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Water Footprint Analysis of Central Asia

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Blue Peace Central Asia

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Water Footprint Analysis of Central Asia

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The BPCA initiative aims to promote and enable sustainable and efficient water resource management at transboundary, river basin level while addressing the challenges of the water-energy-food nexus in six Central Asian states: Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Executive Summary

This report presents the results of one of the first practical applications of the **Water Footprint Assessment** methodology in the Central Asian region. The Water Footprint is a measure of the water use for the production of goods and services. The Blue Water Footprint refers to consumption of surface and groundwater, while the green Water Footprint refers to the direct consumption of rainwater: the grey Water Footprint refers to pollution.

Indirect water use is assessed and expressed through the concept of **Virtual Water Trade**, the amount of embedded water that is used to produce goods that are traded across national borders. Water footprints are used to measure **economic water productivity**, the financial return for one m³ of water consumed.

The countries covered by the assessment are Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The Water Footprint Assessment results show that agriculture has by far the largest Water Footprint and this sector is thus the focus of this report. The Water Footprint of agriculture can be reduced by using water as efficiently as possible.

Green water and rainfed agriculture are particularly important in Kazakhstan. A high dependence on green water for production, translates to a high vulnerability to drought. Serious drought in Kazakhstan has a negative impact on the food security of the whole region as other countries rely on Kazakh rainfed wheat.

Blue water use for irrigation is important for all countries with Uzbekistan being the largest blue water user. Cotton is the main crop using blue water. Annual water withdrawal for agriculture is around 68 billion m³. However, only 33 billion m³ is consumed by crops (Blue Water Footprint), and close to 50% of the water withdrawn is lost due to the state of infrastructure for irrigation water supply and wasteful practices applied. Minimizing these losses can improve the water situation significantly.

The region is a net virtual water exporting region with cotton being the largest blue virtual water export commodity and wheat the largest green virtual water export commodity. As much of the trade of Central Asian countries is between neighbours, there is a large share of virtual water that stays ‘in the region’.

The financial return per m³ of water used for producing and exporting unprocessed crops tends to be low. Trading a primary crop after adding value through processing is generally more profitable not just from a purely economic but also from the point of view of water economic productivity. High-value crops such as vegetables provide a comparably high economic value for water used.

The Water Footprint Assessment for Central Asia identified several opportunities and also concerns in terms of water use efficiency and virtual water trade. The Water Footprint concept in the region can be used to identify differences in the efficiency of water use — green, blue as well as grey water — between sectors, countries, crops or agricultural systems. Defining regional benchmarks along with follow-up field investigations would increase the understanding of opportunities and bottlenecks for efficient water use. Water Footprint metrics can provide evidence for policy making and also measure the efficiency of policies related to water management, agriculture, trade and the economy as a whole. Applying a Water Footprint analysis can support governments in formulating policies that are beneficial both from an economic and a water management perspective.

Among the conclusions drawn by the Water Footprint Assessment at hand, the following can be highlighted:

- Minimizing water losses (for example through investments in infrastructure) and the Water Footprint of production have the potential to improve the water situation significantly;
- Integration of Water Footprint data with drought modelling could be considered for long-term sustainability planning of rainfed agriculture in Kazakhstan;
- Improved stability and trade relations in the region, and an improvement in the dialogue between the countries, would give possibilities for countries to decrease irrigated wheat production that has a low economic benefit per volume of water used;
- Countries should consider how further value can be added to water intensive sectors by the processing of primary crops;
- The countries of the region should also consider switching part of their production and exports from historically grown irrigated crops to economically more advantageous high-value products such as vegetables and fruits;
- The application of Water Footprint Assessments to monitor the changes in Water Footprints and economic value of irrigation water gives an opportunity to analyse the efficiency of investments and the introduction of new policies with the aim of saving water, and
- An improved, joint understanding of Water Footprints and virtual water trade may facilitate the design of future trade and water cooperation agreements, and contribute to food security and economic development throughout the region of Central Asia.

For further work on the application of the Water Footprint Methodology in the region it is suggested to establish a working group with water policy experts from all countries. This working group could outline the next steps for applying Water Footprint methodology in Central Asia.

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1. Introduction

The expansion of irrigated farming in Central Asia during the Soviet era has had a tremendous impact on the availability of water resources, with the most visible effect being the drying-up of the Aral Sea. In the three decades since the fall of the Soviet Union, the five Central Asian states have undergone major socio-political and economic changes. Economic development in the still transitioning economies is heavily dependent on the availability of water resources for irrigation, domestic use and industry. While the Central Asian states recognize this reliance on water, transboundary cooperation at the two river basin levels that provide a large part of the water, Amu Darya and Syr Darya, is still a long way from achieving the potential that it has for mutual benefit. To support in this process, a Water Footprint Assessment of Central Asia was commissioned by the Swiss Agency for Development and Cooperation in the context of the Blue Peace Central Asia initiative to demonstrate a novel tool for evidence-based decision making on water policy.

This report presents the results of one of the first practical applications of the **Water Footprint Assessment**[1] methodology in the Central Asian region. The Water Footprint is a measure of the water use for the production of goods and services. It is a complex indicator which goes beyond water withdrawals to look at consumptive water use and water pollution. It aims to shed light on water use along supply chains and indirect water use that is often overlooked when speaking about water consumption.

Indirect water use in the context of our global economy is expressed through the concept of **Virtual Water Trade**, the amount of embedded water that is used to produce goods that are traded across national borders. See section 1.3.

Water footprints can further be used to measure the financial return for one m³ of water consumed. This is defined as **economic water productivity**. See section 1.4.

This report gives a review of quantitative data and associated interpretations, and is accompanied by a discussion and conclusions section. Some areas of concern regarding blue and green water use have been identified and suitable response measures to reduce the Water Footprint and increase the economic water productivity in the region are proposed.

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[1] In 2002, Arjen Hoekstra, whilst working at the UNESCO-IHE Institute for Water Education, created the Water Footprint as a metric to measure the amount of water consumed and polluted to produce goods and services along their full supply chain. For details on the methodology see: waterfootprint.org/en/water-footprint/global-water-footprint-standard

The report provides an appreciation of the water use and virtual water trade patterns for Central Asia and allows governments and experts to better understand the balance between water and food for human consumption, economic productivity and the environmental water requirements. This knowledge can inform water management policies and practices, allowing for a more efficient and productive use of available water resources in the region.

The Water Footprint Assessment was carried out for domestic, industrial and agricultural water use. The results show that agriculture has by far the largest Water Footprint and thus the focus of this report is on water use in agricultural production on arable land, with only limited references to the domestic and industrial Water Footprint.

1.1. Water Footprint Assessment

The Water Footprint measures the consumption of freshwater resources for producing goods and services. It is different to water withdrawal in that it measures water consumption not abstraction. 'Consumption' refers to loss of water from the available ground/surface water body in a catchment area. Losses occur when water evaporates, returns to another catchment area or the sea, or is incorporated into a product or a service.

