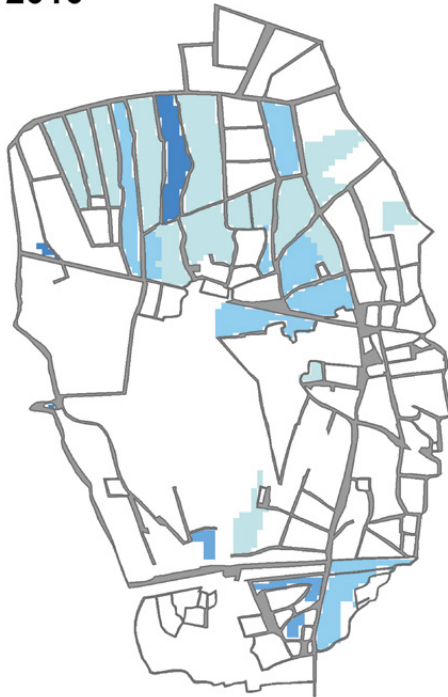


Policy Brief

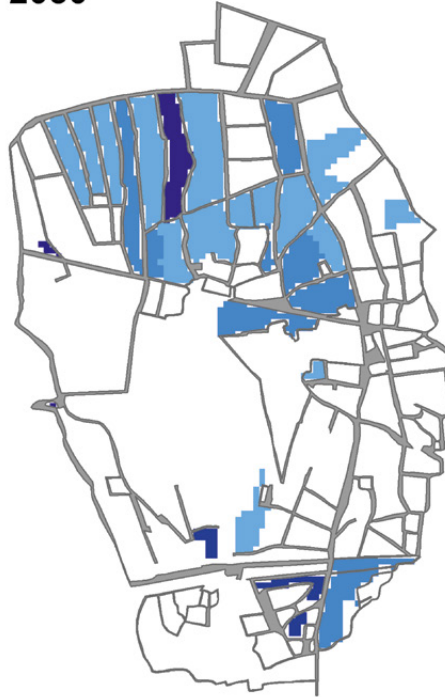
Issue 03/2015

On the Future of Water Management in the Fergana Valley Scenarios for Climate Change, Water Resources and Socio-Economic Development

2010



2050



Change in m³ water
per ton of yield

- <2000
- >2000-2500
- >2500-3000
- >3000-3500
- >3500-4000

Blue Water Footprint for Cotton
in m³ water per ton of yield

- > 4,000 - 5,000
- > 5,000 - 6,000
- > 6,000 - 7,000
- > 7,000 - 8,000
- > 8,000 - 9,000
- > 9,000 - 10,000
- > 10,000 - 11,000
- > 11,000 - 12,000

Projected increases in irrigation water requirements for cotton in the WUA Akbarabad by 2050 - "Business as usual" scenario

Key Messages

≈ Future climate, glacier, hydrologic and socio-economic changes may exacerbate water stress in Central Asia during the summer months by the year 2050.

This challenge can be met by focusing on "no-regret" adaptation measures, including

- ≈ increasing water use efficiencies in irrigated agriculture,
- ≈ adjusting land use in favour of new, less-water consuming "cash crops"
- ≈ strengthening catchment-based IWRM approaches.

Summary

Already today, Central Asia faces water stress with competing water uses and prevailing low water use efficiencies. For the future, climate, hydrologic and socio-economic changes are going to exacerbate the situation. Research undertaken in the frame of the CAWA project revealed that based on the climate model scenarios climate change will result in a further increase of mean annual, winter and summer air temperature, and a substantial further reduction of glacier-covered area in the Tien Shan, e.g. the Naryn basin by 20–60 % up to 2050 compared to the present state. The river runoff regime is expected to shift from a glacio-nival to a pluvio-nival runoff regime with increasing discharge in springtime and decreasing discharge in the summer

months for more pessimistic climate scenarios. By 2050, the increasing temperature triggers an increase in crop water requirements by 5–15 % for most of the traditional crops in the Fergana valley.

A detailed scenario analysis for the Fergana valley showed that the economies can cope with the future conditions if (1) water use efficiencies in irrigated agriculture are increased by applying new irrigation technologies and improving irrigation infrastructure, and (2) the land use is adjusted in favour of new cash-crops like vegetables, fruits, and grapes. These are "no-regret" adaptation measures which the Central Asian economies should undertake to cope with the socio-economic changes alone, even if there was no climate change.

