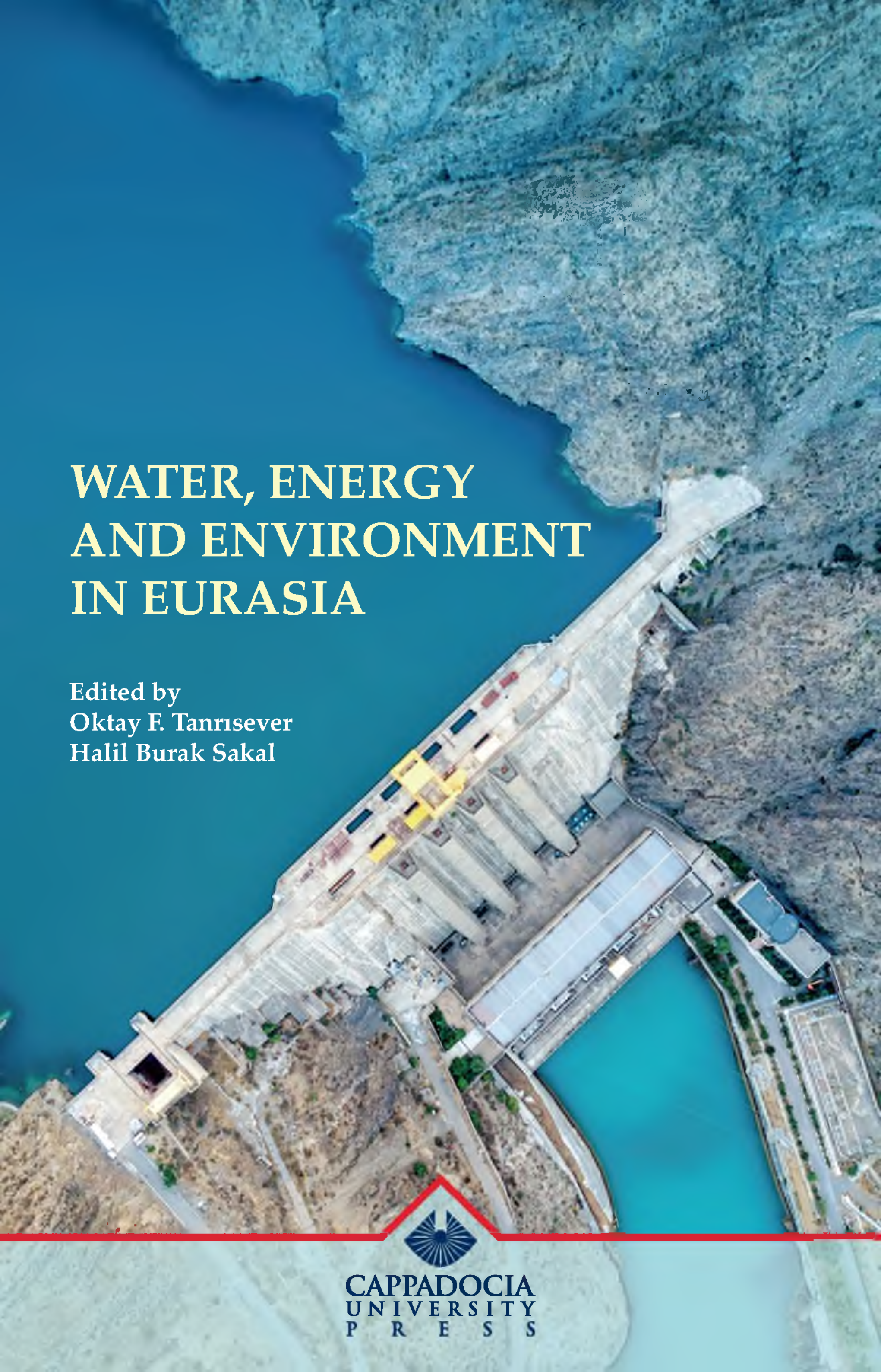

WATER, ENERGY AND ENVIRONMENT IN EURASIA

Edited by
Oktay F. Tanrısever
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Chapter 7

Water Security and Climate Change Challenges in the Transition Economies of Central Asia

Iskandar Abdullaev, Shavkat Rakhmatullaev

Introduction

Central Asia is one of the world's oldest water-dependent regions. Often referred to as the Aral Sea Basin, it is fed by two large rivers –Amu Darya and Syr Darya. Water has been a key component in the socio-economic development of the region throughout its history. The high mountains, broad valleys and great deserts of Central Asia have witnessed the construction of ancient cities, and the emergence and disappearance of civilizations due to the lack of water, and the desertification of gardens and irrigated lands (Dukhovny & De Schutter, 2011). The main element in the survival of any civilization in the Aral Sea Basin has been its access to water, and as a result, a vast and interlinked water infrastructure has developed in the region (Abdullaev, 2012).

Water-related infrastructure is both a wealth and a curse for the region. It is projected that by 2040, all Central Asian countries will be experiencing "extremely high" levels of water stress, among the other top 33 countries in the world (WRI, 2020). Moreover, it is reported that renewable water availability per capita declined by 25 percent between 2002 and 2014 across Central Asian countries (UN, 2018). Failure to invest in water management and improve water security may impede economic growth and job creation, while poor water supply and sanitation will have a direct impact on social stability, health and human capital development (WWAP, 2019; WB, 2019; 2015). Climate change will affect the rural and urban populations differently. Poverty, migration and food insecurity are most prevalent in rural areas. For example, the vulnerability of the rural population to climate-related risks is higher than the urban population due to the existing constraints on the available financial resources, the access to employment opportunities and the fragile physical infrastructure (ADB, 2017).

