Supplementary Materials

Supplementary Results

1. Upstream Agricultural Shortages

As there is no volumetric water agreement between China and Kazakhstan, there is currently no limit to upstream diversion – which could lead to complete depletion of flows [15,61][1]. Interestingly, results indicate that irrigation shortages in China of variable intensity may occur under scenarios where demand upstream increases, due to water availability limitations (see Figure S1). For the current demand scenario (scenario AC1) any decrease in precipitation would result in upstream irrigation shortages with variable intensity depending on temperature. For all scenarios with increased demands compared to the current situation (scenarios AC2, 3, 4 and 5), large shortages occur even for higher precipitation scenarios. Demand scenario AC5, which represents the Environmental Protection Plan of the Ili Valley government, would still result in shortage conditions under no climate change for around 10% of the growing seasons. If demand decreases to 1976 levels (scenario AC6), demand upstream would be satisfied in all growing seasons except for the most extreme reduction in precipitation modeled. These findings indicate that hydro-climatic variables may determine the limits to the upstream expansion of agriculture, and that the current system is already vulnerable to shortages occurring.

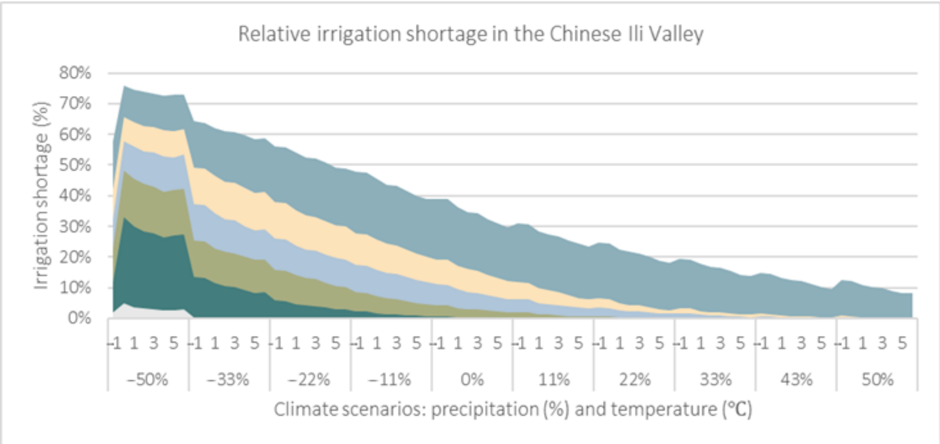

Figure S1. Intensity of irrigation shortages in the Chinese Ili Valley for the different future demand scenarios.

1 This is a worst-case scenario and should be interpreted with caution. Although technically there is no limit to depletion, there are most likely physical limitations. However, there is no data on this and therefore a physical constraint of 0 is adopted.

2. *Trade-offs Among Lower Basin Water Users*

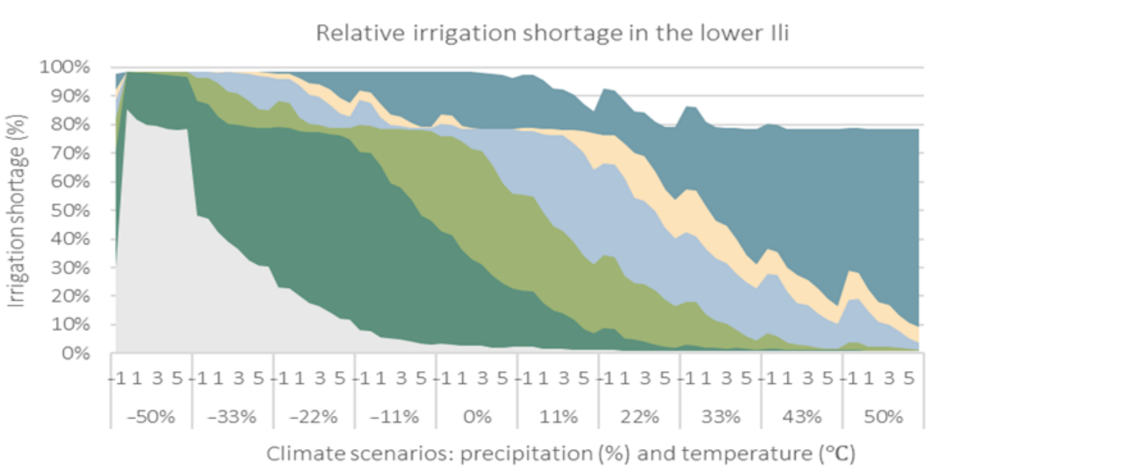

Figure S2. Irrigation shortage in the Kazakh lower Ili region under the 80 future climate change scenarios and 6 upstream demand change scenarios.