Water resources under growing pressure

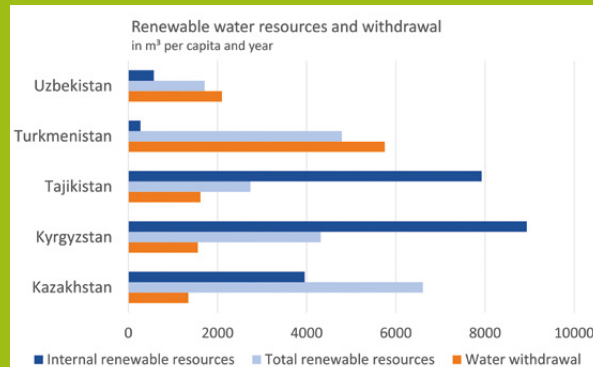
Introduction

The Central Asian economies strongly rely on the available water resources. However, water resources are put under growing pressure from climate and hydrological changes as well as from socio-economic changes. In the Fergana valley shared by the three countries Kyrgyzstan, Tajikistan and Uzbekistan, the population is expected to double by 2050 compared to 2000, and the livelihood for the growing population needs to be secured or even improved, if possible.

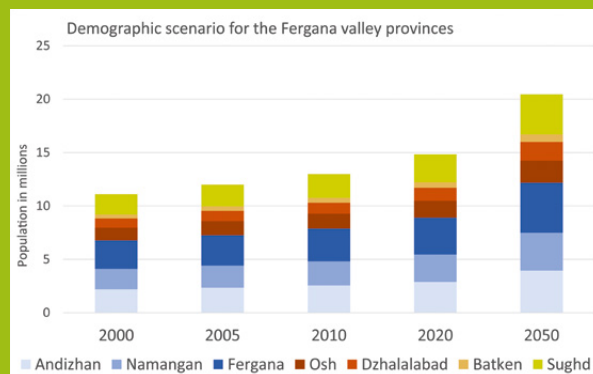
The interaction of the natural and socio-economic factors causes water stress, with climate change exacerbating the other stressors. Scenarios of the future development are a useful tool to assess future conditions and analyse adaptation options. They give decision makers a scientific basis for developing, preparing and implementing adaptation measures.

Within the CAWA project, a range of projections for climate and hydrological changes have been developed by Wuerzburg University, GFZ, and Uzhydromet. Scenarios for socio-economic development have been investigated by SIC ICWC and ZEU. This Policy Brief summarizes the main outcomes and conclusions for interested specialists and decision makers.

Facts and Figures



Available renewable water resources and water withdrawal per capita as for 2012
(Data: FAO, 2013)



Expected population growth in the provinces of the Fergana valley based on the assumption of stable growth rates

Terms and definitions

Uncertainty

An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgement of a team of experts).

Projection

In general usage, a projection can be regarded as any description of the future and the pathway leading to it. A more specific interpretation has been attached to the term „climate projection“ by the IPCC when referring to model-derived estimates of future climate in response to emission scenarios. When a projection is branded „most likely“ it becomes a forecast or prediction. Thus, there is a clear difference between projections and forecasts. A forecast is often obtained using deterministic models, possibly a set of these, outputs of which can enable some level of confidence to be attached to it.

Scenario

A scenario is a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future can unfold. A set of scenarios is often adopted to reflect, as well as possible, the range of uncertainty in projections.

Based on IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*
<http://www.ipcc.ch/report/ar5/wg1/>

Climate change in Central Asia and its impact on water resources

Changes in climate

All projections of future climate change in Central Asia are afflicted with substantial uncertainties. Any of the available projections is only a scenario, not a forecast, and least a forecast of climatic events or anomalies in specific years. The most recent global simulations by CMIP5 models, analyzed in the 5th Assessment Report of the IPCC, found a general warming tendency over Central Asia, with the central 50 % of the CMIP5 models giving a magnitude between +2.1 and +3.4 °C by 2081–2100 relative to the period 1986–2005. The expected precipitation changes over Central Asia are highly uncertain. Annual precipitation is likely to increase: the central 50 % of the CMIP5 models expect an increase of up to +12 % in winter, and a change between -3 and +5 % in summer. Extreme precipitation events are likely to increase.

