Eurasian Development Bank

Efficient Irrigation and Water Conservation in Central Asia

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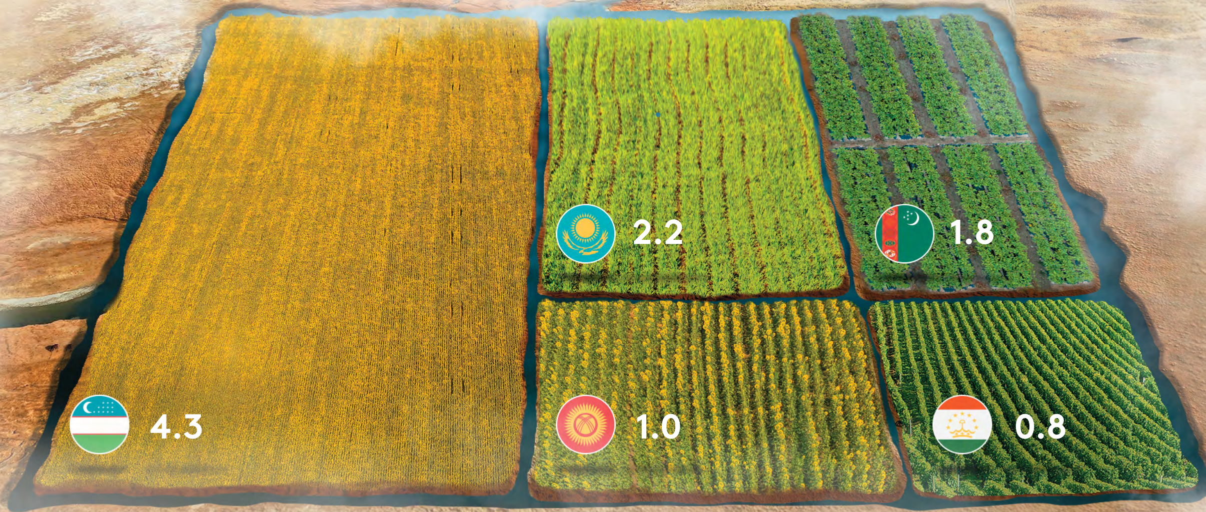
EFFICIENT IRRIGATION AND WATER CONSERVATION IN CENTRAL ASIA

FACTS AND FIGURES

ANALYTICAL REPORT '23

IRRIGATED CROP FARMING IS CRITICAL FOR AGRICULTURAL DEVELOPMENT IN CENTRAL ASIA

10.1 million ha of irrigated lands in CA, 2020



66% gross agricultural output produced irrigated land in CA

80% water used in CA for irrigation needs

HOWEVER, CENTRAL ASIA IS APPROACHING PERMANENT WATER DEFICIT

>50 years the average age of irrigation infrastructure in CA

50% irrigated land in CA exposed to salinisation

40% water lost through filtration. 2/3 is lost in the field

10 km³ Afghanistan's expected water withdrawal from the Amu Darya River

10 PRACTICAL STEPS TO PRESERVE IRRIGATED LAND POTENTIAL, WATER AND FOOD SECURITY

STRENGTHENING REGIONAL COOPERATION

- ESTABLISH the CA International Water and Energy Consortium
- POOL MDBs' financial resources to support project construction of water infrastructure
- CREATE a regional cluster to produce irrigation equipment
- OFFER Afghanistan partnership in CA water management

SCALING UP FINANCE

- USE public-private partnership mechanisms in project construction
- ORGANISE water accounting while engaging water user associations
- Gradually INTRODUCE effective tariffs for irrigation water

PROMOTING INNOVATIVE TECHNOLOGY

- REHABILITATE on-farm irrigation infrastructure
- INTRODUCE digital technology for reliable water accounting, sustainable water allocation, and land quality monitoring
- USE modern technology in irrigation, laser land levelling, and crop farming across the region

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Irrigated lands in Central Asia contribute to 80% of crop production and play a pivotal role in ensuring food security in the region. In the face of significant water stress, Central Asia has nearly reached its limit for extensive expansion of irrigated agriculture. 80% of water resources are allocated to irrigation purposes. However, the efficiency of irrigated land and water use in the region remains critically low. 40% of water is lost due to filtration from irrigation canals, and over 50% of irrigated lands are afflicted by salinisation. To address these challenges, it is imperative to modernise irrigation infrastructure and attract investments for this purpose, including through Public-Private Partnerships. The implementation of effective tariffs for irrigation water, the widespread adoption of water-saving technologies, and the empowerment of water user associations in rationalising water and land resources are all essential steps. The transition to efficient water-saving methods will bolster the productivity of irrigated lands and the responsible use of irrigation water, thereby safeguarding water, food, and environmental security in the region. These measures are of utmost importance, especially in light of the anticipated reduction in the flow of the Amu Darya River.

Key words: Central Asia, water resources, food and water security, agriculture, irrigation, irrigated lands, water conservation.

JEL: F15, L66, N55, O13, Q15, Q25.

The electronic version of this document is available on the Eurasian Development Bank website at https://eabr.org/en/analytics/special-reports/.

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INTRODUCTORY REMARKS BY NIKOLAI PODGUZOV

Nikolai Podguzov,
Chairman of the Management Board,
Eurasian Development Bank

Efficient management of water resources is a critical challenge in Central Asia, an area highly susceptible to climate change. With temperatures surging at a pace faster than the global norm and more frequent droughts and dry spells, this particular region has become increasingly fragile. A case in point was the drought experienced across the region last summer.

River hydrology and groundwater supply conditions are changing significantly. Glacial areas in the region drastically shrank by 30% over the past fifty years. Consequently, the runoff from Amu Darya and Syr Darya rivers is in decline. At the same time, the demand for water is surging, posing significant risks for agriculture and food security.

The Eurasian Development Bank is committed to enhancing sustainable economic growth among its member countries and fostering regional economic cooperation. Accordingly, it directs its loan portfolio, technical assistance, and research towards the water and energy complex in Central Asia.

Our new ground-breaking research report seeks to find comprehensive solutions to the potential water crisis in Central Asia. Agriculture accounts for an overwhelming 90% of the total water usage in the Aral Sea basin. Hence, the key part of the solution lies in facilitating efficient irrigation and enabling cooperative water resource management. This report suggests 10 practical steps, including four to be taken regionally and six nationally. This policy package should enable the region to save enough water annually to move forward sustainably. It, however, requires countries, farmers, and multilateral banks to work together.

I would like to highlight three key considerations:

1. The Central Asian countries should place revamping the irrigation system and adopting water-saving technologies high on their strategic agenda.

2. Regional cooperation is key.

3. Multilateral development banks should join forces to help the region address this issue rapidly and efficiently.

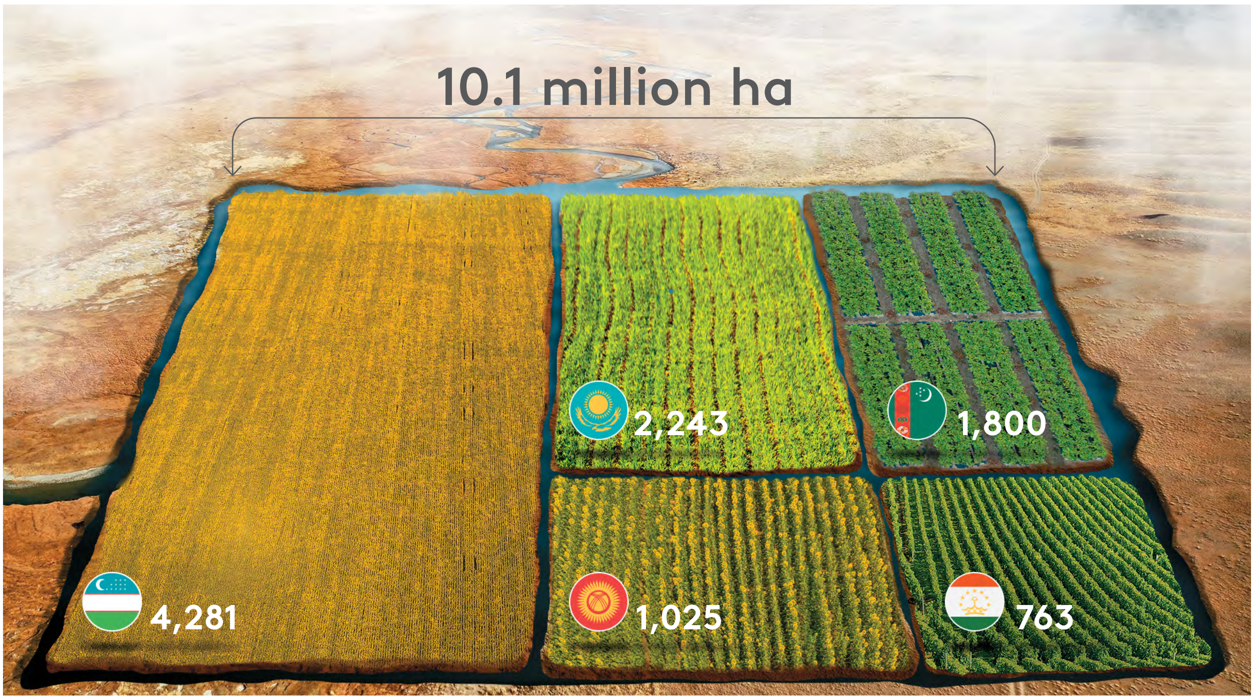
We at the Eurasian Development Bank intend to make a big difference. The global practice has demonstrated the value of the financial, technical, and research contributions from multilateral development banks in facilitating water sector projects. The Bank plans to invest at least $400 million over the next three years in the development of the water and energy sector in Central Asia. We will also provide technical assistance when it comes to water-related matters. All in all, we will do our best to be the region’s reliable partner in the water sector.

SUMMARY

Water scarcity stands out as one of the **principal structural impediments** to socio-economic development in Central Asian (CA) countries. The per capita water supply in CA has halved in comparison to the Soviet era, decreasing from 3,500 m^3 to 1,712 m^3 in 2020. According to international classifications, the CA countries teeter on the brink of being categorised as "insufficiently supplied" with water resources, with levels ranging from 1,000 m^3 to 1,700 m^3 per person per year. Looking ahead to 2050, there is a looming risk of them transitioning into a "water deficit" state.

Agriculture is a key water consumer in the CA countries: 100.4 out of 127.3 km^3/year, or 79% of the water used in the region, is allocated for irrigation purposes (as of 2020). At the same time, irrigated agriculture is the backbone of agriculture and the basis for food security in CA. Irrigated land accounts for nearly **66% of the total agricultural output** in terms of value, with Turkmenistan at nearly 100%, Uzbekistan at 87%, Kyrgyzstan at 85%, Tajikistan at 82%, and Kazakhstan at 40%. In crop production, the average figure for the CA countries reaches 80%. Improving irrigation practices will help address water scarcity and inadequate water use efficiency in the region.

↓ **Figure A. Irrigated Land in CA, 2020, ha thousand**



Source: Eurasian Development Bank (EDB) estimates based on data from statistical agencies.

In 2021, **the overall food self-sufficiency in the CA countries in terms of energy value averaged 90%**. Kazakhstan achieved complete food security at 111%, though certain products experienced shortfalls. Kyrgyzstan (72%), Tajikistan (63%), and Uzbekistan (77%) fell short of ensuring sufficient production for many essential food items and relied heavily on food imports, often through mutual trade. Looking ahead to the long term, **until 2035, the situation with food self-sufficiency in the CA countries is not expected to significantly improve**. In fact, some countries may see the situation worsen.

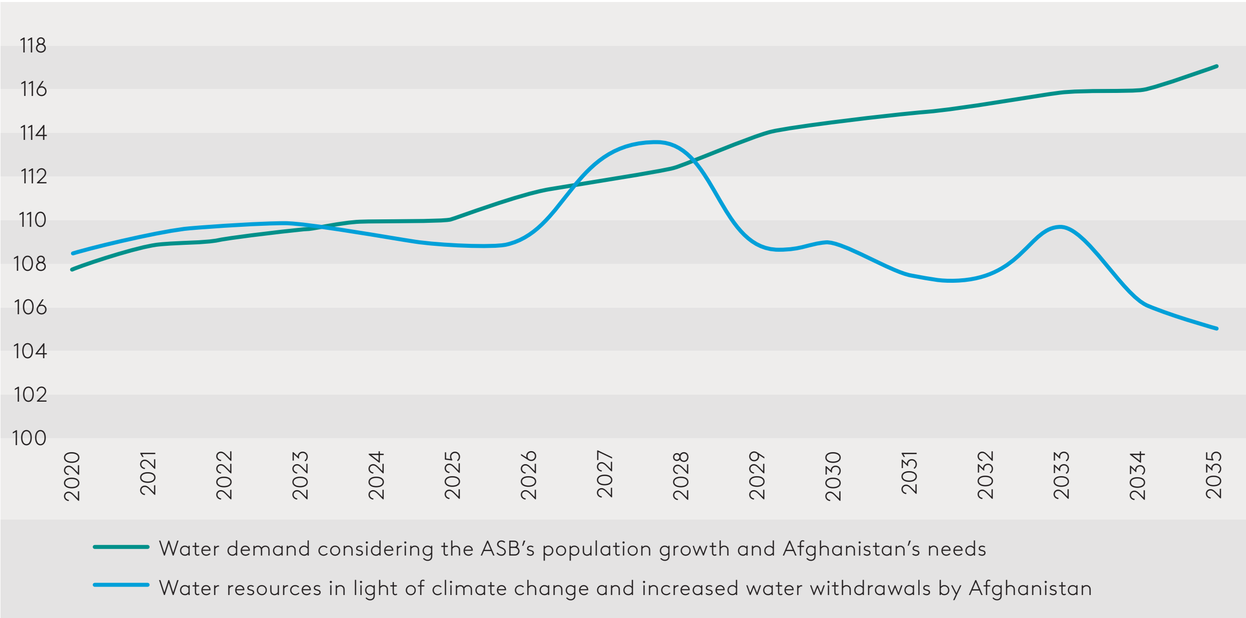
Furthermore, water scarcity and mounting pressure on water resources **prevent CA from reaching its full irrigation development potential**. Irrigation infrastructure in the CA countries is burdened with extensive physical deterioration and lacks adequate technical sophistication. It is poorly equipped with devices for measuring and distributing irrigation water, as well as monitoring its usage in the fields. The average age of inter-farm and on-farm irrigation infrastructure exceeds 50 years, and this figure is even higher for large main canals.

The degradation and salinisation of irrigated lands pose a serious challenge to the CA countries. **Up to 50% of irrigated land in the region is susceptible to salinisation**. This is particularly daunting for small farms, primarily due to their limited financial resources. Many of these farms have become economically unviable, unable to maintain irrigation infrastructure or introduce reclamation measures on their irrigated lands. Consequently, the areas of irrigated land unfit for economic use are expanding, generating risks and threats to food security.

The water deficit closes the door on sustainable agriculture and the profitability growth of farms in CA. Climate change exacerbates water scarcity and brings about devastating consequences for agricultural producers, including salinisation, waterlogging, soil fertility loss, desertification, and abandoned lands.

Water conservation in CA appears to be the only viable solution to effective use of irrigated lands and food and water security in the region. Climate change and growing water demands are fast-tracking the switch to water conservation, along with **the expected reduction of the Amu Darya River flow from Afghanistan** (annually up to 10 km^3 out of 22 km^3 formed in the territory of Afghanistan and out of 80 km^3 of the average annual river flow). Afghanistan's hydrotechnical projects **critically and dangerously reduce access to water in the middle and lower reaches of the Amu Darya**. These risks are particularly high in dry years: the Amu Darya flow during the growing season can potentially decrease by up to 50% or more in the lower reaches of the river.

↓ Figure B. Forecast of Runoff and Water Withdrawal in the Aral Sea Basin (ASB) by 2035, km^3



Source: EDB estimates based on data from SIC ICWC.

CA is highly likely to face an acute chronic water deficit of 5–12 km^3 in 2028–2029. The Afghan factor will have the same strong impact on the water balance in the region as the hydrological regime of low water, climate change, and high demographic growth. The region will potentially experience agriculture, industry, and energy crises. Shortages of food, drinking water, and electricity will cause a mass exodus of people from rural areas to cities and abroad. In his speech in Dushanbe at the meeting of the Council of Heads of States that are founders of the International Fund for Saving the Aral Sea, Kazakhstan's President Kassym-Jomart Tokayev mentioned this issue, estimating the possible number of migrants at 5 million people by 2050.

The socio-economic development of Central Asia requires international cooperation and an integrated approach to water, land, and energy resource management. **The EDB has analysed numerous recommendations for supporting CA and proposes to focus on ten key practical steps.** They will help prepare for the significant changes in water flow in the Aral Sea basin expected in 2028 and compensate for the potential increase in water deficit. These steps can be classified into three major sets of solutions.

First, the causes of institutional water scarcity in CA agriculture should be eliminated internationally and nationally. The CA countries will require a consolidated regional response.

1. **The establishment of the International Water and Energy Consortium of CA (IWEC CA)** will promote sustainable water management and irrigation development in the CA countries. It is one of the most effective solutions, as this consortium could prioritise integrated irrigation projects along with energy projects. It would facilitate collaboration and dialogue between multilateral development banks (MDBs) and the countries in the region.

2. A coalition of the International Fund for Saving the Aral Sea (IFAS), IWEC CA, and MDBs could effectively **attract investments in irrigation**, guided by the regional and national water and energy development strategies of the CA countries. It is a challenging issue, and MDBs operating in the region would serve as financial operators, jointly executing complex projects and attracting additional financial resources from other donors.

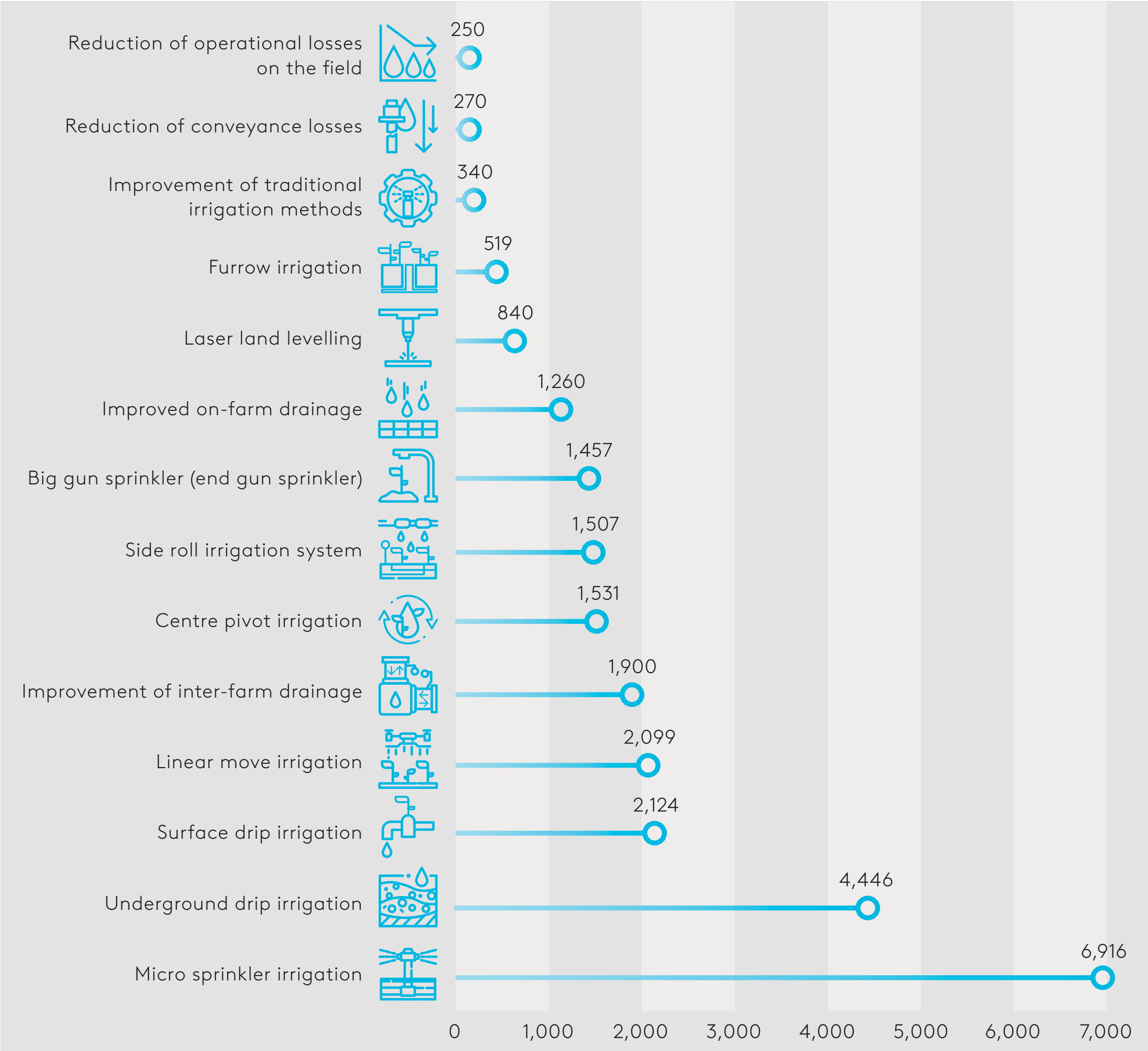
3. **The countries could create a regional cluster specialising in the production of modern irrigation equipment**, tailored to the unique requirements of each CA country. It is essential to establish regional manufacturing facilities for agricultural machinery, specialised reclamation equipment, canal maintenance, repair machinery, and water metering devices. Equipment to be produced would depend on the specific needs and characteristics of each country in the region: sprinkler equipment, sprinklers, pumps, pipe products, attachments, electronic water control, metering devices, and equipment for irrigation system maintenance and repair. CA ranks 5th in the world (in aggregate) after China, India, the USA, and Pakistan in terms of irrigated area. The region represents a capacious irrigation equipment market of $140–320 million (4%–8% of the world market).

4. **The CA countries should consolidate their efforts to strengthen cooperation with Afghanistan and involve the IFAS** and other regional organisations in managing transboundary water resources. The CA countries could benefit from entering into an ongoing dialogue with Afghanistan on water-related issues, as well as Afghanistan's full membership in the IFAS.

The transition to water conservation expects substantial financial resources. The future development of agriculture in CA may face significant constraints due to limited investment opportunities, including the water and irrigation sectors. The maintenance and modernisation of irrigation infrastructure requires financial resources and state-of-the-art technology.

Irrigation is one of the most capital-intensive aspects of agriculture. It is therefore important to fully involve and engage development banks, including multilateral institutions, and it is advisable to focus on expanding the resource base for financing irrigation infrastructure.

↓ **Figure C. Cost of Irrigation Technology in Agriculture, USD per 1 ha of land**



Source: EDB estimates based on data from CRS Report (Stubbs, 2016) and Royal Haskoning, 2003.

5. The attraction of investment is vital to the development of irrigation infrastructure in the CA countries, **including as a public-private partnership (PPP)**. This report analyses the global PPP experience using multiple case studies and concludes that such form of financing is acceptable. State budgets and financial resources of MDBs can equally encourage such projects. MDBs act as integrators of solutions, supporting dialogues with all stakeholders, including water policy makers, government agencies, and organisations, and facilitating multilateral agreements. For instance, MDBs use grants or sovereign lending at subsidised interest rates to fund irrigation projects in CA. The applicable interest rate for financing water sector projects in the region typically averages 1% during the grace period and either 1.5% or a fixed 1% thereafter. The grace period usually spans five to eight years, with loan terms ranging from 20 to 32 years. These terms constrain financing within the sector.

6. It is extremely important to organise **proper water accounting at inter-farm canals and farms** with the participation of Water User Associations (WUAs). In Central Asia, about 40% of water withdrawn from rivers is lost through filtration in the canal system; one-third is lost in the main and inter-farm canal systems, and two-thirds of losses occur in on-farm canals. The key is to strengthen the organisational and legal status of WUAs. This will increase the responsibility and obligations of WUAs regarding water resource use and allow creating legal and economic conditions for the cooperation and partnership of WUAs with state and economic management bodies, as well as farms. These measures will further help switch to the system of paid water supply services for farms.

7. **An optimal and economically justified tariff for water supply services should be introduced in CA stage-by-stage as a crucial reform**. Current tariffs in CA are significantly lower than the economically justified rates, often by a factor of 4 to 15. Gradually incorporating investment charges into the tariff structure will empower water management organisations to invest in the construction, modernisation, and renovation of irrigation systems. Individual farmers cannot afford the required investment, so globally, governments continue to provide subsidies and compensations to irrigated agriculture despite a paid water supply mechanism in place. This is food for thought when it comes to introducing paid water usage in CA and developing sustainable and efficient irrigation models and mechanisms.

Central Asia lacks enough water resources and is reaching the limit of extensive irrigated farming; the region will now have to prioritise **industrial agricultural technology focused on water and energy conservation**. The CA countries should strive to adopt water-saving technology across the region and improve the technical and engineering aspects of irrigation systems, as well as cultivate high-yielding crops.

8. To combat the widespread salinisation of irrigated lands and the decline in soil fertility, **we believe that the countries need to improve their meliorative condition by reconfiguring irrigation and drainage systems**. This will reduce filtration losses by a factor of 3 or 4 and lower groundwater levels by 2–3 metres, depending on the hydrogeological characteristics of the area. For instance, on-farm earthen canals can be transformed into flume canals, and existing systems can be replaced with pipelines for efficient water supply to the fields. Reducing crop water consumption and increasing crop yields will undoubtedly help achieve this objective. The resulting water should be allocated to maintaining the ecological balance of rivers and the natural environment.

9. **We also recommend introducing digital technology in the water sector everywhere** for rational water allocation, accurate water accounting, and an easier transition to the system of paid water supply services for farms. **The introduction of digital water-metering technology is expected to save 12%–15% of water per year**. The countries would also benefit from setting up a long-term system to monitor the ameliorative condition of irrigated lands and soil salinisation using remote satellite diagnostics.

10. The CA countries continue to favour surface irrigation methods. They should be encouraged to turn to **modern technical tools, such as laser levelling of irrigated fields**. This technology facilitates optimised crop management, ensuring even water distribution without losses, accelerating plant growth, and boosting yields. Precise levelling involves new mechanised and water-saving surface irrigation techniques along furrows. On fields levelled with slopes under furrow irrigation, grain and other crop yields can increase by a factor of 1.3–2.3, while saving from 20% to 30% of water per year.

The economies of the CA countries are developing under extreme exhaustion of land and water resources. Water use issues require **new mechanisms and instruments of cooperation in transboundary river basins, with deepening economic integration of the region's countries as the underlying factor**. Only partnerships and mutually beneficial economic cooperation can help address and overcome the long-term socio-economic and environmental consequences of ambiguous natural-geographical and geopolitical factors and high transboundary water dependence in the CA countries.

TERMS AND DEFINITIONS

Ameliorated land: Part of the land available for melioration where land melioration has been carried out.

Demand for irrigation water: Difference between the amount of water required for the planned yield and the amount of natural water available for crops.

Gravity irrigation: An irrigation method where water flows under the force of gravity through covered conduits due to the pressure created by the natural slope of the terrain.

Integrated use of water resources: Use of water resources to meet the needs of households and different sectors of the economy and reach the potential of a given water body.

Irrigated land: Land equipped with a permanent or temporary irrigation network connected to an irrigation source to provide water for the land.

Irrigation and reclamation system: A set of interacting structures and technical means designed for land irrigation and reclamation.

Irrigation norm: An amount of water delivered per year per unit of net irrigated area.

Irrigation practices: A set of irrigation rates and timing.

Irrigation system efficiency: Ratio of the amount of water delivered for irrigation to the amount of water withdrawn from a water source by the irrigation system.

Land available for melioration: Land suitable for economic use and in need of melioration.

Land melioration: Radical improvement of land through hydrotechnical, cultural, chemical, erosion control, agroforestry, agro-technical, and other melioration measures.

Mechanical irrigation: An irrigation method where water is supplied from a water body by a pumping station.

Method of land irrigation: A set of certain measures and techniques of water distribution on an irrigated area and/or transformation of water flow into soil and atmospheric moisture.

Open irrigation system: A type of irrigation system consisting of open canals or flumes.

Resource (water) conservation: Organisational, economic, technical, research, practical, and information activities, methods, processes, a set of organisational and technical measures and activities accompanying all stages of the life cycle of objects for the efficient use and economical consumption of resources (including water).

Soil salinisation: Natural accumulation of water-soluble salts in the soil to the extent that is toxic to crops. Soils with excessive salt content (0.15%–0.25% or more) are called saline soils. These include solonchaks, solonchak soils, and solonetz. Secondary salinisation is often observed on irrigated land when the soil or subsoil water (especially if it is shallow) contains a lot of salts (more than 0.25%) and when excessive water is supplied to the fields or lost from the irrigation network. It can also be caused by irrigation with saline groundwater and discharge water.

Special water use: Water use with application of structures or technical devices. ***Note:*** In some cases, special water use may also include water use without the application of structures or technical devices, affecting the state of water.

Water balance: Results of comparison of water available in a basin or in a given territory with its use at different levels of development of economic sectors.

Water body: A natural or artificial body of water, watercourse, or another object where a permanent or temporary mass of water has clearly distinguished forms and features of a water regime.

Water depletion: Reduction in the minimum allowable surface runoff or reduction in groundwater reserves.

Water management system: A set of interconnected water bodies and hydraulic structures designed to ensure efficient use and protection of water.

Water obstruction: Foreign objects in water bodies.

Water protection: A set of measures to prevent, control, and eliminate the consequences of water pollution, obstruction, and depletion.

Water quality: The condition of water, including composition and properties, with respect to its suitability for specific water uses.

Water reuse system: A type of irrigation system that accumulates water drained from a reclaimed area in collectors (wells, reservoirs) to be reused for moisturisation.

Waterlogged land: Land with soil containing water to the extent that hinders its economic use.

INTRODUCTION

Agriculture is one of the basic and important economic sectors in Central Asia. Agricultural land takes up 73.5% of the region's territory; more than 60% of the population lives in rural areas, and agriculture accounts for over 45% of total employment and averages almost 25% of GDP. At the same time, most of agricultural land (74.8%) is desert, semi-desert, and mountain pasture. Rainfed arable land accounts for less than 14.8%, and irrigated land takes up just 3.5% of agricultural land.

Irrigated crop farming ensures food security in the CA countries. Occupying about 24% of the total cultivated land, irrigated land generates 66% of the region's gross agricultural output (up to 80% of crop production) in value terms. This is because the region's territory is largely located in the zone of insufficient and unstable moisture, and agriculture can develop only under irrigation. Irrigation supports sustainable agricultural production, especially in dry years.

Water shortage creates risks for the food and water security in the region and hinders the social and economic development of the CA countries. Irrigated land only has low-tech irrigation infrastructure available; it is poorly equipped with modern devices for distributing irrigation water within irrigation systems and monitoring its use in the field. The mismatch between water supply and demand leads to regional political competition, excessive extraction of groundwater, which is the main source of drinking water supply, and lower environmental flows in river basins.

The CA countries are increasingly affected by climate change and weather disasters. Their geographical location causes severe droughts and extremely high water stress in some areas. There are numerous factors posing threats and high risks to food security, such as increased droughts and low water periods, changes in the hydrological regime of rivers and the conditions for groundwater feeding. The region's agriculture therefore requires effective natural resource management, adaptation, and climate-smart agriculture, now more than ever.

The report seeks to identify applied technological and regulatory solutions aimed at water conservation in CA. Water conservation seems to be the only solution to retain the irrigated land potential and ensure food and water security in CA. We address the objective in the following way:

Chapter 1 analyses the key structural challenges faced by agriculture in CA, including shortage of water resources and limited capacity for land expansion. It also reviews the current state and future prospects of food security in the region until 2035.

Chapter 2 explores the critical importance of irrigated crop farming for agriculture in CA. It defines the development characteristics, the current status, and the main challenges of the irrigation infrastructure in CA from a regional perspective. The Chapter presents the current global trends in the development of irrigated crop farming, specifically, irrigation technology, investment needs, and financing mechanisms.

Chapter 3 provides a detailed analysis of the state of irrigation infrastructure in CA. It presents the main technical indicators characterising the sector in each country, factoring in sectoral statistics available. We also identify national bottlenecks in the development of irrigation infrastructure. The Chapter overviews relevant government development programmes and analyses the economic feasibility of developing new irrigated areas.

Chapter 4 offers solutions drawing on international experience. In the context of constrained resources and identified issues, the primary focus areas include elevating the status of water user associations in CA, implementing a systematic water accounting system, and modernising on-farm irrigation infrastructure in the region. The key solutions include improving the tariff setting mechanism. The region needs to take a phased approach to introducing an optimal and economically justified fee (tariff) for water supply services. This would promote public-private partnerships (PPPs) in the region to develop irrigation infrastructure. The Chapter also presents possible ways of structuring PPP projects, with each regional actor in mind.

Chapter 5 assesses the impact on CA of the large-scale development of irrigated land and water resources that Afghanistan is undertaking. These projects critically limit the access to water in the region. The situation is radically changing the conditions for interstate water sharing and water use in CA and calls for urgent joint measures to ensure region-wide transition to water conservation.

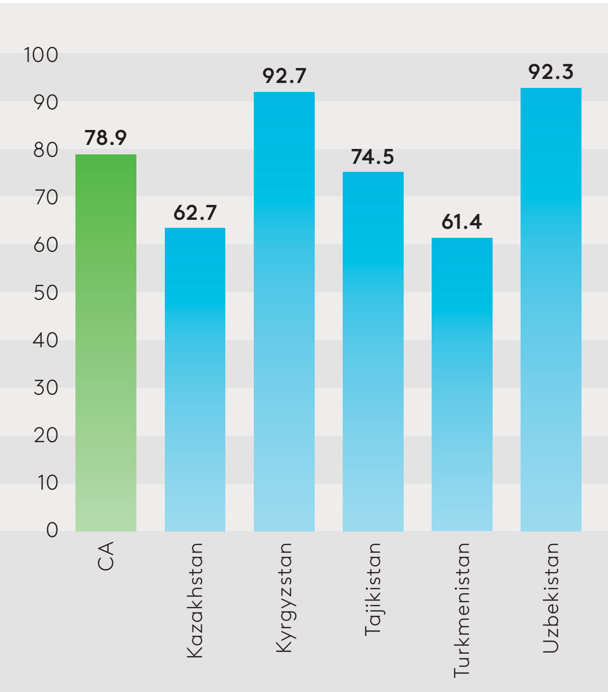
1. CLIMATE CHANGE AND FOOD SECURITY IN CENTRAL ASIA

1.1. Shortage of Water Resources in Central Asia

The shortage of water resources in the countries of Central Asia largely hinders their social and economic development (Vinokurov et al., 2022b). Water withdrawal per capita has halved in CA since the Soviet period, going down from 3,500 m^3 to 1,712 m^3 in 2020. The CA countries will soon be classified internationally as "water stressed" countries (from 1,000 to 1,700 m^3/person/year). The moderate scenario of developments in CA expects this trend to persist until 2050. The CA countries are likely to approach a state of "water scarcity" (1,296 m^3/person/year, while the threshold is 1,000 m^3/person/year) (Vinokurov et al., 2021).

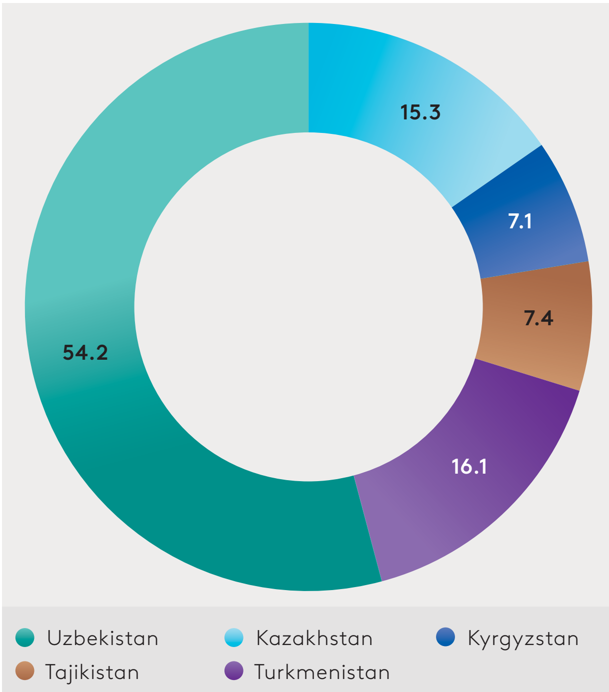
CA is one of the regions that are most vulnerable to climate change (Vinokurov et al., 2022b). Temperatures are rising faster in CA than the global average, having shrunk glaciers by nearly 30% over the past 50 years. This will likely decrease river flow and create risks for agriculture and food security in the region. The water policies of the CA countries are driven by agriculture and the supply of irrigated land with irrigation water: 79% of the water used in the region goes to irrigation (100.4 of 127.3 km^3/year in 2020) (Figure 1). Uzbekistan (54.2%) and Turkmenistan (16.1%) historically specialise in cotton cultivation, so they hold the leading positions in water consumption for irrigation by country. They are followed by Kazakhstan (15.3%), Tajikistan (7.4%), and Kyrgyzstan (7.1%) (Figure 2).

↓ Figure 1. Water Withdrawal for Agricultural Needs in Total Volume, %



Source: EDB estimates based on data from FAOSTAT.

↓ Figure 2. Country Structure of Water Consumption in Agriculture, %



Source: EDB estimates based on data from FAOSTAT.

The overall sensitivity to projected changes in water supply varies considerably across the CA countries since they rely on water resources differently. With fewer water-intensive sectors and generally more abundant water resources, especially in the north, Kazakhstan has the lowest water withdrawal rate in the region. At the same time, as a result of high dependence on irrigated crop farming in Turkmenistan and Uzbekistan, the annual water withdrawals exceed the total annual amount of available water resources. To top it all, Turkmenistan and Uzbekistan receive most of their water resources from other countries.

