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Ensuring climate resilience in Central Asia through the establishment of a water management education program

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ABSTRACT

This article is devoted to the issues of sustainable development in the Central Asia region. The authors have performed an analysis of the state of rational use of water resources. Ensuring climate resilience in water management in Central Asia is a critical challenge in today's world. This problem is of interest in connection with its possible impact on the sustainable development of the region. The purpose of this work is to analyze the current state of the rational use of water resources in Central Asia to identify ways to optimize their management. The study used a qualitative and quantitative analysis of data on water use collected from various sources, as well as a comparison method to assess the effectiveness of existing water management practices in the region. The authors revealed that the unbalanced distribution and inefficient use of water resources in Central Asia led to environmental and socio-economic problems. It has also been found that the existing mechanisms for managing water resources are not effective enough.

Key words: climate change, educational programs, higher education system, strengthening regional cooperation, sustainable development, water management

HIGHLIGHTS

- Ensuring climate resilience in water management in Central Asia is a critical challenge in today's world.
- The purpose of this work is to analyze the current state of the rational use of water resources in Central Asia to identify ways to optimize their management.
- The study used a qualitative and quantitative analysis of data on water use collected from various sources.

INTRODUCTION

Water is perhaps the most important strategic resource in Central Asia. It is an important factor in socio-economic development: about 8.4 million hectares of irrigated agriculture, which is almost 60% of the annual freshwater withdrawal, contributes about 20% to the region's GDP and employs a significant part of the total labor force. The population of Central Asia is projected to increase from the current 70 million to 95 million by 2050. As a result, by 2050, water availability per capita could be reduced by more than 33% compared to today, reaching a water deficit of less than 1,000 m^3 per person per year by 2040, all other things being equal.

Central Asia is a region that has been facing the effects of climate change for many years. According to ecologists and climatologists, this region is experiencing rising temperatures, decreasing precipitation and declining water levels (Aizen *et al.* 2001). These changes are already having a major impact on the economy and the quality of life of the population, including agriculture, water supply and healthcare (Wegerich & Kazbekov 2015).

Given these challenges, the relevance of the problem of ensuring climate resilience in Central Asia is beyond doubt. The effective management of water resources plays a special role in this context, since water is a key element for maintaining the stability of ecosystems and the socio-economic well-being of the region (Cooley *et al.* 2013).

The purpose of this study is to consider opportunities to increase resilience to climate change in Central Asia through the creation of an educational program in the field of water management. To achieve this goal, the following tasks are set:

1. To analyze the existing problems of water resources management in Central Asia in the context of climate change.
2. Assess the needs of the region in the training of specialists in water resources management.

3. Develop the concept of an educational program adapted to the conditions of Central Asia.

Propose measures for the implementation of this program and evaluate the possible benefits of its implementation for the sustainability of the region.

The pandemic has dramatically highlighted the importance of providing clean drinking water, sanitation and hygiene services to every community in a region that has been suffering from environmental degradation for decades. The drying up of the Aral Sea has become one of the most serious man-made environmental disasters in history. Among the serious economic and social consequences of the environmental catastrophe, widespread water-borne diseases and serious health problems caused by the lack of clean drinking water are the main concerns. The population of the most polluted areas suffers from high levels of anemia, tuberculosis and cancer. Children suffer from liver, kidney and respiratory diseases, micronutrient deficiencies, cancer, immunological problems and birth defects.

Climate change is virtually irreversible, and it hits the water sector the hardest. Its effects, including higher temperatures, more frequent droughts and earlier snowmelt, have a significant impact on water availability. The rapid melting of glaciers is currently increasing water flows in some basins, but this effect is expected to be reversed in a few decades. Climate change in Central Asia is a game-changer: it accelerates negative trends such as declining water availability and directly affects the socio-economic development of the region. This change is not linear, but exponential, and its effects are exacerbated by another exponential change – the rising costs of restoring, upgrading and maintaining the deteriorating regional water infrastructure. These two accompanying processes represent a strategic challenge for the region (Figure 1).