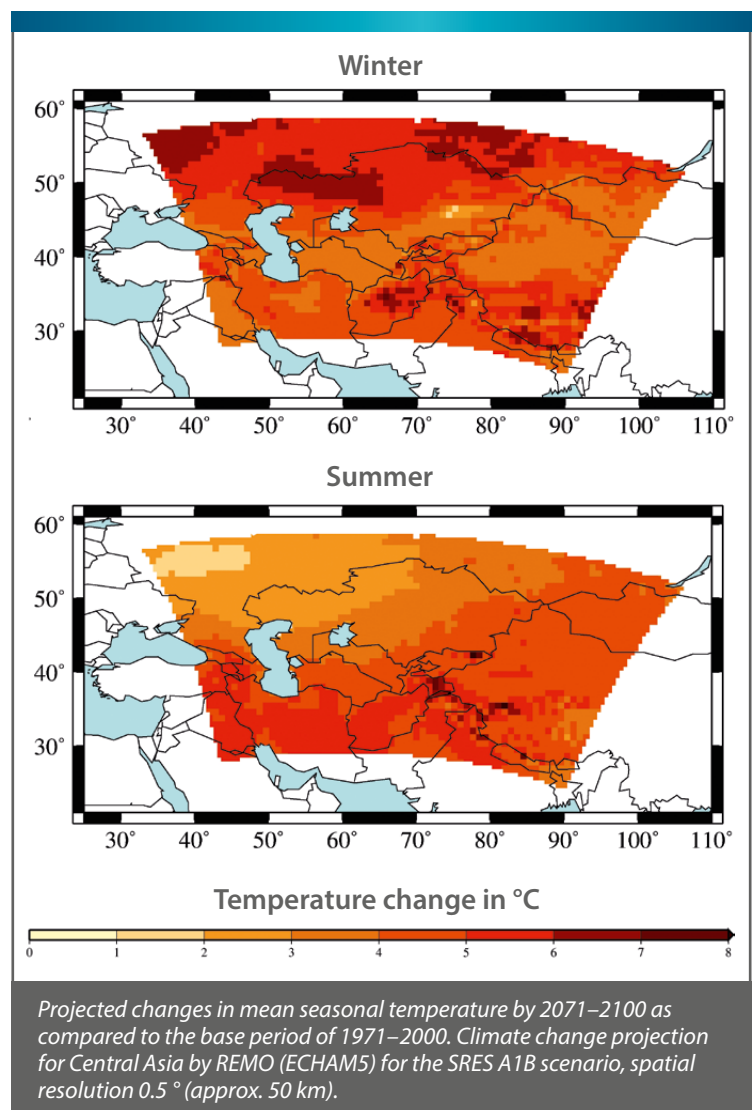
Focus 1

Regional climate model projections for Central Asia

In the frame of the CAWA project, a regional climate model study was undertaken at the University of Wuerzburg to give a more detailed picture of the spatial pattern of climate change in Central Asia (Mannig et al., 2013). Regional climate models use the output of global-scale General Circulation Models (GCMs) and dynamically downscale their results adjusting the findings to the local topography. Their main advantage over statistical downscaling approaches is that they can be applied in data-scarce regions where observational data is insufficient to establish statistical relationships over larger areas. For the study, the regional climate model REMO was used driven by the GCM ECHAM5 for the intermediate emission scenario SRES A1B. REMO simulations were run at a spatial resolution of 0.5° and 0.17° (ca. 50 and 18 km, respectively).

The simulations revealed changes in mean air temperature between +2 and +5° C for summer and winter by 2071–2100 as compared to the base period of 1971–2000. The temperature increase was more pronounced in the winter months over the northern and the mountainous parts of Central Asia, which is assumed to be an effect of a stronger warming in the Arctic and local snow cover albedo feedbacks. (The snow-albedo feedback means that a fresh snow cover is slowing down surface warming by reflecting large parts of the solar radiation back to the atmosphere. Thus, if in the course of climate change, the snow cover extent decreases in space and time, surface warming is going to be more pronounced.)

The regional climate model simulations also showed slight tendencies towards decreased summer precipitation and increased winter precipitation for the mountainous parts of Central Asia. Thus, annual precipitation changes by 2071–2100 range between -50 and +25 mm. However, the uncertainties of these precipitation projections are very high.