The Water Footprint has three components: green, blue and grey.

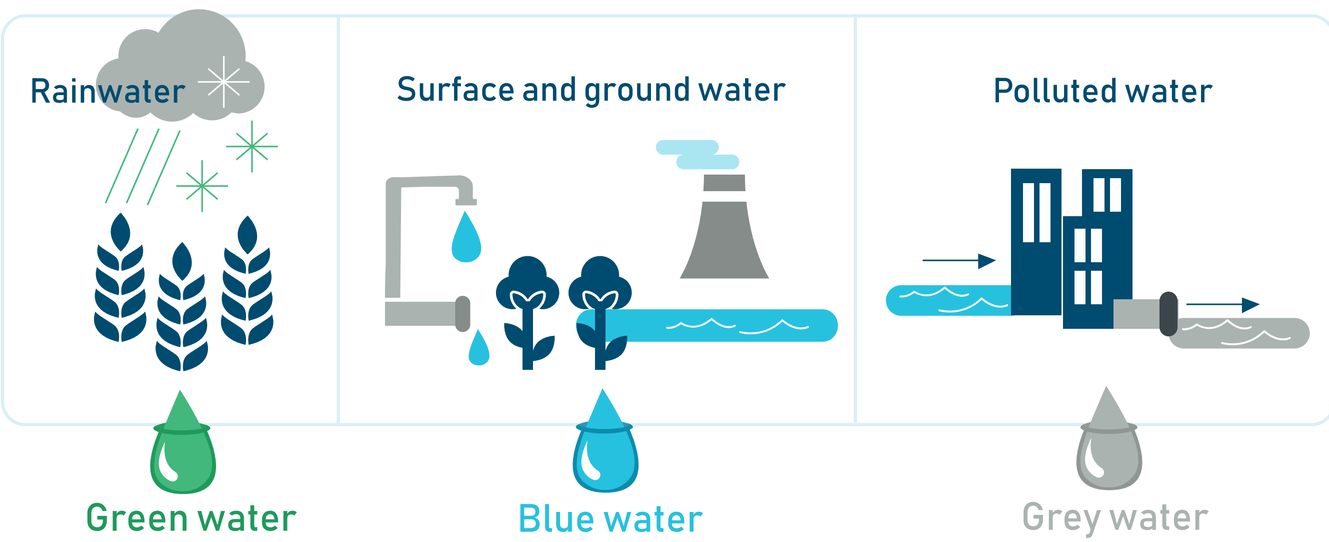

Figure 1. A visual portrayal of the concepts of green, blue and grey Water Footprints

The **Blue Water Footprint** refers to consumption of surface and groundwater and is relevant for domestic, industrial and agricultural use. It indicates dependency on rivers, lakes or aquifers and shows vulnerability to water scarcity and contributes to pressure on water resources.

The **Green Water Footprint** refers to the direct consumption of rainwater and is relevant for agriculture, forestry and horticulture. The Green Water Footprint reflects dependence on precipitation, thus vulnerability to drought conditions. When green water has infiltrated into groundwater or other water bodies it is considered to be blue water.

The **Grey Water Footprint** refers to pollution and is defined as the volume of freshwater that is required to assimilate a given amount of pollutants to reach ambient water quality. In other words, if a pollutant enters a freshwater body, accidentally or discharged on purpose, the Grey Water Footprint indicates how much freshwater is necessary to neutralize the pollutant load. The Grey Water Footprint depends on which ambient water quality standard is used.

Together, these components provide a comprehensive picture of water use by specifying the source of water consumed, either as rainfall/soil moisture (green water) or surface/groundwater (blue water), and the volume of fresh water required for assimilation of pollutants (grey water) (Figure 1)[2].

1.2. National Water Footprints

The national Water Footprint (WF) of production is the amount of water resources used to produce goods and services within the country. This includes the Water Footprint of agricultural, industrial and domestic water use. It is the total volume of freshwater consumed within the borders of the country for production of goods and services that are either consumed within the country or are being exported. It does not include virtual water imports — water used in other countries to produce the goods consumed within the country.

The national Water Footprint of consumption is the amount of water used to produce all the goods and services that are consumed by the people living in a country. The Water Footprint of consumption includes virtual water imports and excludes virtual water exports — water consumed within the country for goods that are exported.

[2] In agriculture the Water Footprint estimated is limited to the precipitation (green water) or irrigation (blue water) during the period of cultivation. It does not take into account access to water before sowing that may be of importance for the establishment of the crop. For example, snow that may be important for the reserves of water in the soil in the spring is not included. This can be seen as a weakness of the methodology.

1.3. Virtual water flows

The virtual water export from a country is the volume of virtual water associated with the export of goods from the area. It is the total volume of freshwater consumed or polluted to produce products for export.

The virtual water import into a country is the volume of virtual water associated with the import of goods into the area. It is the total volume of freshwater used in the exporting areas to make the products.

Virtual water flows (also known as Virtual Water Trade) are used to estimate if a country is losing or gaining water through its trade activities and to help governments in water scarce areas to adapt their production and trade policies to avoid water losses.

1.4. Economic water productivity

Water Footprints can be used to measure the financial return per one m^3 of water consumed. This is defined as economic water productivity. By measuring the economic water productivity, it is possible to optimize water use from that perspective. This insight can help governments to introduce policies with the aim of increasing the monetary value per m^3 of water used. In other words, it helps to identify ways to increase economic water productivity.

The economic value of one m^3 of water used for production is a function of the trade value expressed in a monetary unit. A primary crop can be exported or imported in the form of different product categories with different trade values. For example, there are seven product groups under the primary crop "Wheat": bread, cereals, flour, macaroni, pastry and wheat. As prices differ, the value of one m^3 of water varies between product groups of the same primary crop.

1.5. Water Footprint reduction

Both Blue and Grey Water Footprints in industries and households can be reduced to very low levels or even zero by full water recycling with no pollution added. In a fully closed cycle, there are neither evaporation losses nor polluted effluents. There are limits to decreasing the Water Footprint of crop production, as plants require water for evapotranspiration and growth. However, the Water Footprint of agriculture can be reduced by using water as efficiently as possible. For crops, benchmarks have been developed that indicate the reasonable volume of water per kg of crop when the best available technology is being used.

Table 1. Type of response measures per type of Water Footprint, the examples of agriculture and energy

	Agriculture	**Energy**
Green Water Footprint	Decrease Green Water Footprint (m^3/t) by increasing green water productivity (t/m^3) in both rainfed and irrigated agriculture. Increase total production from rainfed agriculture.	Not applicable
Blue Water Footprint	Decrease Blue Water Footprint (m^3/t) by increasing blue water productivity (t/m^3) in irrigated agriculture. Decrease ratio Blue/Green Water Footprint.	Zero Blue Water Footprint in case there are no losses through evaporation — full recycling.
Grey Water Footprint	Reduced use of artificial fertilizers and pesticides; more effective application. More efficient use of water for irrigation, less salinization of drained water. Grey Water Footprint can be reduced through organic farming.	Zero Grey Water Footprint:- no pollution — full recycling and treatment of remaining return flows.