The region can be divided into two distinct zones based on water use: the northern part favours rain-fed crop farming, while the southern part's agricultural production relies mainly on irrigation due to the arid climate. That said, most southern regions already experience water scarcity, especially in Turkmenistan and Uzbekistan (Umirbekov et al., 2022). Climate change may make water scarcer in this part of the region. Given the current crop structure and projected changes in water availability, increasing water shortages may curb future growth in agricultural productivity in the southern regions.

CA is deeply affected by climate change as a region highly dependent on water resources, with low economic productivity of water use, particularly in the south. Most regions of Turkmenistan, Uzbekistan and southern Kazakhstan already suffer from high water stress, and further deterioration in water availability will badly impact agriculture in CA.

The water supply has plummeted in CA over the past years. A 2021 drought in Mangystau Oblast, western Kazakhstan, caused massive loss of livestock. The heatwave also hit Kyrgyzstan, with the worst damage in Chui Oblast, where much of the country's farmland is concentrated. The scarcity of irrigation water in Uzbekistan led to crop losses and rising prices for seasonal vegetables. The problems caused by river shallowing and drought recurred in the CA countries in the summer of 2022 and in 2023.

In 2023, Kazakhstan's Ministry of Agriculture warned of possible water shortages for water-intensive crops in Kyzylorda and Turkestan oblasts, which depend on water resources from the Aral Sea basin. Farmers started experiencing disruptions in the supply of water in Zhambyl Oblast in mid-April 2023 due to the closure of the Ismail Canal. Atyrau Oblast sources its water from the Zhaiyk River (Ural), along which 80% of farms are located. But getting water to consumers is becoming more difficult every year as the infrastructure built in the 1960s deteriorates. In response to the shortage of irrigation water in Kazakhstan, the rice acreage has been going down for two years in a row. There are also plans to reduce the area reserved for the cultivation of cotton in favour of more profitable crops. Additionally, large cities increasingly experience drinking water scarcity.

Kyrgyzstan faces similar problems. The flow of water in the Alamedin River was down by a factor of 3–4 in the spring of 2023, so farmers were supplied with irrigation water in turns. The Alamedin River supplies water to 7,690 ha of irrigated land in Arashan, Tash-Moynok, Kara-Zhygach, Lebedinovsky, Kok-Zharsky *aiyl okmotu* (rural government districts), and the city of Bishkek. That said, the government restricted the supply of drinking water in some villages around the capital city in mid-May 2023. June 2023 saw the same restrictions introduced in the southern districts of Bishkek itself, home to almost half the city's population. The water inflow to the largest reservoir, Toktogul, is significantly lower than last year.

After three low-water years, the government of Uzbekistan predicts that the volume of water resources will decrease by 10%–15% in the Syr Darya basin and by 15%–20% in the Amu Darya basin in the 2023 growing season, compared to the long-term norm. That said, the agricultural sector uses a third of water unproductively due to outdated irrigation networks and inefficient irrigation practices. Raspberry plantations in the Ferghana district were also left without water, causing them to dry out. Rice crops in the lower reaches of the Amu Darya River are declining, too.

Water scarcity in Turkmenistan has also worsened significantly over the recent years. Rural areas are chronically short of water for agricultural needs. There is now only a third of water in the Amu Darya River compared to the same period in previous years. There is not enough flow to allow water to reach the fields. In addition, there has been very little rainfall amid a general drought, so the soil cannot retain the necessary moisture and needs more water.

Climate change might have a mixed impact on the production of the main crops cultivated in the region. Yields of corn, rice, and soya beans are likely to decline, and yields of wheat and cotton may even increase due to higher temperatures and carbon concentrations. Even then, climate change might well harm cotton and wheat production in the southern part of the region due to the projected decrease in the water available for irrigation.

Most regions in the southern part of CA may see a decline in agricultural production. It does not help matters that some regions over-rely on single crops that are either vulnerable to climate change or too water-intensive. Climate change will have a more adverse impact in areas where agriculture is the main employer and GDP contributor.

Water shortage stands in the way of sustainable agriculture and increased profitability of farmers. It exacerbates environmental impacts and leads to salinisation, waterlogging and loss of fertility, desertification and land diversion.

The shortage has many causes, most of which can be eliminated or mitigated. They distinguish between physical, economic, and organisational water shortage. For example, physical water shortage can occur and change over time as a result of hydrological processes and the impact of climatic factors on them. Physical water scarcity means severe environmental degradation, subsoil water depletion, and water distribution prioritising some groups of water users over others. Authorities use various adaptation engineering water management measures to mitigate physical water shortage. Economic shortage of water mostly comes from scarcity or lack of funds for the maintenance and operation of the water management infrastructure, including irrigation infrastructure. Organisational water shortage is caused by inefficient water policies and poor water management, imperfect legal, institutional, and economic arrangements for regulating water use, and the lack of effective national and sectoral instruments for water conservation.

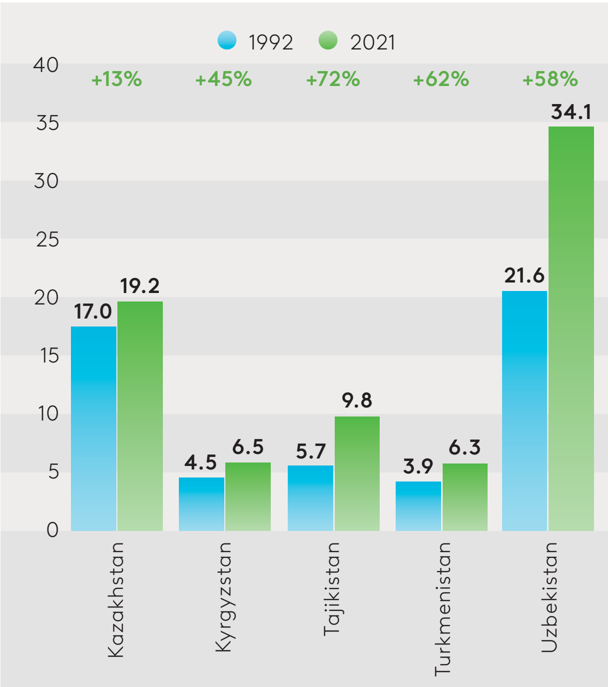
All the three forms of water shortage are present in CA, so the region will benefit greatly from climate change adaptation policies. In particular, these include the development of melioration and the introduction of moisture-saving technologies (Vinokurov et al., 2022a), integrated assessment and planning of the use of land and water resources locally, regionally, and nationally (FAO, 2022b) to address physical water shortage. Institutional changes to the existing mechanisms for regulating the water and energy complex of the region can also improve the water use efficiency in CA. Water crisis, uneven distribution of water among the countries, and mounting environmental challenges call for countries with shared interests to unite efforts and integrate their economies (Vinokurov et al., 2022a). Effective water management is key to agro-industrial development and, thus, food security. These measures will enable solutions to organisational water shortage. Another crucial aspect of addressing the economic deficit in the water sector of Central Asia is the exploration of innovative financing mechanisms for projects.

1.2. Food Systems in Central Asia

Following the collapse of the USSR, the food systems of the CA countries underwent significant changes. The governments introduced certain national programmes to ensure food security, focusing mainly on self-sufficiency in key products; this has been the general trend in agricultural development. For example, grain independence is a goal for all countries, so they develop new unproductive land to grow cereals and expand irrigated land with limited water resources (Figures 3–4).

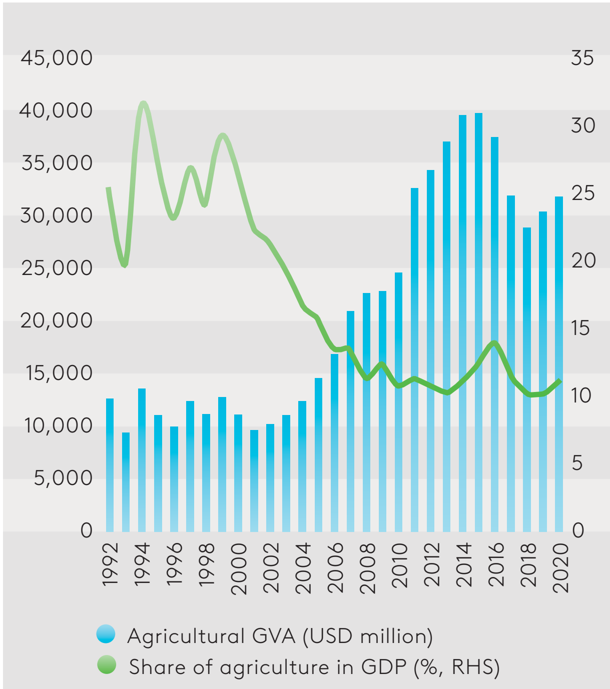
The share of the rural population in the CA countries remains high. It has, however, halved, and its contribution to GDP saw a more serious decline. For example, Kazakhstan's share of gross value added (GVA) in agriculture fell from more than 30% in 1990 to less than 5% in 2022. Kyrgyzstan and Turkmenistan are also experiencing a similar trend. Tajikistan's and Uzbekistan's share of agriculture in GDP has changed less significantly (Figures 5–6).

↓ Figure 3. Population of the CA Countries (million) and Growth Dynamics



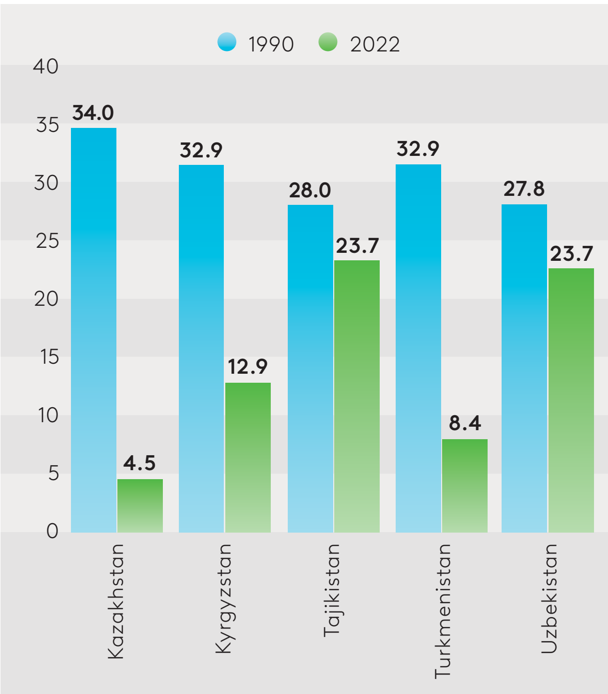
Source: EDB estimates based on data from FAOSTAT.

↓ Figure 4. Agriculture Dynamics, % and USD million



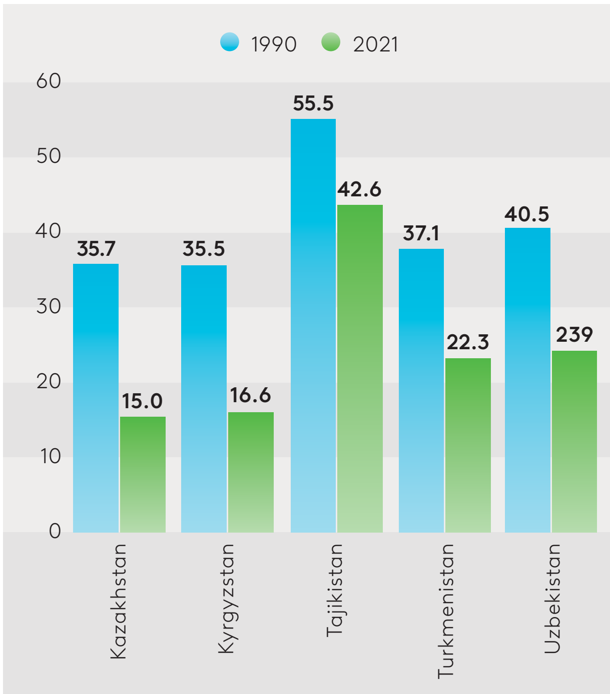
Source: EDB estimates based on data from FAOSTAT.

↓ Figure 5. Share of Agricultural Production in GDP, %



Source: EDB estimates based on data from FAOSTAT.

↓ Figure 6. Share of Employment in Agriculture, %



Source: EDB estimates based on data from FAOSTAT.

Agriculture in the CA countries functions under difficult natural and climatic conditions. They are also geographically distant from global markets and landlocked. The sector has to progress amid severe degradation of agricultural land and pasture, obsolete equipment and backward technologies, and mounting water and environmental challenges. The CA countries' agriculture relies on irrigated crop farming, with extremely limited arable land suitable for cultivation, experiencing the depletion or shortage of water resources.

↓ **Table 1. Average Yields of Crops in the CA Countries and Other Countries, 2016–2020 (hwt/ha)**

Country	Cereal crops	of which:			Oilseeds	of which:			Sugar beets	Potatoes	Vegetables	Melons and gourds	For reference:	
		Wheat	Barley	Corn		Sunflower seeds	Soya beans	Rapeseeds					Application of mineral fertilisers (kg per ha of arable land)	Irrigated land (% of farmland area)
Kazakhstan	12.8	11.7	14.6	57.5	10.0	10.1	20.7	10.6	291.3	198.0	269.9	227.8	4.3	6
Kyrgyzstan	28.0	24.6	22.5	52.2	20.3	12.8	18.3	–	498.1	171.6	210.8	224.2	16.4	69
Tajikistan	36.1	38.4	19.0	61.9	12.2	26.0	–	–	–	201.0	274.7	315.2	37.7	63
Uzbekistan	45.5	44.9	14.4	104.8	13.5	39.1	–	–	–	341.7	483.4	449.1	231.3	83
US	82.5	33.3	41.3	110.4	32.5	18.9	33.5	20.0	688.2	496.6	358.1	422.5	124.9	3
Canada	40.7	34.3	37.5	96.8	23.7	21.3	28.7	23.2	728.9	385.4	249.7	470.8	109.6	1
France	67.4	67.5	60.4	87.2	28.6	22.7	25.6	32.2	820.3	87.2	222.9	188.3	158.9	n/a
Germany	69.4	74.3	65.2	93.4	32.7	20.5	28.4	33.4	736.4	416.9	319.5	–	172.9	3
Italy	54.2	39.4	40.8	102.9	23.1	23.8	36.6	27.1	621.8	286.4	297.9	456.6	96.5	20
Spain	37.6	34.5	33.1	117.1	25.5	12.2	30.0	22.3	884.2	315.6	398.9	558.4	111.2	14
Israel	35.9	22.3	21.1	227.7	27.4	51.6	–	–	621.8	286.4	297.9	456.6	175.9	38
Australia	20.4	19.3	22.4	67.8	17.3	9.9	14.2	12.8	–	393.9	255.1	413.6	85.7	4
China	61.6	55.3	35.2	61.6	28.6	27.1	19.0	20.2	549.5	184.3	249.8	413.4	370.9	n/a
India	32.2	33.1	26.8	29.0	15.2	6.9	11.1	13.2	–	227.3	151.2	247.4	167.5	39

Source: EDB estimates based on data from national statistical offices and FAOSTAT.

The vast majority of agricultural products are sold as raw materials with a low level of processing, while finished products are not competitive enough due to the technological backwardness of processing enterprises, obsolete and deteriorated equipment. The insufficient production results in a strong dependence on imports of many agricultural goods.

One of the defining factors of agriculture in the region is heavy government regulation and its direct involvement in the management of the sector. The government often changes its priorities for agricultural development and revises support measures, subsidy rules, and directions for supporting the export of local agricultural products. The many problems that have accumulated in agriculture are addressed by *ad hoc* government support measures, which take a limited approach to the social aspects of improving production efficiency. The lack of a consistent and comprehensive approach to agricultural problems critically reduces the efficiency of agricultural production and the competitiveness of its products and causes the rural population to migrate more to cities and abroad.

Meanwhile, the CA countries have significant potential both to meet their demand for basic food products and to expand food exports. Amelioration and irrigation systems will benefit the CA countries with arid climates. Despite a high share of irrigated land, Uzbekistan, Tajikistan, and Kyrgyzstan can potentially use it more efficiently and introduce moisture-saving technologies.

1.3. Food Security in Central Asia

As we analyse supply and use balances for the food products that form the core of the food security basket, we can clearly see that the self-sufficiency of the CA countries for most products in 2021 exceeded 80%–95%, a food independence threshold established in the countries of the region. That said, the countries further south are the best performers in terms of production of fruits and vegetables traditionally grown in warm climates. However, inadequate self-sufficiency was recorded in Kyrgyzstan, Tajikistan, and Uzbekistan for vegetable oils, grain, and sugar. Kazakhstan had inadequate domestic production of sugar, as well as fruits and berries.

This self-sufficiency disparity is quite normal[1] among the Eurasian countries, since they have followed divergent paths of economic development, have different natural and climatic conditions and cultural traditions.

There are still significant differences among countries within the region in both food production and food consumption. The year 2018 saw that Kazakhstan's and Kyrgyzstan's households with consumer expenditure below the cost of a rationally standard food basket accounted for 70%–75%, with lower national standards for rational consumption in Kyrgyzstan. This shows that household disposable incomes have low purchasing power, and that the countries fail to provide affordable food products in adequate quantities and variety. Affordable food for all citizens is a pressing issue, so their diet remains unbalanced (Table 2).

↓ Table 2. Self-Sufficiency* for Basic Agricultural Products in CA in 2021, %

Product	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Grain	125	62	61	85	73
Potatoes	104	99	96	80	88
Vegetables, melons, and gourds	108	96	102	99	129
Fruits and berries	38	111	96	93	122
All types of meat	82	87	92	92	96
Milk and dairy products	93	110	99	99	99
Eggs	100	90	98	100	100
Sugar	8	68	0	15	0
Vegetable oils	91	11	24	59	44

Note: * the ratio of physical volumes of domestic production to physical volumes of domestic consumption.
Source: EDB estimates based on data from national statistical offices, FAO, and the Interstate Statistical Committee of the CIS.

1 The target of achieving full or close to full (80%–95%) self-sufficiency across the entire range of food products seems less normal.

In the CA countries, average diets also differ in their energy value. According to FAO, the indicators are lower in Kyrgyzstan and Tajikistan, but they exceed 2,800 kcal per day in Kazakhstan and Uzbekistan. This is the upper boundary of food well-being; it minimises the risks of hunger but is insufficient as a diet and overall comparable to the standard >3,000 kcal per day in developed countries.

Despite progress in achieving food security, Kyrgyzstan and Tajikistan are much smaller economies, so they remain dependent on food imports and are net food importers. Of the countries under review, Kazakhstan is the only net exporter in terms of energy value. As a result, the whole CA region has been food deficient in recent years.

At the same time, all the countries still lack basic nutrients in their diets, and most of the products are cheap and plant-based. Per capita consumption for some types of food remains below the standards adopted in the CA countries, in particular:

- Kazakhstan: dairy and meat products; eggs; fruits and berries; vegetables; bread products;
- Kyrgyzstan: meat and fish products; eggs; vegetable oil;
- Tajikistan: dairy and meat products; fruits and berries; potatoes; vegetable oil.

The actual per capita consumption of some products well exceeds the established rational standards in some countries, primarily sugar, bread products, and vegetables (Table 3).

↓ **Table 3. Actual and Normative (in parentheses) Indicators of Per Capita Consumption of Basic Food Products in the CA Countries, 2021, kg per person per year**

Product	Kazakhstan	Kyrgyzstan*	Tajikistan	Turkmenistan	Uzbekistan**
Bread and other processed grain products	99.2 (109)	156.4 (115/89)	165.8 (145)	186.2 (–)	186.2 (–)
Potatoes	107.4 (100)	99.7 (99/57)	42.9 (91)	96.0 (–)	96.0 (–)
Vegetables, melons, and gourds	230.6 (149)	159.4 (114/150)	227.3 (164)	276.7 (–)	276.7 (–)
Fruits and berries	48.7 (132)	26.2 (124/112)	71.8 (122.4)	102.5 (–)	102.5 (–)
Meat and meat products (in meat equivalent)	78.7 (78.4)	40.1 (61/39)	18.6 (41)	48.2 (–)	48.2 (–)
Fish and fish products* **	15.1 (14.0)	1.4 (9.1/7.7)	n/a (8.4)	3.0 (–)	3.0 (–)
Dairy products (in milk equivalent)	247.0 (301)	204.8 (200/185)	81.1 (114)	303.0 (–)	303.0 (–)
Eggs (units per year)	228.7 (265)	91.3 (183/166)	77.1 (180)	200.2 (–)	200.2 (–)
Sugar	26.5 (17.0)	11.1 (26/22)	16.7 (19.2)	19.3 (–)	19.3 (–)
Vegetable oil	21.1 (12.0)	7.5 (9.1/9.6)	15.9 (16.6)	10 (–)	10 (–)

Notes: * For Kyrgyzstan, the average physiological standards and the minimum consumption standards are given in parentheses (with a slash); for other countries of the CA, actual and (in parentheses) standard indicators are given.
** For Uzbekistan, the actual indicators of per capita consumption of fish and fish products are presented for 2017; rational consumption standards are determined in terms of calories, proteins, fats, and carbohydrates, rather than certain food products (Ministry of Health of the Republic of Uzbekistan, 2017).
*** for 2020.
Source: EDB estimates based on data from government agencies.

The development of cereal crops is key to regional food security, according to the data obtained during the study. Wheat, for example, is one of the staples and used within many foodstuffs. 70% of direct wheat consumption is related to food, and the global wheat consumption is ever-growing.

↓ **Table 4. Production and Domestic Consumption (in parentheses) of Basic Agri-Food Products in the CA Countries, 2021 (million tonnes)**

Product	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan*	Uzbekistan
Grain	16.38 (13.15)	1.33 (2.13)	1.55 (2.54)	1.53 (1.71)	7.64 (10.53)
Potatoes	4.03 (3.86)	1.33 (1.30)	1.02 (1.07)	0.30 (0.37)	3.29 (3.71)
Vegetables, melons, and gourds	7.55 (6.99)	1.34 (1.39)	3.24 (3.18)	0.95 (0.94)	13.14 (10.15)
Fruits and berries	0.38 (1.01)	0.27 (0.25)	0.71 (0.74)	0.42 (0.44)	4.55 (3.74)
All types of meat	1.23 (1.51)	0.24 (0.27)	0.17 (0.18)	0.30 (0.32)	1.66 (1.72)
Raw milk	6.25 (6.69)	1.70 (1.55)	1.04 (1.05)	1.79 (1.80)	11.27 (11.41)
Eggs (billion units)	4.84 (4.82)	0.56 (0.63)	0.75 (0.76)	0.65 (0.65)	7.79 (7.81)
Sugar	0.15 (0.50)	0.05 (0.08)	0.02 (0.18)	0.01 (0.11)	0.02 (0.68)
Vegetable oils	0.36 (0.50)	0.01 (0.08)	0.04 (0.16)	0.05 (0.09)	0.23 (0.68)

Note: * For Turkmenistan, the latest data are available for 2020.
Source: EDB estimates based on data from national statistical offices, FAO, and the Interstate Statistical Committee of the CIS.

For example, grain production in Kazakhstan is well beyond the country's own needs, so it largely expands exports. The situation was less positive for many other categories of food products in late 2021. The region has a slight surplus of production over consumption (vegetables, melons and gourds), balanced production and consumption (potatoes; meat; eggs; milk) or relies on imports (grain; sugar; vegetable oils) (Table 4).

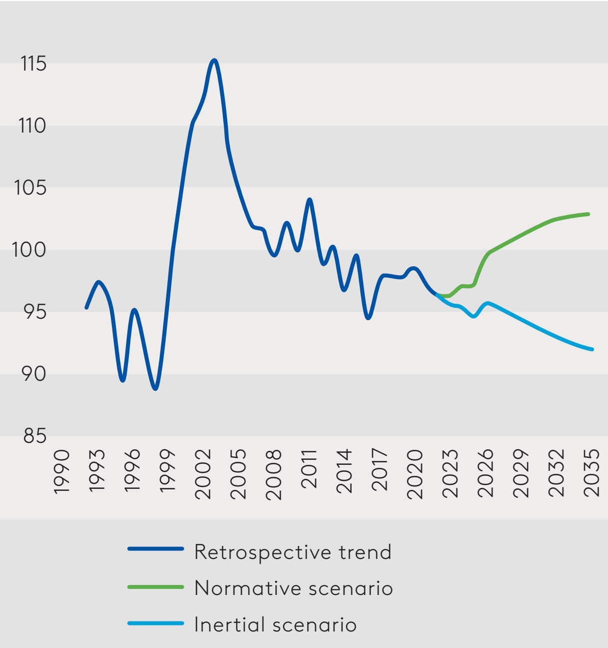
1.4. Prospects for Food Security in Central Asia by 2035

The overall food self-sufficiency in energy value was just 90% in CA in 2021. Only Kazakhstan achieved food security (111%), but it was still insufficient for some products. Kyrgyzstan (72%), Tajikistan (63%), and Uzbekistan (77%) do not produce enough of many basic food products, so they import significant amounts of food, in particular through mutual trade.

CA has a limited potential for agricultural development, so it is unlikely to increase domestic production and food self-sufficiency in the long term, especially if we consider demographic trends and the standards for the energy value of people's diet.

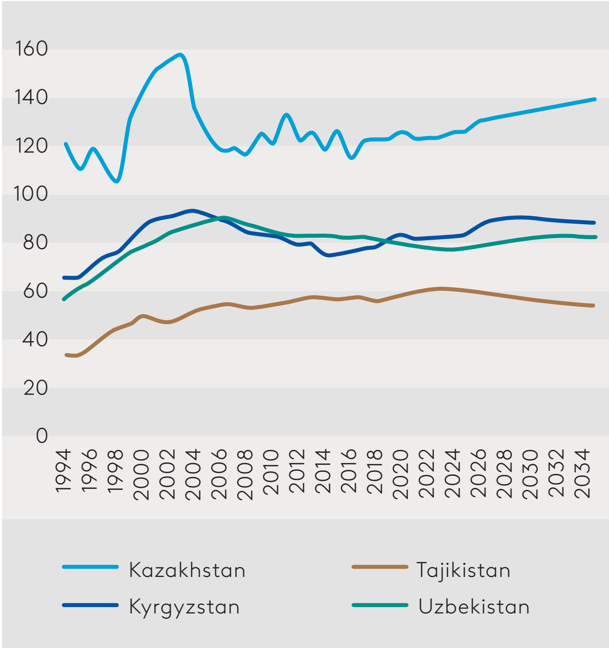
Under both forecast scenarios, Kazakhstan is expected to be the main producer of surplus food up to 2035, mainly due to higher grain production. Economic conditions, the shortage of land, and water resources stand in the way of the development for the rest of the region, and it will have to import more and more of the required food products.

↓ **Figure 7. Dynamics of Food Self-Sufficiency in CA, %, 1990–2035**



Source: EDB calculations.

↓ **Figure 8. Food Self-Sufficiency in CA, under the Normative Scenario, %**



Source: EDB calculations.

The inertial scenario projects a negative result for the region, with a noticeable increase in import requirements by 2035. The normative scenario assumes that constraints on the development of the agricultural sector will have negative implications for Uzbekistan, Kyrgyzstan, and Tajikistan. Some countries will require more food imports due to higher projected consumption compared to the inertial scenario. Nevertheless, Kazakhstan is capable of increasing food production. As a result, the overall export potential of the region will be positive.

The EDB projects the food self-sufficiency situation in CA to stay the course (Vinokurov et al., 2023a) in the long term until 2035. Moreover, some countries might experience a decline due to the constraints and characteristics of the region. There will be numerous factors affecting the development of agriculture in CA: limited potential for developing new areas, a shortage of water resources, high population growth, and muted technological advancement. Rapid demographic growth will continue to exert mounting pressure on agriculture and food security. The region can only achieve food independence by 2035 (103%) if the Kazakhstan government successfully introduces its programmes approved (normative scenario). This country will improve its availability of food to 127%–143% in terms of the energy value of agricultural products and strengthen its position as a net exporter of food products. Kyrgyzstan (76%–89%) and Uzbekistan (69%–83%) will improve somewhat, but only if they launch their national programmes. Tajikistan will have less food available (53%).

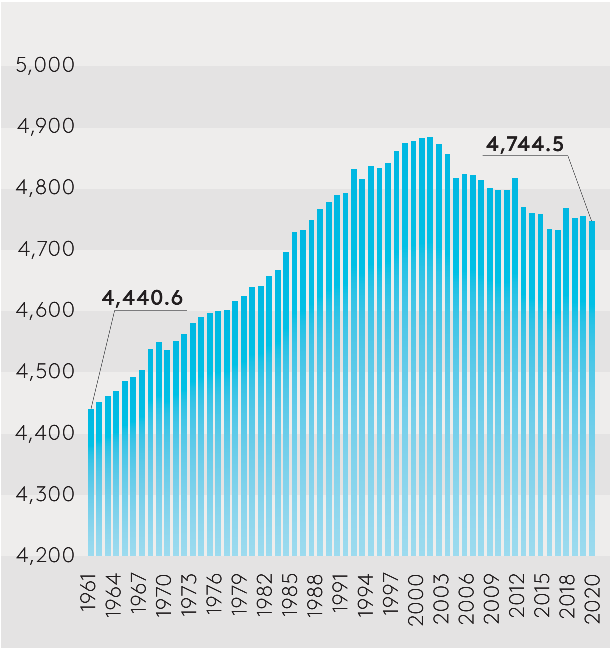
In the future, the scarcity will intensify in the countries with arid climates, limiting the potential expansion of the agricultural land. The efficient management of the CA water and energy complex and water-saving technologies are the obvious solution to the issue of food security. Irrigation is the most effective way for a country to secure yields of crops amid climate change, but it cannot reduce the risk of adverse weather conditions or provide food for the country's population as is due to the almost complete depreciation of irrigation systems and the deterioration of farming standards. The irrigation infrastructure is worn out. New forms of economic management forever changed the structure of sown areas, including irrigated areas, their size, crops cultivated, etc.

2. IRRIGATION INFRASTRUCTURE IN THE CENTRAL ASIAN COUNTRIES AND ITS SUSTAINABLE FUNCTIONING IN THE NEW ECONOMIC ENVIRONMENT

2.1. Global Trends in Irrigation

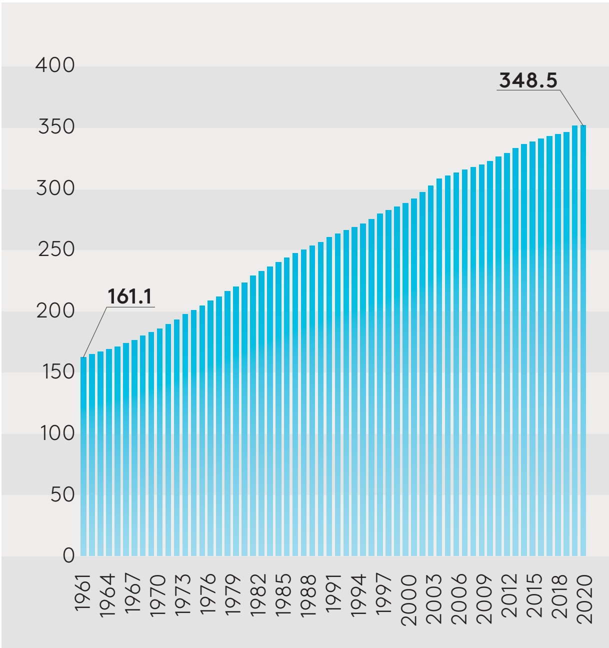
Irrigated crop farming is crucial for sustainable development of the world's agriculture and global food security. Agricultural land amounted to 4,750 million ha, or 36% of the world's land area in 2020. Arable land makes up more than 1,500 million ha, or 32% of the agricultural area. Of this, 348.5 million ha are irrigated. This is about 23% of arable land, despite the fact that more than 40% of global agricultural products are grown on this land. Irrigated land is twice as productive as rain-fed land (FAO, 2022b) (by an average factor of 1.8 worldwide in 2020). Industrial agricultural technologies may well solve food security problems. These include technology adopted in irrigated crop farming.

↓ **Figure 9. Agricultural Land in the World, 1961–2020, ha million**



Source: EDB estimates based on data from FAOSTAT.

↓ **Figure 10. Irrigated Land in the World, 1961–2020, ha million**



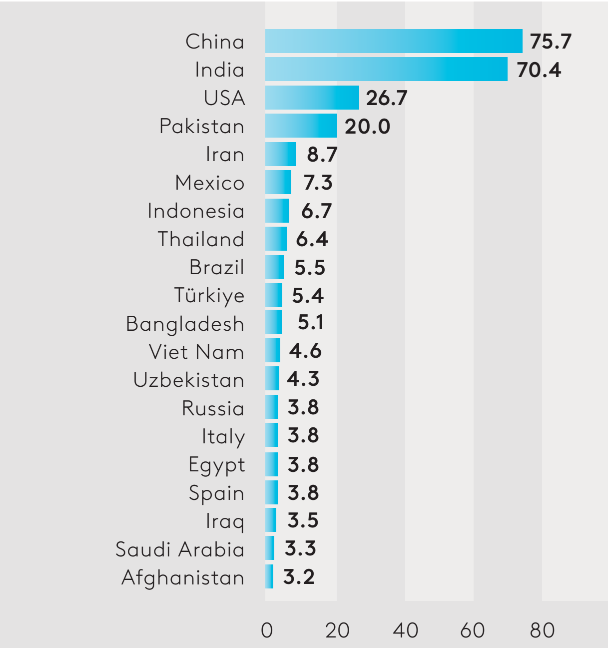
Source: EDB estimates based on data from FAOSTAT.

The largest irrigated area in the world is in China (74.5 million ha), India (72.5 million ha), the USA (26.9 million ha), Pakistan (20.0 million ha), and Iran (9.6 million ha). Of the CA countries, Uzbekistan is in the top 20 (4.3 million ha). In terms of irrigated area, the country is ahead of many countries in the world with much larger arable areas, including Russia.

Irrigated agriculture is vital for agricultural production, especially in developing countries with arid climates. It ensures food security, creates more jobs, and reduces poverty. Climate change will require countries to use irrigation to adapt to the increased frequency of droughts and to reduce the risk of unreliable precipitation. That is why the global area of irrigated land has been steadily growing from 161.1 million ha in 1961 to 348.5 million ha in 2020, or by a factor of 2.2 (FAO, 2022b). That said, the area of agricultural land in the world increased by only 7% over the same period.

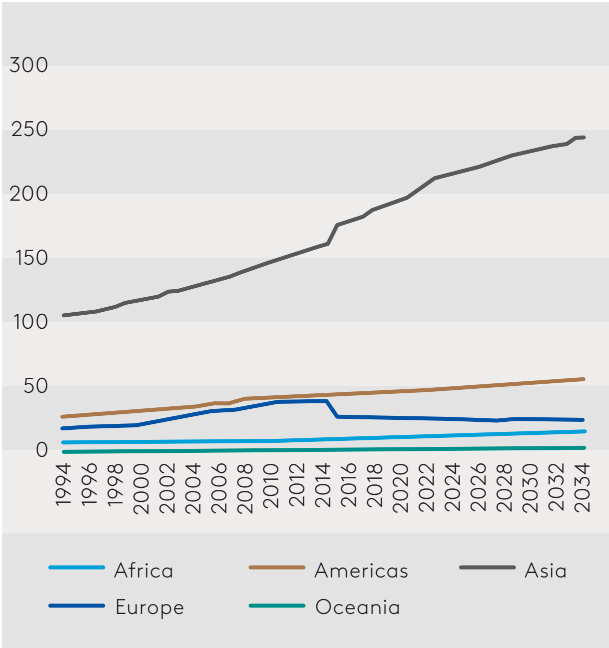
The world has limited options for expanding arable land (Vinokurov et al., 2023a). Irrigation, however, can drive the development of new land. The share of irrigated land in the total area of agricultural land increased from 3.6% in 1961 to 7.3% in 2020. The expansion of the area of irrigated land in the world is uneven. As the most densely populated continent, Asia accounts for most of the increase: 140 million ha of 187 million ha introduced worldwide by 2020.

↓ Figure 11. TOP 20 Countries in Terms of Irrigated Land Area, 2020, ha million



Source: EDB estimates based on data from FAO, 2022b.

↓ Figure 12. Dynamic Development of Irrigated Land by Large Regions, 2020, ha million



Source: EDB estimates based on data from FAO, 2022b.

Industrial agricultural technologies may well solve food security problems. These include technology adopted in irrigated crop farming. The world is now increasingly developing irrigated land through groundwater. New technologies for drilling water wells and lower electricity prices drive higher use of groundwater, particularly in Asia, North Africa, and the Middle East. India, for example, increased the area of irrigated land with water withdrawal from underground sources from 8.7 million ha in 1964 to 39.4 million ha in 2020.

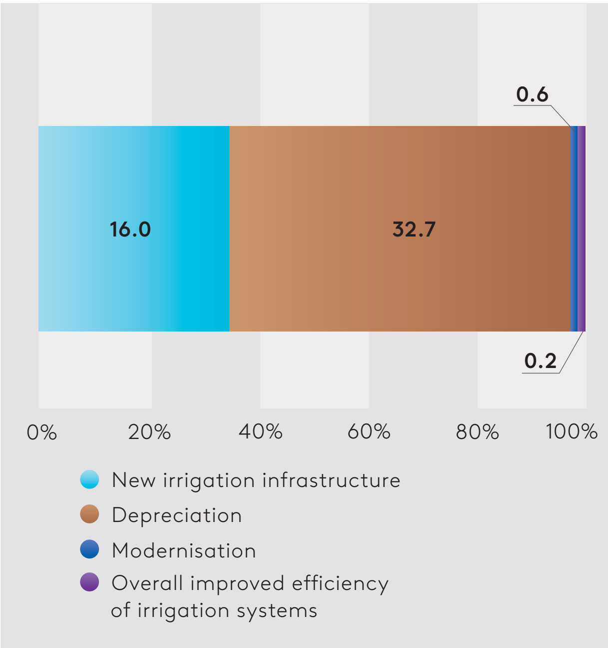
Surface water is the main source of water for 62% of the world's irrigated land, and groundwater accounts for 38%. Approximately 70% of groundwater withdrawal is used for irrigation of food and non-food crops, as well as for animal husbandry. Arid and semi-arid regions tend to use more groundwater (FAO, 2012). The increasing use of groundwater means surface water is now scarcer.