Changes in glacierization

In Central Asia, snow and glacier melt contribute substantially to river runoff in the spring and summer months and thus supply water at a time convenient for agriculture. In warm and dry years, glacier melt may compensate for scarce precipitation and provide a warm-season base flow. Over the past decades, Central Asia's glaciers have suffered substantial losses in area, volume, and mass (see *Focus 2*). Glacier recession will continue also in the upcoming decades, as the glaciers adjust their geometry to the past and ongoing climatic changes (see *Focus 3*). However, this does not imply that all glaciers will disappear in the near to medium term: Glaciers will retreat to higher altitudes and adjust to climate conditions eventually. For the glaciers to survive in the longer term, on the other hand, a substantial decrease in the rate of temperature increase is necessary. The continuous glacier retreat will result in a temporary increase in glacier melt, and thus total river runoff. However, the glacier melt contribution to river runoff is expected to decrease as soon as the glacier has passed the "tipping point" beyond which the increasing melt rates cannot compensate the shrinking of the glacier area. In the long term, summer runoff is expected to decrease due to the reduced glacier volume, whilst the interannual variability in runoff is expected to increase. This may have negative impacts on agriculture and the hydropower sector.

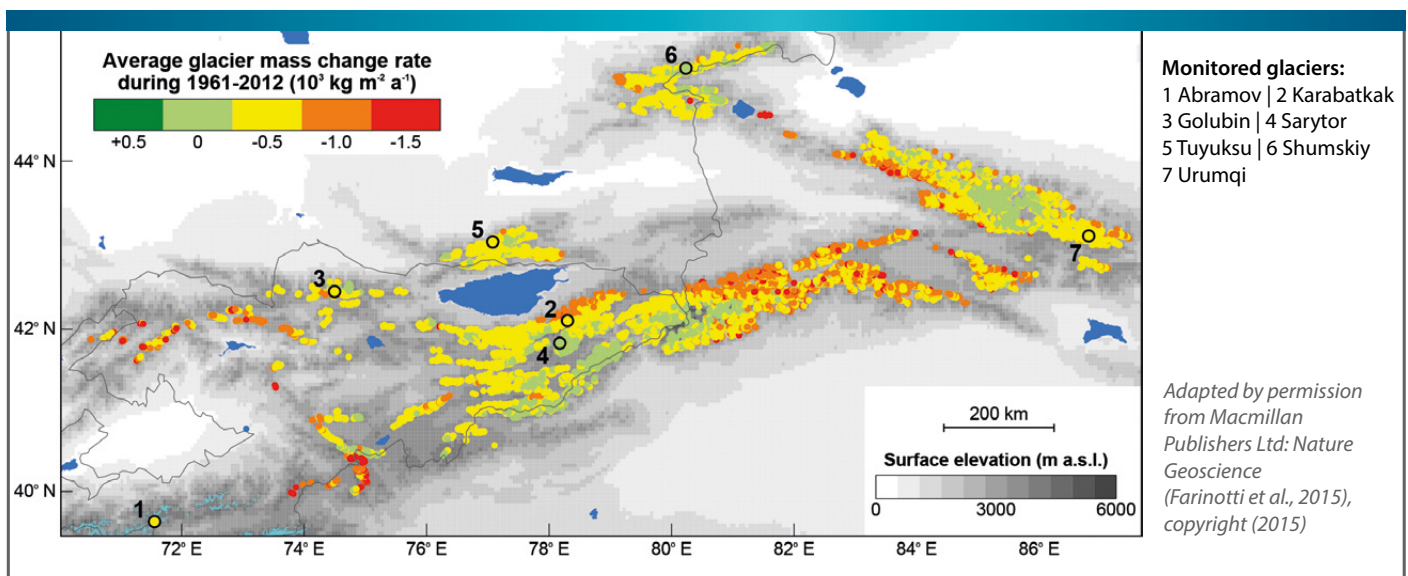
Focus 2

Past changes in glacierization

A regional assessment carried out at GFZ revealed that over the period 1961–2012, the glaciers in the Tien Shan mountains lost around $18 \pm 6\%$ of their area and $27 \pm 15\%$ of their mass (Farinotti et al., 2015). This corresponds to an average annual mass loss of around 5.4 gigatons, though with ± 2.9 Gt per year, the uncertainties of this estimation are still quite large. The biggest mass losses, of -8.0 ± 3.1 gigatons per year, occurred in the 1980s. The mass loss rates show considerable spatial variation: the lowest rates were found in the Central Tien Shan as well as in the north-eastern parts of the moun-

tain system; the highest rates have been detected for the Eastern Tien Shan (Halik range) and the western parts.

This mass loss contributed about of 5–7 % of the annual discharge volume at the gauge Uchterek in the lower Naryn over the period 1961–2012. In the Aksu catchment, with drier climate conditions and a higher degree of glacierization, the additional glacier melt contribution due to glacier recession sums up to more than 10 % of the average annual runoff at the gauge Xidaqiao for the same period.