Related to the economic context, the region may witness a decline of up to 6 percent of its regional GDP (Gross Domestic Product) growth rates by 2050 under a business-as-usual scenario related to inefficient water management regimes (WB, 2016a). The costs of inaction, however, will be far higher, especially under the impacts of climate change. Thus, it is of vital strategic importance to harness the productive potential of water resources and limit their destructive impacts (Strong et al., 2020).

The demand for water, energy and food will increase with the projected population growth in Central Asia, with the 72 million in 2017 projected to increase by 18 million by 2050. Furthermore, the economic outlook for the next 2–3 years is not optimistic for the region, as the traditional sources of export-led growth will be affected due to the low price of mineral commodities (oil, coal, gas and metal) under the coronavirus situation (WB, 2020a). The coronavirus pandemic has led to the most significant negative shock felt since the global financial crisis, and it continues to do severe damage to global activity.

The Central Asian countries remain among the least energy-efficient and most carbon-intensive economies in the world (WB, 2016b). While the governments recognize that the increased use of new renewable energy (e.g., solar and wind) will reduce the economy's carbon intensity, such sources still account for only a fraction of the generated electricity across the countries. Kazakhstan is the only country that has made practical efforts in the solar and wind energy sector, developing large-scale plants to generate electricity on a large scale, while nascent conditions can be observed in all other countries in the region.

The break-up of the former Soviet Union and the subsequent transformation of the region affected all aspects of governance, policymaking and economic activity, i.e., agriculture, industry and environmental policies, during the statehood building process (Guillaume et al., 2015). And still, some processes remain unfinished and in the fluid phase. During the "construction of statehood" in Central Asia, regional integration has been outpaced by the more autonomous development pathways established by each state.

Water has become a key element in both the enhancement and limitation of economic development in the region. Under the expected impacts of climate change, the region may face severe water shortages, equal to 8–10 percent of the current water use (CAREC Institute, 2020). According to different scenarios, the per capita water availability in the region will drop from 2,500 cubic meters/per capita per annum to 1,400 cubic meters/per capita per annum (Varis, 2014). Moreover, the inefficient use of water and the vast amounts of water lost from the water systems will further deteriorate the water situation in the region. The subsequently increased competition for water between riparian nations, economic sectors and communities may lead to both a slowdown in economic development and a loss of political stability (Bernauer & Siegfried, 2012; Leb et al., 2018).

Since the 2000s, the concept of water security has been widely discussed in research and in international development spheres, from the household to the global level (GWP, 2000; Abdulloev, 2020; Xenarios et al., 2019). In earlier approaches, physical water availability indices that tracked imbalances between supply and demand were a central part of researches, such as Falkenmark's water stress index, and the ratio of withdrawal to the availability of water; yet they did not account for inadequacies in the water infrastructure (Srinivasan et al., 2017). Later, an economic water security concept was developed by several authors to account for the role played by the water infrastructure (Sadoff et al., 2015). Moreover, the scale of intervention/analysis (household, community, river basin, country and world) emerged as another major factor; i.e., achieving water security at one scale may threaten water security at different scales (Hoekstra et al., 2018). This holds especially true with globalization, as the production and consumption regions are geographically distinct (Mekonnen & Hoekstra, 2014). Sadoff et al. (2015) claims that water security is not a static goal, but rather a dynamic continuum that alters with changing climates, growing economies and asset stocks, as well as resource degradation.

Looking at water security from a risk standpoint, managing risks and reducing vulnerability to shocks from climate variability and water-related disasters is another arena of adaptation and mitigation. In this context, the Sendai Framework for Disaster Risk Reduction of 2015 can be viewed as addressing a broader scope of hazards and risks for the prevention and mitigation of the shocks linked to natural and man-made hazards (UNDRR, 2019). In making the logical connection between reducing risk and building resilience, the Sendai Framework provides the connecting tissue between the 2030 Agenda for Sustainable Development and the Paris Agreement.

ADB (2016) have developed water security quantitative indicators which are the most comprehensive assessment for the entire Asian region. In nutshell, a region's performance is strongly influenced by its water governance, inefficient resource policies, and its level of dependence on transboundary water resources (Jalilov et al., 2013; Wegerich et al., 2015; Rakhmatullaev et al., 2018). Currently, each country seeks to secure its water, energy, and food resources, but in doing so, compromises the environment. In fact, the current political agendas are borne out of the dominant Soviet self-sufficiency policies that were implemented in response to the Cold War-era realities (Stucki & Sojamo, 2012). Self-sufficiency political modes of production will dominate under the ongoing Coronavirus pandemic, and especially in agriculture. Currently, countries are promoting a highly politicized security approach, compromising:

- Water security: national priorities, climate change adaptation, demand-driven, efficiency improvements, IWRM policies and institutions;
- Energy security: new production, renewable energy sources, energy efficiency policies, transmission systems, energy markets;
- Food security: self-sufficiency, export and markets, distribution, efficiency, crop diversification;
- Environment: protection, rehabilitation, environmental services, eco-tourism, biodiversity.

All nations face the same challenges related to sustainability in the provision of water and energy. Local governments often find themselves in a charge of service delivery, but lack the capacity to fulfill this function (OECD, 2011). Moreover, the engagement of the private sector has proved to be a cumbersome endeavor in water-related sectors, as still most infrastructure is under state jurisdiction.

At an operational level, resilient service delivery requires building and improving the capacity of local water and energy service utilities to assess and identify climate risks and adapt their current practices to sustainable operation and adequately respond to the climate change challenges (WB, 2015). The best international best practices frame three interlinked processes: i) vulnerability assessments of the system; ii) climate-resilient business planning and iii) the development and implementation of an emergency response plan (USAID, 2017). Public utilities are reluctant and unready to interact with outside stakeholders on customer-related matters.

The main goal of this paper is to make a comprehensive assessment of the main issues and perspectives of the irrigation, energy, agriculture and water supply & sanitation sectors in the context of water security, risk management and potential climate change projections. Water footprint assessments of cotton, wheat and rice are presented to understand the current situation in water and land allocation, and their relationship with international trade.