Food security is at risk in many regions due to the more frequent droughts and floods, changes in the hydrological regime of rivers and lakes, and the conditions of subsoil and groundwater recharge. This is especially concerning for developing and poor countries around the world. We expect the renovation of irrigation areas to expand further worldwide and more agro-ameliorative measures as the world faces global population growth, rapid climate change, increased water stress, and limited opportunities for developing new agricultural areas.

Middle-income and developing countries dealing with food shortages will also need to expand irrigated areas. Their irrigated land, however, lacks proper technology and modern devices for irrigation water distribution and monitoring. This is why the first task on their agenda is upgrading the technology and engineering behind irrigation systems, assimilating water-saving technologies, and switching to high-yield crops.

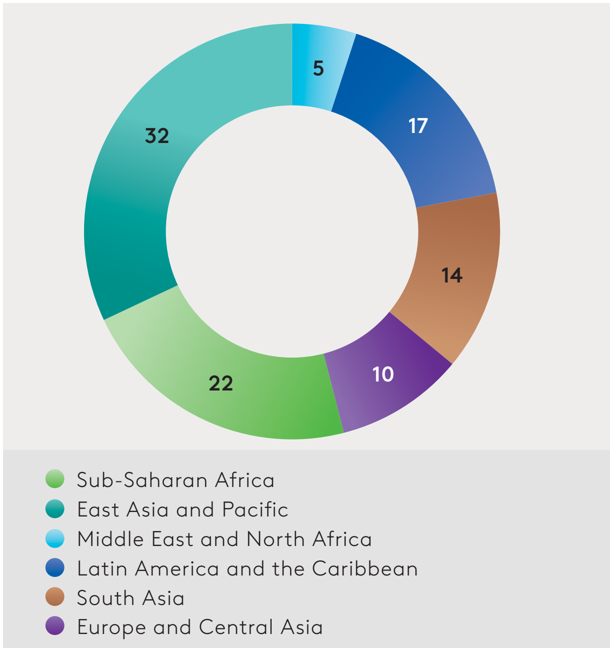
The World Bank estimates the irrigated area to increase by 70% in developing countries by 2050 under its most optimistic scenario (Palazzo et al., 2019). This will come at a price of USD 50 billion per year (in constant 2000 prices). That said, regions will expand irrigation and achieve food availability with varying success. For example, an investment of USD 4.3 billion per year would improve the food availability in Sub-Saharan Africa by less than 1% by 2050, while an investment of USD 6.8 billion per year would improve the food availability in South Asia by 2.5% by 2050.

↓ Figure 13. Annual Expenditures, by areas, USD billion



Source: EDB estimates based on data from Palazzo et al., 2019.

↓ Figure 14. Expenditures on Irrigation System Expansion and Modernisation, by region of the world, %



Source: EDB estimates based on data from Palazzo et al., 2019.

Global investment in the development of irrigated land is now increasingly targeting more efficient water use and water demand management techniques rather than large irrigation infrastructure (dams, reservoirs, large main canals, large areas of irrigated land). For example, the area equipped with drip irrigation in 2018 was almost 70 million ha (21% of the total irrigated area).

High-income countries boost the efficiency of irrigated crop farming thanks to new technologies and sufficient investment resources. This will slightly decrease the area of irrigated land and free up some of the water resources used for irrigation to improve the environment of river ecosystems.

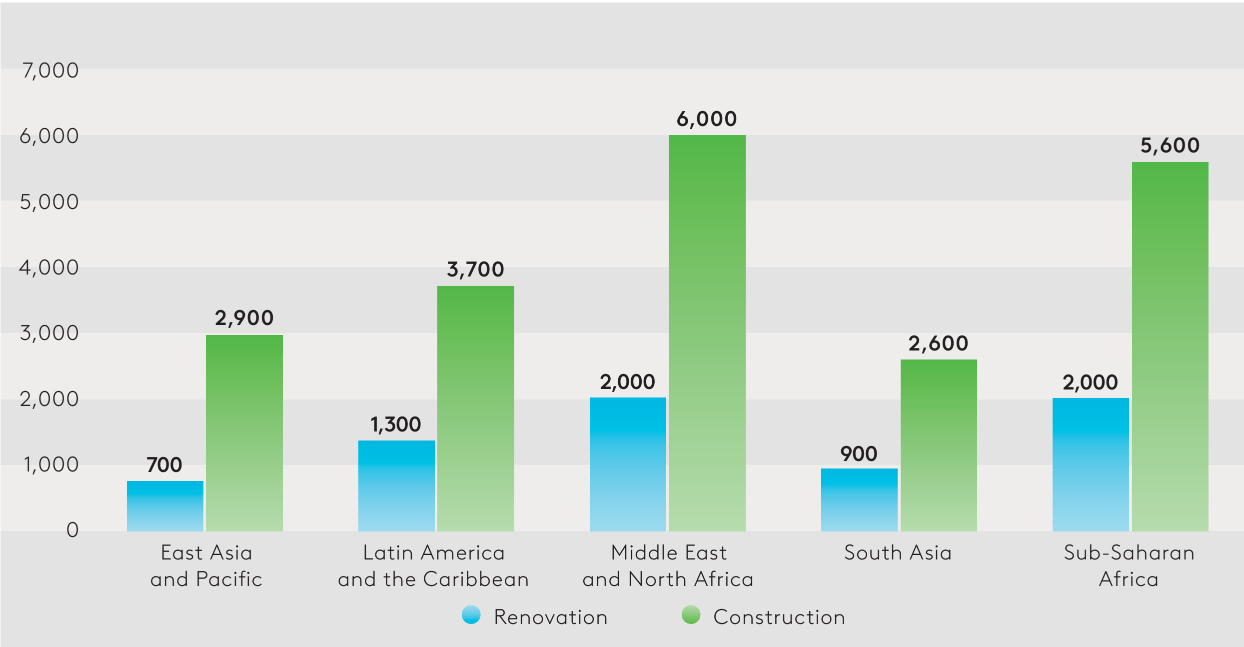
Rapid urbanisation, urban sprawl growth and the retirement of agricultural land are major concerns for global food security because they reduce fertile irrigated land adjacent to cities[2].

[2] Urbanisation and agriculture

It is very difficult for low-income countries to attract irrigation development investment, either domestic or foreign. To address this issue, they will first have to increase the efficiency of domestic investment resources, both public and private, bearing in mind that irrigation is rather capital-intensive. Based on data from 93 developing countries, they will need an average of USD 3,500 per ha to build an irrigation system and USD 1,000 per ha to renovate it. These unit prices are purely indicative: they can vary significantly depending on the specific conditions of a project and should be adjusted accordingly during project development.

Water in agriculture is used to irrigate food and industrial crops and produce livestock feed. After irrigated crop farming, animal husbandry is the second-largest consumer of water in agriculture. Farmers apply intensive and extensive technologies in animal husbandry for pastures and the cultivation of feed crops over large areas. At 26% of the Earth's land surface, pasture systems occupy the largest area of the livestock production system. 33% of the world's arable land is used to grow animal feed. The development of industrial livestock production systems requires more water to grow feed crops.

↓ **Figure 15. Unit Cost of Construction and Renovation of Irrigation Systems across the World, USD per ha**



Source: EDB estimates based on data from Molden, 2007.

Growing demand for agricultural products drives irrigation development to meet human food needs and industrial demand for raw materials, and increases withdrawals of surface and groundwater. At the same time, many regions of the world face shortages of water for irrigation needs, and FAO defines this as a gap between fresh water supply and demand in a given area (FAO, 2012). Water scarcity subjects people, economic sectors, and ecosystems to water stress, creating a water crisis, which affects all water users and is usually long-term (Beits et al., 2008).

2.2. Modern Irrigation Technologies

Modern irrigation technologies will help use limited water resources more effectively, especially when coupled with advanced water management methods. Countries have already made some progress in this area when they transitioned from surface irrigation to more efficient sprinkler and drip irrigation technologies. Surface irrigation, however, is the mainstay of all irrigation technologies and, as such, requires further improvement.

↓ Table 5. Cost of Irrigation Technologies in Agriculture

#	Irrigation technology	Capital costs, USD per 1 ha of land
1	Micro sprinkler irrigation	6,916
2	Underground drip irrigation	2,964–4,446
3	Surface drip irrigation	2,124
4	Linear move irrigation	2,099
5	Improvement of inter-farm drainage	1,900
6	Centre pivot irrigation	840–1,531
7	Side roll irrigation system	1,507
8	Big Gun sprinkler (end gun sprinkler)	1,457
9	Improved on-farm drainage	1,260
10	Laser land levelling	840
11	Furrow irrigation	519
12	Improvement of traditional irrigation methods	340
13	Reduction of conveyance losses	270
14	Reduction of operational losses on the field	250

Source: EDB estimates based on data from Stubbs, 2016 and Royal Haskoning, 2003.

These are cost estimates derived from specific and hypothetical scenarios shared by US government agencies. The capital costs do not include the cost of wells, pumps, and engines. They can vary depending on, for example, the geographical location of the irrigated land.

Irrigation systems used around the world today are not only in charge of field irrigation and drainage. Irrigation involves complex machinery and equipment, including pumping equipment, sprinklers such as Big Gun (Nelson Irrigation Corporation), wheeled wide-catchment frontal and circular irrigation sprinkling machines, drip tapes, pipes and micro sprinklers. Precision technologies (e.g., drones, sensing devices, sensors, mobile applications, etc.) can improve efficiency and reduce costs when growing high-value crops, so they are increasingly used in many irrigation systems.

Irrigation continues using more traditional technologies that have proven their effectiveness. Furrow irrigation is a basic and inexpensive technology for surface irrigation of fields. Micro sprinkler irrigation is expensive but water-saving. This technology uses small nozzles (sprinklers) to cross-spray water in orchards, greenhouses, and fields. Water in drip irrigation is directly supplied in dozed portions through dropper dispensers to the roots of grown plants. This traditional type of technology has two varieties depending on the location of the drip network: underground and surface drip irrigation (Table 6).

There are different types of sprinkler irrigation, which differ in the way the main irrigation machine runs. A centre pivot irrigation system includes long steel beams, sprinkler nozzles, and a pivot (usually electric) placed around a central base that sprays water in a circular pattern in the field. A linear move irrigation system uses hinged sprinklers on wheels that move across the irrigated area of the field. A roll irrigation system distributes water through a pipe with a sprayer mounted on wheels moving between rows.

Irrigation of fields using high-volume sprinklers is recognised worldwide. Its high-capacity sprinklers are installed at certain points in the fields to cover the relevant area with water. End gun sprinklers, or the USA-favourite Big Gun sprinklers, can be installed permanently or on mobile stations.

↓ **Table 6. Irrigation Technologies Application Depending on Natural-Climatic and Meliorative Conditions**

Irrigation technology	Ameliorative condition of soil			Complex topography	Large slopes	Close proximity to the GWT	Mineralised waters	Water shortage
	Salted	light mechanical compound	heavy mechanical compound					
Microsplinker micro-irrigation	-	+	+	+	+	+	-	+
Sprinkling	-	+	+	+	+	-	-	+
Surface	+	-	+	-	-	-	+	-
Underground	-	-	+	+	+	-	-	+
Drip	-	+	+	+	+	+	-	+

Note: * GWT — groundwater table.
Source: EDB estimates based on data from Olgarenko, Turapin, 2020.

Drip fertigation is a new water-saving irrigation technology. It distributes water, as well as fertilisers and other chemicals such as pesticides, through drip systems. It improves water productivity and the efficiency of mineral fertiliser and chemical use. Depending on the yield and other factors, water savings can reach an average of 13%–20% (25%–33% in rare cases) (UNECE, 2023), while the use of fertilisers and pesticides is cut by 21%–33%. This prevents nutrient leaching and subsoil water pollution. The development of drip fertigation might save large amounts of water in an area suffering from increasing water shortages and consequently reduce water stress.

Automated irrigation systems are essential for water conservation, and this improvement can minimise water use. The Internet of Things and automation are already revolutionising agriculture and agricultural practices, allowing for a streamlined and much more efficient process (FAO, 2022c; Bauyin et al., 2020). Sensor systems help farmers better understand their crops, reduce their environmental impact, and conserve resources (Rezac, 2022; Xiuling et al., 2023).

Monitoring sensors and equipment helps develop an effective irrigation management system. They increase food production with minimal water losses. Proper monitoring and data collection can adequately reflect the condition of crops, soil, and weather in irrigated areas in real time using the Internet of Things and wireless sensor networks. These advanced systems efficiently monitor soil and weather and effectively manage water resources (Obaideen et al., 2022).

We expect more AI-based applications in irrigation in the future (Qazi et al., 2022), for example, peripheral devices such as wireless sensors smart enough to make independent autonomous decisions without relying on powerful central servers running AI algorithms. Thanks to recent advances in electronics, embedded systems with more processing power and memory, known as systems-on-a-chip, can provide a comprehensive solution and do not require anything else outside of the chip. We also see the rise in 5G technologies and new autonomous watering and irrigation machinery and equipment; the development of blockchain technology to minimise cyber-attacks on complex information systems for water supply and distribution; and smart irrigation based on big data.

Furthermore, the agricultural sector grapples with exorbitant expenses and meagre returns on investments in conventional technology. Accumulated scientific and practical knowledge underscores that the most economically viable solution to this conundrum lies in the integration of cutting-edge technology into agricultural practices. Innovative techniques for crop cultivation prioritise resource and energy efficiency, environmental sustainability, and the profitability and productivity of irrigated land, all while maximising resource conservation. The expenses associated with incorporating these innovative methods into crop cultivation technology are offset by a substantial increase in crop yields, exceeding 50% (Shadskikh et al., 2020).

Surface irrigation is the predominant method used for irrigated lands in the CA countries. A crucial prerequisite for effective surface irrigation is precise field layout, which aims to rectify existing elevation disparities and create a level or gently sloping surface, depending on the chosen irrigation technique. When fields are properly levelled for furrow irrigation, the yield of grains and other crops can increase by a factor of 1.3–2.3, while the irrigation requirement decreases by a factor of 1.6–2.2. For the cultivation of vegetables and leguminous crops on planned ridges, land productivity experiences a notable boost of 15%–25%. When irrigation occurs on well-planned long strips and furrows spanning 400–500 metres, productivity soars by a factor of 4–8. High-quality field levelling paves the way for the adoption of new mechanised and water-saving surface irrigation technologies, particularly along furrows. Following proper levelling, cotton yields can surge by a factor of 1.3–2.9, while irrigation demand plummets by a factor of 1.6–2.2 compared to unlevelled plots. Cotton cultivation on inclined planes outperforms topographic surfaces, with yields rising by half. On well-planned fields, it becomes feasible to carry out uniform land irrigation with a water consumption rate that is half as much as that required on unmodified plots (Efremov, 2016).

In the case of sprinkler irrigation, proper layout is crucial for ensuring consistent soil moisture distribution and preventing erosion of the upper soil layer or the formation of waterlogged areas in the field. The layout becomes particularly pivotal when transitioning from sprinkler systems to surface irrigation methods. This transition is necessitated by the wear and ageing of the existing irrigation network components and the sprinkler equipment, which often results in substantial expenses for acquiring new machinery and increased expenditures on electricity, fuel, materials, and spare parts.

When renovating existing irrigation systems, surface irrigation is implemented by aligning wide, elongated strips that prevent water from spilling beyond the irrigated area. This irrigation method offers significant advantages, including energy conservation and a substantial reduction in both initial capital investments for land reclamation construction (by a factor of 1.5–2.3) and ongoing operational costs (by a factor of 2.4–2.7). In the CA countries, surface irrigation is widely adopted across extensive areas of irrigated lands, necessitating regular land levelling as a mandatory and recurring measure in land irrigation. When land levelling operations are organised efficiently, the costs involved are offset by achieving consistently high yields and considerable savings in irrigation water usage. Despite the evident benefits of proper land planning, it often doesn't receive the attention it deserves, leading to the inefficient utilisation of irrigated lands and unnecessary losses of irrigation water. The absence of comprehensive planning results in significantly reduced crop yields and the excessive use of irrigation water on these lands (Efremov, 2016).

In general, changing environmental requirements and intensified water risks call for innovations in the water management and irrigation sectors. The development of related technology and its cost reduction promote new water management and irrigation systems. Nonetheless, the effectiveness of any individual irrigation technology, when employed in a specific region, necessitates a period of time for full implementation and the realisation of long-term efficiency gains (US Government Accountability Office, 2019).

Many countries around the world (OECD, 2016) are making agriculture more sustainable by integrating different (including digital) technology to improve its performance. These improvements to irrigation systems will help use water more efficiently and achieve the UN SDGs.

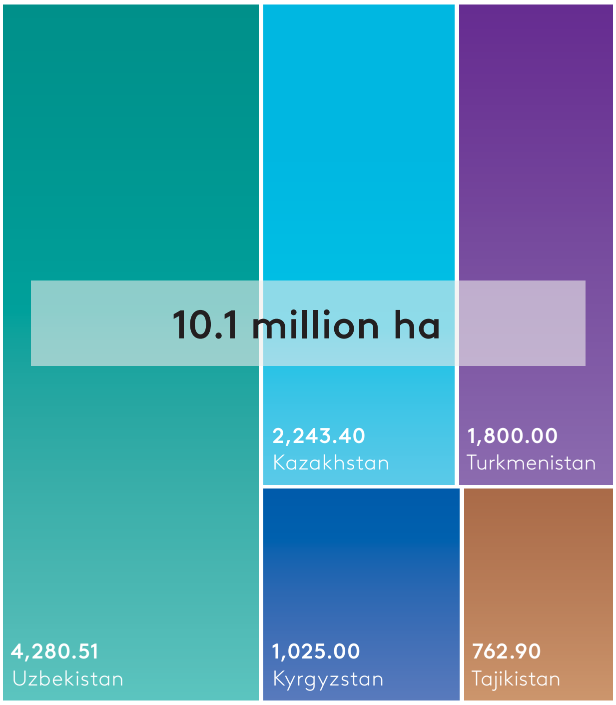
2.3. Irrigated Crop Farming Is the Main Driver of Agricultural Development in Central Asia

Irrigation has historically been critical to agriculture and food security in CA. This is because the region's territory is largely located in a zone of insufficient and unstable moisture, and agriculture can develop only under irrigation. Occupying about 3.5% of the total area of agricultural land, irrigated land generates 65.5% of the gross agricultural product in value terms in the region: about 100% in Turkmenistan, 87% in Uzbekistan, 85% in Kyrgyzstan, 82% in Tajikistan, and 8% in Kazakhstan. In terms of crop production value, irrigated agriculture accounts for a substantial 80% of the total gross output. Irrigation supports sustainable agricultural production, especially in dry years.

Over time, the technology used for irrigation has evolved significantly. From the mid-19th century on, the region developed irrigation systems for cotton growing, and by the early 20th century, the total area of irrigated land was estimated at 3 million ha. Land development intensified after the establishment of Soviet power: the area was already 4.3 million ha by 1940 and 5 million ha in 1960 (CAWATERinfo, 2023). Irrigation systems became more complex, requiring reservoirs, water intake facilities, main and inter-farm canals, drainage systems, etc. In 1950–1980, CA put in extensive work in the challenging steppe and desert regions. The region also renovated irrigation and drainage systems and ameliorated saline land, building the backbone of the region's modern irrigation and drainage systems.

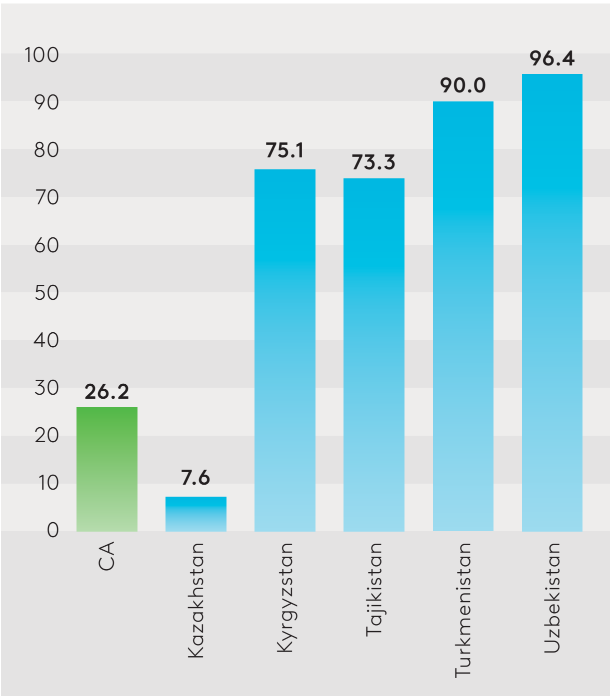
FAO estimates that following the collapse of the USSR, the area of irrigated land in CA declined from 11.3 million ha in 1994 to 9.7 million ha in 2020. EDB estimates put the area of irrigated land in the region at 10.1 million ha at the start of 2022, according to data from national statistical offices and relevant government bodies (Figure 16). This is about 2.9% of the world's irrigated land. Central Asia ranks 5th in the world in irrigated land after such actors as China, the US, India, and Pakistan. 42.3% of irrigated land is concentrated in Uzbekistan. It is followed by Kazakhstan (22.2%), Turkmenistan (17.8%), Kyrgyzstan (10.1%), and Tajikistan (7.5%). Most of the land equipped for irrigation (75% of the total area) is located in the Aral Sea basin.

↓ Figure 16. Irrigated Land Area in CA, 2020, 1,000 ha



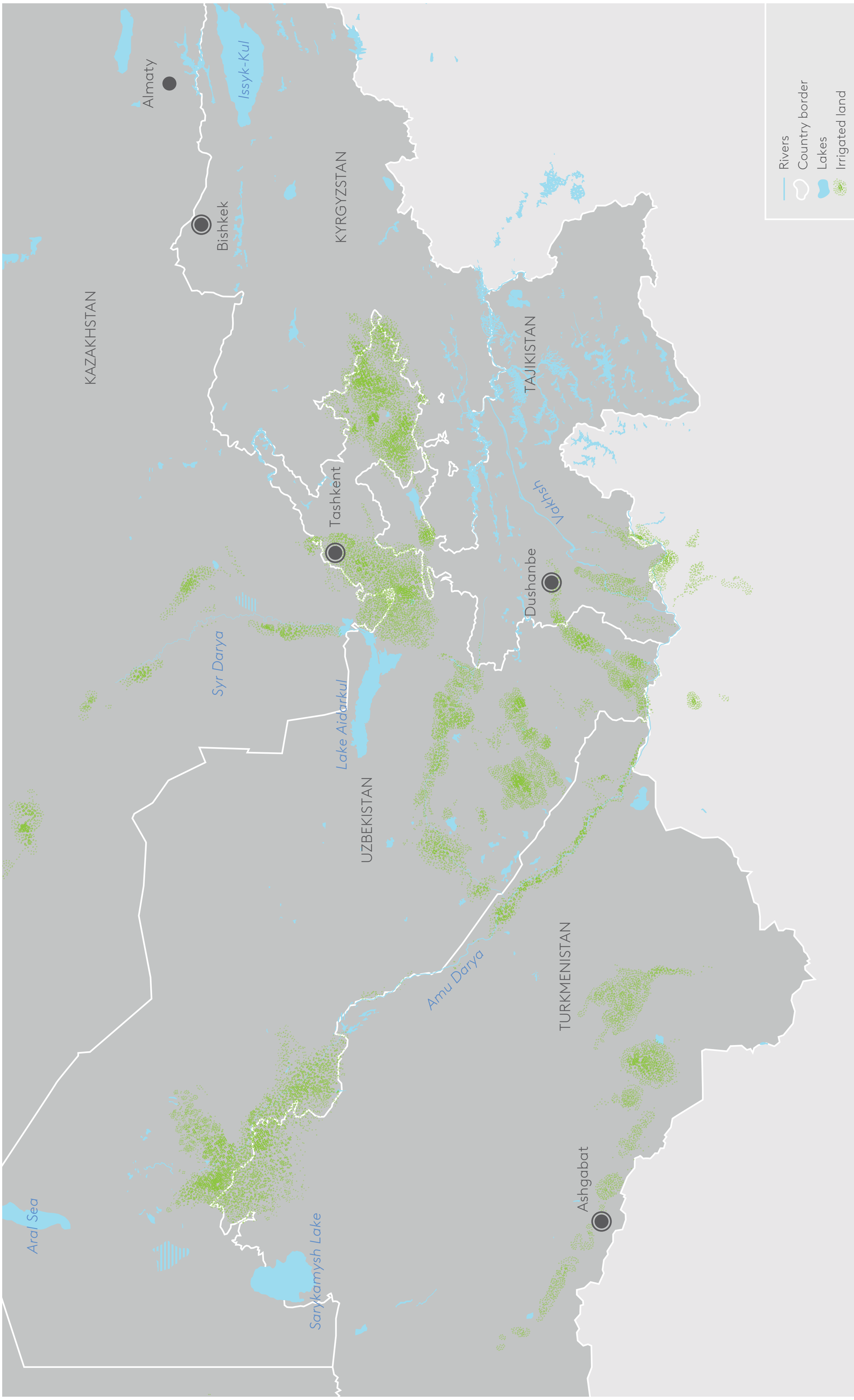
Source: EDB estimates based on data from CA statistical offices.

↓ Figure 17. Irrigated Land as % of Cultivated Land, 2020



Source: EDB estimates based on data from CA statistical offices and FAOSTAT.

↓ **Map of Irrigated Land in the Aral Sea Basin**



Source: EDB based on data from Water Use Efficiency Monitor in Central Asia.

The area of irrigated land in CA has decreased, partly due to a switch to less water-intensive cultivated crops. There have also been some changes to the operation of reservoirs in the upper reaches of transboundary rivers: they fluctuate between irrigation, irrigation and energy, and sometimes even energy only. These changes have affected irrigated crop farming in the region. The period of market reforms saw the decommissioning of unused irrigated land (mainly in Kazakhstan) and a subsequent increase in land degradation, mainly due to its salinisation.

Irrigated land in CA accounts for 26.2% of all cultivated land vs. the global average of 21.2%. The share of irrigated land in the total cultivated area ranges from 73% (Tajikistan) to 96.4% (Uzbekistan). Kazakhstan has a low share of irrigated land, at 7.6% (Figure 17).

Most of the irrigated land in CA has engineered irrigation infrastructure. These areas cover 9.1 million ha, or 94% of irrigated land. These areas mostly (98.2%) use surface irrigation technology. Mechanical irrigation technology (in particular, sprinkler irrigation) is used on only 1.7% of the area and only in Kazakhstan. Uzbekistan features one of the most technically complex surface irrigation systems in the world. It involves reservoirs, pumps, and canals. Complexity comes at a cost, though; it is also one of the most expensive systems in terms of electricity consumption (UNDP, 2007). Of all the countries, only Kazakhstan has land irrigated by spring flood runoff, aka flood irrigation technology. National statistics record the use of drip irrigation technology in Kazakhstan, but it is not significant enough.

FAO estimates the total potential area of irrigated land in the region at 15 million ha. That said, water shortages and high water stress (Vinokurov et al., 2022a) are making CA max out its extensive irrigation development options. Uzbekistan and Turkmenistan are reaching their expansion limits. Their share of developed land is estimated at 87% and 77% of the potential limit, respectively. The region, however, has seen a significant reduction in irrigated areas, partly due to abandonment. Most of the new land in the region is unproductive and requires a greater investment of resources. The situation in Kazakhstan calls for the revision of the irrigation potential in the region because it is obviously overestimated, not to mention the significant discrepancies in statistics between FAO and national agencies and the increased complexity of developing new irrigated areas.

The irrigation infrastructure in the CA countries is characterised by a high (70%–80%) depreciation of water sector fixed assets. The average age of inter- and on-farm irrigation infrastructure reaches 50 years, while large main canals are older than that. The poor technical condition of the irrigation infrastructure makes for poor operation and maintenance of irrigation systems, both by public water management organisations (main and inter-farm irrigation facilities and canals) and by owners of irrigated land (on-farm facilities and irrigation networks), and leads to large overall economic losses.

CA does not use water in an economically effective way either (Vinokurov et al., 2022a), partly due to significant water losses. The studies conducted by Royal Haskoning (2003) revealed major water losses at all stages of its conveyance from the water intake to the field and in the field during irrigation. Water losses were calculated using a bespoke model and a lot of long-term data, which derived average indicators of water losses in the irrigation system and in the field. The system incurs very high losses, seeing only a small proportion of the water used for its intended purpose.

For example, filtration in the canal system loses about 40% of the water withdrawal from rivers; one-third is lost in the main and inter-farm canal systems, and two-thirds of the losses occur in on-farm canals, according to research. The system was supposed to function at 75% efficiency under the project design, much higher than the current 60%, and this includes the expected reuse of drainage water for irrigation. In most cases, farms lose water due to inadequate on-farm water management caused by the extremely poor ameliorative situation of irrigated land, irrigation, and collector and drainage networks.

↓ **Table 7. Comparative Statistics on Irrigated Land in CA, 2020**

	Unit	World	Central Asia	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Agricultural land	(1,000 ha)	4,744,459.5	288,807.50	214,003.20	10,367.80	4,916.00	33,838.00	25,682.50
Agriculture in GDP	(%)		11.12	5.39	13.51	22.61	11.28	26.07
Cultivated area	(1,000 ha)	1,561,449.00	38,528.50	29,685.20	1,364.10	1,041.00	2,000.00	4,438.20
– Share of total area	(%)	11.67	9.62	10.89	6.82	7.36	4.10	9.89
– Per inhabitant	(ha/person)	0.20	0.52	1.58	0.21	0.11	0.33	0.13
– Per rural inhabitant	(ha/person)	0.46	1.01	3.73	0.34	0.15	0.70	0.27
Population	(1,000 inhabitants)	7,790,025.46	74,338.95	18,776.71	6,524.20	9,537.65	6,031.20	33,469.20
Population density	(inhabitants/km^2)			6.89	32.63	67.46	12.36	74.55
Rural population	(1,000 inhabitants)	3,415,663.07	38,139.73	7,948.26	3,979.16	6,868.97	2,863.84	16,479.50
Rural population as % of total	(%)	43.85	51.31	42.33	60.99	72.02	47.48	49.24
Precipitation	(mm/year)	1,170.66	368.2	250	533	691	161	206
Internal renewable water resources	(109 m^3/year)	42,808.60	194.49	64.35	48.93	63.46	1.41	16.34
– Per inhabitant	(m^3/year)	5,495.3	2,616.2	3,427.1	7,499.8	6,653.6	233.0	488.2
Total water withdrawal	(109 m^3/year)	4,031.86	127.27	24.56	7.66	9.90	26.24	58.90
– Per inhabitant	(m^3/year)	517.57	1,712.01	1,308.22	1,174.09	1,037.99	4,351.49	1,759.83
Irrigated land	(1,000 ha)	331,708.28	10,111.81	2,243.40	1,025.00	762.90	1,800.00	4,280.51
– % of cultivated area	(%)	21.24	26.25	7.56	75.14	73.29	90.00	96.45
Realised irrigation potential	(%)	63.92	68.03	59.54	45.62	48.28	76.50	87.09
Agricultural water withdrawal as % of total renewable water resources	(%)	5.28	44.10	14.21	30.06	33.67	65.09	111.23
Irrigated agricultural output in % of total agricultural output	(%)		65.50	7.61	84.63	81.99	100.00	86.62
Area irrigated using electrical equipment in % of total irrigated area	(%)	34.18	32.51	65.97	5.19	38.90	15.79	27.40
Agricultural water withdrawal as % of total water withdrawal	(%)		78.9	62.7	92.7	74.5	61.4	92.3

Source: EDB estimates based on data from Aquastat.

Climate change in the CA region is closely intertwined with drought and desertification processes, resulting in the deterioration of agricultural lands and the degradation of their ameliorative condition. Within the expansive boundaries of CA, various types of geological and landscape deserts can be found. Drought, desertification, and land degradation pose significant obstacles to sustainable development, diminishing food security and exacerbating social tensions and unemployment. The severe environmental degradation resulting from the desiccation of the Aral Sea has further contributed to the deterioration of natural ecosystems, heightened desertification, and increased soil salinisation. The Central Asian countries are signatories to the Convention to Combat Desertification and have completed the ratification process to address these critical environmental challenges.

National reports from the CA countries addressing desertification highlight that irrational use of irrigation water within irrigation systems is a significant contributor to desertification processes in the region. Analysis of aerial data has revealed that nearly all waterlogged basins are inundated with discharge collector and drainage water. These waters have submerged approximately 800 thousand hectares of land in the area, and have affected more than 930 thousand hectares, causing a shift in the composition of pasture fodder plants towards less valuable varieties. The desiccation of the Aral Sea has exposed vast expanses of its seabed, enriched with salts, fertilisers, and pesticides, forming a hazardous mixture detrimental to both humans and the environment. It is estimated that around 70 million tonnes of salts are extracted annually from the Aral Sea basin, spreading over an area spanning 1.5–2 million square kilometres. The sandy-solonchak deserts that have emerged due to the sea's desiccation have become significant sources of dust and mineral salts released into the atmosphere, subsequently contributing to the spread of desertification throughout the Aral Sea region (Alibekov and Alibekova, 2007).

Estimates of annual economic damage stemming from land degradation, attributed to irrational land and water usage, as well as the deterioration of arable land and pasture areas, are approximately 11% of GDP in Tajikistan and Kyrgyzstan — two mountainous countries in the region with limited land resources. In Turkmenistan, degradation leads to damages amounting to 4% of GDP, while in Kazakhstan and Uzbekistan, the estimate stands at 3% of GDP. The majority of these losses can be attributed to the diminished productivity of pastures and the loss of their ecological functions, which transition to less valuable and infertile lands. Research indicates that the costs associated with implementing measures to combat land degradation represent only a fraction of the losses incurred in the absence of action. It is estimated that each dollar invested in land degradation control can yield approximately $5 in returns. Considering the realities of the market economy in the region's countries and recognising that private landowners and small farmers may lack the means and motivation to combat desertification, the CA countries should allocate public funding for initiatives aimed at combating desertification and land degradation (Mirzabaev et al., 2015).

3. COMPARATIVE ASSESSMENT OF NATIONAL IRRIGATION POLICIES IN CENTRAL ASIA

3.1. Republic of Kazakhstan

The total area of registered irrigated land was 2,243,400 ha in early 2022, of which only 1,557,600 ha were in use. This means that 30.6%, or 685,800 ha, are in poor condition and require major repair and rehabilitation. Of the total area used, 1,298.4 ha (80%) are irrigated by the surface (furrow) method. Sprinkler irrigation was used on 185,800 ha, and drip irrigation covered 73,000 ha. Irrigation systems mainly use equipment from past years: outdated DM Fregat, Dnepr, Volzhanka, and DDA-100 MA structures. Some farmers purchase sprinkler equipment, mainly foreign-made, for the irrigation of feed and vegetable crops, in particular, in Pavlodar, Abay, Zhetysu, and Almaty oblasts.

Flood irrigation uses local meltwater or flood water for a single spring water recharge of the soil. It covers 864,000 ha, mainly in the basins of the Ural, Irtysh, Sarysu, Nura, Torgay, Yesil, and Talas rivers. Most of it (84.2%) is hayfield and pasture (15.8%). The productivity of flood irrigation land is low due to the poor serviceability of engineering structures. Of the 184.5 million ha of pasture resources, no more than 80 million ha, or 43% of the country's pasture, is used, which means that more than 100 million ha of pasture are diverted.

The Ministry of Water Resources and Irrigation of the Republic of Kazakhstan is the authorised public administration body in the area of reclamation and irrigation. This governmental body was instituted in compliance with Decree of the President of the Republic of Kazakhstan No. 318, dated 1 September 2023, *On Measures for Further Improvement of the System of Public Administration of the Republic of Kazakhstan*. In addition to overseeing irrigation matters, this authorised body is tasked with responsibilities and authority in the realms of water fund management, water supply, and wastewater management. A subordinate body, Kazvodkhoz RSE[3], has branches (subsidiaries) in each oblast. It maintains and operates water management facilities and structures, group water pipelines classified as republican property. The government partly uses the national budget to procure maintenance and repair services for interstate and interregional facilities from the public. Water users finance the rest of the facilities and structures by paying fees. Owners of irrigated land handle all on-farm irrigation network matters; these include individual entrepreneurs and peasant farms (farmers) (Table 8).

Water management sees deteriorating infrastructure and an unsatisfactory ameliorative situation on almost one-third (685,600 ha) of the registered irrigated land. Irrigated land suffers from low productivity, and the almost complete depreciation of irrigation system facilities and the deterioration of farming standards are clearly to blame. This fails to help solve food security and water conservation issues.

Water accounting has many flaws and is poorly developed in irrigated crop farming. Farm delivery points feature unreliable and inaccurate water metering devices. Water metering is based on outdated methods; not all water metering devices and tools get appropriately calibrated and certified.

[3] RSE is a republican state water management enterprise that operates under the right of economic management.

↓ Table 8. Technical Condition of Irrigation, Collector, and Wasteway Canals

Canal classification	total, km	of which by type of ownership			no owner
		republican	municipal	private	
Main	9,908 (30%)	7,343.5 (21%)*	2,440 (57,1%)	93.8 (33,9%)	30.3
Inter-farm	10,196 (53,5%)	2,811.1 (33,5%)	7,050 (60,2%)	217.4 (39%)	117.8
On-farm	19,533 (73,5%)	3,489.2 (48,6%)	8,192 (70,6%)	6,533 (95,1%)	1,319.7
Collectors and wasteway canals	8,936 (71%)	3,505.9 (76%)	4,855.8 (69,3%)	44.7 (98%)	529.2

Note: * In brackets, the share of canals (%) in poor technical condition.
Source: EDB estimates based on data from the Committee on Water Resources of the Ministry of Ecology, Geology, and Natural Resources.

Obviously, water accounting lacks accuracy and reliability, bolstering the cost of services and encouraging grave corruption offences. There is, unfortunately, no large-scale local production of water metering devices in Kazakhstan; such enterprises would equip all water users in a short period of time, improve water accounting and its reliability, and help collect payments for irrigation water.

That said, Kazakhstan's government might look into transitioning to cost recovery of water supply services and including an irrigation system upgrade investment fee in the tariff. Such measures will reform tariff policies, cut agricultural subsidies, call for water conservation, and promote public-private partnerships (PPPs) when it comes to the efficient use of water and land resources.