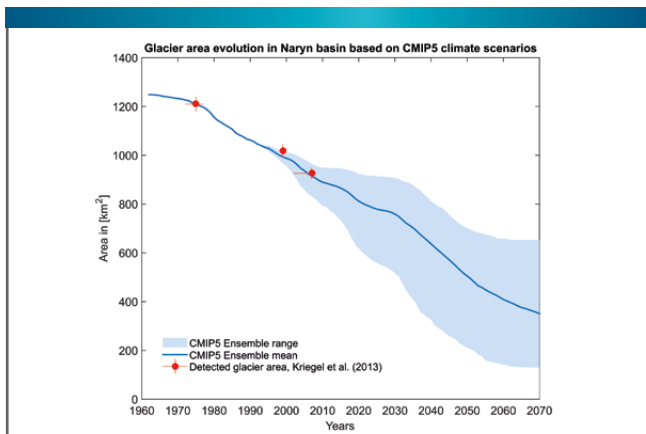
Average annual mass loss of glaciers in the Tien Shan during the period 1961–2012. The assessment is based on an ensemble of glaciological models driven by different global climate data sets. Circles indicate glaciers with available in-situ mass balance measurements for more than 5 years.

Changes in river runoff in the Upper Syrdarya river basin

Model experiments underpin expectations that the seasonality of river runoff in the Naryn basin will change in the upcoming decades, whereas results differ depending on the applied scenario. For the rather optimistic RCP 2.6 scenario an increase in spring and early summer runoff are expected, with decreasing summer runoff only for the warm and dry scenario. For the more pessimistic scenario RCP 8.5, earlier snowmelt will increase the spring runoff while summer runoff will decrease due to receding snow melt and reduced glacier melt contribution in the second half of the 21st century. This will result in a shift from a glacio-nival to a pluvio-nival runoff regime. A pluvial runoff regime is characterized by a higher inter-annual variability in river runoff because precipitation is not accumulated over the winter and released in the spring period. Instead, river runoff responds directly to short-term variations in precipitation.

Focus 3 Projections of future changes in glacierization

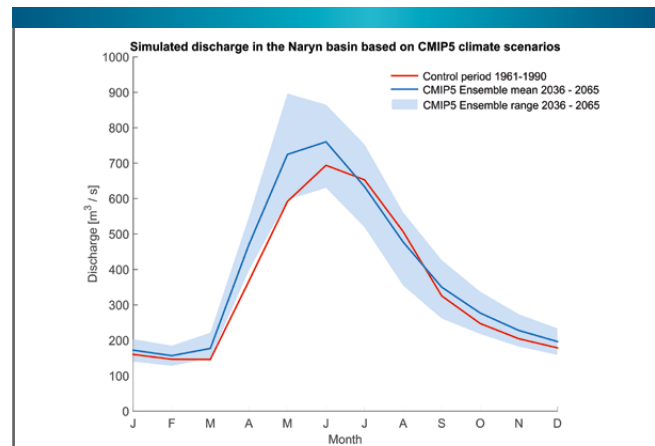
Hydrological model simulations at GFZ using the latest CMIP5 global climate projections show that glacier recession is going to continue in the upcoming decades. For two extreme Representative Concentration Pathways (RCP 2.6 and 8.5) covering the entire range, different General Circulation Models were selected to represent the entire range of possible future scenarios. For the Naryn basin, glacier area is expected to shrink by 20–60 % until the 2050s compared to their present state. This corresponds to a decrease in glacier-covered area from about 1000 km² to 400–800 km² depending on the applied scenario.



Projected changes of glacierized area in the Naryn basin based on the latest set of global climate model projections CMIP5. The climate change ensemble includes different Representative Concentration Pathways (RCPs 2.6 and 8.5) and selected general circulation models representing the range of 61 IPCC models. The glacier changes were simulated using a calibrated hydrological model. Observed glacier areas were derived from satellite remote sensing (Kriegel et al., 2013).

Focus 4 Future changes in river runoff

The hydrological model WASA was used to simulate future changes of river runoff in the Naryn river basin, the main tributary to the Syrdarya. For the set of CMIP5 models enclosing the entire range of Representative Concentration Pathways and different GCMs, the study found increasing runoff in spring and early summer for the optimistic scenarios with little changes in late summer runoff. For the more pessimistic scenario RCP 8.5, the increase in spring and early summer runoff by about 50 % can be accompanied by a runoff reduction in July/August by up to 35 % compared to the control period of 1961–1990.