2. Scope of Work, Methodology and Data

The scope of work for this study is to deliver a Water Footprint Assessment and virtual water trade data for five Central Asian nations (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan)[3] with a focus on agriculture. This exercise has analysed and delivered values for the National Water Footprint of production and consumption, virtual water trade between the five countries and between the five countries and the rest of the world, with selected results of economic water productivity.

The Water Footprint Assessment is a quantitative method reliant on water use data, related to agricultural and industrial production, trade and other factors. The Water Footprint data used in this report come from peer reviewed scientific literature and have been accessed from publicly available global databases. In many cases, models have been used to produce the data. These data have not been verified using local data and will contain the inaccuracies and uncertainties inherent in datasets produced using data aggregated from local sources to the country scale.

A more detailed account of the methodology and aspects related to data needs, including background research, expert consultations, assumptions together with limitations and some further background is given in the Annex.

[3] Afghanistan was not included in this Water Footprint Assessment.

3. Results

3.1. Key findings at regional/country level

In Central Asia, green (rain) and blue (ground and surface) water resources are mainly consumed for crop production. The share of green, blue and grey water uses in the total Water Footprint of production and consumption in Central Asia, as well as an overview of virtual water trade, are found in Figure 2. Traditionally, water management focuses on blue water. The Water Footprint concept also focuses on the use and management of green water – the part of the rainwater used by plants. Green water is important in the whole region, particularly in Kazakhstan where rainfed agriculture is dominant. To put this green water use into perspective, if we total all rainwater used in agriculture in the region, Kazakhstan's share is 77%, while the combined share of the other four Central Asia countries is 23%.

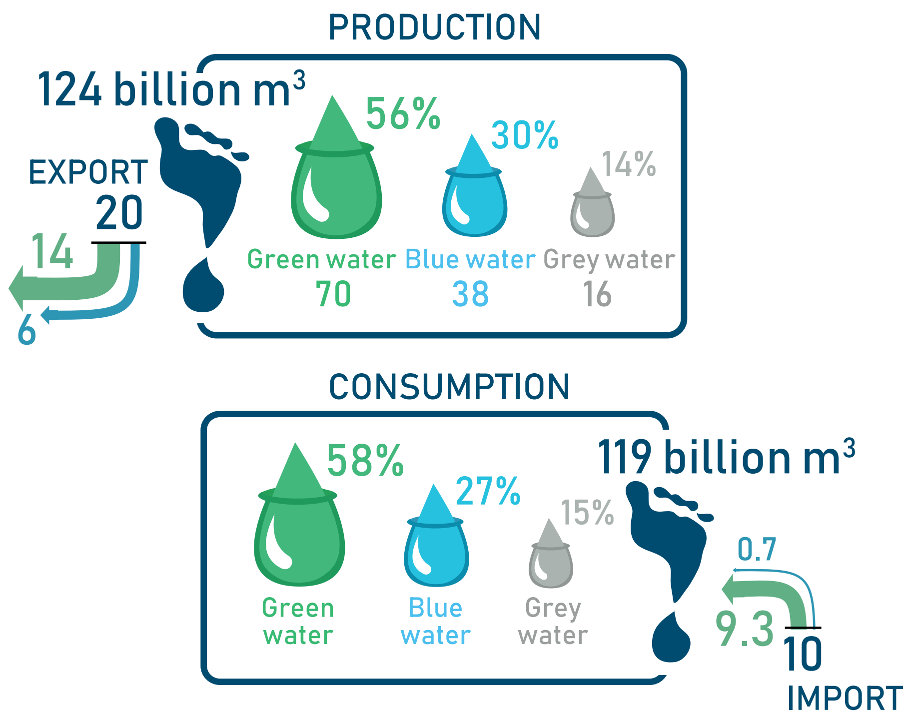

Figure 2. *Import and export figures are in billion cbm.* Water footprint of production and consumption in Central Asia and indicative virtual water flows to and from the region

A high dependence on green water for production translates into a **high vulnerability to drought**. Regional droughts can affect Central Asia's economy and food security considerably. Serious drought in Kazakhstan has a negative impact on the food security of the whole region as other countries rely on Kazakh wheat. The geographical distribution of the Green Water Footprint can be seen in Figure 3.

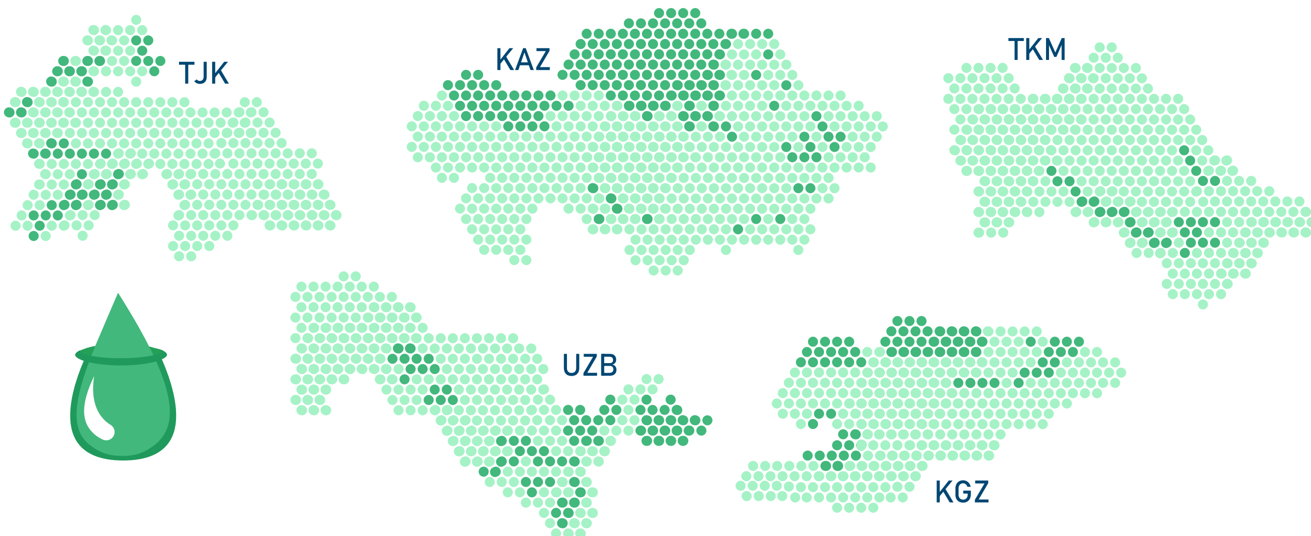

Figure 3. Green Water Footprint of production map, CA region

Annual water withdrawal for agriculture is around 68 billion m^3. However, only 33 billion m^3 is consumed by crops (Blue Water Footprint), and close to **50% of the water withdrawn is lost** due to the state of infrastructure for irrigation water supply and wasteful practices used. Minimizing these losses can improve the water situation significantly including for irrigated agriculture, water for drinking and industry, and water-dependent ecosystems. These water losses are not included in the Water Footprints.