Climate change and GHG emissions

Temperature changes and heat extremes are projected to increase more in the summer months than in cold periods in Central Asia (ADB, 2017). An increase in air temperature will increase the biological water requirements of crops with increased evapotranspiration rates, and as a result, more water will be needed for irrigation (CAREC Institute, 2020). On other hand, a decrease in precipitation is predicted in the summer and fall, while a modest increase or no change in precipitation is expected in the winter months in the region (Rakhmatullaev & Abdullaev, 2014). Moreover, scientific observations and state-of-the-art climate models show an increase in the frequency and intensity of rainfall events in many parts of the world (WWAP, 2020). Extreme precipitation is a pre-condition for mudflows, flash floods, landslides and accelerated rates of erosion and sedimentation, each of which poses a danger to the normal operation of water-related infrastructures and contributes to service disruptions.

Glaciers recession may occur more rapidly due to the warming, which may reduce river flow significantly and negatively impact long-term water availability in some countries (WB, 2016a). At first, the shrinking of glaciers will supply surpluses for the river runoff, but in the future the reduced glacier volume will eventually result in a decrease in summer runoff, at the peak of the vegetation period (WWAP, 2020). For example, extreme rainfall events will lead to flooding, with impacts of physical assets and an increase in turbidity levels, affecting water quality. Increased surface temperatures can lead to algal bloom, affecting water quality and increasing evapotranspiration, thus reducing water supply (UNICEF and WHO, 2019).

All countries in the region are party to the United Nations Framework on Climate Change Convention (UNFCCC) and are signatories to its annex, the Kyoto Protocol and the updated Paris Agreement (Table 1). The countries have submitted their three editions of the national communications on climate change to the United Nations. In the context of climate change adaptation, both the mandate and role of national water management agencies, and water and energy utilities are only supportive, i.e., providing data and information, and participating in the preparation of national communications with other government agencies.

Table 1. Status of climate agreements in Central Asian nations

Country	UNFCCC	Kyoto Protocol	Paris Agreement	National Communication Submission	NDC Submission
Kazakhstan	June 1992 (signed) May 1995 (ratified)	March 1999 (signed) June 2009 (ratified)	August 2016 (signed) December 2016 (ratified)	NC1- November 1998 NC2-June 2009 NC3-June 2013	December 2016
Kyrgyzstan	May 2000 (ratified)	May 2003 (ratified)	September 2016 (signed)	NC1-March 2003 NC2-December 2008 NC3-January 2017	February 2020
Tajikistan	January 1998 (ratified)	December 2008 (ratified)	April 2016 (signed) March 2017 (ratified)	NC1- October 2002 NC2- December 2008 NC3- December 2014	March 2017
Turkmenistan	June 1995 (ratified)	September 1998 (signed) January 1999 (ratified)	September 2016 (signed) October 2016 (ratified)	NC1- November 2000 NC2- November 2010 NC3- January 2016	October 2016
Uzbekistan	20 June 1993 (ratified)	November 1998 (signed) October1999 (ratified)	April 2017 (signed) November 2018 (ratified)	NC1- October 1999 NC2- December 2008 NC3- February 2017	November 2018

Source: National Communications to Climate Change (www.unfccc.int)

The region's countries are lagging in the preparation of their national action plans on climate change mitigation and adaptation. Due to both the scattered nature of the data and the scarce analytical skills, reporting on climate change is becoming an additional burden on state agencies. The capacitating of the national focal points on climate reporting is a major field of intervention for the international partners in Central Asia. Both vertical and horizontal coordination, and coherence in the governance architecture involving a variety of stakeholders have consequently become vital.

Aside from Kyrgyzstan, all countries have ratified the Paris Agreement, and Nationally Determined Contributions (NDCs) have been submitted. The NDC reveals the national efforts to reduce GHG emissions, and to increase resilience and reduce vulnerability to climate change within the context of sustainable development (Table 2). Each country is required to provide its NDCs every five years (FAO, 2018). Intended Nationally Determined Contributions under the ratification of the Paris Agreement determines national measures on post-2020 period climate national action plans.

Table 2. Elements of submitted Intended Nationally Determined Contributions (INDC) across Central Asian countries

Country	Target	GHG	Sectors
Kazakhstan	Intending to achieve an economy-wide 15%-25% reduction in GHG emissions by 2030 compared to 1990	Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6)	Energy, Agriculture, Waste, Land Use, Land-Use Change and Forestry
Kyrgyzstan	Intending to reduce GHG emissions in the range of 11.49 - 13.75% below BAU in 2030. Additional mitigation measures could reduce GHG emissions in the range of 29.00 - 30.89% below BAU in 2030 compared to 2010	Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur hexafluoride (SF_6), Nitrogen trifluoride (NF3)	Energy, Industry, solvents and other product use, Agriculture, Land use, land-use change and forestry, Waste
Tajikistan	The potential to reduce GHG emissions to achieve a target of 65-75% of the 1990 level by 2030	Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O)	Power industry and water resources, Industry and construction, Land use, agriculture and gardening and grazing, Forestry and biodiversity, Transportation and infrastructure
Turkmenistan	Limiting GHG emissions and improving the country's capacity to respond to climate change by 2030 from the 2000 level	Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O)	Energy, Industry, Agriculture, Waste
Uzbekistan	Intending to decrease specific emissions of GHG per unit of GDP by 10% by 2030 from 2010 levels	Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O)	Energy, Agriculture, Industry, Irrigation

Source: UNFCCC (https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx)

Since 1990, all countries have substantially decreased their CO_2 emissions, but are still higher than the global average emission (Figure 1). The analysis indicates that the energy sector is the major emitter of GHG gases, followed by agriculture and industry.