Kazakhstan believes that irrigated crop farming will intensify agricultural production, create a solid feed base for animal husbandry, and develop vegetable farming. They plan to rehabilitate unused irrigated land and expand irrigated land in the central and eastern regions of the country by 2050. Farmers can grow feed and vegetable crops on irrigated land in these areas using modern sprinkler equipment. This area should become a strong feed base for animal husbandry and a major producer of vegetable products (potatoes, cabbage, carrots, etc.).

Large-scale industrial production of feed (hay from alfalfa and other grasses) can be Kazakhstan's top export, not only to the CA market, but also to other regions. We believe that Kazakhstan's central and eastern regions can benefit greatly from creating a regional export market for hay because it will drive irrigated crop farming, especially once international development banks get on board, including the EDB. For example, global hay exports exceed 9 million tonnes, or USD 3 billion, annually (Ganenko, 2020), with 5 million tonnes supplied by the USA, 2.8 million tonnes by Europe, 0.9 million tonnes by Canada, and 0.24 million tonnes by Argentina. The key importing countries are Lebanon, Kuwait, Bahrain, Iran, the United Arab Emirates, Saudi Arabia, China, Taiwan, Korea, and Japan. Alfalfa is the world's most popular raw material for hay production. Countries' additional total demand for hay is estimated to reach 32.59 million tonnes by 2027. Projects to produce feed from hay on irrigated land are very investment-appealing. A tonne of feed (alfalfa) imported by China from the USA costs USD 416 in 2020 vs. USD 258 in 2009. The Russian Federation rolled out the Greenfield project worth RUB 1,165 million for Astrakhan Oblast. It is designed to grow alfalfa on an area of 3,200 ha and will take 4.81 years to reach the payback period. The project proposes artificial drying of alfalfa. This measure will enable early cutting from the field and additional cutting, subsequently ensuring the stable quality of the finished product through hay pressing and its regular supply to the market. The project also mentions high margins per hectare and discusses using large-tonnage vehicles (20 tonnes and more) for feed delivery (APEHF, 2023).

↓ Table 9. Investment Needs for Irrigation Development in Kazakhstan until 2030

Estimate		2024–2025		2026–2030		Total
	unit	per year	total	per year	total	
Re-development of diverted irrigated land	1,000 ha	25	50	50	250	300
Cost	USD million	75.0	150.0	150.0	750.0	900.0
Construction of new irrigation systems	1,000 ha	—	—	10	50	50
Cost	USD million	—	—	40.0	200.0	240
Total	USD million	75.0	150.0	190.0	950.0	1,140.0

Source: EDB estimates based on data from the General Scheme for the Integrated Use and Protection of Water Resources, 2016.

The southern regions of Kazakhstan (the Syr Darya basin) do not plan to develop new irrigated areas — they have almost run out of all their water resources. Their water management policy will prioritise water conservation by rehabilitating, renovating, upgrading irrigation systems, and improving the ameliorative situation of irrigated land. They will also seek to boost water productivity. This will require enhancing the quality of maintenance throughout the region and switching to water-saving technologies for crop cultivation, all in strict compliance with agro-technical requirements.

The moderate scenario of our forecast estimates the re-development of diverted irrigated land at about USD 75–150 million per year, totalling USD 900 million by 2030, at USD 128 million per year. The total irrigated area should reach 1,900,000 ha by 2030 if we factor in new irrigation systems and the rehabilitation of irrigated land. These measures will require USD 1,140.0 million by 2030, or about USD 163 million. Total investment will include contributions from national and local budgets (55%–60%), private financing (10%–15%), external financing (25%–35%), and the annual inflow of foreign investment into the irrigation sector (USD 41–57 million) to total USD 285–400 million by 2030.

Irrigated crop farming can only develop with resource-saving technologies. This is why Kazakhstan plans to produce modern sprinkler equipment. The Ministry of Agriculture of Kazakhstan, Kusto Group (Kazakhstan), and Valmont Industries signed an agreement in January 2021 to build a plant to produce 1,000 Valley sprinklers per year. Metzerplas plans to launch the production of drip pipes in Almaty Oblast, Kazakhstan, at the end of 2023.

3.2. Kyrgyz Republic

Kyrgyzstan's agricultural land area was 10,604,600 ha in 2022, of which 9,002,100 ha (or 84.9%) went to pasture, 1,287,000 ha (or 12.1%) to arable land, and 315,500 ha (or 3%) to hayfields and other land. The irrigated land area available is 1,025,000 ha, or more than 79.6% of the total arable land (National Statistical Committee of the Kyrgyz Republic, 2022). Crop farming depends on irrigated land in the foothills and lowlands. It features an extensive network of irrigation facilities, such as reservoirs, irrigation canals, collector and drainage networks, hydraulic structures, pumping stations, and wells of the on-farm irrigation network (Umarova, 2016).

Small rivers are the main source of irrigation in the country due to the unique terrain. Reservoirs irrigate only 240,000 ha (23.4%); the rest has to make do with unregulated flow, which does not guarantee a stable water supply. Water resources are distributed unevenly over the seasons and across the territory, and the hydrographic features of rivers vary in different ways. This hinders the efficient use of water resources.

Inadequate financing is making Kyrgyzstan's irrigation system unreliable. This endangers agricultural production because the system fails to provide enough irrigation water to irrigated land, especially considering the urgency of recurrent dry years. This is why the country does not use 100,000–110,000 ha of arable land every year (Choduraev and Dzhayloobaev, 2016). A whopping 5.6 million ha also suffer from soil erosion, and 10.7 million ha are subject to waterlogging due to rising subsoil water. Degradation has decreased the productivity of pasture by 30%–40% (Aarnoudse et al., 2018). Anthropogenic impacts have halved the forest area over the last 50 years; forests now make up less than 4% of the country's total area.

The Water Resources Service is the authorised executive government body that regulates relations in water management and use. The Water Resources Service of the Kyrgyz Republic owns the state irrigation fund, which includes:

- inter-farm canals — 5,786.7 km;
- hydraulic structures — 7,659 units;
- gauging stations — 3,236 units;
- pumping stations — 111 units;
- reservoirs — 33 units with a total capacity of 1,617.3 million m^3;
- collector and drainage network — 1,187.1 km.

The length of the inter-farm collector and drainage network is 650.4 km, including the closed network of 27.5 km and the open network of 622.9 km. Of these, 62.0 km of the open network (10%) need mechanical cleaning, and 9.7 km of the closed network (38%) requires washing — they are in poor serviceability. Of the 5,091.2 km of the on-farm collector and drainage network, 2,750.5 km are open, and 2,340.7 km are closed, including 1,052 km of open network (38%) and 486 km (21%) of closed network subject to mechanical cleaning.

Water User Associations were established for the maintenance and operation of the on-farm network. On-farm irrigation canals are to be transferred to the accounts of WUAs and funded by water users, according to Law on Water User Associations No. 38, dated 15 March 2002, and Resolution of the Government of the Kyrgyz Republic No. 234, dated 6 April 2004. WUAs were supposed to maximise the efficiency of water use on irrigated, flooded, and ameliorated land by exercising the right of farmers and peasant farms to use water (Umarova, 2016). WUAs are only a solution, even if existing WUAs serve 72% of the country's irrigated land. Owners also tended to establish one large association in the form of a cooperative or a joint peasant farm within the former borders of a collective farm or a state farm and there were usually no other separate economic entities, so an on-farm water use organisation can remain as it was, with no need for a WUA (OSCE, 2010).

There are currently 476 WUAs in the country, covering 732,800 ha of irrigated land, and there are 10 WUA unions. The on-farm and inter-farm irrigation infrastructure has poor serviceability due to the lack of funds from water users and WUAs and low water charges. Many canals and structures are deteriorating and in need of overhaul, and supply less water to irrigated land (Umarova, 2016). This calls for regular cleaning and thorough washing of the drainage network; otherwise, the ameliorative situation of irrigated land will deteriorate. Ultimately, poor irrigation infrastructure will cause lower crop yields and divert irrigated land from crop rotation. It does not come as a surprise that the activities of WUAs are heavily criticised, so the on-farm irrigation infrastructure was transferred to units of the Water Resources Service of the Kyrgyz Republic for maintenance (Water Resources Service of the Kyrgyz Republic, 2023).

Most irrigation infrastructure has been in operation for 30–40 years or more and is in poor condition due to a prolonged socio-economic crisis, including underinvestment and incomplete reforms in the sector. The government developed its Government Programme for the Development of Irrigation in the Kyrgyz Republic for 2017–2026 (the "Government Programme"). They selected 46 water management facilities according to their relevance, economic and technical state, and social importance for the regions (Ministry of Justice of the Kyrgyz Republic, 2017). The Government Programme requires investment worth KGS 58,786 million to develop 66,500 ha of new irrigated land, increase the water availability on 51,080 ha, switch 9,500 ha from machine water supply to gravity irrigation, and improve the ameliorative situation by 50,000 ha.

The Government Programme receives its funding from the national budget, external sources, and investment (Islamic Development Bank (IsDB), World Bank (WB), Arab Coordination Group, a grant from China, Economic Development Cooperation Fund (Republic of Korea), Asian Development Bank, World Bank, European Bank for Reconstruction and Development).

↓ Table 10. Investment Required under the Government Programme for the Development of Irrigation in the Kyrgyz Republic for 2017–2026, USD million

Stages	total	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Category 1	70.5	14.1	14.1	14.1	14.1	14.1	14.1	–	–	–	–
Category 2	526.6	–	–	–	75.3	75.3	75.3	75.3	75.3	75.3	75.3
Category 3	250.4	–	–	–	–	41.7	41.7	41.7	41.7	41.7	41.8
Total	847.5	14.1	14.1	14.1	89.4	131.1	131.1	117	117	117	117.1

Source: NSC KR.

The government plans to construct and rehabilitate three categories of water management facilities on irrigated land under its programme.

The first category includes irrigation facilities in the pipeline, funded with a grant from China and an IsDB loan, and on-going projects financed by the national budget. These are 17 facilities worth about KGS 4,895 million (USD 70.5 million) that will develop 8,965 ha of new irrigated land, improve the availability of water on 29,340 ha, and switch 2,800 ha from conditionally irrigated land to irrigated land.

The second category covers on-going projects with international financial institutions, donors, and investors (IsDB, WB, Arab Coordination Group, Economic Development Cooperation Fund (Republic of Korea), etc.). This category includes 17 facilities worth about KGS 36,526 million (USD 526.6 million) that will develop 40,256 ha of new irrigated land, improve the availability of water on 9,662 ha, and switch 5,000 ha to gravity irrigation.

The third category covers facilities to be funded domestically and internationally, perhaps with the help of international financial institutions, donors, and investors. This category includes 12 facilities worth about KGS 17,365 million (USD 250.4 million) that will develop 17,350 ha of new irrigated land, improve the availability of water on 12,083 ha, and switch 4,511 ha to gravity irrigation.

The International Development Association (IDA) signed a financing agreement with Kyrgyzstan in Washington on 19 April 2022 to allocate USD 100 million for the Climate Resilient Water Services Project. The IDA will provide a concessional loan of USD 50 million and a grant of USD 50 million. The loan is for 38 years, including a six-year grace period, at an interest rate of 0.75%, payable for 32 years. The project will span seven years, from 2022 to 2028. The agreement will finance the rehabilitation and construction of water supply systems, wastewater disposal and treatment facilities in the villages of Kyzyl-Suu, Bokonbayevo, and Kadzhi-Say in Issyk-Kul Oblast, and the rehabilitation and construction of water supply systems for houses/homesteads in Batken Oblast, in total benefitting 38 villages. The project will finance the rehabilitation of three existing irrigation and drainage systems in the Kara Darya–Syr Darya–Amu Darya river basins (Osh, Batken, and part of Jalal-Abad oblasts). The three irrigation systems will supply water to a total of 28,000 ha of agricultural land managed by 23 WUAs (Akhmatova, 2022).

3.3. Republic of Tajikistan

The Republic of Tajikistan estimates its irrigable land at 1,570,000 ha, and it only used 762,900 ha in 2021. The irrigated land in use has soil degradation: it is 18% stony and 15% subject to salinisation. Statistics say that over 21,000 ha of irrigated land were not sown, and 18,100 ha were diverted in 2021 due to deteriorated hydraulic structures and reorganised farms operating on-farm pumping stations. Most land users lack funds and have limited access to long-term concessional loans, so they do not repair or rehabilitate their hydraulic structures and irrigation and drainage systems. Their consequent condition leaves much to be desired. In fact, the country actually uses less than 600,000 ha due to inadequate irrigation and drainage infrastructure, waterlogging and salinisation of land, and unreliable power supply to pumping stations. Some 563,000 ha of irrigated land are in "good condition", and 133,000 ha are in "satisfactory condition".

↓ **Table 11. Irrigation Infrastructure**

Description	unit	Length/quantity
Total pumping stations	units	390
cascade pumping stations	units	228
Length of pressure pipelines	km	624.67
Length of the irrigation network	km	33,250
inter-farm networks	km	5,259
on-farm networks	km	27,991
Length of the collector and drainage network	km	11,400
inter-farm networks	km	2,200
on-farm networks	km	9,100
Length of irrigation tunnels	km	26
Hydraulic structures	units	7,099
Gauging stations	units	3,858
Electricity consumption by pumping stations	kWh billions	1.3–1.5

Source: data from the Agency for Reclamation and Irrigation of the Republic of Tajikistan.

Water erosion affects 3.7 million ha of the country's territory. Landslides have increased significantly, especially in mountainous areas. Of the 200 cases, 140 were directly caused by deforestation, trimming of landslide slopes, ploughing and excessive watering, and water losses in irrigation systems, i.e., economic activities. Pasture productivity has decreased by 40%–60% over the past 25 years (UNECE, 2017).

The country's formidable topography makes it necessary to use pumping stations to lift water for 40% of the irrigated area, or 280,000 ha. Naturally, these stations consume a lot of electricity or fuel. In order to develop the foothills, Tajikistan built 390 pumping stations with 1,500 units, including 228 cascade stations with 2–7 lifts. These stations are technologically challenged: 99% of the pressure pipework is worn and in need of upgrading; 75% of the pumping units were manufactured more than 60 years ago, and 17% have been in operation for more than 50 years. Main and on-farm canals and their structures are in the same condition. These factors cause about half of the water withdrawn from the source to be lost.

Tajikistan's irrigation sector of agriculture uses 21% of the electricity consumed in the country, while irrigation tariffs are among the lowest in the world. Such irrigation is highly energy-intensive, and this keeps the cost of growing crops expensive and prevents any development of new irrigated land in mountainous areas. Farmers only partially cover the costs of water supply services, including electricity, and the national budget largely funds the costs of water management organisations (World Bank, 2017).

↓ Table 12. Pump Irrigation Areas, ha thousand

	Pump irrigation areas by height of water lifting					
	up to 100 m	100–150 m	150–200 m	200–250 m	250–300 m	Total
Khatlon Oblast	109.051	24.415	26.040	1.627	1.627	162.760
Sughd Oblast	90.562	11.320	1.029	–	–	102.911
Regions of republican subordination	7.995	2.112	3.922	754	302	15.085
Gorno-Badakhshan Autonomous District	92	–	–	–	–	92
Total	207.700	37.847	30.991	2.381	1.929	280.850

Source: OSCE, 2019; World Bank, 2017.

The land reform in Tajikistan divided collective farms into many small *dehkan* farms and discontinued the management of the former collective irrigation systems designed for large-scale production of cotton and other crops. Farmers who lacked funds and equipment were put in charge of on-farm networks and irrigation facilities. Then the country set up WUAs within the former irrigation systems to organise water use by the many *dehkan* farms. WUAs received their financing from water users' contributions. They distribute water among farmers, resolve potential disputes over access to water, and collect payments for water supply.

The Ministry of Energy and Water Resources of the Republic of Tajikistan handles public fuel, energy, and water matters. They are responsible for the related public administration and regulation, both nationally and internationally. They also supervise water, fuel, and energy facilities under construction, develop incentives and activities in the field of renewable energy sources, prevent and eliminate fuel, energy, and water emergencies, and design the methodology for electricity and thermal energy, natural gas, oil, petroleum products, and water tariffs.

The government established the Agency for Reclamation and Irrigation back in 2013. As the name implies, the Agency manages reclamation and irrigation, maintains and repairs irrigation, drainage and other water facilities under its jurisdiction, develops the Cadastre of Land Ameliorative Condition, and monitors the state of bank protection of *sais* (gullies) and rivers. The Agency ensures the passage of water through irrigation facilities and the efficient use of water resources. It is authorised by the government to support WUAs. It has about 20 subordinate organisations, including Tajikgiprovodkhoz Design Institute and the Tajikvodavtomatika State Unitary Enterprise (installation and pre-commissioning).

The country lacks sufficient financing and adequate maintenance and overhaul of its systems. This caused poor irrigation, increased soil salinisation, and limited access to irrigation water for farmers. Rehabilitation of the infrastructure requires significant investment, tentatively estimated at up to USD 2 billion over 15–20 years (UNECE, 2017). Other estimates put the cost of upgrading the entire irrigation system at about USD 10 billion. Over the past 15 years, international financial institutions have invested over USD 200 million in the amelioration and irrigation sector in the form of loans, grants, and technical assistance.

The government of Tajikistan is planning to recommission an area of 16,900 ha under its Programme for the Development of New Irrigated Areas and the Rehabilitation of Diverted Agricultural Land for 2022–2027 (National Water Information System of the Republic of Tajikistan, 2022). The Programme targets the development of new irrigated land and the rehabilitation of diverted agricultural land.

↓ **Table 13. Financing Plan for the Government Programme for Developing New Irrigated Areas and Bringing Unused Land into Use for 2022–2027**

	Irrigated areas that require amelioration, 1,000 ha	Financing TJS 1,000 / USD 1,000	of these, financed from; TJS 1,000:			
			national budget	local budget	fees for water supply services	domestic and foreign investment
2022	1,390	56,737.8/ 4,377.9	6,220	–	–	50,517.8
2023	2,027	60,709.8/ 4,684.4	8,772	100	20	51,817.8
2024	4,310	139,367.8/ 10,753.7	9,430	100	20	129,817.8
2025	4,654	228,453/ 17,627.5	10,994	250	0	217,208.9
2026	2,020	19,291.1/ 1,488.5	11,770	150	30	7,341.1
2027	2,500	58,497.1/ 4,513.7	10,565	200	15	47,717.1
Total	16,901	563,056.5/ 43,445.7	57,751	800	85	504,420.5*
		100%	10.25%	0.14%	0.01%	89.6%

Note: The National Bank of Tajikistan, the official USD to TJS exchange rate was 12.96 as at 1 April 2022;
* including TJS 201.6 million, or USD 20.6 million, under government investment projects.
Source: Ministry of Energy and Water Resources of the Republic of Tajikistan.

The financing for the Programme in 2022–2027 totals TJS 563.1 million, or USD 43,445,700. The average unit cost of developing new irrigated land and renovating irrigation infrastructure is TJS 33,317 per ha, or USD 2,570.8 per ha.

The Water Sector Reform Programme for 2016–2025 (Government Resolution No. 791, 2015) was developed as a roadmap for the transition to integrated water resource management (IWRM). The Programme for the Development of the Reclamation and Irrigation Sector for 2016–2025 extends the provisions of the above Programme and will increase the efficiency of irrigated agriculture, ensure its sustainable financing, and improve the activities of WUAs.

3.4. Turkmenistan

Turkmenistan has got an extremely arid climate, and desert makes up almost the entire territory of the country. Irrigated crop farming is the backbone of agriculture and the largest consumer of water resources, accounting for about 90% of the water used in the country. The country's irrigated area has more than tripled since 1965 and is now 1.8 million ha. Irrigated land accounts for only 4% of agricultural land; the remaining 96% is desert pasture.

The country boasts extensive, albeit deteriorating, irrigation infrastructure. The inadequate condition of the collector and drainage network harms the soil of irrigated land and causes salinisation, or waterlogging (Stanchin, 2016). Water losses in irrigation systems reach 12 km^3, totalling half of the water used in the country (Alibekov and Alibekova, 2007; Gupta et al., 2009). Farmers contribute to partially cover the costs of water management organisations and pay them 3% of their gross product, but they are not charged for water supply. Peasant associations collect this 3% compensation fee. The government uses the budget to pay for the operation and maintenance of the inter-farm irrigation system. This discourages agricultural producers from using water efficiently.

The whopping 90% of irrigated land is in a poor ameliorative situation (Stanchin, 2016). Collector and drainage water is highly mineralised along the right and left banks of the Amu Darya River. The drainage water is diverted to Golden Age Lake (Altyn Asyr), an artificial reservoir located in the natural Karashor Depression. Since 2009, the lake has been replenished by two new collectors, which drain up to 10 km^3 of mineralised drainage water that was previously discharged into the Amu Darya River. The government is planning to increase the lake's capacity to 150 km^3 and to use its water for irrigation after partial desalination. They, however, expected a much bigger supply of collector and drainage water. It is not suitable for irrigation, either, because, even if partially desalinated in a natural way, it deteriorates the ameliorative situation of the irrigated land and causes its diversion.

The irrigation sector of Turkmenistan's agriculture is facing the secondary salinisation of irrigated land, an increasingly challenging issue for the country. Saline land accounts for up to 40%–80% of sown areas in some *etraps* (districts) of Turkmenistan. Some 80% of arable land is risking salinisation in the Karakum River zone, both in oases and unexpected areas. Areas that have been irrigated for a long time tend to have very large stretches of secondary saline soils. The total area of saline land in Turkmenistan is 1,145,200 ha (66.9% of the available land). We can consider 80% of irrigated land saline and vulnerable to degradation if we include slightly saline soils. Cotton yields are reduced by 15% on slightly saline soils, by 30% on moderately saline soils, and by more than 50% on severely saline soils. Rough estimates put the annual shortfall in raw cotton due to salinisation in Turkmenistan at 200,000–300,000 tonnes (Stanchin, 2016).

Cotton (37.9%) and wheat (49.1%) dominate the crop structure; in other words, they total 87% of the country's irrigated area. Turkmenistan is investing heavily in wheat production, hoping to achieve food self-sufficiency but failing to push back against the natural and climatic conditions. What happens is that the yield of irrigated wheat is 12.2 hwt/ha, i.e., less than the yield of rain-fed wheat grown in Kazakhstan. Since wheat is grown on irrigated land, it has a low gluten content. Such wheat is mainly feed grain, not suitable for eating, so Turkmenistan needs to buy wheat of the varieties required for the baking industry.

Domestic production of wheat is much more expensive than its import, for example, from Kazakhstan. Besides, the dominance of wheat and cotton in the crop structure has disrupted crop rotation and affected soil fertility and its natural and economic potential. Vegetable growing, melon growing, and viticulture are highly profitable crop farming sectors in Turkmenistan's agriculture, even in the domestic market. This is why Turkmenistan will need to improve the ameliorative situation of irrigated land, reduce saline land, and renovate irrigation infrastructure to boost the efficiency of irrigated land. We would also recommend optimising the crop structure and switching to high-yield crops, following crop rotation rules and other agro-technical requirements (Stanchin, 2016).

↓ **Table 14. Investment Needs for Irrigation Development in Turkmenistan until 2030**

Activity	unit	2023–2025		2026–2030		2023–2030
		year	total	year	total	total
development of new irrigated areas	1,000 ha/USD million	5/ 25	15/ 75	7/ 35	35/ 175	50/ 250
comprehensive renovation of irrigated land	1,000 ha/USD million	6.7/ 26.8	20/ 80	10/ 40	50/ 200	70/ 280
land amelioration	1,000 ha/USD million	23.3/ 70	70/ 210	20/ 60	100/ 300	170/ 510
improved water accounting for irrigation systems	1,000 ha/USD million	1,750/ 20	1,765/ 60	1,765/ 20	1,800/ 100	1,800/ 160
Total investment	USD million	141.8	425	155	775	1,200

Source: Government of Turkmenistan.

Turkmenistan does not provide official statistics or publish sectoral economic indicators in public sources, so we used the National Programme for the Social and Economic Development of Turkmenistan for 2011–2030, the National Strategy of Turkmenistan on Climate Change, and related publications to assess investment in the irrigation sector up to 2040. The National Strategy of Turkmenistan on Climate Change was updated in 2019. It includes the following agriculture measures to be adopted until 2030:

- comprehensive renovation of irrigated land on an area of 70,000 ha;
- amelioration of 170,000 ha;
- renovation of existing and construction of new hydraulic structures.

The country expects to develop 50,000 ha of new irrigated land by 2030, bringing the total irrigated area to 1,800,000 ha. This will require USD 140–160 million worth of annual investment in the development of new irrigated areas, the comprehensive renovation of irrigated land, and the reclamation of saline land, totalling USD 1,200 million until 2030.

3.5. Republic of Uzbekistan

Uzbekistan's total area of agricultural land is 20.2 million ha, but no more than 4.3 million ha of irrigated, or arable land, or 20.7%. The remaining 79.3% is pasture (Chub, 2007). Land suitable for cultivation is mainly located in river valleys and oases (Sokolov, 2015). The arid natural and climatic conditions of Uzbekistan limit the country's options, leaving it to develop its agriculture with irrigated crop farming (Khamraev et al., 2017).

Agriculture is the largest (90%–91%) consumer of water resources and is the only source for possible water conservation via irrigation. That said, transboundary watercourses form about 80% of the country's water resources. Uzbekistan therefore heavily relies on water supplies from neighbouring countries. The country uses surface water (50.9 km^3/year), exploitable groundwater reserves (0.5 km^3/year), and re-uses collector and drainage effluent (1.6 km^3/year) to supply its economy.

The country has funded a complex water management system consisting of canals, collectors, pumping stations, reservoirs, hydraulic complexes, and other hydraulic structures to serve agriculture and other sectors of the economy. It takes the government over UZS 1 trillion annually to operate this entire huge complex and repair more than 5,000 km of canals. Farms (water users) repair more than 100,000 km of irrigation canal and flume networks and 10,000 units of various hydraulic structures. Uzbekistan has built and renovated about 1,500 km of canals, more than 400 major hydraulic structures, and 200 pumping stations over the past few years (Khamraev et al., 2017). The water management system operates 28,400 km of irrigation canals, 54,432 units of various related hydraulic structures, and 70 water and mudflow storage reservoirs totalling 19.4 billion m^3.

↓ **Table 15. Investment Needs for Irrigation Development in Uzbekistan**

Indicator	Unit	Quantity	Need repairs
Total length of irrigation network, of which	1,000 km	183.4	–
main line and inter-farm networks	1,000 km	28.4	16.5
farm and on-farm networks	1,000 km	155,200	80.7
Irrigation wells, total, of which:	units	12,400	–
inter-farm on the books of the Ministry of Water Resources of the Republic of Uzbekistan	units	4,069	–
farm	units	8,331	–
Total length of the collector and drainage network, of which:	1,000 km	142.9	–
open drainage networks	1,000 km	106.2	–
closed horizontal drainage	1,000 km	36.7	–
vertical drainage wells	units	–	1,530
Reclamation pumping stations	units	178	93
on the books of the Ministry of Water Resources of the Republic of Uzbekistan	units	3,788	–
on the books of farms	units	–	–
Observation wells on irrigated areas	units	27,648	–
Pumping stations on the books of the Ministry of Water Resources of the Republic of Uzbekistan	units	1,687	60%
Pumping units on the books of farms	units	12,280	–
hydraulic structures on main line and inter-farm networks	1,000 km	54.0	–
hydraulic structures on farm and on-farm networks	1,000 km	114.0	–
Inter-farm gauging stations (Ministry of Water Resources of the Republic of Uzbekistan)	units	18,142	11,407
On-farm gauging stations	units	41,130	20,335

Source: based on data from the Concept for the Development of Water Resources of the Republic of Uzbekistan for 2020–2030.

The country has complex terrain and hydrographic features, so about 60%, or 2.58 million ha of irrigated land, requires water from 1,687 pumping stations. The subsequent electricity consumption reaches 8 billion kWh annually. In addition, WUAs, farmers, and clusters operate 155,200 km of irrigation networks and more than 10,280 pumping units. 12,400 units are operated for irrigation needs, including 4,153 irrigation wells in the water management system. The country also operates a collector and drainage network of 142,900 km to improve the ameliorative situation of irrigated land, including an open network of 106,200 km and a closed horizontal network of 36,700 km. There are also 172 reclamation pumping stations and 3,897 vertical drainage wells.

Irrigation systems are managed by the Ministry of Water Resources of the Republic of Uzbekistan and its subordinate organisations. The Ministry handles public administration in the field of water resources and coordinates the activities of government bodies, economic management bodies, and other organisations for efficient use and protection of water resources, prevention and elimination of harmful effects of water. The system of the Ministry includes the Ministry of Water Resources of the Republic of Karakalpakstan, 12 basin administrations of irrigation systems, 53 administrations of irrigation systems and main canals, 152 district irrigation divisions, 14 administrations of pumping stations and power generation, 13 reclamation expeditions, and other subordinate organisations.

The irrigation infrastructure is obsolete and worn-out; its service life exceeds 50–60 years. High energy intensity and low productivity of technological equipment lead to significant water losses and high costs of delivery to water users. The anti-filtration lining on the main and inter-farm canals does not exceed 34% of their length. Only 21%, or 32,500 km, of the farm and on-farm networks are lined: 18,100 km, or 11.7%, are flume networks, and 14,400 km, or 9.3%, are concrete lined. The rest of the network is unlined. The existing flume network has undergone no maintenance in over 30 years, so 70% of the flume network is in poor condition. Of the existing 42 large hydraulic complexes (with a capacity of more than 100 m^3/s), 18 require replacement and modernisation of hydraulic-mechanical equipment, and 5 hydraulic complexes require complete renovation. More than 60% of the pumping equipment on the books of the Ministry of Water Resources has exceeded the standard service life.

More than 80% of Uzbekistan is desert or semi-desert. Economic activity exacerbates desertification to varying degrees on 60% of agricultural land (UNECE, 2020). Irrigated land in Uzbekistan is also highly susceptible to soil salinisation, caused by both natural (primary salinisation) and anthropogenic (so called "secondary salinisation") conditions. Large organisational losses of irrigation water in the field raise mineralised subsoil water and cause secondary salinisation.

Salinisation affects over 60% of the country's irrigated land, in particular 1,935,000 ha. Of these, 520,000 ha are moderately saline, and 87,600 ha are severely saline. This has diverted more than 298,500 ha of irrigated land since 1990. Salinity harms crop yields, especially in severely saline areas (more than 100,000 ha in the country). Crop yields per hectare decrease by 30%–45% in severe salinisation, by 15%–30% in moderately saline areas, and even by 5%–15% in slightly saline areas.

Salinisation can be curbed with leaching and artificial or natural drainage. Uzbekistan built and commissioned thousands of kilometres of collector and drainage networks across the country as part of the large-scale development of land in the 1960s. They also introduced closed horizontal, vertical, and combined drainage, aka advanced types. Each oblast established a reclamation body to monitor the ameliorative situation of irrigated land, combat salinisation, and operate the collector and drainage network.

The irrigated area equipped with artificial drainage in Uzbekistan is about 2,995,000 ha (70% of the irrigated land), and 18% is equipped with closed horizontal drainage. Its depth and drain spacing are respectively almost twice as deep and 4–5 times as wide as in humid regions. This is specific to arid regions, including Uzbekistan. This system maintains a deep subsoil water table and requires a lot of irrigation water to meet crop needs. This puts too much pressure on the drainage systems, causes more frequent cleaning, and, consequently, raises operating costs. Regular drainage of the territory generates large amounts of collector and drainage water and water-soluble salts (Khamraev et al., 2017).

The national budget covers most of the costs of supplying water to agricultural water users. Water bills do not directly depend on how much water users consume, so they hardly encourage productive and prudent use (World Bank, 2022). Water management organisations lack the financial resources to employ water- and energy-saving technologies, reduce maintenance costs, and upgrade infrastructure. 1,503 WUAs operate in the country and provide water to water users, including farmers on an area of 3.7 million ha (Farmanov, Yusupova, 2018). WUAs are critical for the water management system; they supply water to farmers and *dehkan* farms, so it is in the country's best interests to ensure their proper and successful functioning.

WUAs also make sure that available water resources are used efficiently. But they tend to be overlooked in the country's legislation, so they are not involved in water conservation policies and do not provide adequate support to farmers and other agricultural enterprises. This means that on-farm irrigation networks and their hydraulic structures are deteriorating. On 17 April 2018, the President of the Republic of Uzbekistan issued *Resolution on Measures to Organise the Work of the Ministry of Water Resources of the Republic of Uzbekistan* No. PP-3672 to promote the activities of WUAs in the Roadmap for Radical Reform of the Water Sector. The Resolution involves new district WUAs to replace old associations. It will strengthen their physical resources, staff them with qualified personnel, and introduce incentives for workers involved in irrigation and reclamation, operation of pumps, and provision of water services to farmers (Farmanov, Yusupova, 2018).

The country has had to deal with many complex issues of water management and its irrigation sector over the past decades, so it is reforming the water management system to improve its efficiency.

The President of the Republic of Uzbekistan issued Decree No. UP-6024 on 10 October 2020 to adopt the Concept for the Development of Water Resources of the Republic of Uzbekistan for 2020–2030 (the "Concept Document") (National Database of Legislation of the Republic of Uzbekistan, 2020). The Concept Document seeks to meet the ever-increasing water needs of the population, economic sectors, and environment, to ensure the reliable and safe operation of water facilities, as well as the effective management and efficient use of water resources, to improve the ameliorative situation of irrigated land, and to achieve water security in the face of growing water shortages and global climate change.

Every three years, the government approves water development strategies, depending on the priority areas, targets, and indicators of the Concept Document for the period. This is how the Concept Document achieves its goals. For example, the President of the Republic of Uzbekistan approved Resolution No. PP-5005 on 24 February 2021 (National Database of Legislation of the Republic of Uzbekistan, 2020). This Resolution involved the Strategy for Water Resources Management and Development of the Irrigation Sector in the Republic of Uzbekistan for 2021–2023 (the Strategy), developed by the Ministry of Water Resources with the participation of relevant ministries and departments and international experts.

For the first time ever, the Concept Document and the Strategy for 2021–2023 focus on Uzbekistan's new approaches to large-scale rehabilitation of the country's irrigation sector, exhaustively covering infrastructure, policy, and institutional measures that directly affect the power industry, agriculture, water resources, and other sectors of the economy, as well as human capital development. Uzbekistan is essentially the first country in the region to move towards IWRM, a goal to be achieved by 2030.

Uzbekistan's reform of the water and irrigation sectors is, however, nuanced. The country is increasingly facing shortages of water resources, so it is naturally looking to eliminate organisational and technical losses of water resources, especially in the irrigation sector, and focus on water conservation and optimisation of the water balance.

The Concept Document suggests switching to a new system of water use based on payment for services in irrigated crop farming. This will require a revision of relations between agriculture and the national budget and the pricing mechanism for agricultural products that will include compensation for water supply services to farmers (water users). This new mechanism seeks to incentivise economic actors and ensure responsibility for water conservation at all stages of water use. Organisational discharges and losses account for the largest share of the country's irrigation systems, yet they depend entirely on the organisation of the water user's work.

Irrigation systems require renovation and modernisation, but they are highly capital-intensive, and the country has limited financial and investment resources, both internal and external. This is why the Concept Document proposes to water users to eliminate their organisational losses of irrigation water. Where they are significant and more than technical, the first step is non-capital-intensive measures, i.e., organising reliable water metering, streamlining water use and improving water use discipline, prioritising water use among users, reusing discharge water, irrigating and conducting other agro-technological operations on time, etc.

Paid water use will be introduced gradually, stage-by-stage, to achieve all the goals mentioned. Uzbekistan has thus opted for market mechanisms for water use and moved from discussing paid water use to introducing it. Now, the country will finance water management organisations differently, with one more link in the national budget — water management organisation chain. The direct arrangement was not effective in the new market conditions, so the medium (agricultural producer) was added. Water users (agricultural producers) now finance water management organisations based on the quality of their water supply services. This approach will reduce non-recurrent expenditures on the modernisation and renovation of irrigation systems and help switch to paid water use and water conservation.

With its reforms, Uzbekistan is planning to decrease public financing in the sector. It will be shifted to water users by introducing payments for water supply services and outsourcing the economic functions of managing inter-farm infrastructure to non-state entities. Agricultural clusters, with their rising popularity over the past few years, will be expected to perform proper maintenance of irrigation systems and effectively use advanced water-saving technologies. Uzbekistan forms clusters in various sectors: cereals, meat and dairy, fruit and vegetables, horticulture, seed production, but the largest are the cotton and textile clusters. They have extensive investment opportunities for the introduction of advanced technology, in particular, in water use. There are about 120 cotton and textile clusters in the country.

The government is overviewing the system of financing agriculture, seeking to leave the pricing in this sector of the economy to entities other than the state. There are plans to significantly increase government expenditures on the modernisation and construction of water management facilities, research and development, advanced water-saving technologies, and the training of highly skilled professionals. Strategically, they are looking to introduce IWRM and fully cover the use, consumption, and distribution of water between households, economic sectors, and the natural environment. Modernisation projects in the water sector and agriculture require foreign investment, especially as resource-intensive and technologically complex as planned. The Concept Document will attract grants, loans, and technical assistance from international financial institutions and other countries more quickly. Uzbekistan has made significant progress in this area: the country has attracted more than USD 3.5 billion in investment, loans, and grants for agriculture and the efficient use of water resources. Uzbekistan can meet its targets on time, as evidenced by the measures taken and planned up to 2030 to conserve water and modernise agriculture (Niyazi, 2022).

The country engages international financial institutions and donor countries to launch major projects. The World Bank Group's Country Partnership Framework for Uzbekistan includes a specific priority for agriculture and irrigation. The current Country Partnership Strategy of the Asian Development Bank (ADB) promotes comprehensive growth by diversifying the economy and expanding regional cooperation. The IsDB provides financial support in the areas of agriculture, education, energy, health, transport, small businesses, private enterprise, and public finance management. The EU Programme promotes rural development as a key area of partnership. Japan supports Uzbekistan's energy, agriculture, health, human resource development, rural development, transport, and institutional development sectors. The UNDP action plan in Uzbekistan focuses on technical assistance in governance, economic management, and poverty reduction, as well as environment and energy. The Swiss Agency for Development and Cooperation (SDC) has been very supportive in promoting IWRM and even factors in prevention and preparedness for water-related natural disasters (Khamraev et al., 2017).