Uzbekistan is the largest blue water user with a share of 49% of the total in the region (Figure 4). Kazakhstan and Turkmenistan are major blue water users as well. Blue water for irrigation is also important for the smaller countries, Kyrgyzstan and Tajikistan.

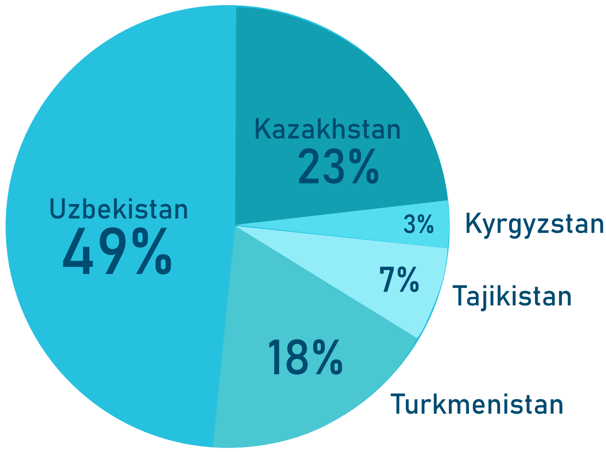

Figure 4. Blue Water Footprint of crop production per country

The largest share of blue water use (irrigation) in the region is for cotton production — 47% — with a concentration in Uzbekistan and Turkmenistan. Cotton is thus the main contributor to water scarcity in the region. Since most of the cotton production is destined for export and related economic gains, water scarcity and hydrological droughts have a negative impact on the economy of the region and farmers. The geographical distribution of the blue Water Footprint in Central Asia can be seen in Figure 5.

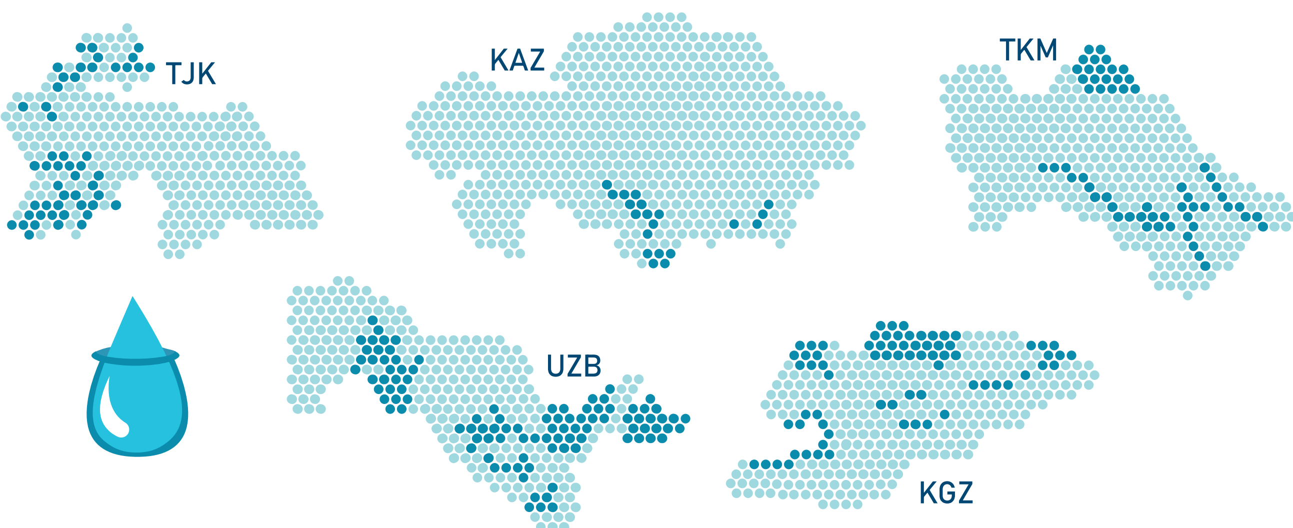

Figure 5. Blue Water Footprint of agricultural crop production, CA region

Uzbekistan and Turkmenistan are the largest cotton growers in the region, but Uzbekistan has a lower Water Footprint per tonne of cotton compared to Turkmenistan (Figure 6). In other words, more cotton crop per drop of water is produced in Uzbekistan than in Turkmenistan. Kazakhstan and Kyrgyzstan have even lower Water Footprints per tonne of cotton.

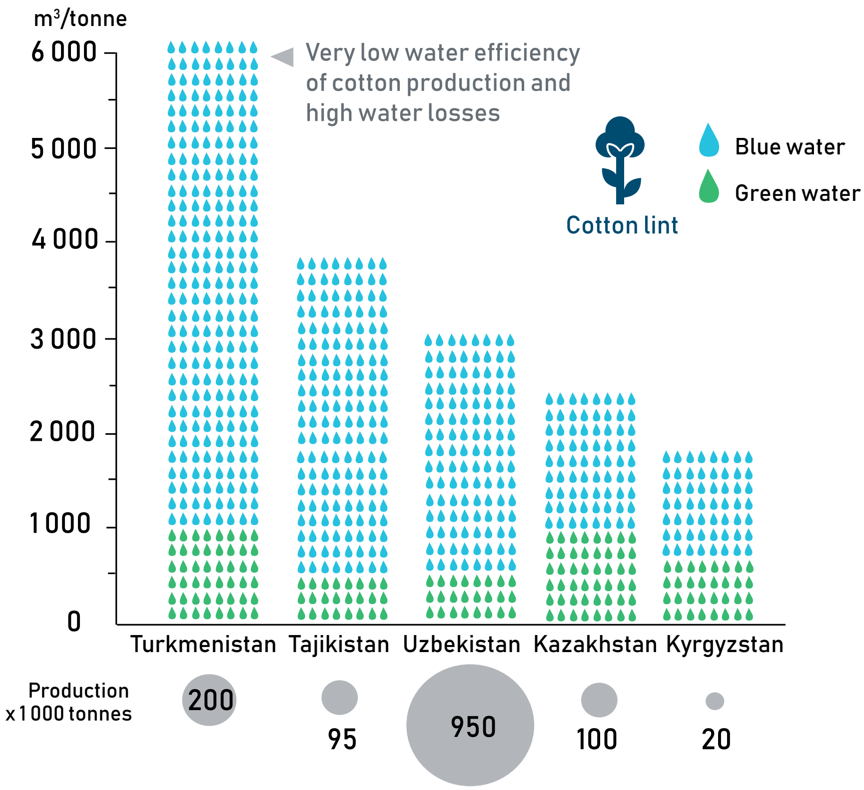

Figure 6. Blue and green Water Footprint and total production of cotton, CA region

Water Footprints of other main crops such as rice and maize, particularly of the blue component, are also significantly larger in Turkmenistan compared to the other four Central Asian countries.