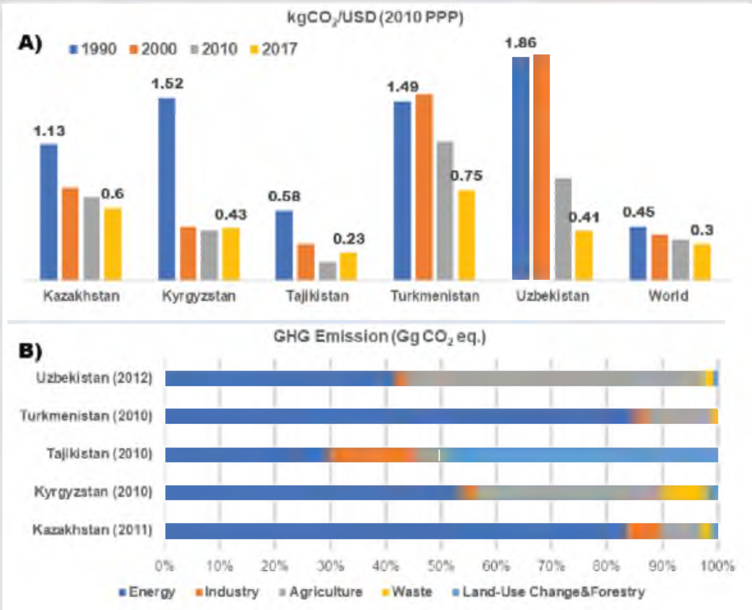

Figure 1. Greenhouse gas emissions A) CO_2 emissions per unit of GDP and B) CO_2 emission by sectors across Central Asian countries. Source: IEA, 2020; National Communications to Climate Change.

Irrigation and drainage

Climate change consequences may transform irrigated agriculture into a restrictively expensive trade (Figure 2). Further temperature increases in the region, where most rivers are fed by snow and glacier melt, will likely lead to changes in river run-off. Long-term projections suggest that the main rivers of

Central Asia will likely experience a reduction in annual run-off (Rakhmatullaev & Abdullaev, 2015; 2016).

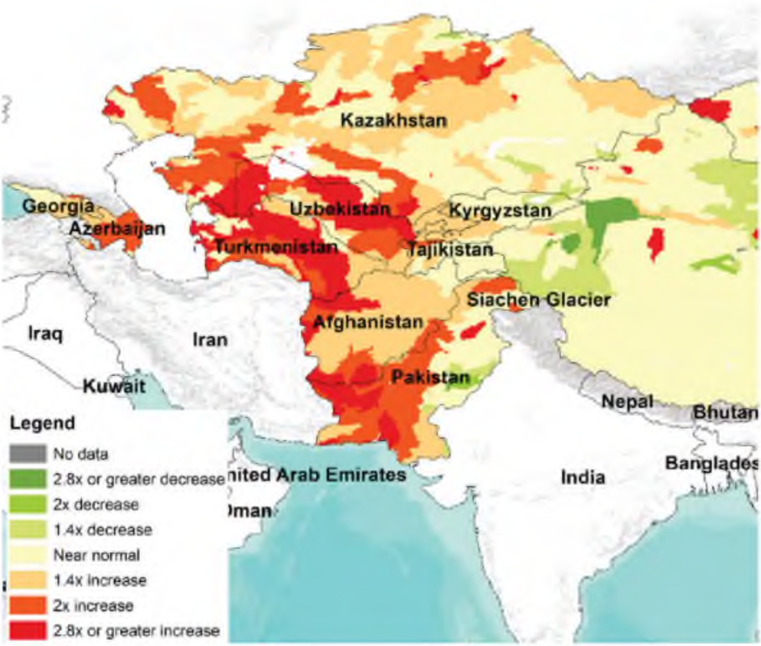

Figure 2. Projected changes in water supply by 2040 under the RCP 8.5 scenario in Central Asia. Adapted from WRI Aqueduct 3.0 (https://www.wri.org/aqueduct).

Currently, the reform of the agriculture, land and water sectors in Central Asia is incomplete. The regulation of agricultural production systems and land ownership is lower than in the Soviet period, although governments still play a significant role in setting production quotas, land distribution and agriculture pricing. The public authorities position themselves as social stabilizers by providing food and water security to the populations, with the downside to this tightly regulated system being the reduced incentive for private financing to the sector, especially infrastructure.

The availability of, and access to water of adequate quantity and quality determines economic performance, social coherence and political stability. All national strategic development programs clearly prioritize an increase in irrigated areas through either new irrigation systems or reclamation efforts (Table 3). This is clear evidence that countries focus on resource extraction rather than productivity gains. All countries claim to have adopted water-saving/conservation measures, yet without practical proof, although water saving could lead to the further expansion of irrigated land, leading to even more water scarcity and a reduction in return flow due to reduced drainage, resulting in a decrease in aquifer recharge and its depletion.

Table 3. Characteristics of irrigated lands in Central Asian nations, and the share of electric power and groundwater sources

Country	Total area equipped for irrigation ('000 ha)	Actual area under irrigation ('000 ha)	Total electric-powered irrigated area ('000ha)	Share of electric-powered irrigated lands (%)	Area equipped for irrigation by groundwater ('000ha)	Share of area irrigated from groundwater (%)
Kazakhstan	2,066	1,265	41	2	2	0.1
Kyrgyzstan	1,023	1,021	51	5	7	1
Tajikistan	742	674	296	40	33	4
Turkmenistan	1,991	1,991	318	16	9	0.5
Uzbekistan	4,199	3,700	1,133	27	274	6
Total	**10,021**	**8,651**	**1,839**		**325**	

Source: FAO AQUASTAT, 2019.