To assess regional climate changes, a series of general circulation models for both the atmosphere and the ocean are commonly used. Various models or combinations of models are typically employed to construct climate change scenarios. In Uzbekistan, for instance, data from six models were averaged: CGCM1-TR, CSIRO-TR, ECHAM4, HadCM3, CCSR-NIES and GFDL-TR. The software MAGICC/SCENGEN 4.1 was utilized for the analysis.

Table 1 provides estimated data on climate change scenarios for Central Asian countries using temperature and precipitation indicators. These scenarios offer possible representations of climate change in Central Asia for the periods up to 2030, 2050 and 2085 compared to the base period of 1961–1990.

In some countries, data from all four greenhouse gas emissions scenarios are considered and averaged (RCP-50 – medium scenario), while in others, scenarios A2 (pessimistic) and B2 (optimistic) are used. This section of the report is entirely based on the results presented in the national reports of five countries.

Impact and vulnerability to climate change

Vulnerability is determined by the extent to which a system can be damaged or harmed as a result of adverse impacts. Vulnerability is assessed based on susceptibility to impacts, sensitivity and the ability to adapt. In other words, when assessing vulnerability, it is essential to evaluate the impact of climate change on a specific sector, the sensitivity of that sector to such changes, and ultimately, the capacity to adapt to anticipated changes.

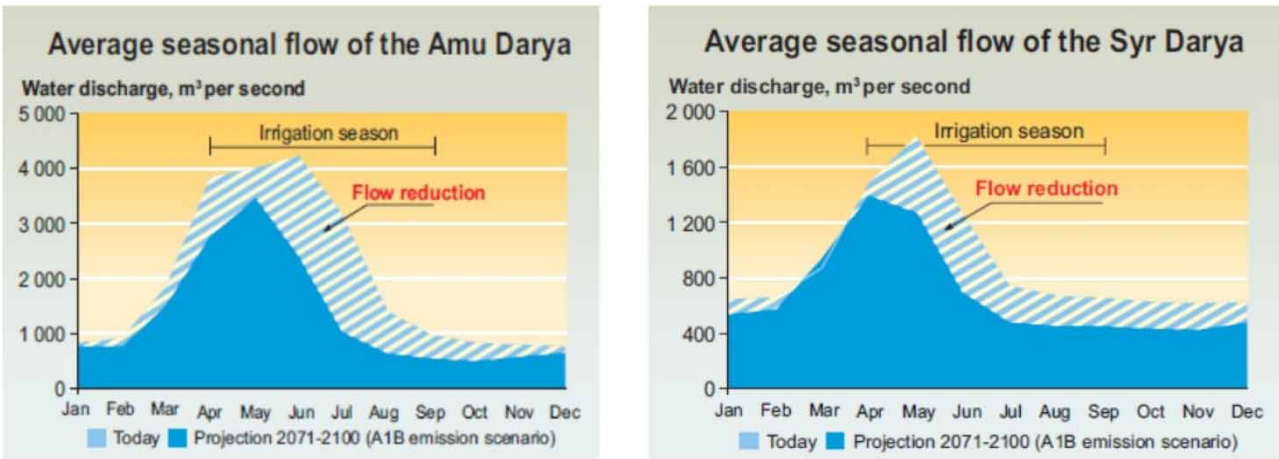

Figure 1 | Projections of average seasonal flows of the Amu-Darya and Syr-Darya rivers.

Table 1 | Scenarios of temperature and precipitation changes for Central Asia

A country	2030	2050	2085
Kazakhstan	T: +1.4 °C	+2.7°C	+4.6°C
	P: +2%	+4%	+5%
Kyrgyzstan (A2;B2)	T: –/ –	–/ –	6.1°C; 4.6°C
	P:		−2.2%; +8/3%
Tadjikistan	T: +0.2–0.4 °C P: +2%	–/ –	–/ –
Turkmenistan	T: –/ –	–/ –	+4.6–5.5°C
	P:		−17–56%
Uzbekistan (B2)	T: 1.2°C	2.2°C; 4.0%	3.3°C
	P: 2.0%		3.5%
Average for CA	T: 1.02°C	3.1°C	4.7°C
	P: 2.0%	4.0%	−2%

Note: T – temperature; P – precipitaion; –/– – no data found.