Projected changes in mean monthly runoff at gauge Uchterek, the outlet of the Naryn river basin and related scenario range (RCP2.6 and RCP8.5). The changes were simulated using the hydrological model WASA driven by different CMIP5 GCM outputs.

Changes in agricultural water requirements

Changes in agroclimatic conditions

Agroclimatic variables characterize the local conditions relevant for crop cultivation, among them the thermal resources and natural water availability (e.g. number of frost and heat days, series of dry / wet days). Changes in the agroclimatic conditions may require adaptation of cropping varieties and patterns. A study carried out by SIC ICWC in the frame of the CAWA project showed that, on the one hand, climate change may have positive effects for agricultural production in the Fergana valley (Stulina et al., 2014). Due to increasing temperatures as projected by the REMO model (see *Focus 1*), the growing period might start 14 days earlier by the year 2100, and the growing season is expected to lengthen by 30 to 38 days. At the same time, the duration of growth stages is shortened, which in total offers the chance to cultivate up to 3 crops over the year. However, soil moisture remains the limiting factor. On the other hand, the frequency of heat days is likely to increase with very high temperatures slowing down plant growth. For cotton, the temperature threshold value is 35° C. In the period 2030–2050, the number of heat days is expected to increase from 48 to 72 compared to the base period 1960–1990. This will largely jeopardize the advantages of increased thermal resources.

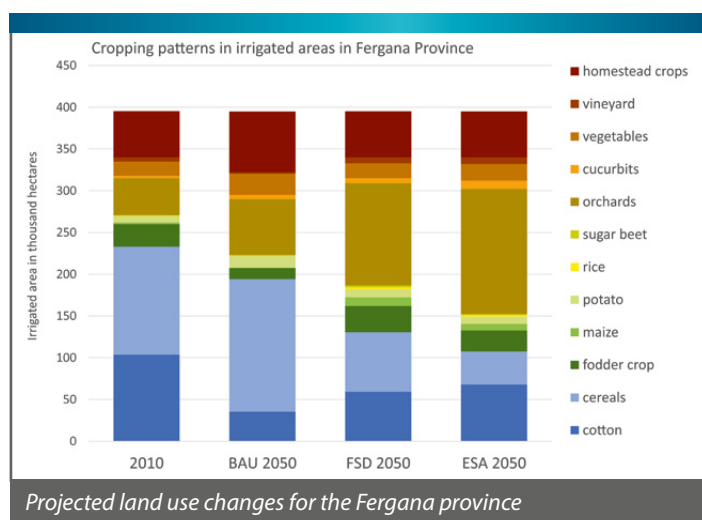
Adapted land use and rise in production

For the scenario analysis carried out by SIC ICWC, basic assumptions were made to project future water requirements (Muminov and Rakhimdzhanov, 2014; Sorokin, 2015). These assumptions concern adaptation of land use strategies (*Focus 5*), changes in crop yields (*Focus 6*), and a substantial increase in animal production. The increasing agricultural production per head of population will substantially improve the food supply to the local population. However, for none of the provinces and none of the scenarios, local food production will actually be sufficient to meet the official recommendations for nutrition standards by the year 2050.

Focus 5

Adaptation of land use strategies

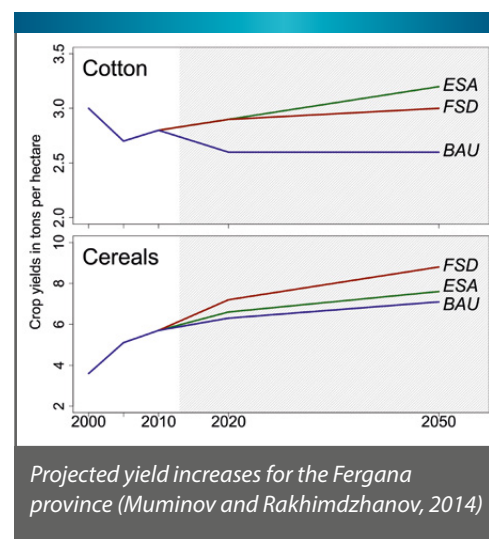
The study by SIC ICWC (Muminov and Rakhimdzhanov, 2014; Sorokin, 2015) elaborated the socio-economic parameters for the future scenarios. The cropping patterns were optimized using the GAMS algorithm to meet the scenario-specific target values for food supply to the population (self-sufficiency) and export revenues. Compared to the current cropping patterns, the share of cotton is decreasing in favour of fruits (orchards, grapes), vegetables and fodder crops. The provinces Fergana and Sughd stand out for their increase in fruit cultivation, as these provinces are particularly suited for it. Cotton cultivation is reduced particularly on less productive areas. However, in the long-term, cotton remains the main crop in the Uzbek provinces Andizhan and Namangan as the secondary products of raw cotton processing (protein meal, cotton-seed hulls, etc.) provide fodder crops to the livestock sector, mainly beef cattle.