The government of Kazakhstan has an ambitious national program in place to increase its irrigated lands by 1 million ha, and to reclaim 0.5 million ha through the construction of 28 new water reservoirs (with a capacity of 3.8 billion m^3) by 2030 (Government of Kazakhstan, 2020). The government of Uzbekistan plans to reclaim about 0.3 million ha through the construction of seven new water reservoirs with a capacity of

45 million m^3 by 2025 (Ministry of Water Uzbekistan, 2020). Furthermore, all countries, over the next two decades, intend to either reclaim and/or increase their irrigated areas.

Around 1.37 million ha of land equipped for irrigation is reportedly not actually being irrigated in the countries due to various technical and financial reasons. In particular, around 0.8 million ha is not being irrigated in Kazakhstan (FAO, 2019). This shortfall may be attributed to the underfinancing of irrigation schemes, the disrepair of hydraulic infrastructures, the depletion of groundwater resources, and most importantly, the degradation of soil quality and the reduction of ameliorative conditions.

The total electric-powered irrigated area is in the region of 1.83 million ha, accounting for approximately 18 percent of the total irrigated lands, costing governments considerable financial resources from their national budgets. Energy efficiency programs will be thus an integral part of mitigation measures. In addition, approximately 325,000 ha irrigated lands are irrigated from groundwater resources, which requires approximately 30 percent more energy than surface water irrigation, and results in significantly higher greenhouse gas emissions (WB, 2016a).

A 1 percent improvement in efficiency could generate US$10 million of savings annually across the five Central Asia countries, and a 10 percent increase in water pumping efficiency could result in regional public expenditure savings of $188 million per year (WB, 2016b). Annually, billions of cubic meters of water are being lifted, conveyed and transported from surface and groundwater sources via a complex infrastructure system of pumping stations, water intake structures, boreholes and vertical drainage systems, due to the prevailing topographical and hydrogeological environments.

In parallel to the national water policy making, the status of the water agencies at a national level has changed. Previously, independent water ministries have been merged with those overseeing agriculture, energy or the environment, and thus the decision-making power and prestige of water agencies have been downgraded (Abdullaev & Rakhmatullaev, 2015). The interests of the Central Asian countries on water are different, e.g., downstream countries try to secure water for irrigation and upstream countries using water for hydro-energy production. The countries of the Central Asia have conducted series of the reforms in water sector. Although mergers with other ministries and reductions in funding have taken place, there have been few changes at the operational middle level of water management agencies (Rakhmatullaev et al., 2013).

For example, the irrigation sector (43 large, 1400 medium and 30,000 small sized electrical pumps) consumes around 20 percent of the total electricity use in Uzbekistan (Rakhmatullaev et al., 2010). Annually, some US$425 million is spent on the operation of pump-lifted systems in Uzbekistan alone (cost per kWh = US$0.047 in Uzbekistan 450 UZS/kWh (http://www.uzbekenergo.uz/ru/activities/tariffs-electric-power/).

Material evidence from a 25-year period shows that the arable land (hectares per capita) in all countries has decreased substantially due to population growth, and there are even more dramatic projections for 2050 (Table 4). According to the UNDP (2013), an average of 18 percent of the population is living on degraded lands in individual countries.

Table 4. Arable lands (hectares per capita) for Central Asian countries

Country	1992	2016	Change (decrease)
Kazakhstan	2132	1652	29%
Kyrgyzstan	0.292	0.212	38%
Tajikistan	0.156	0.08	95%
Turkmenistan	0.381	0.343	11%
Uzbekistan	0.209	0.14	49%
World	**0.232**	**0.192**	**21%**

Source: FAO, 2019.

Soil quality degradation is another important factor in population growth projections. The mean figures do not tell the full story of the availability of arable lands. The spatial distribution and quality of arable lands within a country's geographic regions and among its communities play a significant role in decision-making processes. Regretfully, decision-makers do not fully utilize geo-spatial technologies and knowledge products in their selection of agricultural cropping patterns and land allocation, and the same holds true for the design of national water-saving technology programs, and as a result, the expected outcomes are not achieved. Based on geospatial data, specific addressed support programs (financial or technical) should be designed for mitigation activities for most affected communities, as migration may otherwise occur as people go in search of better places to earn a living.

Governments should promote water and land productivities and the diversification of agricultural production, although the practical uptake is rather limited, despite the existence of national programs with subsidy, tax and financial incentive components. The main reason for this is that a large proportion of the benefits are public, while technology adoption costs are private. One potential way forward may be to expand crop insurance instruments and to raise awareness among farmers, encouraging them to change their behavioral and social norms through education programs.

Water footprint of wheat, rice and cotton

The water footprint of a product is the volume of clean water required to produce the product, measured at the place where the product is actually produced (Aldaya et al., 2010; Mekonnen & Hoekstra, 2014). The green water footprint is the volume of rainwater consumed during the growing period of the crop; and the blue water footprint is the volume of surface and groundwater consumed. The water footprint assessment of crops could inform the production and trade decisions that are most suited to the local environmental conditions. Through such an assessment, a country can strategically treat its domestic water resources through the import of water-intensive products rather than producing them domestically. This paper presents an analysis of three strategic agriculture crops – wheat, rice and cotton – revealing their importance for export revenues and food security.

Wheat is the leading food grain in the human diet, with rice being the second staple food crop across the countries of the region, and the two crops provide 38 percent of the total human calorific intake (FAO, 2019). Wheat is also used as a feed source for the livestock and poultry sectors. On a global scale, wheat and rice have the largest blue water footprints, together accounting for 45 percent of the global total (Mekonnen & Hoekstra, 2014). Around 53 percent of the global cotton fields are irrigated, supporting 73 percent of global cotton production. As would be expected, the largest share of the blue water footprint can be observed in arid and semi-arid regions, where the climatic conditions need to be overcome. In fact, wheat is at the greatest threat from water shortages, as more than half of the irrigated wheat is exposed to extremely high-water stress, and it is projected that by 2040, nearly three-quarters of wheat production will be under threat (WRI, 2020).