Adaptation potential is defined as the 'capability of a system to adjust its characteristics or behavior to broaden the range of challenges it can withstand due to current or future climate change or climatic conditions'.

This chapter employs the research frameworks described above. Data on vulnerability to climate change in Central Asian countries are presented in Table 2. The table provides descriptions of impacts, vulnerability and adaptation potential of Central Asian countries in addressing the consequences of climate change. Data are drawn from multiple sources, second national communications and vulnerability analysis. In the long-term assessment of vulnerability to water resources, a significant reduction in the Central Asian region is possible largely due to glacier melting. According to an interim report from national climate change studies, it is expected that river flows in the Aral Sea basin will decrease by 10–20%. Simultaneously, water consumption levels will increase due to population growth and economic development.

WATER RESOURCES AND AGRICULTURE

The significance of water and the agricultural sector for Central Asia cannot be overestimated. Water is essential for the region's survival. The agricultural and water management sectors are closely intertwined in the Central Asian region, as over 90% of the region's water resources are used for irrigation agriculture. This sector contributes to 30% of the regional GDP and employs over 60% of the workforce. According to official data, 70% of projected damages from adverse weather and climatic conditions are expected to affect the agricultural sector. As an example of climate's impact on living conditions, we can mention the consequences of the 2008 drought in Tajikistan. In that year, wheat crop yields dropped by 30–40%, forcing many farmers who did not achieve their planned harvest to sell their livestock.

Cotton production has traditionally been the cornerstone of agricultural production in the region, but there has been a recent trend toward grain production. Uzbekistan, for example, is the world's second-largest exporter of raw cotton, selling approximately 800,000 tons of this commodity annually. In Tajikistan, two-thirds of the population depend on the outcomes of agricultural production. About two-thirds of the agricultural production in Tajikistan requires irrigation, yet the majority of farmers still practice rainfed agriculture, which is even more vulnerable to drought and climate change impacts. Table 3 provides statistics on the share of agriculture in the economies of the region.

Under the current climatic conditions, the risky nature of agriculture and its dependency on irrigation is increasing the need for modernizing irrigation systems and enhancing the efficient use of water resources. The agricultural production system must be prepared to cultivate new agricultural crops better adapted to new climate conditions, soil composition and moisture levels. One of the primary signs of the decline in the agricultural sector is the migration of rural inhabitants to cities due to extreme difficulties or an inability to maintain a decent standard of living in rural areas. For instance, in Kazakhstan, urban and suburban areas rapidly formed, creating problems not only for urban municipalities but also luring labor away from the agricultural sector.