While it is likely that wastewater treatment and pollutant load discharge data used in this study is underreported, the results of the Grey Water Footprint show that industry (including extraction industries) is the largest water polluter in the region, responsible for 60% of the grey Water Footprint, with domestic use contributing 35% and agriculture approximately 5%.

3.2. Virtual Water Flows

The region is a net virtual water exporting region with cotton being the largest blue virtual water export commodity and wheat being the largest green virtual water export commodity (Figure 7). Cocoa products, not grown in the region, are the largest but still limited green virtual water import commodities.

Total values for virtual water flows to and from the region are given in Figure 8. Dependency on external water resources, outside of the region, is low, with only 14% of the Green Water Footprint of consumption coming from other countries, and 3% in the case of blue Water Footprint. As much of the trade of Central Asian countries is between neighbours, there is a large share of water that stays 'in the region'. In the case of the Grey Water Footprint, the ratio is almost half-half, with 46% of the Grey Water Footprint of consumption coming from third countries and linked to agricultural products.

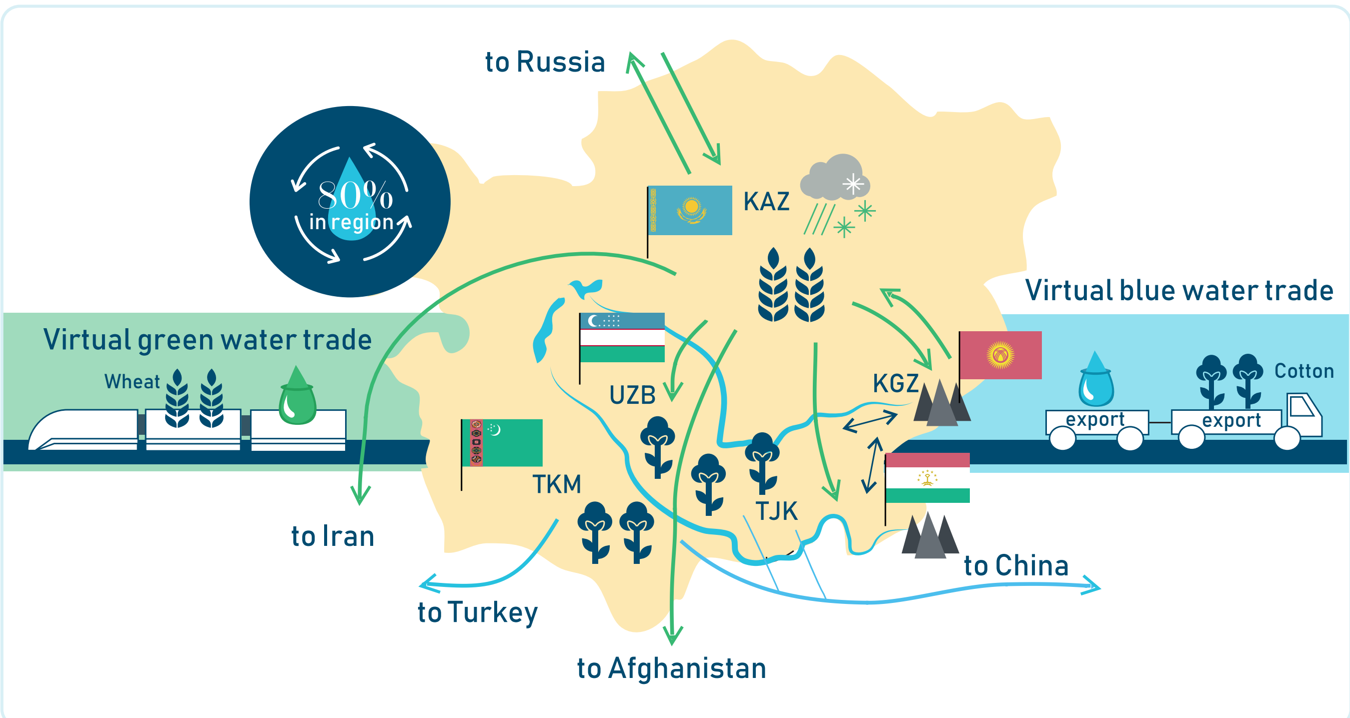

Figure 7. Virtual water export of green (mainly wheat) and blue (mainly cotton) water from Central Asia to the rest of the world