Uzbekistan's national policy for the development of water resources and the irrigation sector will improve the use of water resources. It has a solid scientific foundation and combines technical, innovative, administrative, economic, financial, and investment measures. The Concept Document will help modernise the technology of irrigation infrastructure, replace and re-equip all pumping and power equipment, repair gauging stations, main canals, inter-farm and on-farm canals, reduce the area of saline land, and bring unused irrigated land into use.

↓ Table 16. Forecast for Introduction of Water-Saving Crop Irrigation Technologies for 2021–2023

Area for water-saving technologies								Costs* UZS billion/ USD million
2021–2023		of which:						
Total, 1,000 ha	of which drip irrigation	in 2021		in 2022		in 2023		
		total, 1,000 ha	of which drip irrigation	total, 1,000 ha	of which drip irrigation	total, 1,000 ha	of which drip irrigation	
790.0	700.74	230.0	210.74	260.0	230.0	300.0	260.0	5,605.9/ 531.74

Note: * taking into account the related annual Resolutions of the President of the Republic of Uzbekistan.
Source: based on data from the Concept for the Development of Water Resources of the Republic of Uzbekistan for 2020–2030.

These measures will boost the productivity of irrigated land, a reform priority in the irrigation sector in Uzbekistan. The President of the Republic of Uzbekistan stated in his Resolution No. PP-113, dated 5 April 2023, that the country is looking to introduce large-scale innovative technology in irrigated crop farming to generate revenues of up to USD 4,800 per ha of irrigated land (National Database of Legislation of the Republic of Uzbekistan, 2023). For example, there are plans to build 4 ha of greenhouses to grow 8 million certified seedlings *in vitro* in fruit and viticulture laboratories. Vegetables will be grown intensively on an area of 28,200 ha. Apart from that, they seek to generate income from the sowing of repeated crops on 783,000 ha of sown areas released from grain and field margins. The reform also involves a new system of project financing for project owners. New intensive orchards and vineyards, agro-industrial complexes, and food processing lines will be leased out to businessmen paying 10% in advance, 10% to the project owners, and 80% in instalments over 10 years. Agricultural producers will enjoy a new information system, Agroplatform. On average, 250–300 ha of standard orchards and vineyards will be established in each region at a cost of USD 2.2–2.6 million.

Box 1. Establishment of a 1,000 ha Vineyard and Orchard in Fergana Oblast, Uzbekistan

The Altyarak district of Uzbekistan's Fergana Valley created a large 1,000-hectare complex consisting of a vineyard and an orchard. The project cost is estimated at USD 8.8 million and includes the construction of wells and reservoirs, as well as the introduction of drip irrigation. The average cost of developing 1 ha of orchards, including the installation of irrigation systems, is approximately USD 8,800. Up to 15,000 tonnes of produce worth USD 6.5 million can be harvested from the vineyard and orchard.

The areas are planted with a variety of fruit and berry crops to maximise land use. For example, 560 ha of land have been planted with grape varieties such as Husaini, Kelinbarmok, Rizamat, Kishmish. Apple, cherry, and apricot seedlings have been planted on an area of 300 ha. Watermelons, as well as other crops depending on market demand — red peppers, bell peppers, cucumbers, greens, and other melons and gourds — are also grown between the rows.

The countries of the region can take a page out of Uzbekistan's book and try to copy the success of its water sector reform, adapting it accordingly. Water management reforms are supposed to change the way water resources are treated internationally, nationally, municipally, and locally. This change of attitude was adopted in the Concept for the Development of Water Resources of the Republic of Uzbekistan for 2020–2030. None of the water management objectives can be achieved without a thorough study of existing water resources, the document runs, and they require accounting, conservation, and protection from pollution. Even developed markets task their public administrations with assessing and accounting for water resources and combating pollution and the harmful effects of water. Uzbekistan's concept of water use has an agenda, with some national water policy priorities to improve national water security and ensure effective management of water resources. Measures of any kind seek to expand resource opportunities of the public water fund and improve the condition of water sources. Various sectors of the economy are required to interact and cooperate in water-resources-related matters, both during water protection and use decision-making and the actual introduction of reforms/measures. They make up IWRM and are featured in the water sector reform legislation of the Republic of Uzbekistan.

4. ORGANISATIONAL AND ECONOMIC MEASURES TO IMPROVE THE EFFICIENCY OF IRRIGATION INFRASTRUCTURE AND IRRIGATED LAND

4.1. Retrofitting of On-Farm Irrigation Infrastructure as a Priority to Improve the Efficiency of Irrigated Land and Water Conservation

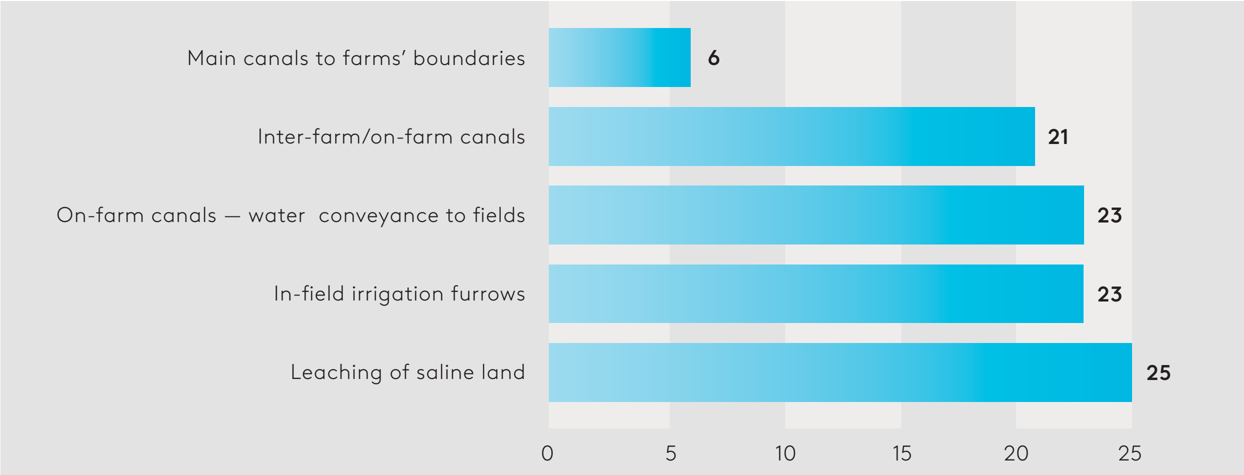
The main line part of the irrigation infrastructure is critical for the efficiency of irrigated land use. To maximise land use, this segment, along with its on-farm segment, requires maintenance and proper operation. Most farmers have low incomes and cannot afford to maintain on-farm networks and pay for water delivery services. The national budget is no help either: the allocations for the operation of the main line and inter-farm sections of the system are insufficient at best. To top it all, the industry lacks capital investment and investment in modernisation and renovation, so irrigation systems suffer from poor serviceability across the region, causing salinisation and waterlogging of irrigated land, as well as major economic losses for *dehkan* farms and the country.

The on-farm irrigation infrastructure network for irrigated land is on the books of farms that operate and repair it independently. With the dissolution of collective and state farms and the creation of small farms, many on-farm irrigation and drainage networks have, for organisational and legal reasons related to land use, been transformed into inter-farm networks that are not covered by maintenance and operation activities. This is why up to 30.6% of Kazakstan's or Kyrgyzstan's available irrigated land is used as non-irrigated land or diverted (Bureau of National Statistics of the Republic of Kazakhstan, 2022).

Irrigation water losses in the water distribution network and in farms' fields are very different. This depends on many factors, including the type of soil, condition of the infrastructure, operation conditions, and methods. Many can be traced back to poor land planning that forms waterlogged or under-watered field sections (Abdullaev et al., 2007). Overused water leads to large losses, increasing subsoil water, and secondary salinisation of land. Seepage through canal slopes and bottoms also causes significant water losses, as less than 30% of the canals are faced or equipped with anti-filtration lining. Approximately 40% of drainage water is discharged into desert depressions, wasting a valuable resource.

Operational losses of irrigation water on irrigated land have raised subsoil water and salinised land, particularly in the middle and lower reaches of rivers. They cause large losses of water and crops and high costs for collector and drainage network maintenance and saline land leaching. Yield losses are particularly pronounced in the lower reaches, despite cotton and wheat's salt tolerance. The CA countries' resulting economic losses total USD 1,754 million per year, or about 30% of the value of potential regional output.

↓ **Figure 18. Water Losses in the Irrigation System in % of Water Withdrawal**



Source: EDB estimates based on data from Royal Haskoning, 2003.

In 1991, public water management organisations delegated the maintenance and operation of the on-farm network to the owners of irrigated land, setting up various WUAs in the CA countries. Understandably, they had different corporate and legal forms due to the specifics of the legislation in each country (Mirzaev, 2017). The predominant forms of WUAs were associations of farmers (AFs), associations of *dehkan* farms (ADFs), production cooperatives (PCs), joint-stock companies (JSCs), unions of consumer cooperatives of water users (UCCWUs), and limited liability partnerships (LLPs).

The following types of WUAs operate in the CA countries at present. Kazakhstan dissolved UCCWUs and other forms of WUAs in 2015 and has since replaced them with agricultural production cooperatives (APCs). Kyrgyzstan's and Uzbekistan's WUAs are multi-task organisations that both supply water and provide other types of services to farmers (peasant farms). Associations of peasant farms (APFs) (Turkmenistan) and WUAs (Tajikistan) are the main corporate and legal forms of association of water users in these countries (Mirzaev, 2020).

As we have mentioned, the WUAs tend to have various corporate and legal forms in the CA countries. They are local government organisations responsible for the maintenance and operation of irrigation systems and other water supply systems locally (OSCE, 2019). For example, WUAs have the following rights under the Law of the Republic of Tajikistan on Water User Associations (National Centre of Legislation under the President of the Republic of Tajikistan, 2006):

- to sign contracts with public water administrations and water users;
- to acquire the necessary resources to prepare the irrigation system for the irrigation season in time;
- to collect a fee for irrigation services (FIS) and other established payments from water users;
- to create a federation, unions, or associations of water users that operate based on approved articles of association;

The responsibilities of the WUAs are as follows:

- to maintain irrigation facilities and, if needed, build new facilities;

- to ensure fair distribution and control over the efficient use of water in accordance with agro-technical and ameliorative standards;

- to pay the FIS to the Agency for Reclamation and Irrigation based on the amount of water used;

- to resolve disputes and disagreements between WUA members on water use issues.

These responsibilities and rights leave no room for misconstruction; the activities of the WUAs under Tajikistan's Law are transparent and accessible to all their members, especially when it comes to finance. The general meeting of the members — aka the supreme body of the WUA — elects the Board of Directors and the Audit Commission. The Commission controls the activities of the WUA and its compliance with financial and economic rules. The Dispute Settlement Commission, also elected by the general meeting of WUA members, deals with disputes that arise between WUA members in the course of its activities. The Board of Directors, consisting of 5–7 WUA members, exercises advisory and supervisory functions and appoints the Executive Director (OSCE, 2019).

Due to shortcomings in the legislation and organisational, legal, and economic support, WUAs have not been given the opportunity to function as self-governing organisations ensuring reliable operation of on-farm irrigation infrastructure and implementing water conservation policies among farmers (OSCE, 2019). Reforming water management and irrigated crop farming will improve water use efficiency and cover the costs of maintaining the inter-farm network because the responsibility will fall on WUAs. In some cases, however, the powers of the WUAs do not match their responsibilities.

The delegation of control over an irrigation system has had mixed success around the world, partly because countries have different understandings of what a delegation — full or otherwise — truly means. Any water management reform sooner or later deals with water rights or rights to use water, meaning that farmers must have guarantees that they will receive irrigation water on time and in full. Such water rights will ensure greater accountability of WUAs to farmers and make them more cooperative, confident they will receive the water. WUAs act as operators and intermediaries between farmers and a public operating organisation. Their activities are supposed to benefit farmers, reduce operating costs, contribute to water conservation, and improve water distribution within the irrigation system (Zekri, Easter, 2010).

When it comes to irrigated crop farming, the highest costs were recorded for irrigation (25%), crop nursing (20%), and the fertiliser system (15%). This and similar technology, once more advanced, can significantly reduce costs, improve crop yields, increase the productivity of irrigated land and water, and shift towards water conservation.

↓ Table 17. Crop Cultivation Technology and Cost Composition, %

Soil treatment	Sowing	Irrigation	Crop rotation	Fertiliser system	Nursing	Harvesting
10	10	25	10	15	20	10

Source: Kosichenko et al., 2011.

Water conservation measures should focus on the on-farm network because it experiences the largest losses of irrigation water. This is where WUAs can reach their administrative potential. They should actively participate in water demand management, i.e., introducing the water tariff (for water supply services) and streamlining the collection of water charges from WUA members or farmers (peasant, *dehkan* farms). A reasonable water tariff and timely settlements with water management operating organisations will reduce irrigation water consumption and make farms use water-saving technologies (FAO, 2011).

We have analysed irrigation system renovation projects based on the assessment of the unit cost of rehabilitating on-farm irrigation and drainage infrastructure networks per unit area for every country in the region. The analysis shows that the unit cost is USD 713 per ha in Kyrgyzstan, USD 1,440 per ha in Uzbekistan, and USD 1,040 per ha in Tajikistan. We assume an average unit cost of USD 1,000 per ha to estimate the investment required to rehabilitate the on-farm network (Royal Haskoning, 2003). These unit costs highly correlate with the corresponding global costs.

↓ Table 18. Options for Irrigation System Renovation and Retrofitting and Types of Work

Comprehensive renovation of the irrigation system	• More water available • Renovation of the main line and inter-farm networks and the hydraulic structures • Renovation of the collector and drainage network	• Renovation of the on-farm network and hydraulic structures • Improvement of the ameliorative situation of land • Introduction of new irrigation equipment and methods
Partial renovation of the irrigation system	• Renovation of the main line and inter-farm networks • Advanced hydraulic structure designs	• Renovation of the on-farm network • Capital land levelling • New water metering devices
Irrigation system retrofitting	• Retrofitting of pumping stations and hydraulic structures • Linings and anti-filtration measures	• Replacement of sprinklers and irrigation equipment • New water metering devices

Source: Kosichenko et al., 2011.

Modernisation is on a par with rehabilitation and renovation for irrigation infrastructure; it is becoming increasingly relevant in the new context. The World Bank defines modernisation as the "process of upgrading infrastructure, operations, and management of irrigation systems to sustain the water delivery service requirements of farmers and optimise production and water productivity" (Dankova et al., 2022). Consequently, the modernisation of the irrigation system is supposed to be continuously improved to meet the maintenance needs of farmers; current government plans for social and economic development are the only way for modernisation to see the light. Modernisation improves the functionality of all components of the irrigation infrastructure, including all tangible and intangible assets that contribute to the growth of products on irrigated land and their inclusion in supply and marketing chains.

We believe that improving water use should come first on the agenda, especially when it comes to economic entities. Firstly, farms (water users) create the main added value of agricultural products; secondly, water losses here reach 50% or more of the total losses in the irrigation system. A year or two will be enough to tell whether or not the measures are effective for improving water use and agro-technical and ameliorative water conservation. All we have to do is look at the increase/decrease in yields and income gained/lost by the farmer.

Differentiating the irrigation rate for moisture-deficit crops will optimise their yields and prevent soil degradation and erosion during irrigation (Babichev et al., 2018). The key is to account for changes in water demand under different climatic conditions. This is where ground-based meteorological stations come in to ensure that the data for irrigation are representative. These data should be transparent, i.e., provided to direct users, so daily monitoring of weather and water consumption forecasts is a must. In fact, Korea, Italy, and other countries already use this system. Korea has one meteorological station per 1,000 ha of irrigated land. In contrast, there is one station per 30,000–80,000 ha in the CA countries.

In addition, the data acquired from modern high-resolution satellites would help rapidly assess the volume of lakes and reservoirs, ice reserves in mountain glaciers, water in snow cover, the state of surface water, and soils. The results can be used in IWRM, along with scientific and applied research in the region (Masumov, 2014).

4.2. Systematic Water Accounting Is the Basis for Water Conservation and New Economic Policies in Irrigated Crop Farming

Irrigation systems in the CA countries lack proper water metering devices and equipment. In Tajikistan, for example, the information received from regional reclamation and agricultural water supply administrations shows that the country's water metering stations are experiencing a technological crisis, and their numbers are shrinking. According to 2018 monitoring data on irrigation and reclamation systems operated by state-owned entities, only 48% of water metering stations were operational (in good or satisfactory condition), while 52% were not operational and required renovation or repair. Only 9% of water metering stations were equipped with water metering devices and special technological equipment, while 39% failed to even have a water level gauge. At present, the region lacks supplies to radically improve the situation. This is why cheaper and more affordable measurement tools and methods for open canals of reclamation systems might be a step in the right direction.

Organising water accounting on inter-farm canals is not enough. WUAs should ensure thorough water accounting on both inter-farm and on-farm canals. Unfortunately, the countries of the region do not produce gauging equipment, except for the Kyrgyz Republic; they import it from other countries (Masumov, 2014). Each country in the region should adopt water conservation programmes for irrigated crop farming and:

- provide online information for water management operating organisations and WUAs on water content in river basins and water withdrawal from water sources for irrigation;
- hire a WUA hydrometer engineer;
- equip gauging stations with modern water metering devices integrated with the basin and the centralised water information system;
- organise the production of modern water metering devices and other measuring equipment in accordance with the standards of the CA countries;
- draft agreements on the joint construction and maintenance of water-balance gauging stations for transboundary rivers where they cross state borders.

Today's environment requires high technical support for optimal control of plant development. Managing the "soil — plant — atmosphere" system is a difficult task, as it involves assessing the temporal changes in plant parameters, climate, soils, hydrogeological conditions, etc. The management of crop formation using IT and software is the most realistic option yet.

Technology in irrigated crop farming optimises crop formation, drastically reduces water consumption, eliminates its loss through unproductive discharges, and efficiently allocates irrigation water to farmers (water users). Technology can be used to collect the necessary information about a particular field: soil and weather conditions, crop conditions, etc., and to subsequently advise farmers (water users). Empirically speaking, decision support systems (DSS) save irrigation water, help promptly apply agro-technical measures, and foster significantly higher yields.

These factors call for research on the regular adjustment of crop irrigation and watering standards and the development of the best irrigation conditions in accordance with the agro-technical requirements. Irrigation and watering standards and the crop irrigation conditions are always factored into the design and operation of the irrigation system and its elements, i.e., canals, water control structures, etc. Ultimately, they determine the capital and operating costs required to build water intake facilities, main and distribution canals, and to maintain the water management system. Excessive irrigation rates and irrigation standards raise construction costs for reclamation and irrigation facilities and pose high investment risks. Understated rates and standards mean the irrigation system does not reach its potential, hiking operating costs.

4.3. Improvement of the Tariff Setting Mechanism for Water Supply Services

Irrigation infrastructure is a very capital-intensive sector of agriculture. Its assets are in constant need of upgrade, renovation, and ensuing significant investment. Investment needed and investment attracted rarely go hand in hand; global trends speak to that. The lack of investment resources affects the irrigation infrastructure and crushes the economic and social efficiency of irrigated crop farming. It accumulates high costs and compromises the water use conditions and the ameliorative situation of the land.

We have also analysed the current macroeconomic conditions in the CA countries and assessed their future conditions. The countries expect high investment proposed in the irrigation development programmes, including foreign investment, and such figures imply a longer rollout. The limited financial capabilities promote the governments' regulation of the design, financing, construction, functioning, and repair of irrigation infrastructure (Qasim et al., 2000).

The lack of sufficient government support and financing compared to the period of 1970–1990 curbed irrigated crop farming in the CA countries. It was not even enough to enable compliance with the agro-technical and ameliorative requirements for crop cultivation. Moreover, the restructuring of the agrarian sector of the economy, decentralisation of agricultural production, and a sharp reduction in farm size have deterred the development of agriculture and highly efficient production.

The lack of adequate public and private financing is to blame for the poor condition of irrigation systems; there is just not enough money for their proper maintenance. Clearly, the countries should focus on channelling their resource base to finance irrigation infrastructure. Therefore, a phased introduction of an optimal and economically justified fee (tariff) for water supply services is now more relevant than ever. Existing fees should be optimised to recover the current costs of operating and maintaining the on-farm irrigation infrastructure.

An investment contribution component should be introduced gradually in the tariff to cover the direct costs of providing water supply services. This will help state-funded water management organisations invest in new construction, modernisation, and retrofitting of irrigation systems. The amount can be determined as shares of the value of fixed assets on the books of state-funded water management organisations or as shares of the annual cost of water supply.

The introduction of paid water use in CA is an important element of ongoing reforms, particularly in Uzbekistan and Kazakhstan. Choosing market mechanisms for water use is economically feasible and can solve many of the water sector's issues.

In the CA countries, the water supply fee only accounts for the volume of water actually delivered to the water user, based on the productivity of the main and distribution canals of irrigation systems. All farm delivery points are equipped with water meters or water flow sensors that are calibrated according to established procedures.

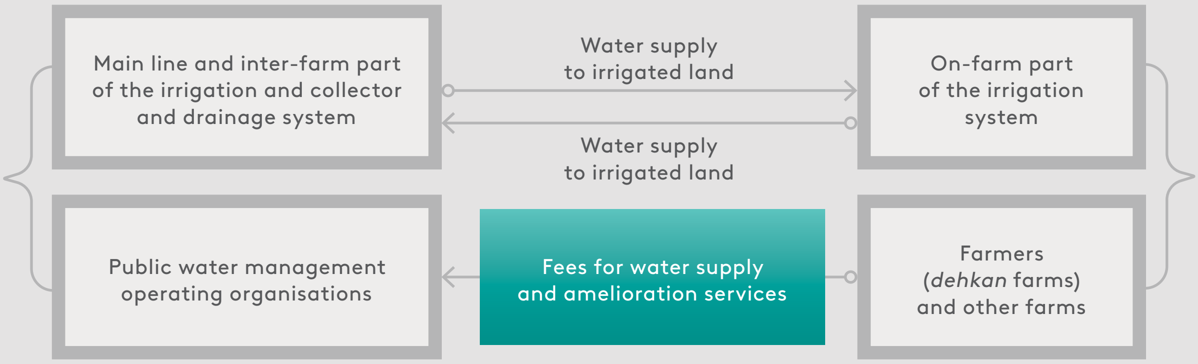
There are two types of water supply tariffs in irrigated crop farming: a single-rate tariff (per square metre) and a dual-rate tariff (per hectare and per square metre), as well as their different variations (Manzhina and Medvedeva, 2018).

The single-rate tariff includes all costs payable by water users and charges in accordance with the legislation in force.

A dual-rate tariff system factors in changes in the natural and climatic conditions and the business operations of water management organisations.

Box 2. Cooperation between Key Players in Irrigated Crop Farming in CA

An open irrigation system consists of a main canal, inter-farm canals, farm canals, and on-farm distribution canals (distributors). The main canal supplies water from a river, reservoir, well, etc. to inter-farm distributors. Inter-farm canals supply water to individual farms or crop-rotation areas. Farm canals supply water to each farm and to individual large irrigation areas when it comes to large farms. On-farm canals (distributors) supply water to crop-rotation fields or irrigation areas. A must-have collector and drainage network regulates the water-salt regime of soils and ensures the drainage of mineralised leaching water and subsoil water outside the irrigated areas. This maintains the favourable ameliorative situation of irrigated land.



The public operating service under the water management authorities is established in irrigated crop farming at irrigation, flooding irrigation, flooding, and collector and drainage systems, reservoirs, canals, hydraulic complexes, pumping stations, bank protection structures, and other inter-farm reclamation systems and water management facilities.

The dual-rate tariff comprises two rates. The first rate (per hectare) features semi-fixed costs, and they ignore the volume of water supplied. The second rate (per cubic metre) includes semi-variable costs, and they depend on the volume of water actually supplied to the association (cooperative, union, etc.) or to an individual farm, as well as charges in accordance with the legislation in force. The per-hectare rate is determined per 1 ha of irrigated area, covers the semi-fixed costs of the water management organisation, and is charged to the water user regardless of the quantity of water supplied to the WUA (cooperative, union, etc.) or to the farm.

The per-hectare part covers the costs of operation and maintenance of the irrigation system to be paid by the water users: salaries and wages, communication services, current repairs, depreciation of fixed assets, utilities, materials (fuel and lubricants, spare parts, etc.), and an increase in inventory costs, maintenance of hydraulic structures and pumping stations.

The per-metre rate is determined per cubic metre of water supplied to the water user and covers the semi-variable costs of the water management organisation. These include, for example, the cost of electricity for main pumping stations (lift and intermediate), the cost of recurrent repair of electrical and hydraulic-mechanical equipment for hydraulic structures, the cost of commissioning, etc., based on planned water supply volumes less the costs associated with water losses on the inter-farm network (Vasilyev et al., 2012).

The single-rate tariff is the common go-to in the countries of the region, calculated either per unit of area or per unit of water supplied. It is the most acceptable pricing mechanism that factors in all the costs of water management organisations. Besides, differentiation among consumers is based on fixed indicators — the volume of water used or the area of irrigated land. A water management organisation's cost of delivering water to agricultural producers depends on the cost of the required materials and work.

CA water management organisations that supply water to agricultural producers receive subsidies from the budget. This is where they partially source their funding. Agricultural producers pay fees, thus covering the remaining costs (Manzhina and Medvedeva, 2019). The tariff for supplying water to agricultural producers, however, does not fall under the investment category for the inter-farm part of the irrigation system.

↓ Table 19. Tariff Rates for Irrigation Services in the CA Countries, 2019

Country	Provider of water management services	tariff rates	
		local currency	USD*
Kazakhstan**	WMO	16.135 KZT/m³ (machine water supply)	4.15 cents/m³
		29.5 tiyns/m³ (gravity water supply)	0.074 cents/m³
	APC	1,600–2,500 KZT/ha	4.1–6.43 USD/ha
Kyrgyzstan	WMO (DWMA)	3 tiyns/m³	0.043 cents/m³
	WUA Union	4 tiyns/m³	
	WUA	400–800 KGS/ha	6–11 USD/ha
Tajikistan	WMO	2*** dirams/m³	0.21 cents/m³
	WUA	40–120 TJS/ha	4–12 USD/ha
Turkmenistan	DFA	3% of farmer's yields	
Uzbekistan	WUA	25,000–50,000 UZS/ha	2.6–5.2 USD/ha

Note: * US dollar exchange rate: USD 1 = KZT 388.62 (Kazakhstan), USD 1 = KGS 70 (Kyrgyzstan), USD 1 = TJS 9.52 (Tajikistan),
USD 1 = UZS 9,500 (Uzbekistan);
** Kazakhstan established flat tariffs for all regions of Kazakhstan in 2018, depending on the type of water supply (machine or gravity). Previously, tariffs varied from region to region. There are plans to raise tariffs for irrigation services every year (until 31 July 2023). The above tariffs are for water management organisations (net of VAT) from 1 August 2019 to 31 July 2020. In addition to the fee for irrigation services, Kazakhstan also has a tax on water as a resource (see the section on the economic mechanism for managing water resources).
*** Until 2018, the tariff had been 1.5 dirams/m³
Source: EDB estimated based on data from OECD (2021a, 2021b).

The CA countries approach their agricultural and irrigation policies differently, as evidenced by tariffs for water supply services to agricultural producers. The countries charge varying fees for crop irrigation water, and sometimes the difference can be striking: 0.043 cents/m^3 in Kyrgyzstan and 0.21 cents/m^3 in Tajikistan. Kazakhstan charges 4.15 cents/m^3 for machine water supply (OECD, 2021a) (Table 19).

The fees that water management operating organisations collect for the services are much lower than the costs they incur. The maintenance costs for the main line and inter-farm sections of the irrigation system vary considerably between countries in the region:

- 17 USD/ha in Kazakhstan;
- 26 USD/ha in Kyrgyzstan;
- 73 USD/ha in Tajikistan;
- 64 USD/ha in Turkmenistan;
- 153 USD/ha in Uzbekistan.

The significant difference is attributed to the large share of electricity costs in Tajikistan and Uzbekistan, where more than 40% of irrigated land is supplied with water by pumps.

The required (projected) costs of operation and maintenance of on-farm infrastructure components by farms that are water users also differ and are as follows:

- 10 USD/ha in Kazakhstan;
- 12 USD/ha in Kyrgyzstan;
- 22 USD/ha in Tajikistan;
- 16 USD/ha in Turkmenistan;
- 68 USD/ha in Uzbekistan.

The actual tariffs for water supply services to water users are several times lower than required (by a factor of 4 to 15). The CA countries suffer from high water losses during its conveyance and use, but payments fail to contribute to water conservation or the improvement of water productivity.

Dual-rate and multi-rate tariffs for irrigation water are more common in developed countries (Vasilyev et al., 2012). Japan's combined or dual-rate tariffs account for many components. They are a go-to for settlements between water users and water supply organisations. For example, the payment depends on the volume of water supplied, the area of irrigation, the type of irrigation equipment used, and the profitability of irrigation or the profitability of crops grown on irrigated land. Public policies encourage, and sometimes indirectly subsidise, the production of certain types of agricultural products and the introduction of certain irrigation practices that are the most resource-saving.

The pricing of irrigation water is the most diverse in the US. The price of water depends on the geographical location, the source of water withdrawal, and the institutional mechanisms governing the types of water rights and arrangements. For example, some farmers get water at a very low price (USD 5 to USD 10 per 1,000 m^3) because they have riparian water rights or exchange agreements with federal authorities. Other farmers pay a much higher price (USD 20 to USD 100 or more per 1,000 m^3), perhaps because they have less favourable contracts, or they buy water from state-level irrigation agencies. The price can go as high as USD 100 per 1,000 m^3 and higher for farmers who buy water in the market because it is the end of the irrigation season or because they want to improve the water supply for perennial crops. In this case, the cost of water tends to depend on the pressure on the regional or basin ecosystem. When groundwater is used as a source of irrigation, tariffs are also higher. This is understandable because it hikes the energy consumption for water supply (water lifting with pumping equipment) and because there are certain, decades-old limits. For example, California's main source of water withdrawal is groundwater, so the average cost of pumping water to irrigate an area of 1 ha is USD 195.

The US Reclamation Reform Act of 1982, its amendments of 1986, and the Central Valley Project Improvement Act of 1992, limit the supply of federally subsidised irrigation water to 390 hectares of owned or leased land. Farmers irrigating land in excess of the 390-hectare limitation must pay the full-cost rate for the water. In this case, subsidies do not hinge on water consumption and do not interfere with the freedom of choice of crops. At present, there are three federal payments legislated in the US:

- Fixed contract rates are payments set in original long-term contracts (for example, 40-year contracts) that remain unchanged under the terms of the contracts. These contract rates include two components: 1) reimbursement of capital costs under the Central Valley Project, less interest; 2) annual operation and maintenance costs.

- Cost of service rates are payments that become contractual for irrigated counties upon renewal of existing long-term contracts with the Bureau of Reclamation. The payments include:

  1) annual operation and maintenance costs;

  2) reimbursement of the capital costs, less interest, to the extent that the capital costs are fully reimbursed by 2030;

  3) payment of arrears for the costs of operating and maintaining water supply systems not included in the payments under the previous contract (from 1 October 1985), including interest.

- Full-cost rates, which were established by amendments to the Reclamation Act introduced in 1982 by the Reclamation Reform Act. These payments include:

  1) reimbursement of operation and maintenance costs;

  2) the federal government's capital expenditures on irrigation;

  3) unpaid operation and maintenance costs, including interest.

The payment rate in Israel is based on the quantity and quality of water consumed by the user for irrigation. For instance, farmers pay for the first 50% of the licence limit for clean (natural) water at a rate of 0.20 USD/m^3, the next 50%–80% at a rate of 0.25 USD/m^3, and 80%–100% at 0.30 USD/m^3. Excessive water withdrawal is subject to a fine of 10 times the tariff.

European Union countries can also lead by example (Berbel et al., 2019) when it comes to water resource taxation and tariff setting. The tariff system is adapted to local regulatory conditions and includes various taxes and tariffs to finance water services and improve water use efficiency. For example, France, Portugal, Italy, and Spain use different systems of taxation for agricultural water withdrawal to recover the costs of regulating, storing, and managing water supply at the basin level. Under the Water Framework Directive, France, Portugal, and Italy levy an additional water withdrawal tax, applicable to all water sources (surface and groundwater), to encourage water conservation and to incorporate environmental and resource costs of the irrigation system.

4.4. Financing the Construction and Modernisation of Irrigation Systems: International Practices

Irrigation projects around the world are financed by various financial instruments and actors, according to an OECD study (2022).

However, global experience indicates that irrigated agriculture, despite the successful application of water charge mechanisms, relies on subsidies funded by public resources. The scale of necessary investments in irrigation infrastructure often exceeds the financial capacity of individual farmers. Therefore, investments directed towards the creation and maintenance of irrigation infrastructure, which includes dams, main canals, pipelines, aqueducts, pumping stations, drainage systems, and flow control structures, are typically the responsibility of the state. This is primarily due to the high social significance of ensuring access to water, the imperative of food security, and the state's capability to secure substantial debt financing with guarantees.

Simultaneously, water users can contribute to the costs associated with the modernisation and upkeep of irrigation systems through various forms of payment, including water usage fees. However, their participation in financing irrigation systems is not always consistent (Ward, 2010). One hindrance often lies in the expense of financing investments. Nevertheless, the availability of low-interest loans can boost the interest of end users in the modernisation of irrigation systems at the grassroots level. As a result, the extent of water users' involvement in financing irrigation systems varies significantly and is largely contingent on the economic incentives motivating farmers to access these systems. For instance, the Lemos Valley Irrigation District in Spain stands out as an example where local farmers declined further utilisation of the irrigation system due to a lack of sufficient incentives (Table 20).

Irrigation systems are undoubtedly important for the socio-economic development, so national governments cover most of the cost of new investment and make up the balance with foreign aid, international loans, private investment, and even individual donations. Further government actions should account for the specifics of agriculture, provide subsidies for ameliorative measures, and help take out affordable loans and attract investment.

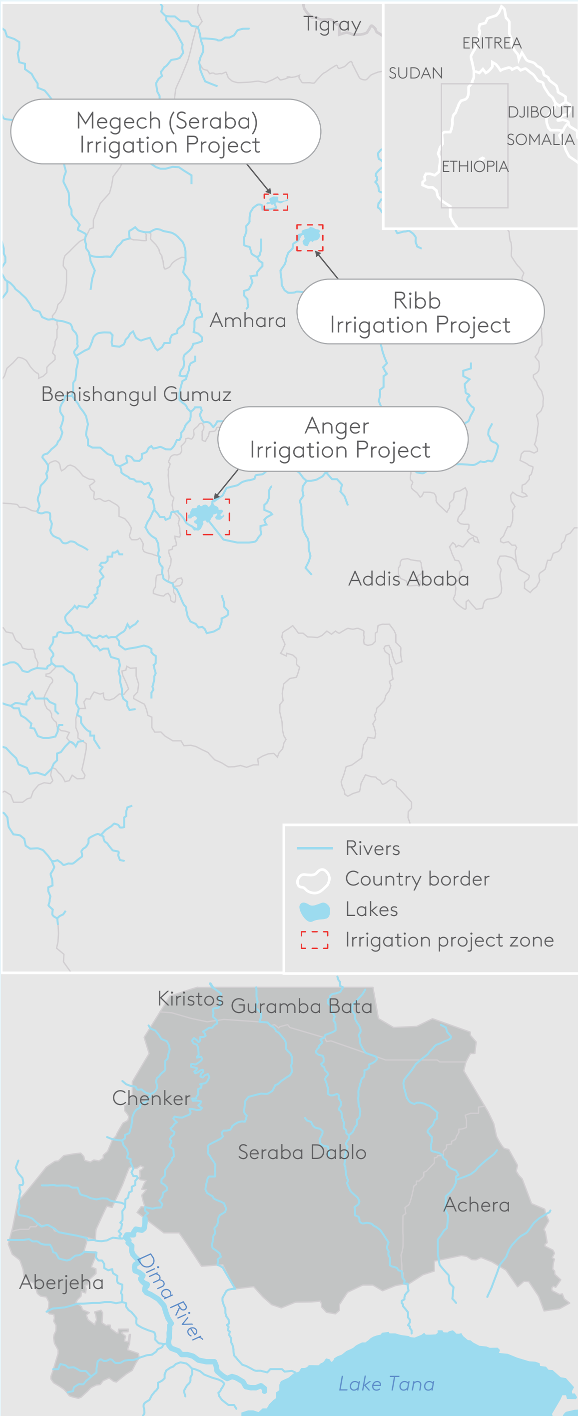
Using tariff payments for the supply of water for irrigation that include a modernisation and renovation component might improve irrigation infrastructure serviceability in due time, global practices show. Engaging various PPP institutions will facilitate matters because they will foster the inflow of investment into irrigation development (Manzhina and Medvedeva, 2019). This is an empirically acceptable solution to finance the water market. In this case, the concessionaire can be either a state-funded organisation or a legal entity that is a water user (for example, an agricultural cooperative, organisation, etc.), willing to improve water supply.

↓ **Table 20. Sources of Financing for Water Management and Irrigation Infrastructure**

Actors	Functions
Water users (households, farmers, industrial enterprises, and other water users)	• Main users of water and irrigation system • Financing and development of basic technical facilities of the water and irrigation system on inland fields • Payment of tariffs for water use • Formation of water user associations and participation in the development of local water and irrigation systems through these associations
Contracting organisation	• Association, co-operative, project company, water user association, local government body, etc. • Day-to-day management of an irrigation project
Local public authorities	• Attraction of financial resources • Financial support for project implementation
Public finance authority	• Fiscal risk assessment • Financial support for project implementation through grants, loans, guarantees for external loans, state benefits and preferences, subsidies • Attraction of large external loans from international financial organisations/development banks
State authority on water management	• Water policy formulation • Provision of water resources • Tariff setting
Environmental and water agencies	• Accumulation of financial resources from various sources • Expert support, advisory functions
Non-governmental organisations and local communities	• Funds raising through voluntary individual donations or grants from international organisations
Local banks and other financial institutions	• Provision of short-/medium-term loans at market rates
Foreign banks and export credit agencies	• Provision of financing volumes against corporate/state guarantees
Multilateral financial institutions and development banks	• Provision of long-term credit facilities on favourable/market terms • Grant support • Monitoring of irrigation project implementation in terms of fiduciary role of the lender • Expert support for the project and capacity building of the contracting organisation • Provision of technical assistance in irrigation system establishment and management

Source: EDB based on analysis of international experience.