Results show that downstream irrigation districts are sensitive to shortages under different climatic conditions (see Figure S2). Current demands in the upper Ili result in downstream shortages of more than 30% for water futures with reduced precipitation and show rapid improvement in irrigation water availability under increased precipitation scenarios. However, for all growth scenarios (AC2, 3, and 4) high downstream shortages persist even for higher precipitation scenarios. This indicates that the water requirement of the lower Ili agricultural area will not be satisfied even under significant increases in total flows if demands upstream increase. For the environmental protection plan (scenario AC5), a 33% increase in precipitation would be required to limit downstream irrigation shortages to 30% of the requested amount. Furthermore, shortages are particularly large during August (see Figure S3). The implications of these shortages reach further than limitations on food production: irrigation withdrawals downstream are currently not limited, and therefore environmental flows to Lake Balkhash amount to what is left after irrigators take their share in the growing season. Irrigation shortages therefore also result in low flows to the downstream delta. This emphasizes the tension between agricultural water use and environmental requirements in the basin, and the competition for water among different agricultural users in the transboundary basin.

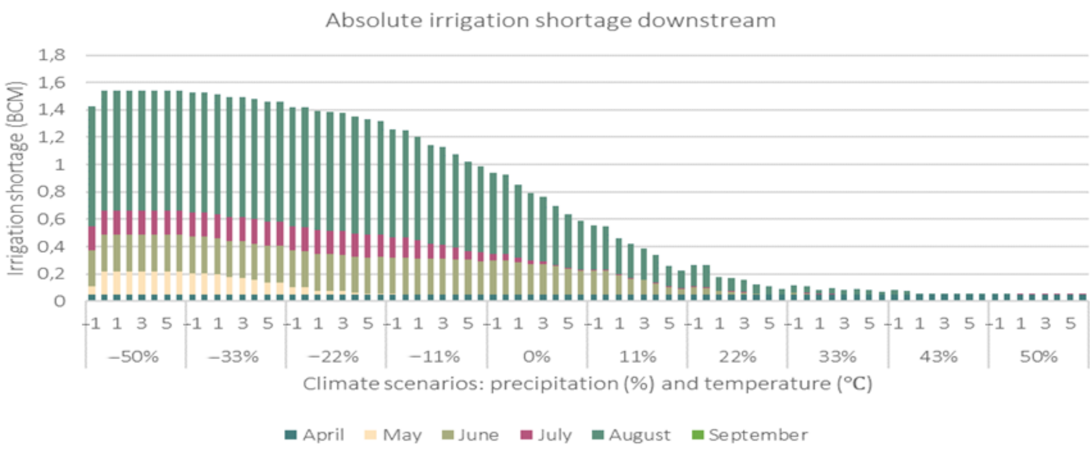

Figure S3. Absolute irrigation shortage per month in the lower Ili under upstream demand scenario AC1, with the shortages per month added up to annual shortage.

Finally, the results provide an insight into water security for irrigation, energy and environmental flow requirements in the IBB lower basin (see Figure S4). A transition from current demands (scenario AC1) to more rice cropping (scenario AC2) would result in a higher risk for the same climate scenarios. These increased risks may still be offset by higher precipitation and temperatures. The shift indicates that the basin may already be operating at the limit of sustainability, as more water is required to sustain both upstream and downstream uses simultaneously. The most extreme upstream demand increase scenario (AC4), would result in very high to high risks under all climate conditions, and no climate scenario can alleviate this pressure.