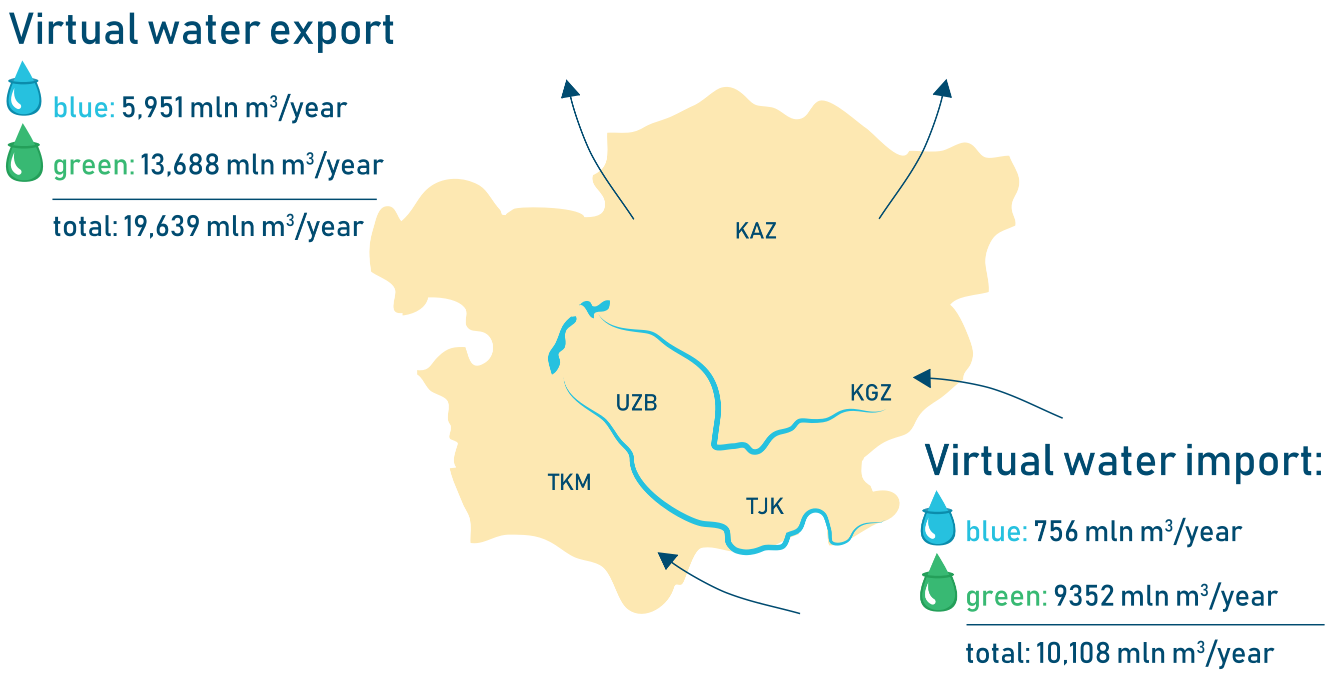

Figure 8. Virtual water flows to and from the CA region (based on data sets 2009–2018)

While the blue water export from the region is still dominated by cotton, there is a decline in blue virtual water exports observed over the past ten years due to declining acreages of cotton and its export.

Within the region an important flow from Kazakhstan to the other Central Asian countries of virtual green water is related to the export of rainfed wheat, sunflower and other crops. There are also green as well as blue water flows reflected in export of fruits such as apricot, plums and grapes from the other countries to Kazakhstan. Significant blue water flows between the countries are related to cotton exports from Uzbekistan to Kazakhstan and from Turkmenistan to Kyrgyzstan, Tajikistan and Uzbekistan, and rice from Kazakhstan to Kyrgyzstan, Tajikistan and Turkmenistan.

3.3. Economic water productivity and virtual water trade

The economic water productivity analysis for Central Asia shows that the financial return per m³ of water used for producing and exporting unprocessed crops tends to be low.

There are differences between countries with regard to the economic value of one m³ of water for the same primary crop product. For example, the average export value for water in the production of wheat is higher in Tajikistan than in Kazakhstan and Turkmenistan. Tajikistan produces almost twice as much wheat per volume of green water as Kazakhstan. Reducing the Green Water Footprint of wheat production for Kazakhstan will increase its economic water productivity.

Similarly for cotton, Turkmenistan exhibits a significantly lower value per exported m³ than its seemingly more water efficient neighbour, Uzbekistan.

Vegetables provide a comparably very high economic export value for water used. A comparison between crops and countries with regard to economic water productivity is found in Table 2.

Table 2. Average export value $/m³ water and total water export per country/crop

Country	Average $/m³, cotton	% of total water export, cotton	Average $/m³, wheat	% of total water export, wheat	Average $/m³, vegetables	% of total water export, vegetables
Kazakhstan	0.21	1.5	0.34	80	3.21	0.003
Kyrgyzstan	0.11	25	0.51	1.5	3.00	0.3
Tajikistan	0.15	28	1.01	2.4	4.54	0.02
Turkmenistan	0.06	63	0.34	16	6.72	0.003
Uzbekistan	0.59	77	0.69	6	7.03	0.4

Table 2 shows the percentage that a crop represents in the total virtual exported footprint of a country. This gives an understanding of the total trade balance and could allow policymakers to make choices about where to make sustainability investments with the optimum usefulness from a water-economy perspective.

Most of the water is traded via staple crops such as wheat, cotton and barley, and fruits such as apricots and plums. In the case of commodity crops such as wheat and cotton high volumes of water are exported for relatively low $ values per m³ of water used.

Despite a relatively high economic value per tonne cotton has a low economic water productivity. The economic value is estimated to be as low as 6 $ cents per m^3 in Turkmenistan (Table 2). Wheat is another example having a high Water Footprint (m^3/ton) and low economic value ($/ton) while vegetables have a lower Water Footprint and a particularlyhigh economic value.

3.4. Processing of crops adds value

Trading a primary crop after adding value through processing is generally more profitable, not just from a purely economic point of view but also from a water economic productivity point of view. The increased economic added value per processing step can be high with the trade value per m^3 water used for irrigation/production also increasing significantly.

An economic analysis may focus on the main primary crops exported by the countries in Central Asia compared with examples of categories of processed products. As wheat is the biggest agricultural export product of Kazakhstan, this crop dominates in terms of total economic export value. However, exporting wheat only brings 0.07 $ per m^3 of water consumed for its production, while exporting wheat processed into pasta or breakfast cereals can generate 0.25 to 0.68 $ per m^3.

The same principle applies for other crops such as barley and cotton. In the case of barley, processing to malt before exporting increases the added value of water from 0.08 to 0.18 $ per m^3 according to calculations based on Kazakh data. In the case of cotton, a similar case of value added applies for 'cotton lint' and 'cotton carded and combed' compared to the value of the harvested cotton crop.

4. Conclusions and Recommendations

Society and sectors such as agriculture and industry have significant problems with access to water. At present and in particular for a future sustainable development under conditions of continuing climate change, it is crucial that water management is improved in Central Asia.

The Water Footprint Assessment for Central Asia has identified several opportunities and also concerns in terms of water use efficiency and virtual water trade. Water Footprint Assessment is an instrument that can provide measurements of volumes of water consumed at country level, in different sectors and regions, and for specific purposes such as irrigation of individual crops. Water Footprint measurements can indicate if a crop, product or service is produced efficiently based on comparisons with world or regional benchmarks. Thus, Water Footprint metrics can provide statistical evidence for policy making related to water management, agriculture, trade and the economy as a whole.

In the following sub-sections, conclusions are drawn and recommendations made based on the results of the Water Footprint Assessment while taking into account a broader perspective of water management in Central Asia. Some thoughts on opportunities and bottlenecks in the future use of the Water Footprint methodology in the region are found in section 4.1. In 4.2 a few conclusions with relevance for water management policy and agricultural practice on the national and regional levels are highlighted. Finally, in section 4.3 a "way forward" on how to usefully develop and apply the Water Footprint approach in the region is suggested.

4.1. Application of the Water Footprint concept in Central Asia

The Water Footprint concept in the region can be used to identify differences in the efficiency of water use – green, blue as well as grey water – between sectors, countries, crops or agricultural systems. Some specific options for follow-up in the agricultural sector are given in the following. Defining regional benchmarks along with follow-up field investigations would increase the **understanding of opportunities and bottlenecks for efficient water use** and bring to light where best practices can be shared between regions and neighbouring countries.

The Water Footprint concept can play an important role as an **indicator for the effectiveness of policy interventions**. Water footprints, measured at yearly or at other relevant time intervals, can reflect the outcome of new policies introduced.