Case 1. Irrigation Project: Megech-Seraba Irrigation Project (Ethiopia)



PPP Project Description

The Megech-Seraba Pump Irrigation and Drainage Project is in the northern part of the Lake Tana subbasin, in Amhara National Regional State. The project irrigation system covers around 4,040 ha. The project benefits more than 2,000 farms.

The water supply system includes a 20.7-kilometre main canal from the pumping station, which pumps water from Lake Tana at a rate of 6 m^3/s.

The project includes 12 secondary canals and 12 sub-secondary canals with a total length of 59.4 km, 140 tertiary canals with a length of approximately 180 km that branch off from the secondary and sub-secondary canals and serve irrigated fields through field ditches, and 14 night storage ponds that provide irrigation for 12 hours a day while maintaining pumping and flow in the main canal at the required minimum.

PPP Form

The government passed a resolution in 2010 to recognise Water User Associations (WUAs). WUAs coordinate the actions of water users and maintain tertiary canals.

In 2012, the government of Ethiopia signed a contract with a French operator, BRL Ingénierie, to provide **operation and maintenance (O&M) services** for the Megech-Seraba Project.

The contract is for the extended 8-year management of the irrigation system. A new local government body will then be trained by the PPP contractor to further take on the responsibilities.

Project Cost and Financing

The total project cost is estimated at **USD 110 million**, of which:

- USD 100 million is funded by the IDA, the World Bank Group;
- USD 7.1 million will be financed by the government of Ethiopia;
- USD 2.9 million will be contributed by farmers.

The government of Ethiopia, in agreement with the World Bank, prepared the Ethiopian Nile Irrigation and Drainage Project. The Project will finance up to 20,000 ha of new irrigated areas and prepare a detailed feasibility study for an additional 80,000 ha.

International Stakeholders

Public-Private Infrastructure Advisory Facility (PPIAF). In 2006, PPIAF helped the government of Ethiopia prepare an action plan to develop irrigation public-private partnerships (PPPs) in the areas of Megech, the Ribb River, and Anger Valley. Following the agreement on the appropriate PPP model, PPIAF also helped draft bidding documents and the model transaction agreement for the Megech-Seraba Irrigation and Drainage Project in North Gondar in 2010.

***International Development Association**, a credit institution that is part of the World Bank Group*. Funding for the Nile Irrigation and Drainage Project in Ethiopia that includes the Megech-Seraba Project.

Long-Term Benefits of the PPP Project

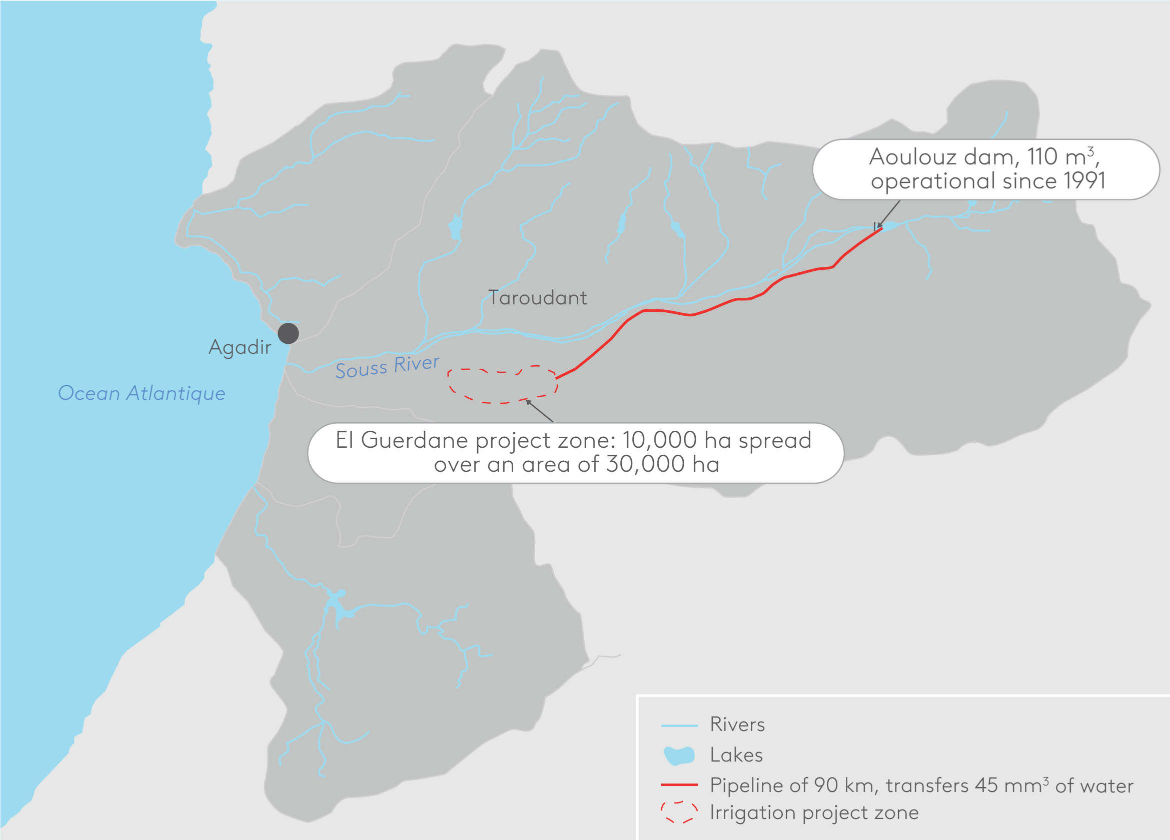
- Improved intensity of crop cultivation on more than 4,000 ha of agricultural land thanks to water for irrigation provided during the dry season.

- Improved soil fertility and consequently increased crop diversity, owing to irrigation and drainage.

- Increased and stabilised household income from agriculture for more than 2,000 farmers.

Improved institutional capacity of public organisations responsible for water management and agricultural development, both regionally and locally.

Case 2. Irrigation Project: Guerdane Irrigation Project (Morocco)



PPP Project Description

The Guerdane Irrigation Project in Morocco is a brownfield construction and operation project for a new water supply system as part of the existing irrigation system. It also seeks to provide water for the irrigation of 10,000 ha of citrus groves, which produce 50% of the country's total citrus crop. The project plans to construct and operate a 64 km water pipeline and a 300 km irrigation network.

PPP Form

Under the Build-Transfer-Operate (BTO) contract, Amenssous will manage the water supply and maintain the transmission and distribution infrastructure for 30 years**.**

Amenssous is a company founded in 2004 to finance, build, and operate the Guerdane Irrigation Project. Amenssous is owned by the following consortium:

- 64% by ***Omnium Nord Africain (ONA) Moroccan State Consortium*** (controlled by the royal family);
- 20% by ***Caisse de Dépôt et de Gestion***, Moroccan State Investment Bank;
- 15% by ***InfraMan,*** *a Saudi-Arabian company;*
- 1% by ***Compagnie Nationale d'Aménagement du Bas Rhône Languedoc*** (BRL), a French developer operating in the water sector.

The Moroccan Ministry of Agriculture, Rural Development, and Maritime Fisheries signed a special contract with the company to delegate government functions in the water sector.

Project Cost and Financing

The capital expenditures on the new infrastructure amounted to **MAD 850 million** (currently equivalent to **USD 88 million**), of which:

- The government of Morocco directly subsidised **USD 44 million** through the Hassan II Fund and provided a concessional loan of USD 24.6 million (1% interest rate);
- Water users (farmers) contributed up to **USD 6 million** through a fixed connection fee of USD 600 per hectare;
- The operator's contribution is estimated at **USD 38 million**, about 43% of the project cost.

International Stakeholders

The International Finance Corporation, *part of the World Bank Group,* advised the government of Morocco on the PPP irrigation project and helped select the management consortium.

Long-Term Benefits of the PPP Project

- The world's first PPP irrigation project has become the poster child for similar projects in the region.
- It created Morocco's first private infrastructure operator for irrigation projects.
- Transparent and competitive bidding lowered the expected price per unit of water to USD 0.15 per m^3.
- The groundwater depletion risk was mitigated, hitting the main PPP project target.
- Privileges are given to the government for the transfer of privately funded technologies.
- The project had been 100% connected as early as 2009.

The project supplies water to more than 1,900 individual farmers: it improves irrigation, provides general access to water services, and benefits the local economy by improving the incomes of 11,000 people.

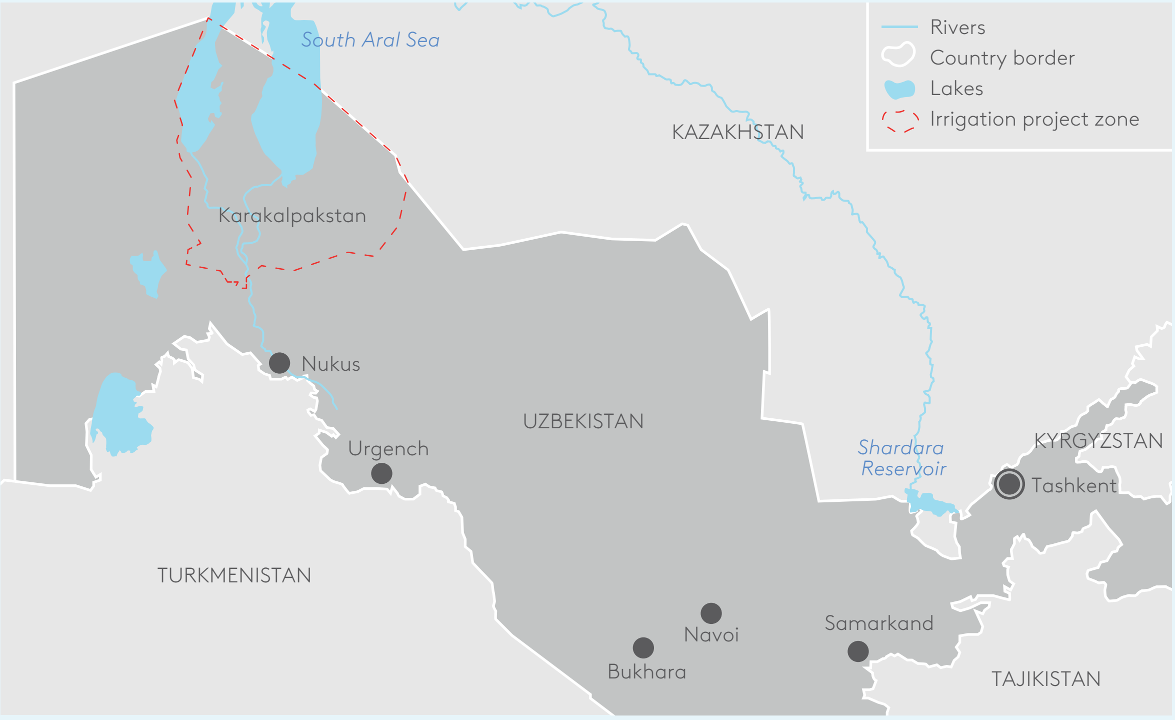
Multilateral development banks are also active participants in such PPP projects. The improvement of prospects for water and irrigation system development became possible specifically due to the foreign assistance of international donors and MDBs, as evidenced by international experience.

MDBs help fund long-term projects, usually in the form of loans and grants, that support economic and social development in developing countries in a region (Antropov, 2019). Unlike other banks, MDBs offer financing and advice to aid economic advancement, and their shareholders are sovereign states. MDB financing has a multiplier effect, and MDBs use it to address the shortage of infrastructure investment. For example, the World Bank estimates that MDBs mobilise an additional USD 2–5 in private investment for every dollar they invest in private sector operations. MDBs can also promote cooperation to improve regional infrastructure investment climate, including water management and irrigation infrastructure. They can therefore mediate disputes among neighbouring countries in a transboundary river basin that hinder cooperation. MDBs facilitate access to energy networks because well-developed regional infrastructure can effectively connect energy producers and consumers (Wurf, 2017).

The geographic reach of MDBs mainly covers the world's agricultural regions and emerging markets. MDB activities can potentially ensure the systematic use of water and irrigation resources. MDBs vastly improve the use and protection of water resources and irrigation systems through grants, loans, and guarantees. For example, many irrigation projects have been implemented with the support of the World Bank, the African Development Bank, and the International Fund for Agricultural Development. The water sector support programme ran in 50 countries in Africa, Asia, and Latin America. These increased water availability in the regions, hence higher yields. Of all MDBs, only the World Bank and the Asian Development Bank offer sovereign financing for irrigation projects in CA (Vinokurov et al., 2021).

MDBs are solution integrators, acting through dialogue with all stakeholders, including water policy makers and organisations. They also help achieve multilateral agreements. Guarantee programmes are a way for MDBs to increase funding for irrigation projects, mobilise different types of finance, and accumulate enough funds.

Case 3. Irrigation Project: South Karakalpakstan Water Resources Management Improvement Project (Uzbekistan)



Source: World Bank, map of water management and irrigation projects in Karakalpakstan.

Project Description

The South Karakalpakstan Water Resources Management Improvement Project for Uzbekistan seeks to restore irrigation and improve water management in the project area sustainably and financially.

The project has three components.

The first component, Modernisation of the Irrigation Network, will restore the irrigated area in South Karakalpakstan and boost the economic benefits of the network.

The second component, Modernisation of Agriculture, will improve irrigated agricultural production in the project area and compel farmers to maximise their water resources use by intensifying and diversifying crops, investing in cotton harvest mechanisation, and promoting.

The third component, Project Management, Monitoring, and Evaluation, will encourage the Ministry of Agriculture and Water Resources and the Project Implementation Unit to manage, monitor, and evaluate the project more efficiently (including procurement and financial management) through consultation, training, and financing of incremental operating costs.

Delivery

The project was launched when the World Bank approved the credit line to support the irrigation project on **12 June 2014**.

The planned project completion date is **31 July 2023**.

International Stakeholders

International Development Association (IDA World Bank), *a credit institution that is part of the World Bank Group*. The Association approved most (72%) of the total loan for the irrigation project in South Karakalpakstan in 2014.

International Bank for Reconstruction and Development (World Bank), *the World Bank's main credit institution*. It funded the South Karakalpakstan Water Resources Management Improvement Project in the Republic of Uzbekistan, in particular, the Modernisation of the Irrigation Network key component in South Karakalpakstan.

Project Cost and Financing

The total cost of the project is **USD 337.43 million**, of which:

- USD 76.64 million is covered by the Ministry of Finance of the Republic of Uzbekistan;
- USD 242.50 million is covered by the International Development Association (IDA World Bank);
- USD 18.29 million is covered by the International Bank for Reconstruction and Development (World Bank).

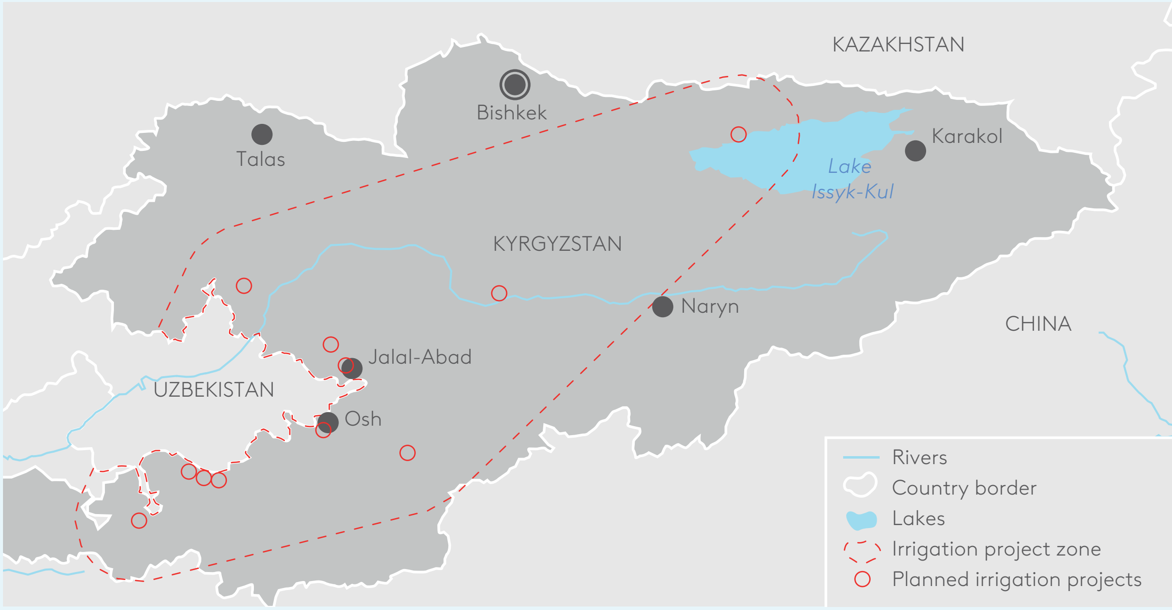
The three components of the major project were financed as follows:

- USD 273.9 million for the Modernisation of the Irrigation Network;
- USD 55.4 million for the Modernisation of Agriculture;
- USD 8.1 million for the Project Management, Monitoring, and Evaluation.

Project Performance Results

- Irrigation service delivery improved in quality on 87,170 ha (98% of the project area).
- The irrigation system benefits 64,420 farmers (vs. the target of 56,000).
- Crops are diversified, and the area under non-cotton/wheat crops has increased from 6,500 ha to 28,172 ha (vs. the target of 8,000 ha).
- The project has rehabilitated 133 km of main canals, including re-profiling and water control structures (vs. the target of 109 km) and 694 km of secondary canals, including water control structures (vs. the target of 550 km).
- The project created an area of laser land levelling of 15,381 ha (vs. the target of 12,000 ha).

Case 4. Irrigation Project: Agricultural Productivity and Nutrition Improvement (Kyrgyzstan)



Source: World Bank, map of water management and irrigation projects in agriculture.

Project Description

The irrigation project seeks to improve agricultural productivity and ensure food and nutrition security for rural households in selected areas across the country.

Delivery

- The project commenced on **11 December 2015**.
- The project will be completed on **30 June 2023**.

International Stakeholders

The Global Agriculture and Food Security Programme (GAFSP) is a multilateral financing platform for improving food and nutrition security worldwide. Launched by the G20 in the wake of the 2007–2008 food price crisis, GAFSP works to build sustainable agriculture and food systems in poor countries.

The World Bank is responsible for the overall management of the project.

Project Cost and Financing

The total cost of the project was **USD 38 million,** provided **as grant support** through the Global Agriculture and Food Security Programme platform.

The components of the major project were financed as follows:

- USD 26.26 million (or 69.1%) for the Rehabilitation and Modernisation of Irrigation and Drainage Infrastructure;

- USD 5.19 million for the Agricultural Advisory Services;
- USD 3.70 million for the Nutrition Improvements;
- USD 2.85 million for the Project Management.

Project Performance Results

- Farmers' yields of crops have increased by 65% (vs. the target of 10%).
- The irrigation and drainage system covers 34,767 farmers (vs. the target of 26,000).
- The area equipped with irrigation and drainage systems has increased by 64,632 ha (vs. the target of 60,000 ha).
- Thirty-one (instead of thirty) water management associations have been set up to regulate water supply and consumption locally.

Guarantees can improve the creditworthiness of a project and attract long-term loans from local and international sources to finance water management and irrigation infrastructure. There are direct guarantees and guarantees with the involvement of government bodies, and both types could work in this case.

MDBs help mitigate risks for other water management project stakeholders. They share financial risks, expertise, and knowledge. MDBs are also willing to offer cut and dried, transparent solutions where the water situation has come to a halt. Governments and beneficiaries generally welcome the contribution of MDBs and other donors in the water sector.

4.5. Cluster Organisation of the Water and Energy Sectors in Central Asia

The global economy is undergoing dramatic changes: the focus is now shifting from hierarchical management to horizontal linkages, from traditional forms of asset integration to quasi-integration. The CA economies are integrating into the global food economy, so these changes are affecting them, too. For example, they might look into creating local, national, and international irrigation and energy clusters, provided that these keep the hydrographic basin of a transboundary river united, and existing regional basin organisations manage it. There are common goals and prerequisites for cluster creation: interdependent water and energy infrastructure, food and energy security.

Cluster integration factors in the underlying natural factors, such as climate change and its impact on water resources. The hydropower and irrigation sectors have a lot of negative factors, but they can all be minimised with upgrades, energy and water conservation, promotion, and innovation. This is one of the advantages of clusters: research and innovation go hand in hand, and structures that are willing to adapt to new technology are in their element. In fact, the Agricultural Development Strategy of the Republic of Uzbekistan for 2020–2030 features a similar approach to agricultural development and water sector reforms (National Database of Legislation of the Republic of Uzbekistan, 2019). The irrigation and energy cluster should have close ties with the hydropower sector and water and energy supply services provided to the irrigation sector. This cluster will bring together the region's water management and agricultural organisations and hydropower enterprises that share the water and energy infrastructure.

Public operating organisations under the water management authorities maintain and operate the main line and inter-farm parts of the irrigation system, including hydraulic structures, while owners (tenants) of irrigated land maintain and operate the on-farm part. Inter-farm drainage systems are also serviced by operating organisations under the water management authorities and are financed from the national budget. This arrangement is common in the CA countries, but as a form of PPP, it needs further improvement.

Investment in irrigation development goes to the state, represented by authorised water management and agricultural bodies and the owners of irrigated land (farmers, *dehkan*, peasant farms, etc.). They clearly share an interest in maximising land and water use, so promotion of PPPs is in order. PPPs seek to attract private capital for irrigation infrastructure projects. PPP projects are initiated by authorised government bodies, local authorities, and private businesses of any corporate and legal form following the established procedure (EEC, 2017). PPPs combine the contributions of each party to achieve a common goal. All parties are equal within PPPs, and so are their relations and responsibilities that are formalised in agreements, contracts, and other official documents. They also share costs and risks, and all benefit from the results.

Improving technological components of crop cultivation, combined with crop irrigation, can reduce costs and increase land and water productivity. The solution comes from the local government body and its authorised bodies in the water management sector and agriculture. The local government can regulate municipal property, so they should have a say in picking a PPP model for the renovation, construction/renovation of on-farm and inter-farm irrigation infrastructure. Picking cannot be random, though; they refer to the range of tasks or types of work to be delegated to the private sector as part of the project under consideration (i.e., delegating design, construction, management, operation, etc.); the scope of the project; the quality control of the project; the distribution of risks between the public and private sectors and risk management; and the ways to cover private sector costs (the payment mechanism to be used) (Reznichenko, 2010).

We believe that PPPs for on-farm irrigation infrastructure should build on existing water management institutions. We recommend turning to an existing WUA and setting up a special purpose vehicle; it will encourage the local government body to organise a tender and will generate two resulting contracts:

- a long-term lease contract for on-farm irrigation infrastructure facilities to render maintenance and water supply services to farmers (water users) (the "Operator");
- an investment contract for the renovation of the on-farm irrigation infrastructure (the "Investor").

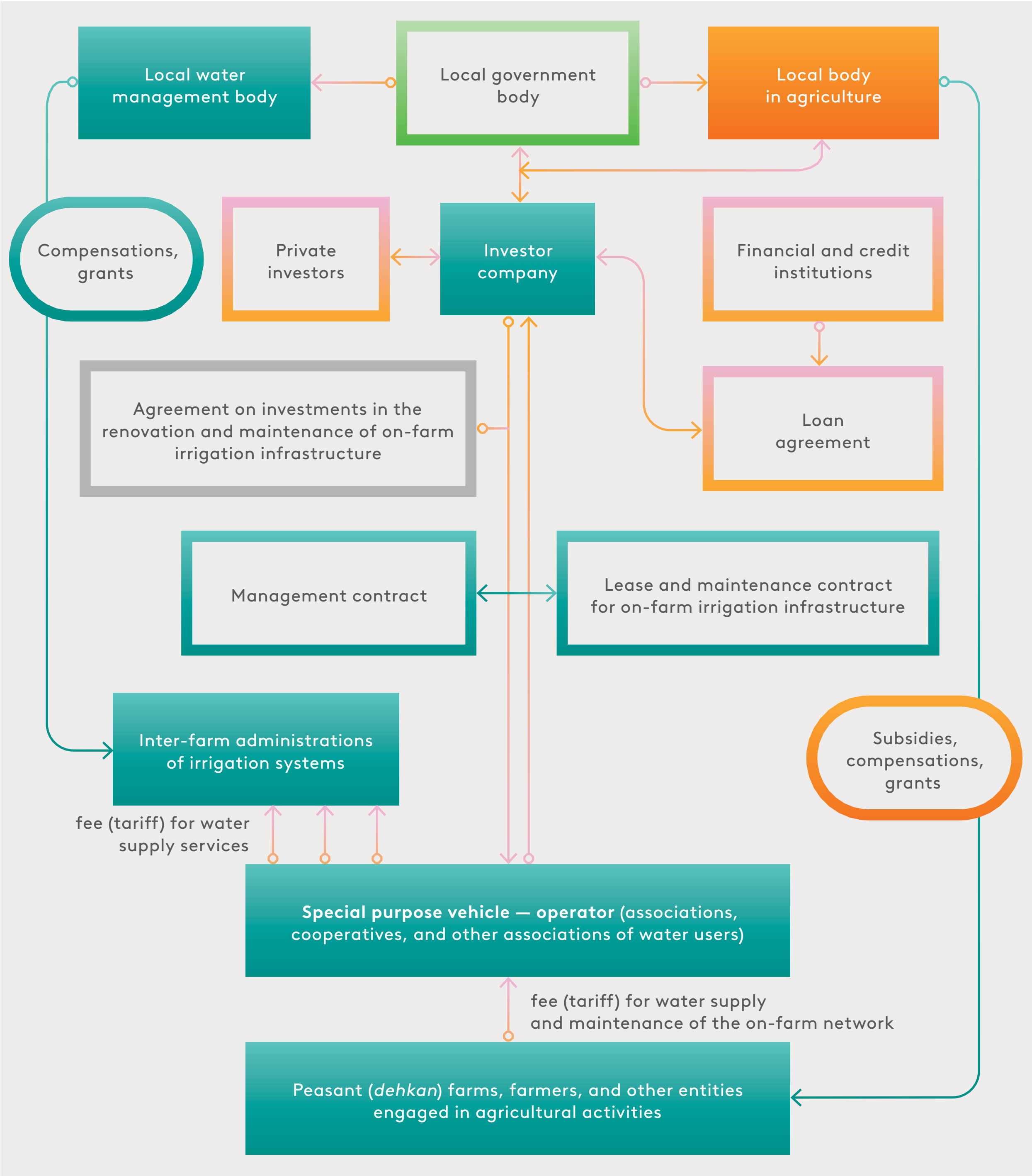
The special purpose vehicle combines the functions of the operator and the investor and:

- receives payment (per tariff) from water users for the services provided;
- attracts debt financing for the investment programme;
- based on the service targets, improves their quality, the reliability of the system, and the availability of services for the end user.

The local government regulates the activities of the special purpose vehicle. For example, it sets reasonable tariffs and tracks maintenance progress.

We propose the same PPP mechanism for the inter-farm irrigation infrastructure sector and for large water management and irrigation facilities. The involvement of the local or central government bodies is optional and subject to discussion because it depends on who owns the facilities (municipality or state).

↓ **Figure 19. Flow Chart of Financing Projects for Renovation and Maintenance of On-Farm Irrigation Infrastructure in the PPP Format**



Source: EDB.

Governments might also look into irrigation and food clusters and their integration with water management organisations operating irrigation infrastructure. Economists consider a cluster a community of economic entities, closely related industries that contribute to each other's competitive growth. It is an alternative to economic sectors because it is an industrial complex based on geographical proximity, with networks of professional suppliers, major producers, and consumers linked by a technological chain. Clusters can develop, expand, and eventually evolve into other forms of cooperation. Their flexibility is an important advantage over other forms of economic system organisation. Cluster integration factors in the underlying natural factors, such as climate change and its impact on water resources. The hydropower and irrigation sectors have a lot of negative factors, but they can all be minimised with upgrades, energy and water conservation, promotion, and innovation. This is one of the advantages of clusters: research and innovation go hand in hand, and structures that are willing to adapt to new technology are in their element (Mironenkov and Sarsembekov, 2009).

International financial institutions are eager to draft national cluster policies and put forward cluster initiatives in the CA countries. These can include financing, technical assistance, grants, development programmes, and strategies. The WB, for example, provides technical assistance based on cluster development approaches and methodologies.

Kazakhstan sees clusters as "an important tool for promoting industrial development, competitiveness, and economic efficiency". Kazakhstan's cluster initiatives are divided into two groups: highly specialised clusters based on geographical proximity and a national cluster covering the western region of the country and oil and gas companies. The country expects to add innovation clusters by 2050. Kazakhstan's cluster policy is looking to "transition from industrial clusters based on value chains in traditional economic sectors to innovation clusters based on key competencies, knowledge transfer, and technology in innovative entrepreneurship" (Chkoniya and Meshkov, 2019).

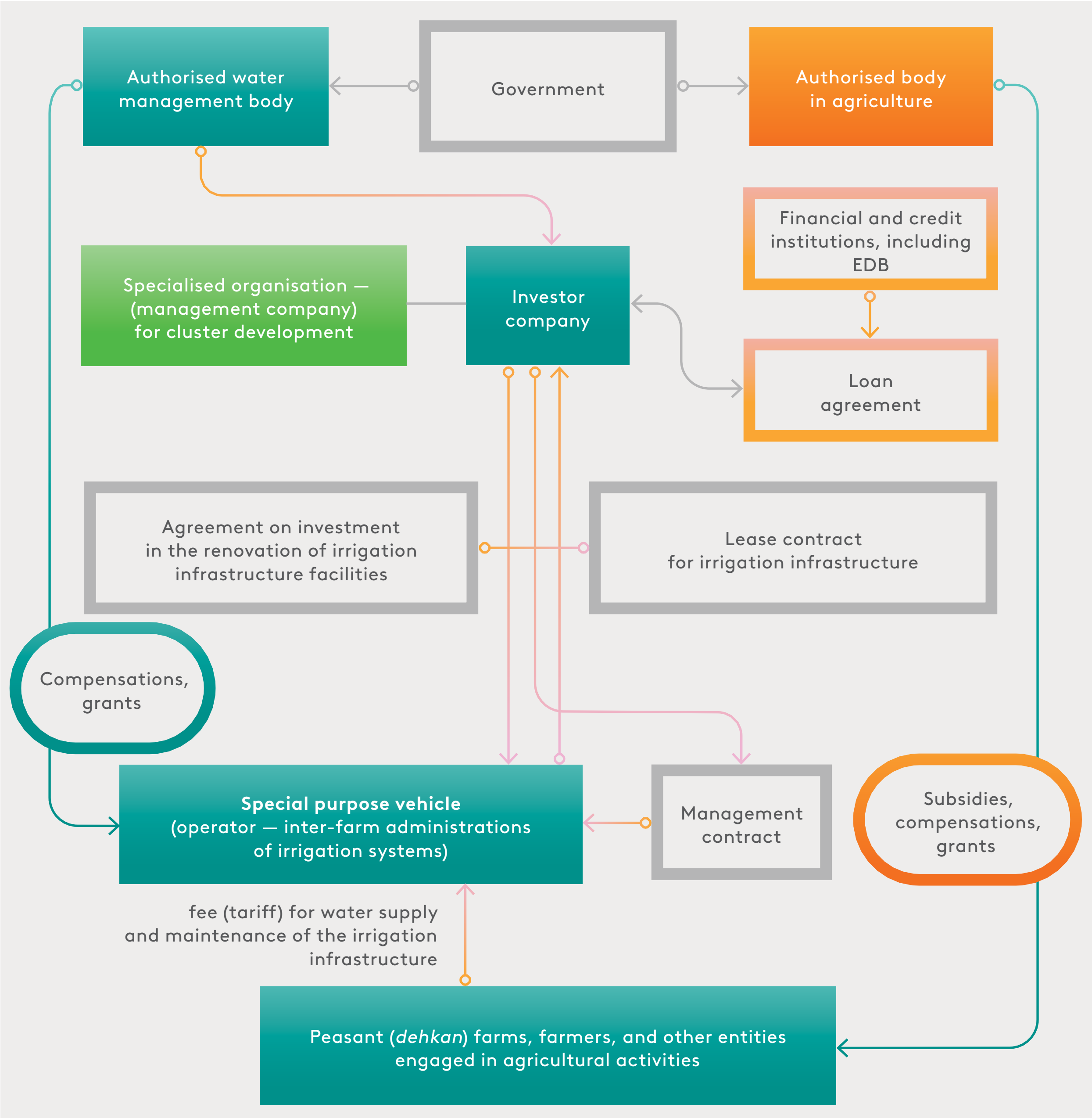
Kyrgyzstan lists its cluster initiatives in the Concept of Regional Policy of the Kyrgyz Republic for 2018–2022. The Concept defines clusters as points of regional growth. National strategies identify specific areas for cluster development in Kyrgyzstan, particularly in the light industry. A highly efficient and competitive light industry will have a significant multiplier effect on the economy and create growth points in different regions of the country.

Tajikistan set cluster development goals in 2016 as part of the adoption of the National Development Strategy of the Republic of Tajikistan up to 2030. According to the Strategy, the country will proceed to the second stage of the Strategy to accelerate investment-encouraged development (2021–2025). The second stage will improve the competitiveness of the national economy, help it integrate into global and regional value chains, and promote the development of the country's regions. To develop clusters, Tajikistan is planning to attract foreign and domestic investors to get them to invest in the real sector and infrastructure. The Strategy also lists cluster-potential sectors: the agro-industrial complex, industry, education, transport and logistics, and the creative economy. These clusters will create competitive production chains to ensure import substitution and expand exports (Figure 20).

Uzbekistan is also investing heavily in agricultural clusters and cooperatives as part of its agricultural reform. Modern infrastructure and advanced technologies for clusters are high on the country's agenda. This system enables a complete "field to fork" production chain and creates new opportunities for expanding exports. Clusters increase producers' incomes through high yields. There are 463 agricultural clusters in Uzbekistan in all areas of agriculture (cotton and textile production, grain growing, fruit and vegetable growing, rice growing, etc.). The clusters cover 2.2 million ha of agricultural land.

PPPs can potentially finance large irrigation infrastructure facilities on transboundary watercourses of interstate importance, such as hydraulic complexes and reservoirs, main canals with structures, pumping stations, etc. The difference is that these projects require significant financing due to their scale. Large transboundary irrigation facilities can also receive financing under PPPs, provided that international financial institutions lend a hand. When structuring such projects, it is essential to follow the principles for cross-border PPPs as outlined by the EDB (Vinokurov et al., 2023b). Adhering to these principles can expedite and streamline the project initiation and launch process while mitigating the risks associated with project implementation (Figure 21).

↓ **Figure 20. Flow Chart of Financing Projects for Renovation of Cluster Irrigation Infrastructure Facilities in the PPP Format**

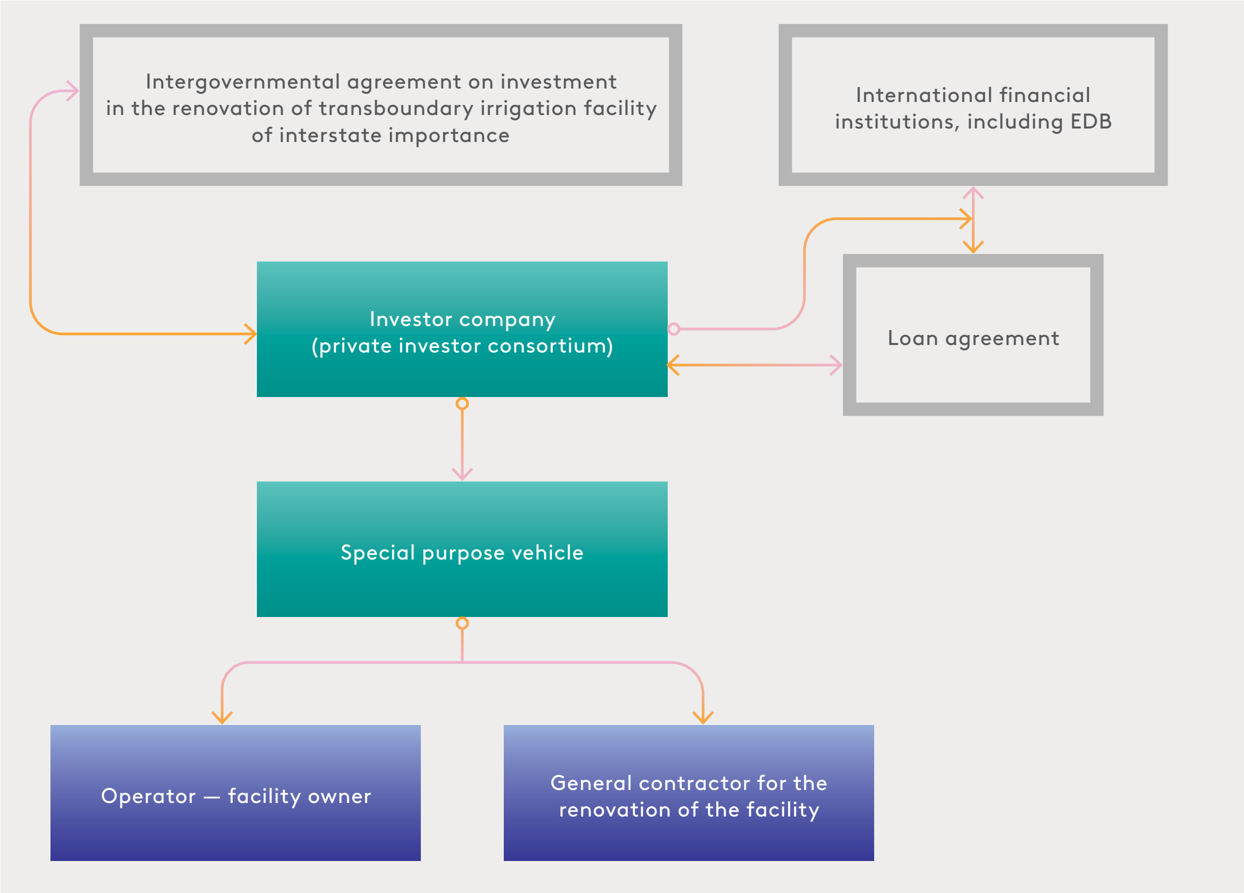


Source: EDB.

