased inefficiencies, and population growth and upstream expansion of irrigated crops have increased demand. These developments have increased pressure on water resources, basin inhabitants, and the environment. Analysis of our research shows that communities, WUAs, districts, provinces, and national water bodies cooperate locally and across national and ethnic boundaries in response to water scarcity, droughts, and flash floods. The outcomes of cooperation, however, do not always improve the basin environment or living standards, and cooperation is likely to be strained in the coming decades by climate and population trends, among other issues.

Recommendations

Based on our research, we offer the following recommendations. First, future studies and projects in the Khojabakirgansai should build on current cooperation and local perceptions of climate change. Second, the purpose of the proposed upstream dam and reservoir should be jointly revisited. Although the reservoir was originally anticipated to create additional irrigated land in Kyrgyzstan, a *conventional* approach to water management, the primary purpose of the reservoir, if it is constructed, should be to enable more water control of the increasingly variable basin hydrology, a *precautionary* approach. This could simultaneously assist in mitigating flash floods and storing water for periods of scarcity, which benefit both riparian states. In parallel, *regenerative* measures aimed at

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improving the basin environment should be jointly envisioned and undertaken, for example, further expansion of orchards and large-scale afforestation. Third, we encourage the establishment of a permanent basinwide institution or platform, representing diverse upstream and downstream stakeholders, and making it easier to agree upon, plan, and implement local development priorities. Such an institution could help improve data collection and sharing, build trust, and work effectively to expand cooperation on extreme events and regenerate the environment. The respective processes toward this are currently underway at both local and national levels, with support and facilitation from a number of donors and implementing agencies.

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