Table 2 | Regional impacts and vulnerability to climate change in Central Asia

Impact (T and R)	Vulnerability by sector
Temperature	Water resources
- Under scenario A2 (pessimistic), by the end of the 21st century, the increase in average annual air temperature compared to the baseline period (1960–1990) will range from 4.7°C in Kyrgyzstan to 5.5°C in Turkmenistan (Table 1)	- In Kazakhstan, for example, by 2030, water resources in mountainous areas will increase between 0.8 and 4.5% to 14.0–22.5%, while in the lowlands there will be a decrease in 7.0–10.3%.
- Under scenario B2 (optimistic), the expected increase in annual air temperature will be 1–1.5% lower than under scenario A2. For example, in Uzbekistan, the long-term average temperature increase is expected to be +4°C for A2 and +3.3°C for B2.	- In the short term (until 2030), water resources in the Amu-Darya basin may decrease from 5 to 8% compared to the current level, while deviations will be minimal for the Syr-Darya basin.
Precipitation	- By 2050, water runoff in the Amu-Darya and Syr-Darya basins will dry up from 10 to 15% and 6 to 10%, respectively.
- Precipitation scenarios are ambiguous. While an increase in precipitation is expected in winter until the end of this century, a decrease in summer precipitation can be expected in some areas.	- In the northern plains of Central Asia, water resources will decrease by 6–10% by 2030 and 4–8% by 2050.
Extreme events	Agriculture and ecosystems
- Increased risk of dangerous and extreme hydrometeorological phenomena such as hail, drought, extremely high or low temperatures, etc., which will cause an increase in the frequency of emergencies, including heavy rainfall, mudflow floods, landslides, avalanches, floods and droughts, and earthquakes.	- The main water stresses in Central Asia will be in the irrigated agriculture sector, resulting in overall productivity declines in the range of 15–50%.
	- Livestock productivity will decline with a reduction in pasture land and a 30% reduction in the fertility of existing pastures.
	- Water scarcity and droughts will severely affect water availability for natural resources in general, resulting in loss of biodiversity, deterioration of water quality, increased risk of forest fires and loss of soil fertility.
	Hydropower
	- Under the most unfavorable climate change scenarios, the total hydropower potential of the rivers flowing into the Issyk-Kul River could be reduced to more than half of its former level by 2100.
	Health
	- Increase in infectious diseases and incidents of infection, including malaria.
	- Increase in circulatory diseases, malignant neoplasms and cardiovascular diseases.
	- Increased risks of heat and cold stress in the population.
	- Increase in gastrointestinal diseases in areas of inadequate water supply, especially in rural areas.
	Glaciers
	- Between 1957 and 1980, glaciers in the Aral Sea basin lost 115.5 km^3 of ice, equivalent to about 104 km^3 of water. The losses amounted to almost 20% of the total ice reserves available as of 1957.
	- In Tajikistan, for example, the country's snow cover could decrease by 20% and glacier area by 25–30% during the current century.
	Mudflows
	- An increase in mudslides is possible;
	- With climate warming by 2–30°C, the upper boundaries of watersheds will rise to above 4,000 m and the watershed area will increase several times, which will turn out to be a potential source of mudflows.

Table 3 | Share of agriculture in Central Asian countries (employment and GDP)

A country	Percentage of the population employed in agriculture	Share of agriculture, % of GDP	Main export goods (agriculture)	
Afghanistan	67%	53%	Wheat	
Kazakhstan	<10%	<10%	Cereals	
Kyrgyzstan	55%	35%	Cotton, garden, crops	
Tadjikistan	–	25%	Cotton	
Turkmenistan	–	30%	Cotton	
Uzbekistan	40%	20%	Cotton, cereals	
	Area (thousand hectares)		Production volume (thousand tons)	
A country	Irrigation[a]	Cotton[b]	Cotton	Garden crops[c]
Afghanistan	1.5	<20 (1%)	<15	–
Kazakhstan	3,450 (16%)	200 (6%)	180	5.3
Kyrgyzstan	1,050 (77%)	<30 (3%)	48	2.45
Tadjikistan	630 (68%)	220 (35%)	172	1.6
Turkmenistan	1,750 (94%)	540 (31%)	219	1.2
Uzbekistan	3,990 (89%)	1,450 (36%)	1.17	5.75

[a]The percentage of irrigated arable land is indicated parentheses.
[b]The percentage of irrigated land occupied for cotton crops is indicated parentheses.
[c]Fruits, vegetables, root crops and tubers.

The water management sector will experience the harshest consequences of climate change in situations involving the management of transboundary water resources. This is because different methodologies are used by countries for assessment, and complexities arise in joint management of transboundary waters. Water in Central Asia is an extremely politicized issue due to its uneven distribution among countries. The figure below vividly illustrates the situation, which exacerbates the atmosphere of regional negotiations on water resource issues. The level of mutual trust among participants in such negotiations is extremely low. According to the International Crisis Group, there are several reasons for these conflicts.

The unified regional water supply system was established during the Soviet Union but is now managed by five independent states.