The analysis shows that the areas cultivated for the three crops in question range from 22 percent in Kyrgyzstan to 81 percent in Turkmenistan, while Uzbekistan uses around 46 percent of the total water uses in Central Asia for the cultivation of these three crops. This high number can be attributed to the practice of salt leaching in Turkmenistan and Uzbekistan. Briefly, the share of total renewable water resources used across all countries in question for the production of wheat, cotton and rice is 17 percent, 8 percent and <1 percent, respectively.

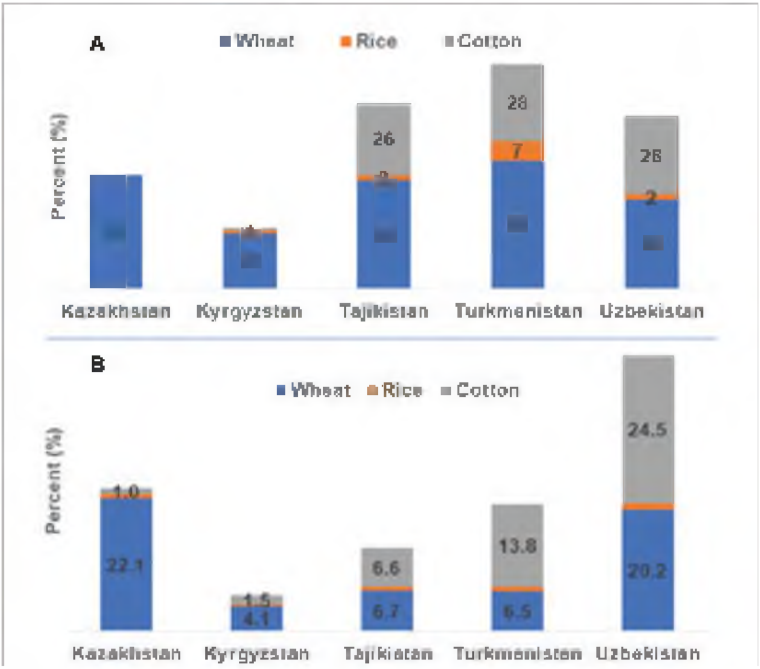

Figure 3. Distribution of A) area sown B) water used for production of wheat, cotton and rice in Central Asian countries. Source: based on FAO data (2020).

Wheat is grown on 39 percent of the total agricultural lands (i.e., ca. 14.7 million ha) in the region, ranging from 20 percent in Kyrgyzstan to 41 percent in Kazakhstan (Figure 3). The wheat basket of the region is Kazakhstan which produces around 63 percent of the total on regional scale (i.e. 23.4 million tons) (FAO, 2019). Winter and spring wheat varieties are cultivated both in rainfed (mostly in Kazakhstan) and irrigated areas. The average global total water footprint for wheat is estimated to be 1,620 m3/ton (Mekonnen & Hoekstra, 2014). The total footprint estimates for crops are different and region-specific. For conformity purposes, the average global footprint was used. A total of 37.8 billion m^3 of water (both irrigated and rainfed) is needed to grow wheat in the region. For wheat, the water footprint per ton of irrigated and rain-fed agriculture is very similar to the global average.

Cotton is grown on over 2.1 million ha of irrigated lands (8 percent out of total in Central Asia), and Turkmenistan and Uzbekistan are among the top producers in the world. The total cotton production of the region is estimated at 5.1 million tons. The average global total water footprint for cotton is about 3,589 m^3/ton (Mekonnen and Hoekstra, 2010), and a total of 18.3 billion m^3 of clean water is needed to grow cotton in the region. Rice, as the third strategic crop, is sown on 337,000 ha in the region, with Turkmenistan (138,000ha) and Kazakhstan (104,500ha) being the largest producers. On regional scale, the total rice (paddy) production is reported to be 1.1 million tons. The average global total water footprint for rice (paddy) is around 1,486 m^3/ton (Mekonnen and Hoekstra, 2014). A total of 1.7 billion m^3 of clean water is needed to grow rice in the region.

The total water used for both rainfed and irrigated cultivation of the three crops is estimated at 57.8 billion m^3 (around 25 percent of the total renewable water reserves of Central Asian region). The analysis of the water use clearly indicates that the governments of Tajikistan, Turkmenistan and Uzbekistan need to re-think the diversification of their cropping structure and improve water allocation, taking into account the projected climate change impacts.

It is clear that countries still allocate a disproportionate amount of agricultural land and water resources to wheat and cotton, as strategically at least 15–20 percent of land should be used for walnuts, vegetables, fruit and sunflower crops. Such a re-allocation of cash crops does not contribute only to water savings yet create opportunities for employment in rural areas, increased food security and provides healthier diets with vitamins. International trade becomes distorted when countries in arid areas continue to produce water-intensive goods at an ever-increasing financial and social cost.

As the analysis reveals, the export of the selected agricultural commodities constitutes only, on average up to a quarter of the total export quantities (Table 5). Kazakhstan is the main breadbasket in the region, and supplies most of the flour to all Central Asian countries and Afghanistan. For example, in Tajikistan, cotton exports bring in around 20 percent of all foreign revenues, while cotton, fruit and vegetables account for 25 percent of foreign revenues in Uzbekistan.

Table 5. Exports of the selected agricultural produce by Central Asian countries for 2017

	Wheat (US$)	**Rice (US$)**	**Cotton (US$)**	**Edible fruits and nuts (US$)**	**Edible vegetables (US$)**
Kazakhstan	965,447,000	25,960,000	101,976,000	14,562,000	126,769,000
Kyrgyzstan	-	335,000	37,611,000	29,169,000	63,162,000
Tajikistan	-	42,000	204,928,000	11,379,000	4,302,000
Turkmenistan	2,535,000	-	309,872,000	3,053,000	8,803,000
Uzbekistan	20,484,000	-	1,029,933,000	543,935,000	307,714,000
Total	**988,466,000**	**26,337,000**	**1,684,320,000**	**602,098,000**	**510,750,000**

Source: International Trade Center, 2020.