Countries in Central Asia have a stated aim to increase the economic value of agricultural products for export. In this context the processing of agricultural products is of special importance. Applying a Water Footprint analysis can support governments in formulating policies that are beneficial both from an economic and a water management perspective. Water Footprint insights can ensure that governments do not choose economic gain at the expense of depletion of water resources, but **promote a shift to high-economic-value AND low-water-footprint crops and products**.

4.2. Conclusions

i. A very high, and in many cases inefficient, blue water use for irrigation and production of crops such as cotton is an important feature in the region. Almost half of the water withdrawn is further lost due to the state of infrastructure for irrigation water supply. **Minimizing these losses (for example through investments in infrastructure) and the Water Footprint of production can improve the water situation significantly including for irrigated agriculture, water for drinking and industry, and water-dependent ecosystems.**

ii. The region is dependent — including from a crucial food security perspective - on green water. Production of the important crop, wheat, but also other rainfed crops, mainly in Kazakhstan, is vulnerable to drought. **Integration of Water Footprint data with drought modelling could be considered for long-term sustainability planning of rainfed agriculture in Kazakhstan but also other countries in the region.**

iii. With the exception of Kazakhstan, the Central Asian states try to strike a balance between a more stable food production under irrigation "at home" and imports of wheat, the key crop, to ensure that there is a good level of food security should trade be hindered in any way. Irrigated wheat demands much water and is frequently of a lower quality than the rainfed wheat produced in Kazakhstan. The other countries in Central Asia try to balance their own production with imports. **Improved stability and trade relations in the region, would give possibilities for countries to decrease irrigated wheat production that has a low economic benefit per volume of water used** as demonstrated in the Water Footprint Assessment. In this context political will and good neighbourly relations are important as a basis for dialogue and cooperation.

iv. Large differences in the national Water Footprints of specific crops were observed. For example, Turkmenistan exhibits a comparably high Blue Water Footprint for cotton production. The climatic and soil differences are likely to play a role along with the possible difficulties in comparing data from different countries. However, **a closer look at the contrasting efficiency of water use between countries and regions identified by the Water Footprint Assessment may reveal interesting patterns that can help to develop production and a more efficient use of water**.

v. The economic value per m^3 of virtual water for primary crop exports tends to be low. All countries in the region have a stated aim to add value to primary crops to increase the economic value of agricultural products for export. Wheat flour has become important for Kazakh exports as has production of textile garments to complement Uzbek cotton exports. Nevertheless, staple crops such as wheat, barley and cotton represent the dominant share of virtual water traded. **Central Asian countries should consider how further value can be added to water intensive sectors by processing of primary crops.**

vi. The Water Footprint Assessment of Central Asia makes a case for governments and farmers to consider **switching part of their production and exports from historically irrigated crops such as cotton and irrigated wheat to economically more advantageous high-value products such as vegetables and fruits which have a higher economic water productivity**. Efforts are already being made in the region[4] but such efforts need to be supported by improvements in trade relations and procedures, storage and transport infrastructure, and access to new markets. With the support of the Water Footprint Assessment, the impact of agricultural and trade policies on water consumption can be monitored.

vii. There is a range of positive on-going policy interventions and investments to increase water use efficiency in the region. Specific state programmes are being implemented in Kazakhstan and Uzbekistan. Modern methods for irrigation, lining of canals, introduction of new crops or changing cropping patterns are a few of the elements. There is a need to introduce higher tariffs for water use (demand-side management). **The application of Water Footprint Assessments to monitor the changes in Water Footprints and economic value of irrigation water gives an opportunity to analyse the efficiency of investments and the introduction of new policies with the aim of saving water.**

[4] For example, Uzbekistan is making considerable efforts to develop citrus fruit production and export, and so called "Agroexpress" trains are organized from several countries to quickly transport perishable agricultural products to importing countries.

viii. Much needs to be done to improve the accurate calculation of Grey Water Footprint. For agriculture, the Grey Water Footprint analysis normally include pollution caused by nutrients and pesticides. Optimizing fertilizer input and improving timing and application techniques of agrochemicals are important related counter-measures. Organic instead of conventional farming is one option to reduce the grey Water Footprint. Organically farmed soils may give the additional advantage of a higher water holding capacity and better infiltration rate. Additionally, a future in depth Water Footprint Assessment might allow for the salinity of drained and reused irrigation water to be taken into account. For the **Grey Water Footprint, better data reporting on domestic, industrial and agricultural wastewater treatment and discharge, and diffuse pollution from agriculture is needed** to conduct an analysis that better reflects realities on the ground.

ix. The Water Footprint Assessment is an evidence-based and cross-sectorial tool that can be used to better understand how water is consumed not only directly for domestic, industrial and agricultural uses, but also how neighbouring states benefit from each other's water resources through trade. **An improved, joint understanding of Water Footprints and virtual water trade is important for the dialogue between countries. This understanding could facilitate the design of future trade and water cooperation agreements and contribute to food security and economic development throughout the region of Central Asia.**

4.3. Water Footprints Assessments in Central Asia — The way forward

While this report has focused on agriculture, it is recommended that in going forward **the perspective is broadened to also include the Green, Blue and Grey Water Footprint of other sectors**. There is a need for an integrated approach, for example looking at the Water-Energy-Food-Environment Nexus.

Good data and statistics are essential for any analysis and policy development, and for long-term and short-term planning. One of the main hurdles of this study was access to consistent country-level and basin data. To establish a basis for a broader analysis involving also other sectors than agriculture, **there is a need for more complete, standardized and transparent data collection with storage in a digital format**. This would make it possible to make better Water Footprint Assessments that can serve as a basis for improved decision-making across sectors. Innovative data collection methods such as remote sensing and satellite imagery may complement locally reported data and could improve precision of future Water Footprint Assessments.

In collaboration with local and regional actors such as development partners, universities, non-governmental organizations, research institutions including the Scientific-Information Center of Interstate Coordination Water Commission of Central Asia (SIC-ICWC) and also the Regional Environmental Centre for Central Asia (CAREC), **the Water Footprint concept could be introduced into the region for discussions involving experts and decision makers** as a basis for developing a better understanding of its potential for the region. Training programs for water management experts, policy makers in relevant sectors, researchers etc on the Water Footprint concept would help to clarify the approach and also initiate a dialogue on its application.

A working group with water policy experts from all countries in the region could be established. Ideally, the working group would be set up within a regional framework such as the International Fund for Saving the Aral Sea (IFAS). The working group could be tasked with developing a report outlining agreed-on next steps for testing the Water Footprint methodology in Central Asia. Its work could include reviewing available data and statistics, defining regional benchmarks, setting up protocols for the exchange of information and joint reporting etc. Ideally experts from the region would drive the process with the support of international development partners and international consultants.