The economies of Central Asian countries are primarily based on irrigation agriculture, and income is distributed exclusively among the elites of each country, which entrenches their hold on power.

Central Asian countries quickly adopted positions on water resources that were advantageous to each of them individually, simultaneously increasing consumption to unsustainable levels.

Countries located downstream of rivers, militarily and economically stronger, compared to those located upstream, which has led to an asymmetric distribution of power, particularly evident when water disputes arise.

From Figure 2, it is evident that there is a significant imbalance between upper and lower reaches. In addition to transboundary issues related to water distribution, trends such as the growth in communal water consumption, driven by population growth and economic development, the absence of an acceptable agreement on transboundary water resource management and the projected increase in annual average air temperatures are also manifesting. All of these issues further exacerbate the problem of water resource scarcity in the Aral Sea basin.

Priorities of planned climate adaptation measures

According to Table 4, the priority climate adaptation measures proposed in the water resources and agriculture sectors in Central Asia are mainly focused on preventive measures to reduce the level of impact and vulnerability to the consequences of climate change. These measures include improving water resource management at the national and transboundary levels, increasing the efficiency of water resource use, especially in irrigation agriculture, expanding the list of cultivated crops and rational utilization of pasture lands. It is also noted that reservoirs on mountain rivers and protective engineering hydraulic structures should be designed with the goal of addressing glacial melt. This emphasis on primarily taking preventive measures