The regional countries differ in their approaches to food security. For example, Turkmenistan and Uzbekistan emphasize food self-sufficiency, while others consider a liberal trade regime and activist agricultural development policies to be the path to food security. In the 2016–2021 period, the government of Uzbekistan has been persistently working to transform its cotton- and wheat-growing zones (about 400,000 ha) into horticultural production areas (Ministry of Water Resources of

Uzbekistan, 2020). The high concentration of two crops, combined with the restrictions on exports of other crops, means that farmers have limited means to adapt to the changing yield and price conditions.

The potential of horticulture is enormous in terms of water consumption and higher value-added margins, i.e. the gross margin per hectare is up to five times that of cotton and wheat (WB, 2020b). In addition, research has shown that horticulture requires at least twice as much labor as cereal crops. With the rapid development of agriculture-related e-commerce and digitization, there are opportunities to increase exports to neighboring China and Russia, although access to those markets is constrained by stringent food safety standards.

While the institutional transformation is concerned mostly with the change in governance and management, the ownership, operation and maintenance responsibilities of water-related infrastructures are still under state jurisdiction. Already in Kazakhstan and Kyrgyzstan, the private ownership of some hydraulic infrastructures, such as low-level hydropower facilities, is being introduced, while the state ownership of the hydraulic infrastructure is being maintained in Turkmenistan and Uzbekistan. In Tajikistan, some concession management is in the hands of private entities.

Water supply and sanitation

Before 1990, in the Soviet era, the living standards in the countries in question were at a higher level than those of other Asian countries, including water supply and sanitation (WSS) access and coverage. Across 5 Central Asian countries, 75–95 percent of people have at least basic access to drinking water and sanitation, yet the safely managed potable water and improved sanitation situation are worrisome (UNICEF and WHO, 2019). On one hand, national statistics still report on "high levels of access" mainly in urban areas. However, these indicators do not reflect current physical conditions of the water/sewerage infrastructures that are outdated, outsized and deteriorated. The situation as regards both sanitation and drinking water is not promising for rural areas. Most importantly, in the quality of service, there is significant inequality between and within provinces, communities and even neighborhoods. At present, public financial/fiscal programs for maintenance have been substantially reduced, along with the degradation of institutional and organizational capacities (WB, 2015).

Paradoxically, governments and utilities continue to focus their limited capital only on the expansion of piped networks. First, a piped water connection on the premises is considered an "improved source" in both Joint Management Programme (JMP) definitions, although there is no assurance that the quality of water delivered to the household is potable (Smita and Kingdom, 2019). A piped connection that delivers unreliable, poor-quality water is still counted as an "improved source".

Access to WSS systems is relevantly better in the capitals and large urban centers of Central Asian countries, while rural areas are generally in a poor condition. Sanitation usually takes the form of latrines and septic tanks. The coverage of sewer connections is declining in countries, both in urban and rural areas, remaining low both in urban and rural areas, with wastewater being collected, but generally not treated as many wastewater treatment plants are functioning only nominally (UNICEF and WHO, 2019). As a result, most wastewater is discharged into water bodies without proper treatment. There is no accurate measurement, registration or monitoring of water production and consumption. Water losses are high, water metering is low in the countries (UN, 2018). Non-revenue water is as high as 50 percent, yet official statistics only report around 30 percent, with the difference being explained by the fact that water is charged based on consumption norms rather than being based on actual readings from metered networks (WWAP, 2019).

There have been serious reforms focusing on regulatory, financial and institutional factors, yet the overall governance framework is still in transition. As a result, OECD (2011) rightfully points out "continued political interference has prevented water utilities from operating as autonomous institutions on a commercial basis, whether privately or publicly managed". Administrative decentralization should be described as declarative, yet fiscal resources and decision-making have remained at the central level. Tariff levels and collection rates have increased, yet in practice, they barely meet the operational costs. For instance, user charges rarely recover half of operational costs of utilities (OECD, 2011), and the resulting shortage of funding prevents adequate maintenance, rehabilitation and improvement. Another prevailing observation relates to the increasing tariffs. As the population has not seen any improvement in services, there is opposition to further tariff increases.

The new economic reality is reflected in the new laws allowing private ownership of WSS infrastructures. The private management of WSS is only reported in Kazakhstan, while the other four Central Asian countries still maintain the state ownership and management of the WSS networks (WB, 2015). The engagement of the private sector has proven to be a cumbersome endeavor. Service interruptions can be attributed to either technical causes, such as pipe breaks and sewerage clogs, or financial pressure to reduce the cost of electricity used by the operational pumps. Such interruptions can lead to networking contamination by microbiological and other pollutions. In order to enhance sustainability, electricity tariff subsidies, both explicit and implicit, must be reviewed to improve the sector's financial sustainability.

Energy

Approximately 90 percent of the generated global power is water intensive. Energy is required mainly for the provision of water services, just as water resources are required for the production of energy. Economies are still heavily dependent on coal, oil, natural gas and hydropower for electricity generation, contributing to the greenhouse effect (Figure 4A). Hydropower provides more than 90 percent of the electricity in Kyrgyzstan and Tajikistan, while natural gas generates more than 80 percent of electricity in Turkmenistan and Uzbekistan. Coal is the primary source of electricity generation in Kazakhstan. All countries have ambitiously pledged to develop their solar and wind options, yet without any practical proof, with exception of Kazakhstan. The transition from fossil fuels to renewable energy faces two interlinked constraints: i) the underpricing of fossil fuel supported by subsidies, and ii) the risk of stranded assets of state-owned companies with their vested interests (ESCAP, 2020).