We recommend involving MDBs to attract finance for such projects and ensure effective control over the use of funds and the quality of work performed. This means, however, that stakeholders would have to comply with the conditions of project financing. MDBs can provide the necessary technical assistance and help prepare documentation for financing major irrigation infrastructure projects.

Further construction projects will boost the development of the region in the water management sector, not only for irrigation and hydropower generation. They will combat natural phenomena, drought, and low water conditions and address water shortages. These measures require an improvement in the legal and institutional principles of PPP activities. They should go hand in hand, posing no risk to the water supply for neighbouring countries and the ecosystems of river basins. In addition, countries should remember to comply with international regulations and commitments undertaken to protect and efficiently use the resources of transboundary rivers (Mironenkov and Sarsembekov, 2009).

↓ Figure 21. Flow Chart of Financing Projects for Transboundary Irrigation Infrastructure of Interstate Importance in the PPP Format



Source: EDB.

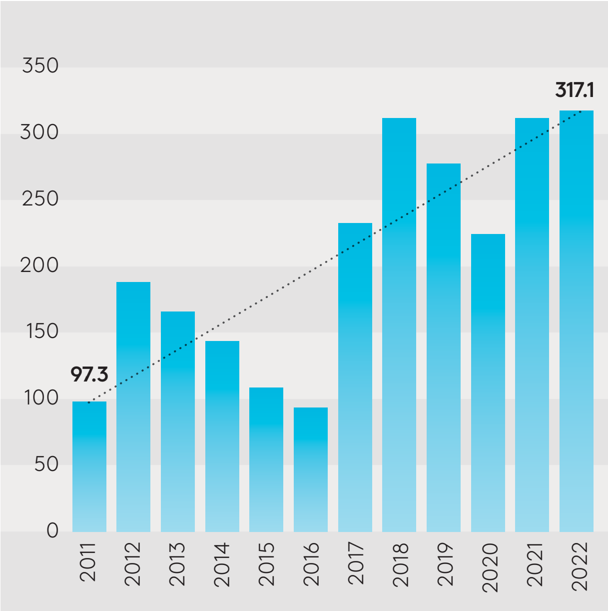
4.6. Establishment of a Regional Cluster for Modern Irrigation Equipment Production in Central Asia

The production of irrigation equipment and related parts and machinery in the CA countries is now at the initial stage. The Republic of Uzbekistan produces numerous irrigation equipment — drip irrigation systems, fittings, fertiliser dispensers, taps and valves for irrigation control, external drippers and other accessories for irrigation, as well as pumping stations and water meters. The main consumers of products manufactured in Uzbekistan are industrial cotton and textile clusters, such as Mergantex and Agrocluster in Bukhara. In addition to production, Uzbekistan's enterprises are also engaged in irrigation installation and utilisation services.

Kazakhstan is only planning a handful of projects. Metzerplas, for example, is looking to open a drip pipe plant in Almaty Oblast in Kazakhstan in late 2023, and Valmont Industries intends to launch the production of advanced irrigation systems in Kazakhstan by 2025.

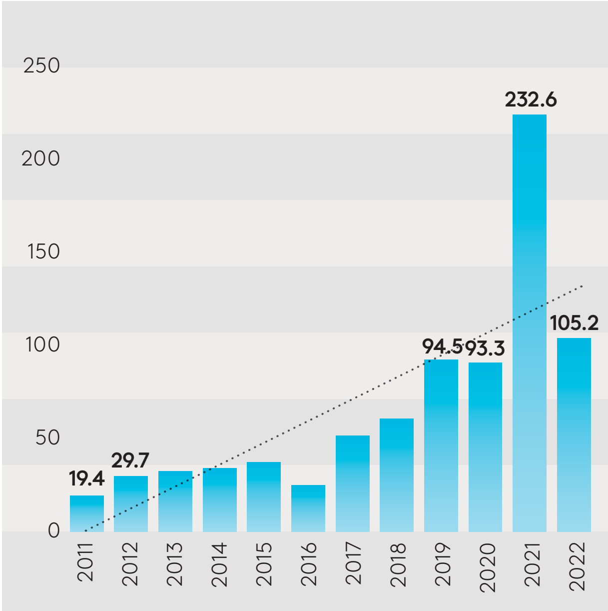
Despite the ongoing initiatives to develop domestic production of irrigation equipment and systems, imports still dominate in Central Asia. Annual imports of irrigation equipment reach $230 million (Figure 23). In this context, enterprises and companies from the USA, UAE, Turkey, Austria, Germany, and Italy have played a significant role in CA. These include Valley (USA), Zimmatik (USA), Reinke (USA), TL (USA), RKD (Spain), Western (UAE), Lindsay (Turkey), Bauer (Austria), Beinlich (Germany), Ocmis, RM, Nettuno, Idrofoglia, Irtec, and Irrimec (Italy). All of this equipment is designed for operation within a closed irrigation network, featuring automated operational modes, multifunctional capabilities, utilisation of computer-based control and management systems, a wide array of modifications and options, and a keen consideration of specific application conditions. Apart from that, Chinese water-saving technologies are actively applied in cotton growing in the Republic of Uzbekistan, together with the Tashkent Institute of Irrigation and Agricultural Mechanisation Engineers.

↓ **Figure 22. Imports of Agricultural Equipment* to the CA Countries, 2011–2022, USD million**



Note: * FEACN codes 8432, 8436
Source: EDB estimates based on data from Trademap.

↓ **Figure 23. Imports of Irrigation** Equipment to the CA Countries, 2011–2022, USD million**



Note: ** FEACN codes 842441, 842449, 842481, 842482
Source: EDB estimates based on data from Trademap.

The cost of equipment from foreign manufacturers, as assessed through information resources and proposals from foreign manufacturers and dealer centres, is as follows:

- Wide-catchment sprinklers of circular action: $75,000–$100,000 (basic machine with a service area per season of up to 70 hectares).
- Wide-catchment sprinklers of frontal action: $90,000–$120,000 (basic machine with a service area per season of up to 70 hectares).
- Hose reel sprinklers with hydraulic drive: €35,000–€42,000 (basic machine with a service area per season of up to 70 hectares), or €35,000–€42,000 (basic machine with a service area per season of up to 30 hectares).
- Drip irrigation systems: $20,000–$25,000 (basic module with a service area for the season of up to 70 hectares), or $20,000–$25,000 (basic module with a service area of up to 10 hectares).
- Stationary sprinkler systems: $25,000–$30,000 (basic module for a service area of up to 10 hectares).
- Micro sprinkler systems: $30,000–$40,000 (module for 10 hectares).

The cluster approach (Delgado et al., 2016) may well address the lack or shortage of domestic irrigation equipment because it seeks to develop the production of machinery and equipment for agriculture and irrigation and to improve the competitiveness of rural regions in the CA countries. The geographical proximity of irrigated land in the CA region — the areas of the Amu Darya and Syr Darya rivers and the basins of the Chu and Talas rivers — is also an advantage for agro-industrial clusters. Domestic production of equipment and machinery for irrigation and watering will maximise water use in the region: the production of such equipment and machinery will account for local conditions and help reach the industrial potential of areas that are exclusively agricultural (Gálvez-Nogales, 2010).

↓ Table 21. Cost of Irrigation Equipment of Different Types of Foreign Production

Irrigation technology	Price (average, USD thousand)	Cost, USD per 1 ha
Wide interceptor circular sprinkling machines	84.6	1.23
Front-acting wide-spreading sprinklers	104.6	1.54
Hose reel sprinkler machines	32.3	1.52
KI-10 — irrigation sets (semi-permanent) based on quick-assembly pipelines	13.8	1.38
Drip irrigation systems	69.2	2.3
Stationary sprinkler systems	26.9	2.69
Micro sprinkler systems	30.77	3.08
Surface irrigation technologies	76.9	0.77

Source: Olgarenko, Turapin, 2020.

Collaborative efforts within the industrial cluster should focus on creating high-performance and multifunctional sprinkler systems and other machinery that implement "precision irrigation" technologies. The goal is to enhance reliability, improve working conditions and safety, employ new technologies and materials, reduce material and energy intensity, and standardise modules and assembly units. The next generation of irrigation systems and machinery should operate at low pressure and deliver high-quality irrigation by optimising water supply algorithms. These systems should combine irrigation with the simultaneous delivery of water, nutrients, disease and pest control substances, chemical ameliorants for soil structuring, plant growth regulators, and photosynthesis activation. This approach aims to conserve resources by reducing water, fertiliser, electricity, and fuel consumption during the construction, reconstruction, and operation of irrigation systems using state-of-the-art technology, coupled with material intensity reduction through innovative design solutions. Automating the technological irrigation process and applying nutrients and other substances allow for achieving high technical, economic, and quality standards. Control systems should continuously monitor and regulate the water regime to maintain optimal moisture levels in the soil (Olgarenko, Turapin, 2020).

The success of the cluster initiative can further be bolstered by the presence of a consistent and substantial demand for agricultural equipment as a whole, as well as for irrigation equipment and systems in particular. The demand was on the rise for both during 2011–2022: by a factor of +3.3 for agricultural equipment and by a factor of +5.4 for irrigation equipment. This can undoubtedly boost the development of the cluster initiative. The region's growing population and increasing water scarcity (Vinokurov et al., 2022a) call for cooperation in the production of water management and irrigation equipment and systems. The expansion of own domestic production capabilities can build upon the existing mechanisms for subsidising the acquisition of irrigation machinery and equipment. Currently, these subsidies are primarily directed towards imports, inadvertently bolstering foreign producers.

A successful cluster of irrigation equipment in CA should boast continuous innovation and internationalisation of businesses. We can see their success in the case of the Croatian Agricultural Equipment Cluster and the Transatlantic Cluster Initiative connecting the USA and Germany. These clusters hit resounding success in the industrial development of agricultural machinery (irrigation equipment) production as the countries advanced their strong agriculture. These cooperation projects flourish in the region thanks to the continuous technological improvement of the manufactured equipment and the export of the products.

Support for the agricultural machinery (irrigation equipment) cluster initiative can also develop the regional agricultural supply chain (Sonobe and Otsuka, 2006). In addition, the irrigation equipment cluster initiative in the CA region will open up opportunities for local farmers to access loans, quality resources, and technological equipment (Otsuka and Zhang, 2021), including small farmers (Bizikova et al., 2020).

4.7. Risks of Improper Management of Investment Projects

Project management, decision-making, risk management, and change management are major stumbling points for infrastructure projects. Poor project management usually causes delays and cost overruns.

Improving the planning and selection of infrastructure projects might address any issues with irrigation project management. When it comes to future infrastructure development, we recommend looking first at demand management, upgrades for existing infrastructure, and other low-investment solutions, and saving more expensive options, such as building new infrastructure or major upgrades, for last.

Studies show that most completed projects fail to meet their original financial budgets and deadlines. Many countries studied this phenomenon around the world, including Malaysia, Saudi Arabia, Jordan, Kuwait, Hong Kong, and Thailand. The results show that there are differences and similarities in the causes of delays. Some of the reasons given included delays and disruptions such as design changes, delays in paying contractors, delays in information, funding problems, poor project management, compensation issues, and disagreements. In Australia, cost overruns are 13%–19%, and time overruns are 10%–69% in traditional and new procurement systems. New procurement systems have 11% cost overruns and 13%–25% time overruns (Muiruri and Bett, 2020).

Management studies conducted in Tanzania, Uganda, Nigeria, South Africa, and Mozambique show that poor project management practices lead to delays and disruptions in construction projects and cost overruns. The studies identified the following main causes of delays and failures: design changes, delays in paying contractors, delays in information, funding problems, poor project management practices, compensation issues, and disagreements over the assessment of work done. The study estimates that 62% of water management projects in Africa fail because of inconsistent project delivery, weak political commitment, inadequate joint monitoring and evaluation, poor resource planning, incompetent project staff, and other factors.

Project planning boosts the efficiency of water projects. For example, all stakeholders can now participate in decision-making and allocate key responsibilities. The planning should also involve identifying the stages for cost reduction. Monitoring and evaluation of project delivery boost the efficiency of irrigation projects (Muiruri and Bett, 2020).

Most countries treat water management as a technical issue. Water management is mainly approached as a solution to an engineering problem. They have a limited understanding of the issues it actually brings up, i.e., political and social dimensions and risks that find their outlet in corruption.

Corruption affects both private and public water management services. According to Transparency International, corruption in the water sector increases capital expenditures by an average of 30% worldwide. The water management sector receives substantial public funds, so corruption is very likely to occur in the award of contracts for the construction and operation of water management facilities. The water management sector has a strong capital intensity; it is twice as high as for other types of utilities. Large water management, irrigation, and dam construction projects are complex and difficult to standardise, making them a breeding ground for potentially large illicit revenues from public procurement and hard-to-detect abuse.

Irrigation systems also have many corruption-prone elements. This wastes allocated funds and reduces the stability of irrigation for farmers. Corruption is pervasive in the water supply chain, from policy development and budget allocation to operational activities and billing systems. Corruption in the irrigation sector hampers food security and water supply: the less water available, the greater the risk of corruption in the control of water resources (Transparency International, 2008).

5. AFGHANISTAN AND WATER RESOURCES IN CENTRAL ASIA

Approximately 75% of Afghanistan (total area: 652.23 thousand km^2) is mountainous, so the country has limited arable land, mainly in the north-western and south-western regions. The modern period in Afghanistan's history includes the abolition of the monarchy in 1973 and the proclamation of the Republic of Afghanistan, followed by almost half a century of political and inter-ethnic armed conflict (Hicks, 2022). As world powers had military forces deployed to Afghanistan, the confrontation escalated between different groups in the country. The turning point was in August 2021, when the internationally condemned Taliban, a movement that had previously ruled Afghanistan in 1996–2001, returned to power.

Afghanistan, embroiled in a long and destructive war, is in a deep economic crisis. In early 2021, Afghanistan's population reached 40.1 million, and 75%, or more than 30 million people, live in rural areas. The population growth (% year-on-year) is 2.9%. GDP per capita (at current prices) does not exceed USD 368.8, while GDP per capita at PPP is USD 1,516.3, placing the country at the bottom (191) of 192 countries (World Bank, 2023). The Human Development Index (HDI) is estimated at 0.478, and Afghanistan ranks 180th out of 191 countries (UNDP, 2022). Extremely limited access to food for the population is one of the dangerous consequences of the country's economic collapse.

According to the UN, some 19.7 million people in Afghanistan, or almost half the country's population, are at risk of food insecurity, the greatest social disaster in the country's history. Acute malnutrition exceeds emergency thresholds in 27 out of 34 provinces. Without international support, Afghanistan is unable to rebuild its economy. The country cannot afford to import food and other essential goods; its foreign exchange reserves and grants are frozen and are unlikely to revert back. The EU froze its development aid to Afghanistan but has recently announced a support package worth EUR 1 billion "for the Afghan people and neighbouring countries, addressing the urgent needs in the country and the region". Japan will provide about USD 190 million in humanitarian aid to Afghanistan through international organisations. China intends to deliver grain, winter supplies, vaccines, and medicines worth CNY 200 million (USD 31 million), and will provide additional material and technical support. The US is allocating USD 64 million in new humanitarian aid to people affected by the ongoing humanitarian crisis in Afghanistan, primarily through organisations such as the UN and UNHCR. International organisations such as UNHCR, FAO, and others are also stepping up their aid campaigns (Holzhacker, 2021). The World Bank assists FAO with the Afghanistan Emergency Food Security Project, designed for 2022–2023 for a total of USD 195 million. The FAO food security project is one of three projects totalling USD 793 million approved by the World Bank to provide urgent and essential livelihood and health services, in addition to food assistance, to the people of Afghanistan (FAO, 2022a).

The CA countries are providing humanitarian and other assistance to Afghanistan to help overcome the crisis (Okimbekov, 2022). The country's economic collapse and frequent droughts have devastating impacts on the country's wellbeing, underlying a food crisis. The situation requires drastic measures, for example, rapid rehabilitation of irrigation infrastructure and the expansion of irrigated land for food crops. Climate change is behind food insecurity in the country: more than half of Afghanistan's agricultural land depends on spring precipitation, which is susceptible to climate change. The average annual temperature in Afghanistan has risen by 1.8°C since 1950, and droughts are the most frequently reported shock experienced in the country, increasing over the past two decades. In the mid-1990s, Afghanistan irrigated 3.2 million ha of agricultural land (FAO, 2022e). This figure has since fallen to 1.8 million ha due to hostilities hindering maintenance of the irrigation infrastructure.

Afghanistan's post-conflict economic development strategy, should the internal political situation normalise, includes the expansion of irrigated land and, consequently, food supply. But this requires more water resources, mainly in the Amu Darya River basin (Okimbekov, 2016). Afghanistan heavily invests national budget funds and mobilises foreign loans and credits to restore irrigated crop farming and build new reservoirs and irrigation systems. The country also seeks to develop large areas of irrigated land in the north and north-east of the country, so it turns to irrigation and hydropower projects dating back to the pre-conflict period, including with the participation of the USSR. Afghanistan intends to create a major food base for the country in this region, and land development will begin there in any case, regardless of any international agreement on the division of the Amu Darya River flow (Zonn et al., 2018).

The Amu Darya River is the largest river in CA. It originates in the Hindu Kush, Afghanistan, where it is known as the Vakhandarya. After merging with the Pamir River, it is called the Pyanj, and below the confluence with the Vakhsh River, it becomes the Amu Darya. The length of the Amu Darya from the head of the Pyanj River is 2,540 km, and its basin area is 309,000 km^2. After the confluence of the Pyanj and the Vakhsh rivers, the Amu Darya, "having passed 1,440 km mainly through desert, flows into the Aral Sea" (Shults, 1968). The Pyanj River flows along Tajikistan's southern border and can also be used by Afghanistan. Of the 1,374.2 km of the Tajik-Afghan border, 1,184.4 km run along the Pyanj River, and 189.8 km are on land (Ministry of Foreign Affairs of the Republic of Tajikistan, 2023). The Amu Darya then crosses the borders of Tajikistan and forms a 144-kilometre stretch of border between Afghanistan and Uzbekistan. The Murgab and Tejen (Gerirud in Afghanistan) rivers, also part of the Aral Sea basin, originate in Afghanistan and end in Turkmenistan. The Gerirud River forms the Iranian-Afghan border and then, leaving Afghan territory, forms the Iranian-Turkmen border. The Amu Darya only receives tributaries for the first 180 km, while in the middle reaches, two large right tributaries — the Kafirnigan and the Surkhan Darya — and a left tributary — the Kunduz — discharge into the Amu Darya.

The flow of the Amu Darya is mainly formed by the Pyanj and Vakhsh rivers; they are fed by melted snow and glacier water. The peak river flow rate is observed in summer, reaching its bottom in January and February (Vinokurov et al., 2021). Its total flow is estimated at 80 km^3 per year, of which 62.5% is formed in Tajikistan, 27.5% in Afghanistan, 6.3% in Uzbekistan, 1.9% in Kyrgyzstan, and 1.8% in Turkmenistan. There are many estimates of the flow generated in the Amu Darya basin and its existing tributaries. For example, according to the government of Afghanistan, the water resources of the Amu Darya River are 80.2 km^3, of which 24 km^3 (30%) are formed in Afghanistan and 49 km^3 (61%) in Tajikistan. According to other estimates, the contribution of rivers in Afghanistan to the Amu Darya's flow ranges from 13.5 km^3 to 24.6 km^3 (Dukhovny, 2008) (Table 22).

Afghanistan's water resources are not evenly distributed across the country. The Helmand basin covers 49% of the country's territory, but it accounts for only 11% of the country's water resources. The Kabul River basin occupies 12% of Afghanistan's territory and accounts for 26% of its water resources. Almost 60% of the country's water resources are concentrated in the "big" Amu Darya, Gerirud, and Murghab River basins, and they make up about 37% of the country's territory (Klemm and Shobair, 2010). Consequently, the country considers this transboundary basin, shared with the CA countries, to be key to irrigation and hydropower development in Afghanistan. Afghanistan is engaged in large-scale irrigation programmes and projects that radicalise the balance of transboundary water use in CA and exacerbate water shortages in the middle and lower reaches of the Amu Darya, mainly in Uzbekistan and Turkmenistan (Okimbekov, 2013).

↓ Table 22. Average Annual Flow of the Amu Darya and its Formation in Riparian Countries

Riparian countries of the Amu Darya basin	Average annual river flow	
	km^3	% of average annual flow
Tajikistan	50.0	62.5
Afghanistan	22.0*	27.5
Uzbekistan	5.0	6.3
Kyrgyzstan	1.5	1.9
Turkmenistan	1.5	1.8
Total for the Amu Darya basin	80.0	100

Note: * Afghanistan uses 5 km^3 for irrigation and other purposes of the 22 km^3 of the Amu Darya River flow formed in the country.
Source: Klemm and Shobair, 2010.

Irrigated land development has been on the rise since the 50s (1.0 million ha) to the 00s (4.7 million ha). This has plummeted the Amu Darya's flow below its headwaters; it does not even reach the Aral Sea (Yasinskiy et al., 2010). There are large areas in the middle reaches of the Amu Darya River in Uzbekistan suitable for irrigated crop farming, but they are elevated and located far from the river's stem stream. These include the Karshi steppe and the Bukhara region, where unique pumping stations supply water to irrigation areas. More than 60 large, medium, and small canals take water from the Amu Darya for irrigation: the flow rate of more than 600 m^3/s in the Karakum Canal; 250 m^3/s in the Karshinsky Canal; 400 m^3/s in the Amu-Bukhara Canal; 500 m^3/s in the Tashsakinsky Canal; 200 m^3/s in the Pakhtaarninsky Canal; 200 m^3/s in the Klychniyazbai Canal; 500 m^3/s in the Kyzketken Canal; 300 m^3/s in the Suenly Canal, etc. (Ismagilov and Kan, 2006). The Amu Darya has a high turbidity of 3,300 g/m^3 and ranks second in the world (after the Yellow River) in terms of suspended sediment load. The high saturation of the river with stream-bed-building sediments causes *deigish*, and this leads to intensive river-bed development and the collapse of the banks under the conditions of the meandering riverbed. *Deigish* causes huge economic and environmental damage, taking over developed areas and destroying engineering and irrigation infrastructure (Artykbaeva et al., 2018).

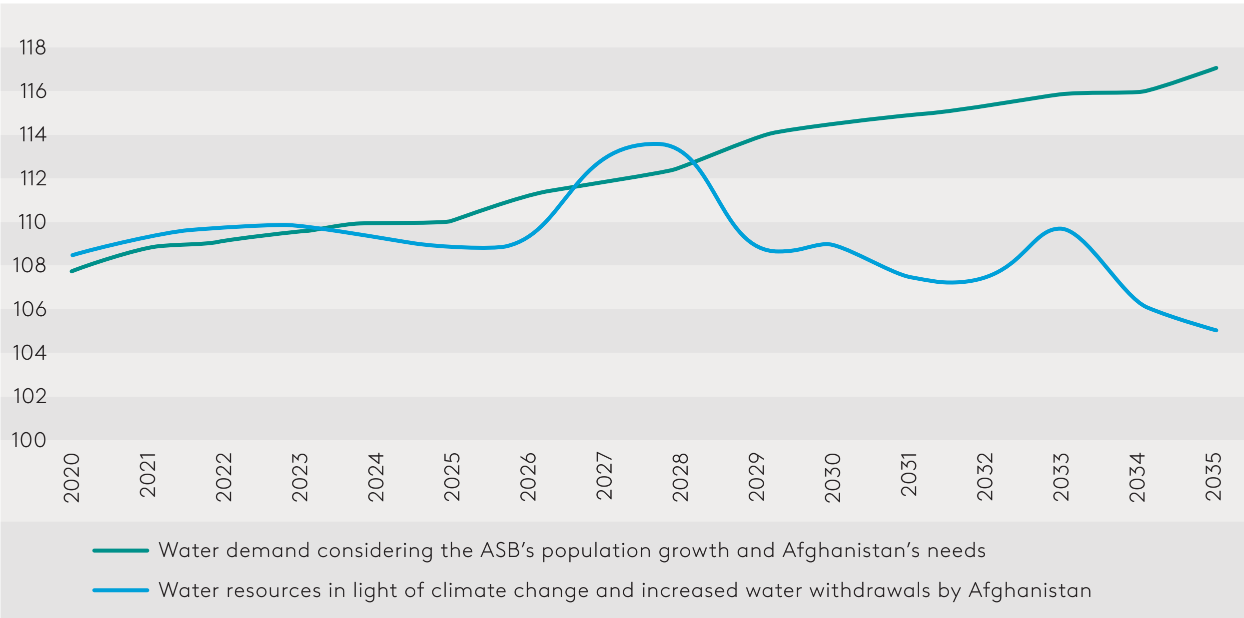
The post-conflict economic recovery in Northern Afghanistan will require accelerating the development of the hydropower and irrigation sectors and increasing the area of irrigated land in this region. According to the World Bank, 385,000 ha are irrigated in this zone, with an expected expansion to 443,000 ha, including 148,000 ha directly from the Amu Darya basin and the drainless Khulm, Balkh, Sary Kul, and Shirintagao rivers. Afghanistan has still managed to prepare projects for the construction of new HPPs and large irrigation systems in northern Afghanistan, turning to international donors and consultants for help, despite suffering from an armed conflict between external and internal forces. The country is looking to develop up to 500,000 ha (up to 1 million ha, according to the World Bank estimates) in the Pyanj basin, 166,000 ha in the Kokcha River basin, 120,000 ha in the Kunduz River basin, and 10,000 ha in the Pyanj River basin. In addition, there are plans and projects to develop hydropower resources in the Pyanj River basin with the construction of a few medium-sized HPPs. The country did the research and feasibility studies for these projects back in the 1960s and 1970s, with the support of the USSR (Dukhovny, 2008). Until recently, Indian companies and Indian funds delivered most projects to rehabilitate and renovate medium and large irrigation facilities in Afghanistan, for example, the major construction of a hydropower complex on the Kabul River. The total capacity of the cascade of HPP reservoirs on the river will be 5.8 km^3, including: 0.41 km^3 in the Totum-Dara, 0.53 km^3 in the Barak, 1.3 km^3 in the Panjshir, 0.4 km^3 in the Bagdara, 0.22 km^3 in the Khaijana, 0.4 km^3 in the Kajab, 0.35 km^3

in the Tangi-Wadag, 0.5 km³ in the Gat, 0.4 km³ in the Sarobi, and 0.29 km³ in the Lagman (Okimbekov, 2016).

The construction of the Qosh-Tepa Canal on the Pyanj River is the largest irrigation project in northern Afghanistan. The country turned to USAID to develop the project feasibility study in 2018 (USAID, 2018) and officially launched the canal construction in 2022. The National Development Corporation of Afghanistan (NDC) is the general contractor; it is a multi-sectoral entity established by Decree of the President of Afghanistan in 2020. The construction of water management and hydropower facilities is high on the agenda for the NDC of Afghanistan. The Qosh-Tepa Canal is located in the northern part of the Afghan province of Kunduz, approximately 300 km northwest of Kabul, and includes a water intake facility, a main canal, and hydraulic structures for water control. The purpose of the canal is to develop 500,000 ha of irrigated land in the provinces of Kunduz, Balkh, Jawzjan, and Faryab. Irrigated areas can grow significantly higher due to additional water being pumped to higher irrigated areas by pumping stations. Medium-sized HPPs to be built will supply them with electricity.

The expected withdrawal of up to 10 km³ of water from the Pyanj River by the Qosh-Tepa Canal affects Turkmenistan and Uzbekistan. Even in normal water years, it will cause uncovered water shortages in the middle and lower reaches of the Amu Darya and subsequent water stress for all sectors of the economy in Uzbekistan and Turkmenistan. The flow of the Amu Darya varies yearly and seasonally, with low-water periods occurring every 4–5 years and high-water periods every 6–10 years. The typical long periods of low water endanger the water supply in Uzbekistan and Turkmenistan. The situation might become worse once Afghanistan completes its Qosh-Tepa Canal. According to SIC ICWC estimates, Turkmenistan and Uzbekistan will have 65% water available for withdrawal (the ratio of the long-term average flow generated within the countries to their water withdrawal in %) in the middle and lower reaches during a period of low water, as opposed to the typical 80%. Moreover, water withdrawal through the Qosh-Tepa Canal can reduce the river's flow in the lower reaches by up to 50% during the growing season because it is difficult to maintain an equitable distribution of water between the middle and lower reaches of the Amu Darya.

↓ Figure 24. Forecast of Runoff and Water Withdrawal in the Aral Sea Basin (ASB) by 2035, km³



Source: EDB estimates based on data from SIC ICWC.

Potentially, the canal could utilise almost the entire flow of the Amu Darya River generated in Afghanistan (Hydrosolutions, 2023). The construction of the Qosh-Tepa Canal in Afghanistan, designed for large-scale land irrigation and diverting a significant portion of the Amu Darya's upstream water, poses a threat to existing water use and water-sharing agreements among the Central Asian countries. Its potential consequences extend far beyond the region. Uzbekistan and Turkmenistan face a high risk of agricultural sustainability loss, impacting related economic sectors, including foreign economic activities. By fundamentally altering the water balance in the Amu Darya River basin, the Qosh-Tepa canal may lead to geopolitical instability and diplomatic tensions. The evolving situation necessitates Afghanistan's involvement in the establishment of an international legal framework for the cooperative utilisation of transboundary water resources in the Amu Darya, adapted to the new realities. International negotiations can be supported by contemporary hydrological modelling, trade-off analysis, and monitoring, including space-based remote sensing. Stakeholders can effectively leverage these advanced technologies, which should aid in making objective, data-driven decisions (Hydrosolutions, 2023).

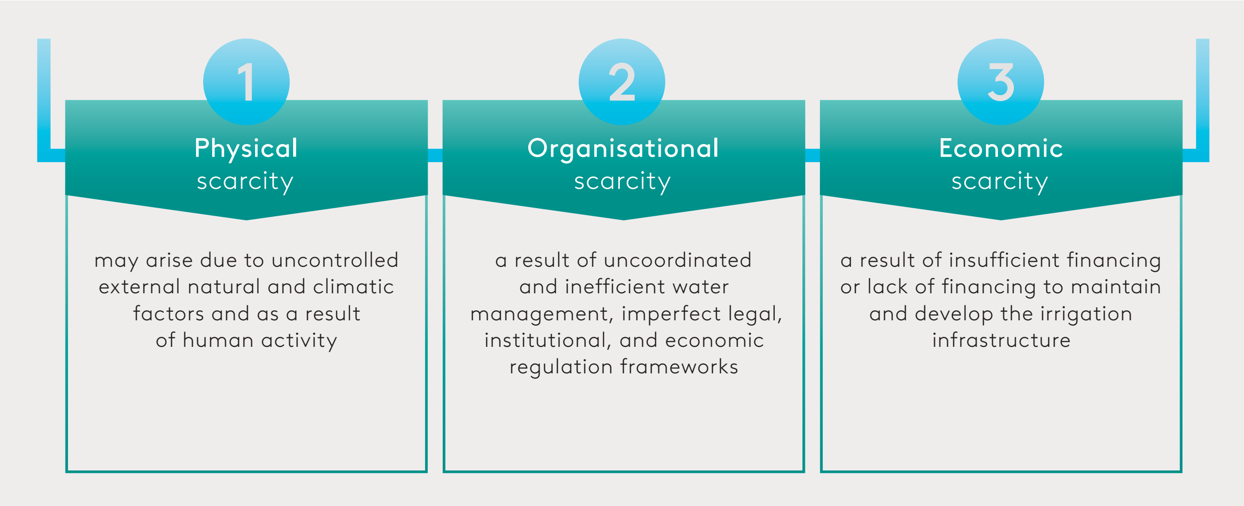
Afghanistan's projects critically reduce access to water in the middle and lower reaches because they involve water withdrawal in the upper reaches of the Amu Darya that alters and lowers the river's flow (Mamadshoev, 2023). There is a high risk of massive river flow reduction, especially in low water years. An interstate regional policy is obviously in order, with the participation of Afghanistan; it will regulate water use and distribution of water resources in the Amu Darya River basin (Zonn et al., 2018).

Unfortunately, the CA countries were unwilling to cooperate with Afghanistan and did not take into account the consequences of its planned large-scale post-conflict rehabilitation of water management, hydropower, and irrigation facilities. There are no agreements between the CA countries and Afghanistan on sharing water resources in the Amu Darya basin. Future projects to expand the area of irrigated land in north-western Afghanistan will alter the existing inter-state water sharing arrangement in the region. The CA countries might have to work together to cooperate with Afghanistan and invite it into IFAS, ICWC, ICSD, and other regional organisations to solve transboundary water issues. This is why the CA countries should focus on transitioning to water conservation, primarily in the irrigation sector of agriculture, across the entire region.

CONCLUSIONS AND RECOMMENDATIONS

Climate change exacerbates water scarcity in Central Asia. We feel its impacts through various detrimental outcomes, including land salinisation, waterlogging, reduced soil fertility, desertification, and land abandonment. These factors collectively **limit the potential for sustainable agriculture and the profitability of farms**. In CA, water scarcity takes on three distinct forms, categorised as physical, economic, and organisational water scarcity. Fortunately, countries can address and alleviate many of the underlying causes of water scarcity.

↓ **Figure 25. Three Forms of Water Scarcity in Central Asian Agriculture**



Source: EDB.

I. Measures to Eliminate and Mitigate the Causes of Physical Water Scarcity in Central Asian Agriculture

The economies of the CA countries are highly energy- and water- intensive, primarily in the agricultural and industrial sectors. The GDP water intensity indicator shows whether water is used efficiently, whether water-saving technology is available, and whether transportation sees a reduction in water losses. It also indicates if water infrastructure is (in)adequate. Consequently, **water and energy conservation will help address food security challenges through technologically advanced agricultural methods**. This transformation should primarily begin with the adoption of these practices in irrigated agriculture requiring the continued overhaul of irrigation systems and comprehensive agro-reclamation measures for conserving water. Food, land, water, and energy are closely intertwined, so their nexus gives rise to new forms of economic cooperation, division of labour, and integration.

To ensure food security, the CA countries have multiple items high on their agenda: adopting water-saving technology across the region, enhancing the technical and engineering standards of irrigation systems, and promoting the cultivation of high-yielding crops. **Existing irrigation and drainage systems require reconfiguration** because it will help resolve the prevalent issue of salinisation in irrigated lands and declining soil fertility. This measure will potentially minimise filtration losses (three- or fourfold) and lower groundwater levels (by 2–3 metres), contingent upon the hydrogeological conditions of the irrigated lands. The countries will have to reduce water consumption for crop cultivation while finding a way to increase crop yields; otherwise, the objectives set cannot be achieved. The resulting conserved water should be used to maintain the ecological balance of rivers and enhance the overall natural environment (Aidarov and Pankova, 2016).

Irrigated agriculture opens the door to the extensive use of **precision agriculture**, a state-of-the-art technology in agricultural science and the digital economy. This promising technology can help achieve the highest returns on investment in agriculture. This calls for the promotion of information resources, crop management practices, irrigation equipment, and irrigation technology within irrigated agriculture. In particular, the technology will require automation, optimisation of crop composition, efficient use of return and wastewater from irrigated lands, and introduction of measures to prevent filtration in canals, among others.

CA countries favour surface irrigation methods. This paves the way for extensive land levelling using modern technical means and methods, for example, laser levelling of irrigated fields. This technology encourages crop care, distributes water on the field evenly without any losses, accelerates plant growth, and increases their yield (Nurbekov et al., 2016).

The region requires a long-term system to monitor the reclamation state of irrigated lands and soil salinisation, in particular, to inspect them remotely (via satellite diagnostics). In fact, existing methods of satellite diagnostics of soil salinisation can provide reliable information promptly, depending on the properties of the object under observation (Pankova et al., 2016).

Agriculture and irrigation can also capitalise on **digitalisation** as an integration of scientific and innovative solutions designed to improve the quality and reliability of irrigation services that contribute to food security. Digitalisation in the water sector will effectively address rational water allocation, reliable water accounting, and, consequently, the region's transition to payment for water supply services to farms.

The limited availability of cultivated land and water resources calls for **regional specialisation in crop production** because it will yield high-quality products at a reduced cost. Local food programmes, however, tend to overlook the potential benefits of regional specialisation and food trade, resulting in increased production costs, a decline in product quality, and ultimately, reduced competitiveness for the CA countries in both domestic and international markets. The most economically and environmentally friendly approach is to trade agricultural products, particularly cereals, due to their high water consumption.

II. Measures to Eliminate and Mitigate the Causes of Economic Water Scarcity in Central Asian Agriculture

CA countries' capital investments in main and inter-farm irrigation networks rely on special budget allocations. **A shortage of funds could significantly deteriorate the reclamation infrastructure's condition and functionality**. Consequently, the technical state of irrigation systems will directly impact the profitability of agricultural production and the productivity of irrigated lands.

Investment opportunities, or lack thereof, may hinder the future development of agriculture in CA, particularly in the water and irrigation sectors. The irrigation infrastructure requires extensive repairs or complete overhauls using contemporary technology. Simultaneously, irrigation ranks among the most capital-intensive aspects of agriculture. The average unit cost for constructing an irrigation system stands at $3,500 per hectare, with the cost of reconstruction amounting to $1,000 per hectare, according to data from 93 developing countries. With new water-saving technology, the construction cost can reach $7,000 per hectare.

The primary reason for the poor condition of irrigation systems is the lack of public and private funding for their proper maintenance. Investment is therefore key to irrigation development in low-income countries in the region. **Substantial efforts and planned interventions should expand the financial resources available for financing irrigation infrastructure**.