Focus 6

Rise in crop yields

The scenario analysis is based on the assumption that crop yields will increase in the future for the ESA and FSD scenarios (see info box on the right). The yield increases are explained by various improvements in agricultural techniques and practices, among them the adoption of innovative irrigation techniques, the increasing use of fertilizers and new fertilizing methods, improved planning and execution of field works, introduction of new crop varieties, improved seed quality, multi-year crop rotation, and monitoring of plant diseases and pests (Muminov and Rakhimdzhanov, 2014).



Changes in water requirements

Future water requirements were assessed by SIC ICWC and ZEU using the ReqWat and Spare: Water models, respectively (Stulina et al., 2014; *Focus 7*). Both models agreed that due to changing climate conditions an increase in crop water requirements is expected. For the BAU scenario, the irrigation water requirements would increase substantially. However, the implementation of innovative irrigation technologies allows savings of irrigation water of up to 20–25 % for sprinkler irrigation (cereals) and up to 40–50 % for drip irrigation (cotton, fruit, vegetables, maize). This could stabilize or even slightly reduce the irrigation water demand in the long term while significantly increasing yields.

Focus 7

Future water requirements

Using the Spare:Water model, researchers at ZEU analysed the future water requirements given the climate scenarios provided by the REMO simulations. The calculations revealed an increase in crop water requirements by 4–13 % for cotton and 6–9 % for wheat for normal years by 2050. The irrigation requirement (without considering innovations) would therefore increase by up to 14 % for cotton, and up to 38 % for wheat. For wheat, a substantial increase in irrigation water demand

is expected due to substantial decreases in winter precipitation as projected for the Fergana valley by REMO.

For the three Uzbek provinces Andizhan, Fergana and Namangan, a total irrigation water requirement (blue water footprint) of 7.88 km³ per year was calculated for the reference year 2010. By 2051–2080, the blue water footprint could increase by around 7 % to 8.42 km³ per year for the BAU scenario.

Socio-economic scenarios

Scenario BAU

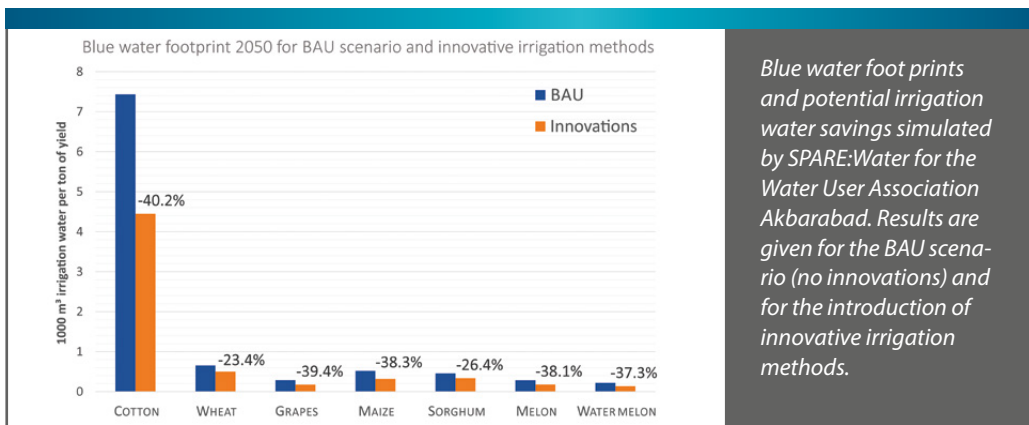
“Business as usual” – assumes no changes in the land use strategies, cropping varieties and patterns, and irrigation methods.