Ironically, the effects of climate change on the availability of water may have direct implications on hydropower generation and the cooling of thermal plants, and thus may force countries to increase their dependence on coal and oil further, and in turn, their carbon emissions. For example, energy shortages linked to low reservoir levels already intermittently force the use of coal-fired energy. Governments come under pressure to rebalance fossil fuel subsidies with support for cleaner energy sources in the light of their Paris commitments. In many parts of the world, peak electricity demand is observed during the summer months for air conditioning instead of the winter months for heating, i.e., there has been a seasonal shift. As a result, hydropower operational regimes need to be operated in different modes, against their design parameters.

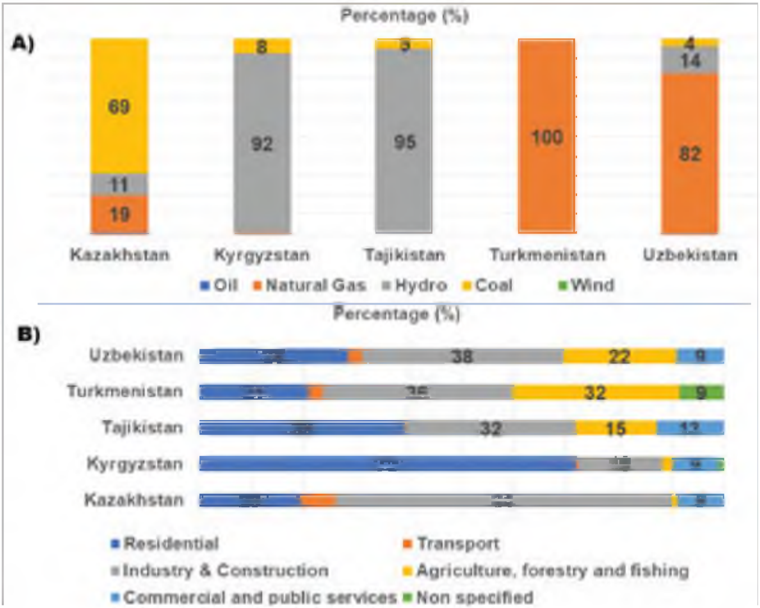

Figure 4. A) Electricity generation by source B) Electricity final consumption by sector in 2017 across Central Asian Countries. Source: IEA, 2020.

An analysis of the electricity use structure shows that that two sectors, industry & construction and residential, on average account for around 37 percent and 36 percent of total electricity usage, respectively across 5 Central Asian countries. It is predicted that the demand from the residential sector will increase due to population growth and the digitization of the economy. Decision-making should, therefore, focus on the design of energy efficiency programs or mitigation and adaptation measures to satisfy the specific needs of these sectors.

At present, in all Central Asian countries, good legislation requires more of practical implementation, in order to increase share of the renewables in energy balance. Unfortunately, solar, wind and biofuels (modern renewables) account for only a very small part of electricity generation all five Central Asian countries. This means that governments are declaring green economy and resource-efficient economic models as their strategic development milestones in the absence of any practical proof of such a paradigm shift. Electricity power transmission and distribution losses are reported in the range of 10–25 percent, not taking into account unregistered theft. The root cause is an old and inefficient energy infrastructure and industrial machinery, and the equipment assets inherited from the former Soviet Union.

Conclusion

A water footprint assessment indicates that all countries in Central Asia should rethink how to use their limited water and land resources most efficiently for agricultural production. The impact on international trade resulting from the projected climate change impacts, and especially related to water availability, requires more careful approaches. In addition, balanced agricultural cropping systems utilizing climate-smart varieties are prerequisites for the resiliency of countries in terms of food security and foreign revenues. Moreover, under the Coronavirus pandemic, agriculture has emerged as the most promising driver of economic development and employment.

Physical infrastructures are facing numerous problems, such as infrastructure fatigue, biophysical issues, and problems with operation and maintenance on national levels, and this will have an impact on the sustainable functioning and delivery of the intended services. Accordingly, it is of strategic importance that safety assessments and technical audits be carried out for all water- and energy-related facilities, especially infrastructures with shared transboundary aspects. Water pricing is one, albeit often unpopular, mechanism for the promotion of more efficient water use, but now is the time for the reinforcement of the irrigation service delivery in the region. Regional electricity trade is a proven approach to financial sustainability.

New stakeholders and public actors will become critical in the efforts to meet energy and water-related challenges, while the traditional actors (technocratic bureaucrats) may lose power and influence. The greatest challenge is ensuring the practical implementation of stakeholder participation at the lowest operational utility levels. The increased participation of stakeholders and actors requires open-source, easy-to-access information and user-friendly data management systems to be in place to support decision-making and early warning objectives. Information and communication technologies are essential assets for modeling, early warning systems, streamlining billing and monitoring purposes.

Besides the pursuit of new technical solutions, new political and economic frameworks need to be designed that promote cooperation and integrated planning among sectors. Integrated planning and cross-sector cooperation will leverage possible synergies for the reduction of costs, the assessment of trade-offs, demand-side interventions and the decentralization of services, thus ensuring the sustainability of the infrastructure and sectors. Accordingly, the continuation of the irrigation and water supply & sanitation sector reforms in all countries must be carefully monitored. The provision of support to the national reforms should be based on reform performance, not on requests from the line ministries.

The reduction and insufficiency of financing have been major obstacles standing in the way of sustainable and reliable water supplies to all sectors in almost all countries. Irregular financing also prevents long-term planning in the sector, and leads to serious delays in operation and maintenance. Almost 70 percent of irrigation infrastructure; 50 percent of water supply systems and 50 percent of energy facilities are outdated and in need of rehabilitation or replacement. Such a scale ensures the irrigation and the supply of water & sanitation remain investment hungry. Governments must therefore introduce incentives within the water sector to make it attractive to private and international investors.

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