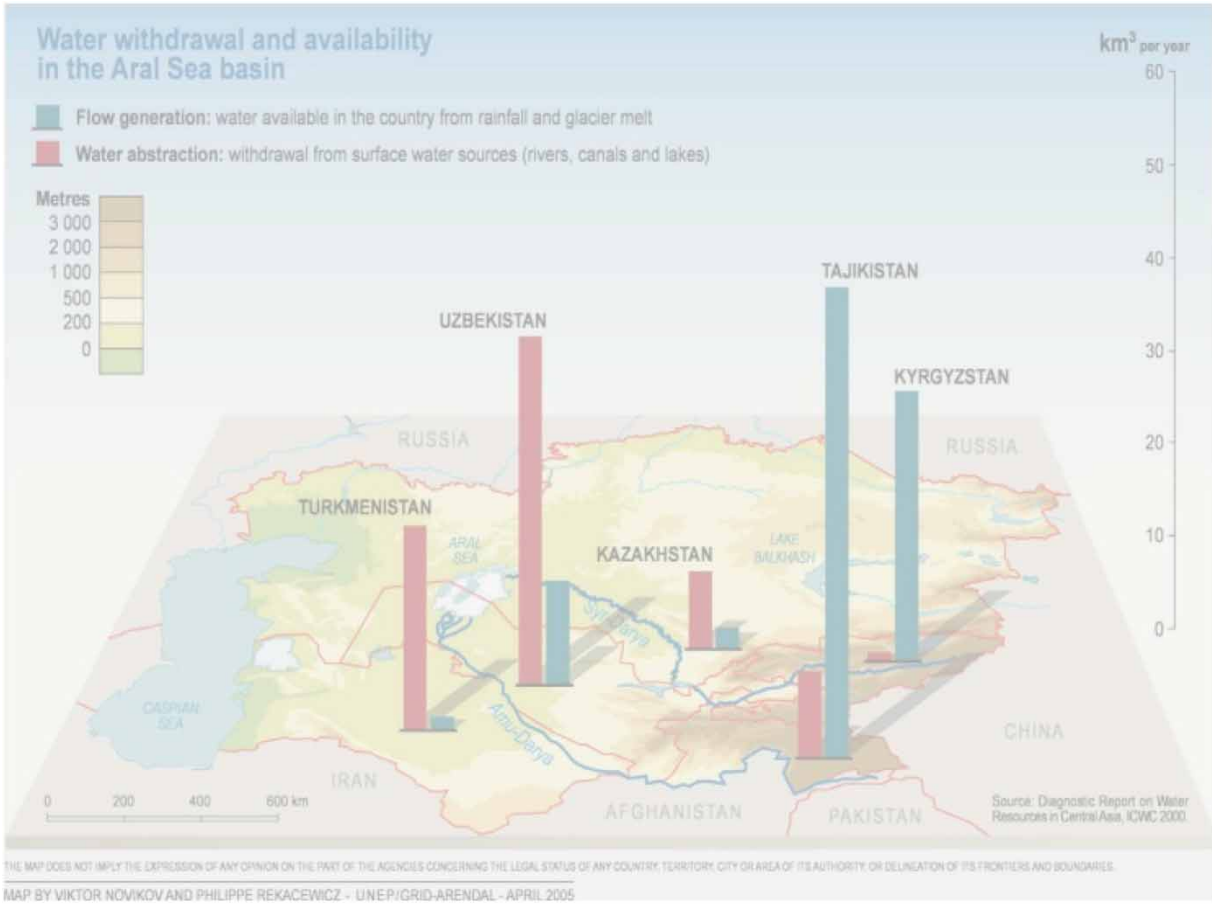

Figure 2 | Water withdrawal and availability in the Aral Sea basin.

indicates that the governments of Central Asian countries are attempting to address current issues that mainly improve the planning and management process, as well as enhance technical, technological and scientific capacity. Table 4 compiles a register of planned climate adaptation measures, as outlined in the National Communications of each country in the region.

Climate change is leading to fundamental changes in the global economy: the decarbonization of production and consumption. The countries of Central Asia, which are heavily dependent on exports of commodities – primarily energy and ore – must invest in diversifying their economies while coping with the consequences of 30 years of under-investment in water infrastructure. If the region fails to meet these strategic challenges, it could face a severe and irreversible collapse in services that would threaten its stability and security. A better managed water sector can play a critical role in the sustainable recovery of the region. It can provide a solid foundation for economic growth, prosperity and the reduction of social, economic and environmental inequalities.

Achieving long-term energy security at a time of growing international pressure to decarbonize economies is a key challenge for Central Asia. Increasing the share of renewable hydropower in the energy balance of the region is also closely related to the development of irrigation and environmental protection. Kyrgyzstan and Tajikistan have huge hydropower potential but still often face energy shortages during the winter.

According to the United Nations Special Program for the Economies of Central Asia (SPECA), only 6% of hydropower potential is currently used in Central Asia. The full development of the planned cascades of large hydroelectric power plants will increase the export potential of these two countries. The export of cheap and clean electricity through the trade and energy corridor Central Asia – South Asia to Pakistan will contribute to the economic development of Afghanistan – helps to strengthen regional stability and security. The capacities created as a result of many years of regulation on

Table 4 | Main planned climate change adaptation measures in water and agriculture

Country	Main planned climate change adaptation measures
Kazakhstan	- Sustainable management of irrigated (southern regions) and rainfed (northern regions) agriculture (crop rotation, water saving, irrigation system);
	- Improve transboundary water resources management, since almost half of the country's annual runoff comes from neighboring countries (water consumption norms, bilateral and multilateral agreements, IWRM);
	- Adapt the coastal zones of the Aral and Caspian Seas and Lake Balkhash;
	- Implement IWRM at national and regional levels;
	- Diversify and improve sustainability of grazing practices.
Kyrgyzstan	- Improve management of river surface runoff;
	- Improve irrigation system efficiency (e.g. by minimizing water losses);
	- Introduce economic incentive mechanisms for better water management.
Tajikistan	- Improve the efficiency of water resources use in the irrigation system – drip irrigation and spray irrigation;
	- Develop and implement measures to improve the efficiency of water resources use;
	- Cultivate crops that are resistant to drought and soil salinity (Tajikistan UPE, Oxfam reference, 2010).
Turkmenistan	- Increase the efficiency of the irrigation system;
	- Use additional sources of water resources, such as low-salinity drainage water, groundwater and treated industrial and municipal wastewater;
	- Increase water storage capacity (build new dams).
Uzbekistan	- Improve the efficiency of irrigation system and water conservation;
	- Increase crop yields and livestock productivity;
	- Transboundary water resources management;
	- Implement IWRM at all levels;
	- Develop better management systems in the water sector;
	- Combat soil degradation;
	- Adopt preventive measures in the health sector;
	- Create conditions for preserving and maintaining lake and river ecosystems.

the two main rivers of the region will significantly increase the resilience of the countries of Central Asia to climate change.