Annex: Methodology and data

The project followed the Water Footprint Assessment methodology developed by the Water Footprint Network as outlined in Water Footprint Assessment Manual: Setting the Global Standards *(Hoekstra et al, 2011)*. For the Water Footprint of agricultural products, data from Mekonnen and Hoekstra (2011, 2014) was used.

The Water Footprint of agricultural production was calculated using the datasets on primary crops from FAOSTAT (2020) for the period 2009–2018. All agricultural products were included in the analysis, but the representation of results in charts and figures only show the crops which contribute with more than 2% to the total Green/Blue WF: all other crops under this threshold are grouped under the category 'others'.

For the virtual water trade, a simplified model based on the FAOSTAT database was used. This database does not include all the product flows, and for this reason virtual water import/export volumes may differ somewhat from actual trade volumes. However, the comparison with previous studies in which a more detailed trade matrix was used showed that the differences were not substantial. It can be confidently stated that overall trend was well captured in the analysis.

The model also excluded further dis-aggregation of the industry sector. For this sector the annual quantity of self-supplied water withdrawn for industrial uses was used. It can include water from renewable freshwater resources, as well as water from over-abstraction of renewable groundwater or withdrawal from fossil groundwater, direct use of agricultural drainage water, direct use of (treated) wastewater, and desalinated water. This sector refers to self-supplied industries not connected to the public distribution network.

Literature review & desktop research

The Water Footprint Assessment is a quantitative method reliant on large amounts of data on water use, agricultural and industrial production and consumption, trade and other factors. The main method for gathering the necessary data to run a Water Footprint Assessment is to make a literature review of Water Footprint related information for the Central Asian region as well as data collection on production and trade information (export & import), crop yields, water use per sector and water tariffs via desktop research on national statistics, agriculture and environmental local organizations.

The preliminary literature and desktop analysis identified those areas where local data can be accessed and those where it is preferable to use international databases. For example, a scan of the national statistics websites and reports found the following results on crop yields and production:

Kyrgyzstan for 10+ crops; Kazakhstan for 6 crops; Tajikistan for 3 crops; Uzbekistan and Turkmenistan – not available. Nitrogen application rates were found only for Kazakhstan. A similar lack of data availability situation was found for animal products.

Looking at national trade data, in a first scan we found reports from Kyrgyzstan for aggregate industry categories; Kazakhstan detailed data for five countries but less detailed for the rest of the world; Uzbekistan total trade with a given country in USD; Tajikistan – total imports/exports without specifying country/goods and no data from Turkmenistan. This has led to the use of international databases for the virtual water trade analysis, which offer trade data in a consistent format for all countries, though some limitations specified below were also identified.

The virtual water export and import and the economic analysis was performed using the global data on Water Footprint of products from WaterStat and data on the import of products (International Trade Centre, ITC).

Information on water use per sector (agriculture, domesticand their sub-sectors) information also varies significantly if national statistics are compared. Due to a lack of consistency in publicly reported data on water use per sector per country, internationally reported data was used here too (Aquastat).

For the two river basins, Amu Darya and Syr Darya, Water Footprint analyses were derived from the data obtained from the CAWATER database of the Scientific-Information Center of Interstate Coordination Water Commission of Central Asia (SIC-ICWC).

For the economic analysis, the product groups from the Food and Agriculture Organization (FAO) were used in addition to the primary crops selected for the simplified Water Footprint assessment model.

To account for inconsistencies and data blanks, a mixed methodology was applied that allows both for consistent analysis and, where available, the use of local and recent data.

Expert consultations

In the inception phase of the study, time was allocated specifically for investigations into local data availability. After the initial desktop research on publicly available resources, consultations with CAREC and SIC-ICWC took place to ascertainto what extent retrieval of local data is possible. The local expert involved in the study contacted a variety of statistical bureaus and local authorities in the five countries to inquire for additional data and consultations. None of these reach-out attempts were successful.

Assumptions and limitations

The delivery of results as described in the scope of work is highly dependent on the availability, consistency and quality of data. The following limitations and assumptions were identified upon analysing the data retrieved from FAO, ITC and CAWATER:

- The results of a Water Footprint exercise are highly dependent on data quality. Data collection and reporting on water use at national level in the Central Asian countries is often incomplete or inconsistent when comparing local to international sources.
- Water footprint of crops and crop products is calculated following the approach defined in Ercin et al. (2019), which adjusts Water Footprint values by crop yields each year. Original Water Footprints are based on Mekonnen and Hoekstra (2011).
- International trade: soybean, sugar cane, cocoa, coffee and palm oil are distributed along global production locations other than direct trade partners. For example, all five countries import chocolate from Russia but Russia does not produce cocoa, thus chocolate is assumed to be imported from Ghana and Ivory Coast indirectly (second degree trade partner).
- By-products are converted to primary crop products in assessing virtual water trade. For example, pasta imports/exports were converted to their wheat equivalent.
- Water footprints are calculated at country level, using national averages. These might be different than specific regional values of imports.
- Water footprints at the river basin level are calculated using country level Water Footprint per crops adjusted by using yields at the river basin level obtained from the CA-Water database[5].
- Water withdrawal and industrial water use were assumed to be only 10% consumed as blue Water Footprints, the rest is assumed to be grey Water Footprint.
- Industrial virtual water trade is calculated based on the economic value of trade, in terms of m^3/USD.
- Water footprints are based on model outputs and not calibrated by withdrawal for agriculture. Thus, it may be different than total withdrawal volumes.
- Industrial virtual water trade calculations and analysis were performed only for Kazakhstan and Kyrgyzstan and only for the years 2009–2013 due to lack of data availability for the years 2013–2019.

[5] www.icwc-aral.uz/resources.htm

- Industrial trade import data does not exist for Tajikistan, Uzbekistan and Turkmenistan in international statistical databases, and were therefore excluded from this analysis.
- Trade statistics between Tajikistan, Turkmenistan and Uzbekistan exist only for 2017 and 2018 and on very few commodities. Therefore, virtual water trade analysis between these three countries may not reflect reality.
- Virtual water trade volumes between Central Asian countries differ for each country analysis as the countries report different values for import and export between each other. As a result, the virtual water export figures for wheat to one of the other CA countries might not be equal with the virtual water import figures for wheat for the same country, for example.
- Water Footprint of production and consumption of agriculture is presented as an average of 2009–2018. However, trade statistics were not available for each year in this range. For example, some trade volumes for all countries were missing for 2010.
- Water footprint calculations followed the methodology described by Ercin et al. (2019) and Hoekstra et al. (2011).
- The Water Footprint data used in this report come from peer reviewed scientific literature and have been accessed from publicly available global databases. In many cases, models have been used to produce the data. These data have not been verified using local figures and will contain the inaccuracies and uncertainties inherent in datasets produced using data aggregated from local sources to the country scale.
- As all data in this study were developed using the same models, they do support comparative analysis. The data are averages from the relevant countries over the years: 2009–2018.

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