A reasonable tariff system for water supply services in CA should be introduced gradually, stage-by-stage. The required rates are marginally higher (4–15 times) than the current tariffs for water supply services to farm-water users in CA. The introduction of a fee for water usage is becoming a vital component of the ongoing reforms, particularly in countries like Uzbekistan and Kazakhstan. Gradually including investment charges in the tariff structure will enable water management organisations to invest in new construction, modernisation, and the renovation of irrigation systems. Nevertheless, international experience has shown that irrigated agriculture around the world still requires significant subsidies from the state, despite any success achieved with paid water supply mechanisms. Farmers all over the world simply fail to afford the necessary investment.

Since tariff payments for water supply in irrigation include costs for the modernisation and reconstruction of irrigation infrastructure, they can **increasingly encourage various Public-Private Partnerships to attract investment in irrigation development**. Drawing from the experiences of other countries, this funding method can be considered quite viable. **MDBs** actively participate in such PPP projects; in fact, the financial resources of international donors and MDBs improve water and irrigation system development prospects worldwide, as has been demonstrated globally.

Given the limited financial capacity of farms, **state regulation** is still required for designing, financing, constructing, operating, and repairing irrigation infrastructure facilities (Qasim et al., 2000). The countries will obviously have to focus on attracting investment in irrigation infrastructure and optimising the funds raised. A McKinsey study revealed that it is possible to reduce costs by 40% for the same amount of infrastructure investment. In other words, by adopting best practices in selecting and launching new infrastructure projects and extracting more value from existing infrastructure, infrastructure efficiency can be improved by as much as 60% (McKinsey Global Institute, 2013).

One of the most effective ways to optimise infrastructure spending is by selecting the best, high-yield projects for infrastructure portfolios. Once countries eliminate poorly designed projects and choose the best options, it can free up some capital investment. Planning will help identify the most favourable projects, and it should be rooted in broader socio-economic objectives established through the policy-making process. The selected projects should align with these objectives (Nikulina, 2015).

The irrigation sector requires a lot of time to be put in, as set out in the national programmes of the CA countries; they attract significant domestic and foreign investment and expand public-private partnerships for this very purpose. **It follows that proper design and technical documentation drafting are in order, with a focus on quality and timing**. The sector looks for novel approaches to funding scientific and design research, organising the activities of design institutions, and training design engineers for the water sector. The government is supposed to strengthen the design industry and preserve the repository of design innovations, regardless of the legal status of the development organisation and its access to such repository. To reduce the risks associated with significant investments in the construction or renovation of irrigation systems, they will need access to accurate and up-to-date information, a potentially major challenge to be encountered during the preparation and launch of investment projects.

III. Measures to Eliminate and Mitigate the Causes of Organisational Water Scarcity in Central Asian Agriculture

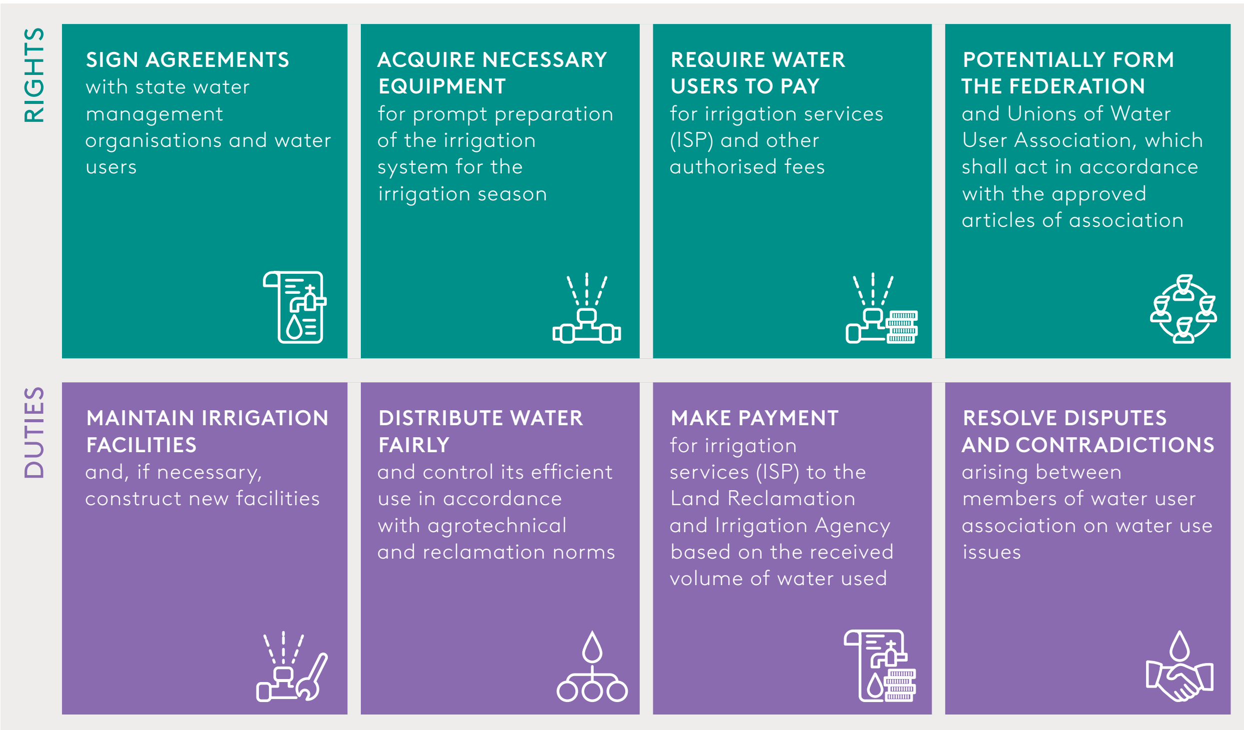
On-farm infrastructure components need upgrading and updating as much as main irrigation infrastructure; it is a prerequisite for enhancing the efficiency of irrigated land use. In CA, approximately 40% of the water drawn from rivers is lost due to filtration in the canal system. One-third is lost in the main and inter-farm canal systems, while **two-thirds of the losses are attributed to on-farm canals**. We therefore recommend the following measures:

- **Expanding public-private partnerships** and outsourcing within the water sector, with the transfer of certain water management facilities for use by farms, clusters, and other organisations.

- **Strengthening the organisational and legal standing of water user associations**, creating the necessary legal and economic conditions for these associations to collaborate with governmental and economic management bodies, as well as farms.

- **Elevating water quality standards** to align with national legislation and the commitments required for achieving environmental sustainability.

↓ Figure 26. Rights and Duties of Water User Associations in Solving Water Deficit



Source: EDB.

The issue of water-energy integration remains one of the most complex challenges in the interstate relations of the CA countries. More than half of the irrigated areas in Tajikistan and Uzbekistan rely on water supplied by pumping stations that consume significant amounts of electricity. During the growing season, the highest demand for irrigation water is met through increased water releases from reservoirs and HPPs situated along transboundary rivers. The electricity generated by these HPPs could be used to power large and medium-sized irrigation pumping stations in the region's countries. Politically and economically, it makes sense **to integrate the irrigation and energy sectors within the CA economies**. This integration could combat water scarcity and effectively redistribute surplus electricity during the summer. Consequently, a regional mechanism will help foster synergy between irrigation and hydropower and thus address issues related to regulating interstate water use and enhancing hydropower sustainability. Such integration could be one of the goals of the International Fund for Saving the Aral Sea.

MDBs' funding is critical for the sustainable development of the water sector and irrigation, particularly when it comes to adapting to the impacts of climate change. We strongly advise establishing **the International Water and Energy Consortium of Central Asia** because it will facilitate productive interactions and dialogues between MDBs and the countries within the region. Such consortium would primarily focus on the execution of irrigation projects. MDBs operating within the region would function as key financial operators in charge of launching complex projects and leveraging additional financial resources from other donors. The Interstate Commission for Water Coordination in Central Asia could coordinate regional investment policies in the irrigation sector and ensure that financing decisions align with the national irrigation priorities and strategies of member states. The IFAS Executive Committee will support governments in developing national plans aimed at enhancing cooperation on transboundary water bodies and facilities and their priority financing. The coalition, comprised of IFAS, the IWEC CA, and MDBs, should join forces to stimulate investments in irrigation, following the regional and national water and energy development strategies of the CA countries.

The development of industrial production within the agricultural machinery, agrochemicals, and irrigation equipment sectors is high on the regional cooperation agenda. There are substantial risks associated with the execution of large-scale irrigation system reconstruction programmes and the attraction of investments, primarily due to the insufficient capacity of the local construction water industry and its suboptimal location in relation to the planned facilities. Remarkably, agricultural machinery production is currently bound to Kazakhstan and Uzbekistan in the region. The countries lack specialised land reclamation equipment, canal maintenance and repair machinery, water-metering facilities, and other essential equipment. This calls for a regional cluster in charge of the production of modern irrigation equipment and machinery, accommodating the specific needs and characteristics of each country within the region. Such regional cluster can see the light through PPP involving MDBs and can be based on an intergovernmental agreement among the interested parties.

Scientific research and innovative solutions in the water sector may promote the sustainable development of agriculture and irrigation in the CA countries. Water resources in irrigated agriculture should be allocated and used according to dependable data, including information on the specific irrigation requirements of various crops and the ameliorative conditions of irrigated lands. These studies should serve as a scientific and methodological foundation, guiding the development and introduction of comprehensive measures aimed at optimising irrigation practices, adjusting irrigation norms, and incorporating water-saving technology. The data collected should underpin the establishment of irrigation regulations, the refinement of irrigation norms, the introduction of engineering and reclamation measures to combat soil salinisation, the introduction of new irrigation methods and techniques, improvements in collector and drainage systems, the reduction of water losses during irrigation, and advancements in water-metering facilities, among other aspects.

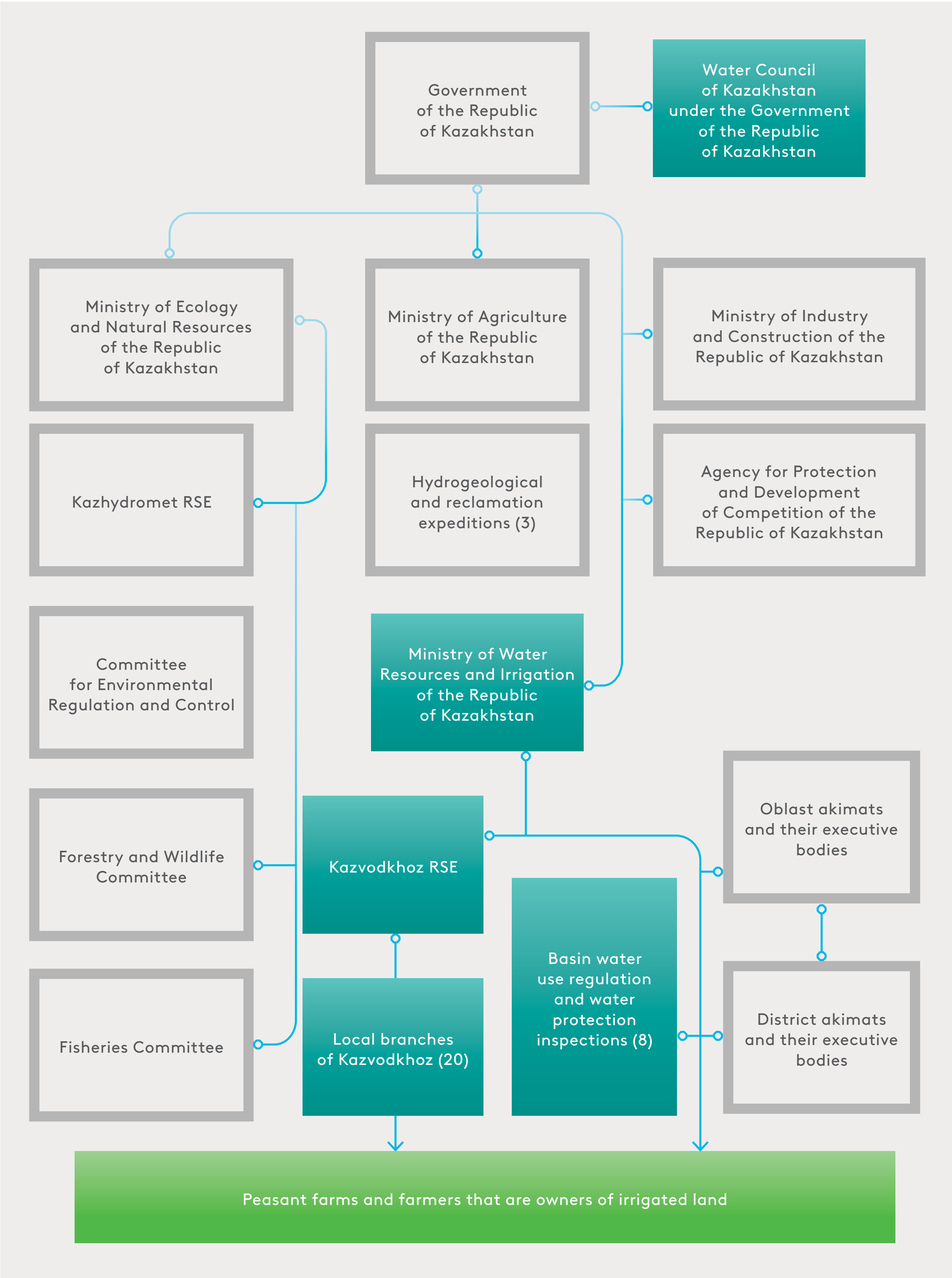
Transitioning to water-saving practices appears to be the only solution to retain the irrigated land potential and ensure food and water security in CA. The urgency of water-saving policies stems not only from climate change, increased water demand, and growing water deficits but also from the anticipated reduction in the inflow of the Amu Darya River from Afghanistan. Despite the country's involvement in armed conflicts, changes in ruling regimes, and external and internal pressures, the development of hydropower and irrigation in water resources has been a priority for Afghanistan over the past few decades.

Large-scale irrigated land and water development **projects in Afghanistan** have a critical impact on access to water in the middle and lower reaches of the Amu Darya River, especially for Uzbekistan and Turkmenistan in dry years. The flow of the Amu Darya during the growing season in dry years could potentially decrease by up to 50% or even more in the lower reaches of the river. Afghanistan has turned to external consultants for help in successfully preparing projects for the construction of new HPPs and large-scale irrigation systems. This situation fundamentally alters the conditions for interstate water allocation and use in the region. It calls for immediate collaborative measures to transition comprehensively towards a water-saving policy across all sectors of the economy, particularly irrigated agriculture. **Simultaneously, the CA countries should consolidate their efforts to enhance cooperation with Afghanistan and involve organisations like IFAS** and other regional bodies in managing transboundary water resources.

The economies of the CA countries are evolving amidst severe strain on land and water resources. Water use issues require **new mechanisms and tools for cooperation in transboundary river basins, primarily rooted in deeper economic integration among the region's countries**. The strengthening of partnerships and mutually beneficial economic cooperation are key to overcoming the long-term socio-economic and environmental consequences of complex natural-geographical and geopolitical factors, along with high transboundary water dependence in the Central Asian countries.

ANNEXES

↓ 1. Irrigated Agriculture Management in the Republic of Kazakhstan



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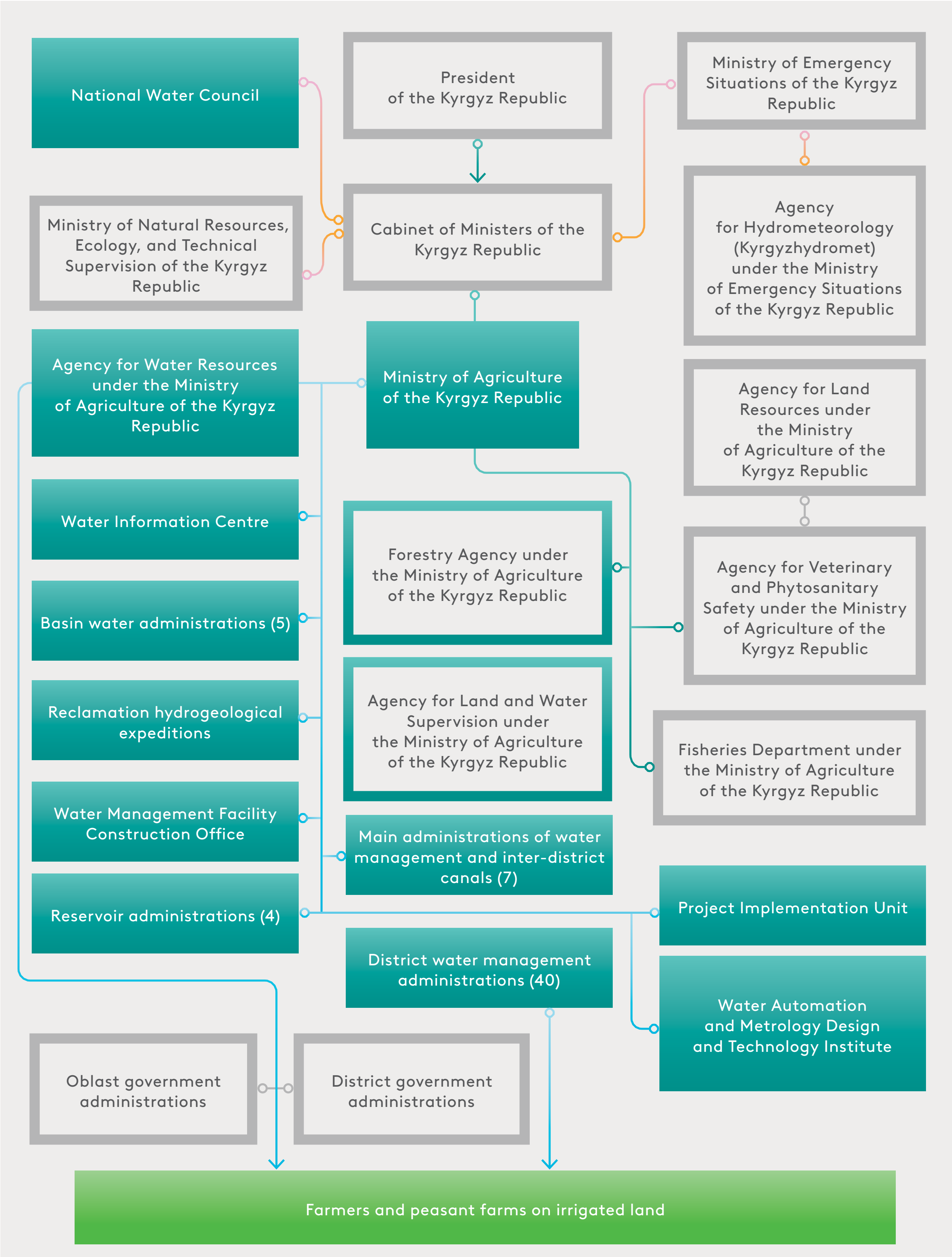
↓ 2. Irrigated Agriculture Management in the Kyrgyz Republic



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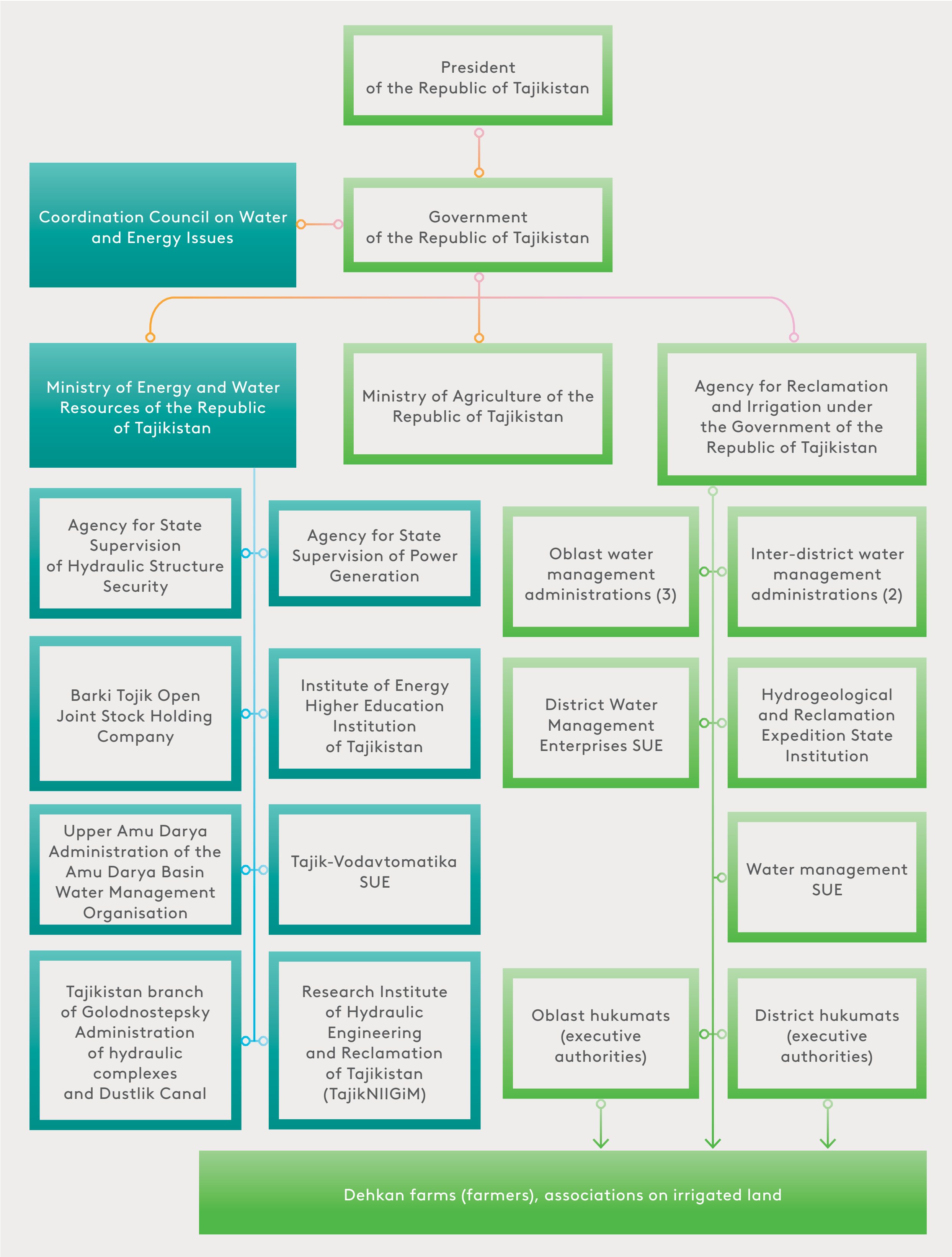
↓ 3. Irrigated Agriculture Management in the Republic of Tajikistan



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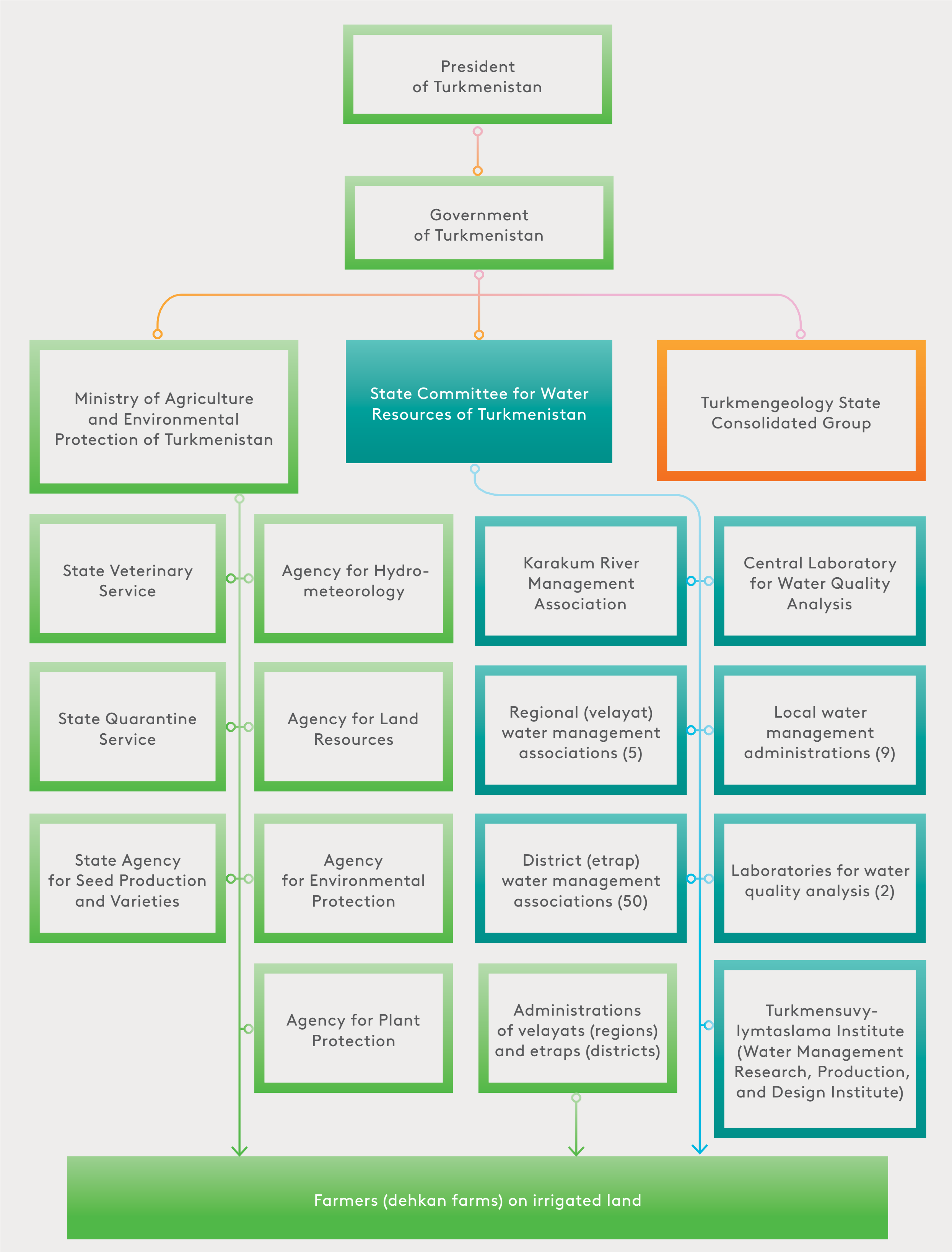
↓ 4. Irrigated Agriculture Management in Turkmenistan



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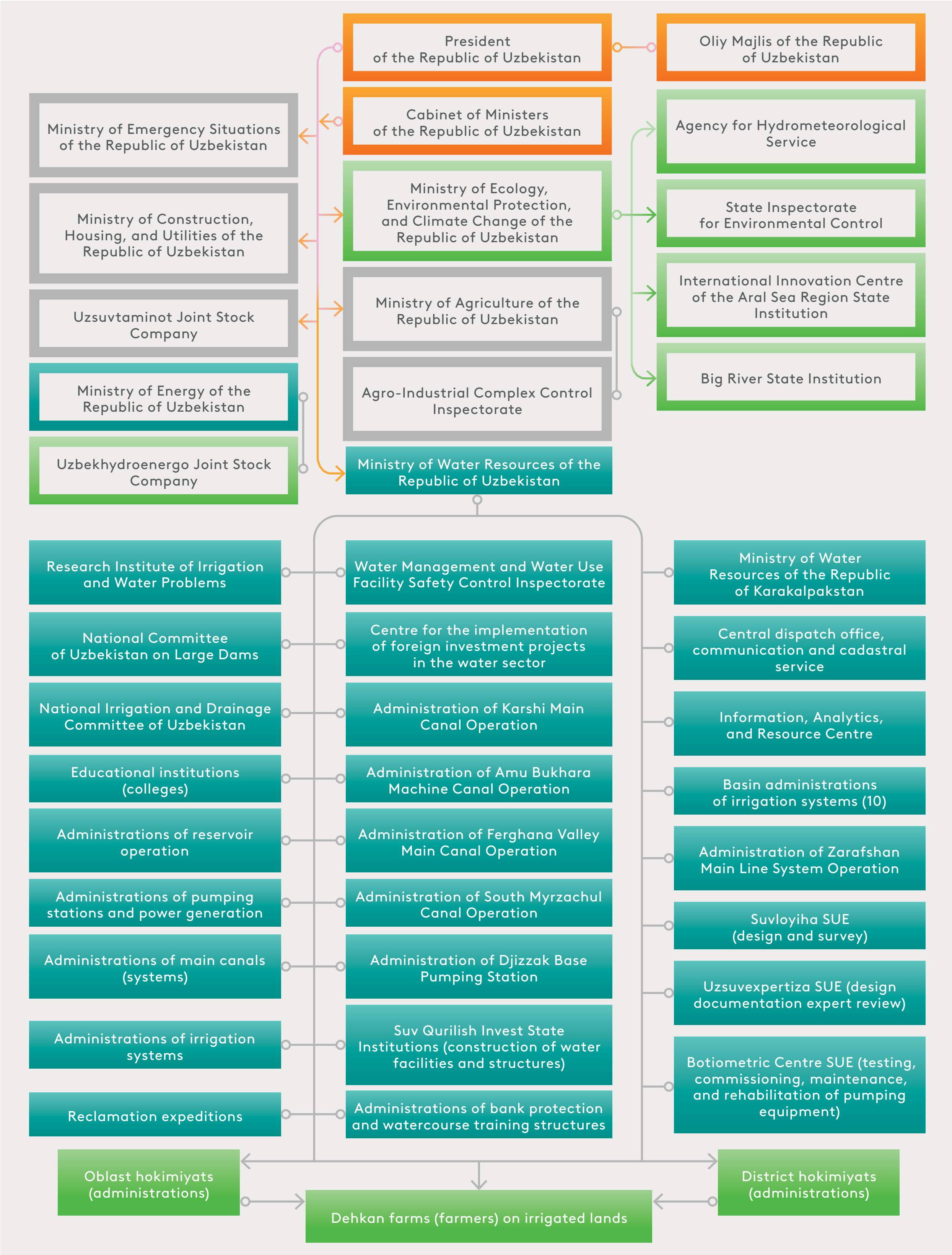
↓ 5. Irrigated Agriculture Management in the Republic of Uzbekistan



Source: EDB.

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ABBREVIATIONS

APC — agricultural production cooperatives

CA — Central Asia

CIS — Commonwealth of Independent States

EDB — Eurasian Development Bank

EEC — Eurasian Economic Commission

EU — European Union

FAO — Food and Agriculture Organisation of the United Nations

FAOSTAT (United Nations Statistics Division of the Food and Agriculture Organisation) — Corporate Statistical Database website of the Food and Agriculture Organisation of the United Nations

FIS — fee for irrigation services

GDP — gross domestic product

HPP — hydropower plant

IDA — International Development Association

IFAS — International Fund for Saving the Aral Sea

IsDB — Islamic Development Bank

IWEC CA — International Water and Energy Consortium of Central Asia

IWRM — integrated water resource management

JSC — joint-stock company

KR — Kyrgyz Republic

MDBs — multilateral development banks

NDC — National Development Corporation of Afghanistan

NSC KR — National Statistical Committee of the Kyrgyz Republic

OECD — Organisation for Economic Cooperation and Development

OSCE — Organisation for Security and Co-operation in Europe

PC — production cooperative

PPIAF — Public-Private Infrastructure Advisory Facility

PPP — public-private partnership

RK — Republic of Kazakhstan

SDG — Sustainable Development Goal

UAE — United Arab Emirates

UCCWU — union of consumer cooperatives of water users

UN — United Nations Organisation

UNDP — United Nations Development Programme

UNECE — United Nations Economic Commission for Europe

USA — United States of America

USSR — Union of Soviet Socialist Republics

WB — World Bank

WUA — Water User Association

% — per cent

ha — hectare

hwt/ha — hundredweight per hectare

kcal — kilocalorie

km — kilometre

km^3 — cubic kilometre

kWh — kilowatt-hour

m — metre

m^3 — cubic metre

m^3/s — cubic metres per second

USD — United States dollar

USD/ha — United States dollars per hectare

Macroeconomic Review

(RU)

A regular EDB publication, which provides an overview of the current macroeconomic conditions in the EDB member states and estimates their development in the short-term perspective.

Macroeconomic Outlook

(RU/EN)

EDB Macroeconomic Outlook 2023–2025

The analysis summarises economic developments in the Bank's member states in early 2023 and provides key macroeconomic projections for the region's countries until the end of the year and for 2024–2025.

Report 21/1

(RU)

Promoting the Role of the EAEU Currencies in Global Transactions

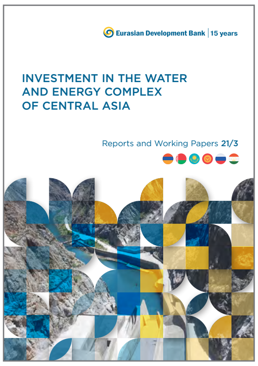
EAEU currencies service around 2% of global trade. As for the EAEU countries, payments in their currencies have notably increased over the past seven years — their share in trade flows jumped from 63% in 2013 to 74% in 2019.

Report 21/2

(RU/EN)

Uzbekistan and the EAEU: Prospects and Potential Impact of Economic Integration

The report estimates the potential effects of Uzbekistan's integration with the EAEU and outlines promising areas for cooperation between the current Union member states and Uzbekistan.

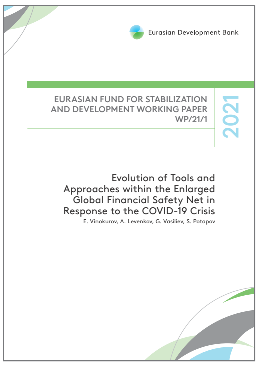


Report 21/3

(RU/EN)

Investment in the Water and Energy Complex of Central Asia

The report analyses Central Asia's water and energy complex after 30 years of independence of the five Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) and assesses their cooperation in the water and energy complex.



Working Paper WP/21/1

(RU/EN)

Evolution of Tools and Approaches within the Enlarged Global Financial Safety Net in Response to the COVID-19 Crisis

This working paper provides the analysis how the GFSN responded to pandemic on global level and on regional level (in the EFSD countries).

Working Paper WP/21/2

(RU/EN)

Total Debt is So Much More Than Just Sovereign Debt. Contingent Liabilities in Armenia, Belarus, Kyrgyz Republic, and Tajikistan

This study aims to contribute to understanding the potential risks and impacts of both explicit and implicit contingent liability shocks on government fiscal and debt positions in the EFSD recipient countries.

Report 21/4

(RU/EN)

EDB Monitoring of Mutual Investments

Mutual investments in Eurasia, calculated using a new methodology, reach US $46 billion. FDI has been growing steadily since 2016.

Report 21/5

(RU/EN)

The International North–South Transport Corridor: Promoting Eurasia's Intra- and Transcontinental Connectivity

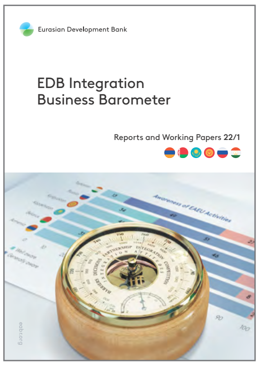
Linking up the INSTC with Eurasian latitudinal corridors could ensure around 40% of container traffic.

Joint report by the Eurasian Development Bank and the Global Energy Association

(RU/EN)

Green Technologies for Eurasia's Sustainable Future

The report is prepared by the key international industry experts and young scholars. It contains the results of technical research aimed at solving today's energy challenges and helping to reduce the carbon footprint in Eurasia.



Report 22/1
(RU/EN)

EDB Integration Business Barometer

About 73% of companies feel positive about the EAEU and say it makes doing business easier.

Report 22/2
(RU/EN)

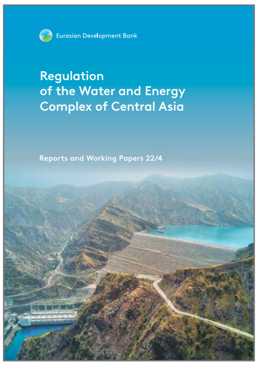
International North–South Transport Corridor: Investments and Soft Infrastructure

The study assesses the investment potential of the INSTC, identifies barriers to its development and provides recommendations on how to eliminate them.

Report 22/3
(RU/EN)

The Economy of Central Asia: A Fresh Perspective

The report provides a renewed perspective on Central Asia as a large, dynamic and promising economic region and analyses its current structural changes and major growth areas.



Report 22/4
(RU/EN)

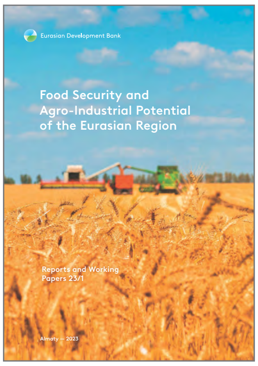
Regulation of the Water and Energy Complex of Central Asia

The report scrutinises historical data and international experience to suggest five institutional solutions for effective regulation and development of Central Asia's water and energy complex that would benefit all countries of the region.

Report 22/5
(RU/EN)

EDB Monitoring of Mutual Investments — 2022

This report continues the series of publications detailing the findings of a long-standing research project monitoring mutual direct investments of the CIS countries and Georgia.



Report 23/1
(RU/EN)

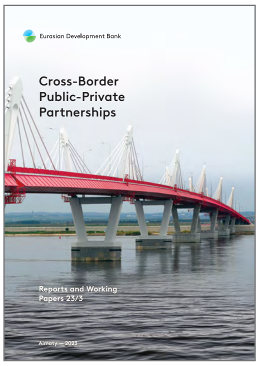
Food Security and Agro-Industrial Potential of the Eurasian Region

Based on the balance approach, the report analyses the production, resource, and export potential of the agro-industrial complexes of the EAEU countries, Tajikistan, and Uzbekistan for the period until 2035.

Report 23/2
(RU/EN)

Global Green Agenda in the Eurasian Region. Eurasian Region on the Global Green Agenda

The report provides a comprehensive analysis of the challenges and prospects for low-carbon transition in Eurasia, covering EAEU countries, Tajikistan, and Uzbekistan.



Report 23/3
(RU/EN)

Cross-Border Public-Private Partnerships

The report outlines the criteria and scope of cross-border PPP projects, evaluates their potential for fostering cross-border infrastructure development in the EAEU, Central Asia, and the South Caucasus, and suggests guidelines for the successful implementation of cross-border PPPs in the region.

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EURASIAN DEVELOPMENT BANK

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