The small economies of the upstream countries (Kyrgyzstan and Tajikistan) are unable to attract the huge amount of investment needed to fully develop their hydropower potential. Strengthening regional cooperation, including an agreement on joint ownership, control and investment in regionally significant water infrastructure, will help attract climate and green development funds, as well as private investment. Governments are fully aware of the capital-intensive nature and long payback period of infrastructure investments. Stable agreements and close cooperation between trusted parties are a sine qua non for a favorable investment climate. The implementation of joint projects in the water and energy sector will multiply the successes of recent years and will bring great benefits to all countries. Such projects have many advantages:

- producing cheap, renewable, clean energy to meet growing demand;
- achieving water security and guaranteed, timely releases of water for irrigation in each country of Central Asia, even in the face of climate change, through the construction of reservoirs capable of long-term and seasonal regulation;
- saving oil, gas and coal reserves, which are now intensively used for electricity generation;
- reducing CO_2 emissions;
- reducing the risks caused by extreme weather conditions such as droughts and floods, which cause significant damage every year.

Achieving sustainable water management even under the most conservative climate change scenarios will require coordinated efforts in several areas: managing demand by increasing water productivity, developing multi-year storage facilities to

ensure adequate supply during dry years or during droughts, and creating a modern institutional and legal framework to ensure joint and integrated water resources management (IWRM) at the national and transboundary levels. A new vision, culture and mentality for regional cooperation need to be developed: governments should choose green, forward-looking, cross-border and regional solutions if they offer the best results in the interests of more than one country. According to a recent study by Adelphi[1] and CAREC (2023),[2] the cost of the difference between current limited cooperation on water and the benefits that could come from full cooperation is more than US$4.5 billion per year for Central Asia.

Improved water management and enhanced regional cooperation are essential to achieve the Sustainable Development Goals (SDG 6.5) calls for the implementation of IWRM at all levels by 2030, including 'through transboundary cooperation where appropriate'.

When planning further actions, experts and politicians are fully aware of the need to improve regional cooperation on water, including the need to improve existing legal and institutional frameworks. All countries in the region have begun to adopt the principles of IWRM, but efforts to strengthen regional cooperation on water – such as the development of a water-energy consortium or the institutional and legal strengthening of the International Fund for Saving the Aral Sea – have been hampered, in particular by the lack of human potential. For the same reason, the countries of Central Asia have not been able to agree and implement new joint regional solutions to the problems of the water sector.

The lack of human potential, the small number of experts and researchers with comprehensive knowledge of the problems of the water sector, has become the main stumbling block on the path to achieving economic and environmental sustainability of the water sector in Central Asia. Countries in the region spend less on research and education in the water sector as a percentage of their GDP than any other region in the world. With rare exceptions, the sector fails to offer competitive wages and attractive career opportunities for young people, further exacerbating the shortage of skilled workers. The historical roots of the current problems go back more than 30 years.

An introduction to the topic cannot be complete without mentioning the work of scientists in this field. Many researchers, including Bernauer & Siegfried (2012), have considered water resource management in the context of global climate change, but focusing on the specifics of Central Asia remains an important point that requires more detailed analysis.

In conclusion of the introduction, it should be noted that the creation of an educational program in the field of water management can be a key element in the strategy of adaptation of Central Asia to climate change.

MATERIALS AND METHODS

Costs of economic and political transformation in the water sector

As the first stage of the study, the authors performed an extensive review of the scientific literature. This provided an insight into existing water management practices, as well as identified problems and proposed solutions in the context of climate change in Central Asia. Works devoted to the issues of water resources management, climate change, as well as educational programs in this area were studied.