Scenario FSD

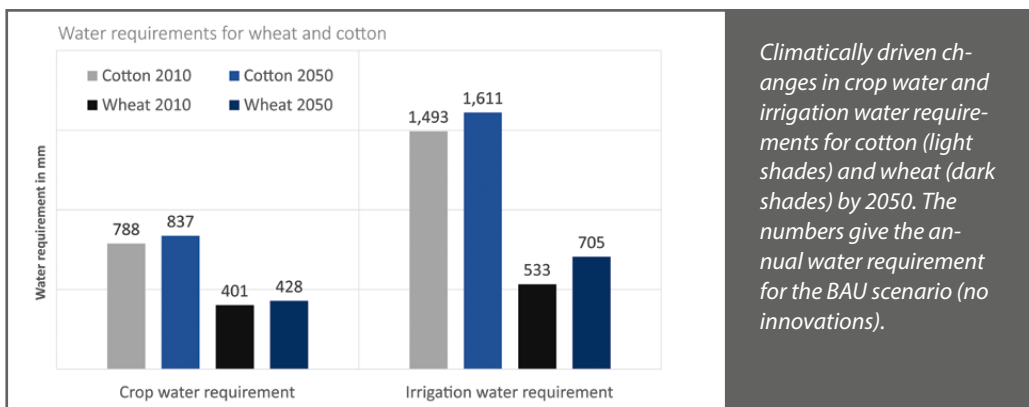
“Food security and diet change” – development towards national food security with a change in lifestyle. This includes an increase in livestock production (incl. meat, eggs, milk). Assumes the introduction of new irrigation technologies and a shift from cotton and cereal production towards fodder crops and maize.

Scenario ESA

“Export-oriented sustainable adaptation” – assumes a change in land use strategies and opening of the agricultural commodity market. Introduction of new irrigation technologies, shift from cotton production towards new “cash crops” (fruits, vegetables, grapes).



Blue water foot prints and potential irrigation water savings simulated by SPARE:Water for the Water User Association Akbarabad. Results are given for the BAU scenario (no innovations) and for the introduction of innovative irrigation methods.



Climatically driven changes in crop water and irrigation water requirements for cotton (light shades) and wheat (dark shades) by 2050. The numbers give the annual water requirement for the BAU scenario (no innovations).

Recommendations to policy makers

Main risks

In the upcoming decades, the population and the economies in the Fergana valley will face substantial challenges. The changing environment with increasing air temperature, reduced runoff in the rivers during the vegetation season and more frequent droughts and heatwaves may result in reduced water availability, which will have a high impact on agricultural production threatening food security and the livelihoods of large parts of the population. This comes at a time when the population in the Fergana valley is growing rapidly with water demands increasing.

Potential adaptation measures

Policy makers should urgently develop and implement adaptation programs focusing on:

Adjustment in technologies and infrastructure. The main focus should be on increasing water use efficiencies by introducing innovative irrigation technologies (e.g. sprinkler, drip irrigation). This requires substantial investments but is expected to have the highest impact with regard to water savings. Other measures include the adaptation of cropping patterns in space and time, the promotion of winter-time crops when precipitation is higher, the reduction of water-intensive crops, and introduction of new, drought and salt resilient crop varieties, and the reuse of waste-water and irrigation return flows where possible.

Introduction of Integrated water and land resources management (IWLRM). New technologies require the introduction of new management

approaches to unfold their full potential. This includes the introduction of a catchment-based (as opposed to administrative boundaries) planning and management, e.g. in river basin organizations, and water user associations. Scientifically based methods, such as the analysis of crop and irrigation water requirements presented in this Policy Brief, should be applied to take decisions about land and water use.

Disaster risk management. Risk management should be integrated into water and land use planning at all management levels. This encompasses the development of monitoring, forecasting and early warning systems for climate and hydrological events as well as for the use of land and water resources.

Diversification. Livelihood and economic diversification strengthens the resilience of economies and population to climate-related hazards. Economic transformation may create new incomes for the population which are less vulnerable to changes and variability in river flow.

Building capacities. The long-term success of adaptation relies on the awareness and knowledge of decision makers, resources managers, and water users. Public participation in IWLRM and adaptation planning is one way to achieve this. Furthermore, universities should integrate geoscientific methods and approaches into their curricula, and take over a more active role in supporting life-time learning by offering vocational trainings for water and land resources managers.

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Picture credits

Blue Water Footprint, ZEU, p.1 / Demographic scenario, SIC ICWC, p. 2 / REMO scenarios, B. Mannig, p. 3 / Future glacier reduction, GFZ, p. 4 / Runoff scenarios, GFZ, p. 5 / Cropping patterns and Yield scenarios, SIC ICWC, p. 6 / Blue water footprint and water requirements, ZEU, p. 7

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