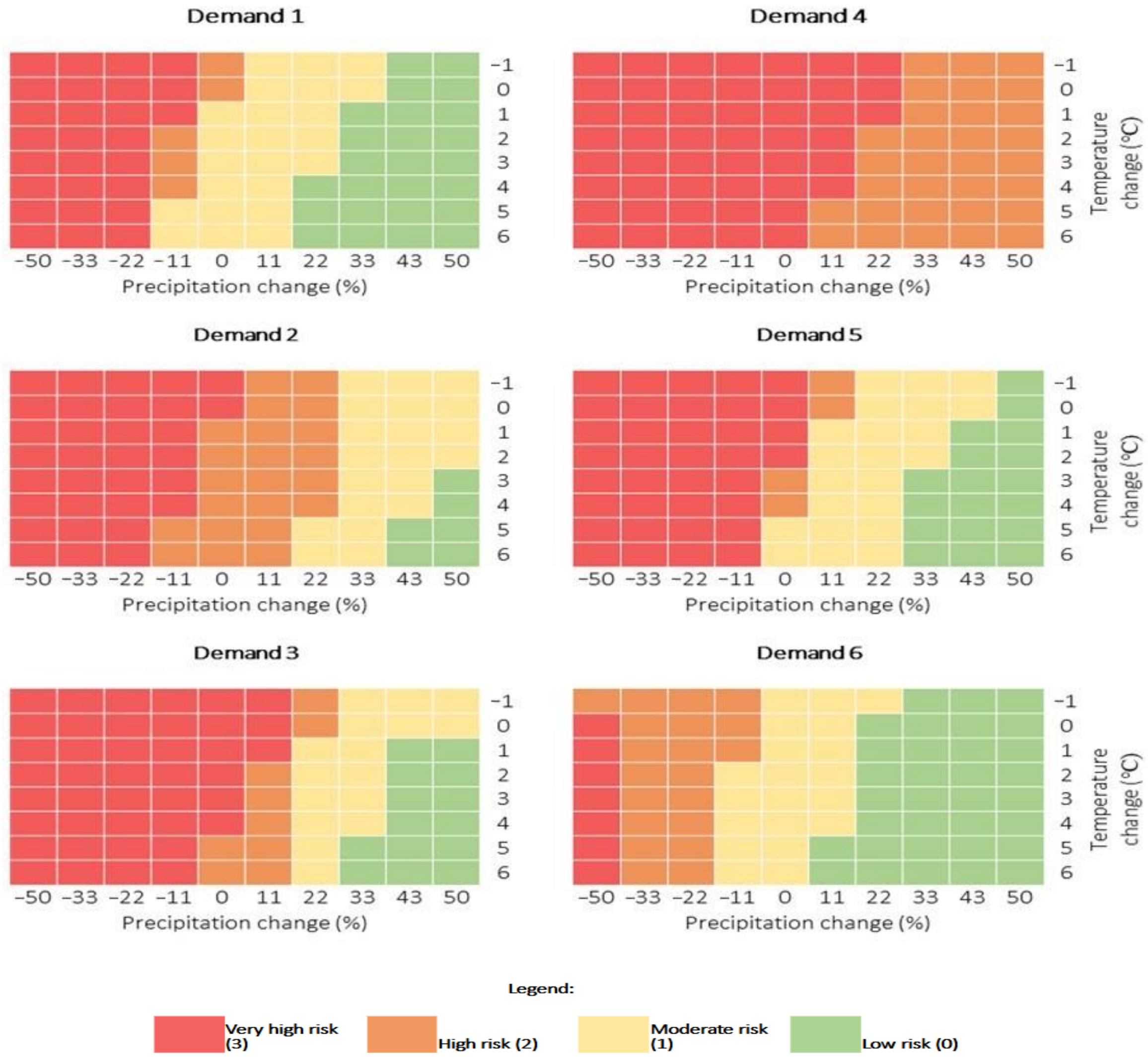

Figure S4. Surface map of the sustainable water futures for the water-energy-food related sectors downstream. The number of risk thresholds crossed (0–3) is used as a proxy for overall water security risk in the lower basin under precipitation and temperature change. Criteria for a sustainable water future per sector are: annual flows into the delta of 11 BCM in more than 51% of modelled years (based on Section 3.1), annual energy production greater than the mean value of recorded production (1000 MHW) and downstream irrigation shortages below the 80th percentile.