To obtain data on the current state of water resources and problems of their management in Central Asia, the authors used reports from international organizations such as the World Bank, Food and Agriculture Organization (FAO) and Intergovernmental Panel on Climate Change (IPCC), as well as national statistical data from the countries of the region.

Surveys and interviews were conducted with experts in the field of water management and climate change from educational institutions, scientific institutions and government organizations in Central Asia. This made it possible to identify the attitude of specialists to the problem and to obtain information about the needs for education and training.

After gaining independence, the countries of Central Asia inherited an integrated water and energy system from the Soviet Union. Large reservoirs in the upstream countries (Tajikistan and Kyrgyzstan) stored water during the winter and released it during the growing season to meet the needs of irrigated agriculture in the downstream countries (Kazakhstan, Turkmenistan and Uzbekistan). Downstream countries imported summer electricity from their upstream neighbors and provided them with energy and fossil fuels during the winter. While the countries of Central Asia have trained generations of world-class

[1] Europe's leading independent think tank on climate, environment and development https://www.adelphi.de/en

[2] The Central Asia Regional Economic Cooperation (CAREC) Program is a partnership of 11 countries and development partners working together to advance development through cooperation

hydraulic engineers to build and manage vast water infrastructure in the region and in the rest of the world, thanks to Soviet Union development cooperation and decolonization efforts, management and decision-making on economic, financial and investment questions remained in the hands of Moscow.

After 1991, with the emergence of five independent countries, the integrated system of regional water resources management gradually disintegrated: neither the weak legal framework, consisting of about 30, sometimes conflicting agreements and declarations, nor the emerging and poorly functioning market, could guarantee the timely release of a sufficient amount of water during the irrigation season. The upstream countries, under economic and social pressure, were increasingly forced to switch their large reservoirs from irrigation to energy mode in order to provide their population with energy in the winter.

The political and economic transformations that began in 1991 led to a sharp drop in the GDP of the countries of Central Asia. The water sector was hit particularly hard, from which it has not yet fully recovered. As a result of 30 years of underinvestment, the region's water infrastructure is being destroyed, resulting in huge losses of water during transportation and storage. The World Bank estimates that 79% of irrigation water is lost along the way or during storage. The introduction of modern water-saving technologies in agriculture is hampered by insufficient private investment. According to an Asian Development Bank (ADB) in the Kyrgyz Republic study, the countries of Central Asia need to invest $33–38 billion annually in the proper maintenance, operation and modernization of regional water infrastructure, which is far beyond the capacity of their economies.

Based on the data collected and the analysis performed, we developed the concept of an educational program in the field of water management, adapted to the conditions of Central Asia. During the development process, the authors considered the opinions of experts and studied the experience of existing educational programs.

To assess the potential impact of the proposed educational program on the resilience of the region to climate change, a SWOT analysis model was applied. This method made it possible to assess the strengths and weaknesses of the program, as well as the opportunities and threats associated with its implementation (Table 5).

In concluding this section, it should be noted that the methods used were selected based on their reliability and applicability to achieve the objectives of the study. Data collection, literature analysis, surveys and interviews with experts, as well as the development of the educational program concept and its evaluation, allowed us to obtain a comprehensive understanding of the problem and offer reasonable recommendations for its solution.

Results and consequences of political and economic transformations in higher education

According to the analysis of data from reports of international organizations and national statistics, water resources in Central Asia are under threat due to climate change. There is a trend towards a decrease in the volume of surface waters and the drying up of some water bodies.

The results of surveys and interviews with experts have shown that the existing mechanisms for managing water resources do not always adequately respond to climate change. Problems have been identified, such as the imperfection of the legislative framework, the lack of qualified specialists and the limited technical resources.

Most experts agreed on the need to strengthen the professional training of specialists in the field of water resources management. Key competencies needed to work effectively in the face of climate change were identified.

As a result of the analysis, the concept of the educational program was developed, which includes the following modules: basics of hydrology, water resources management, adaptation to climate change, legal regulation and international cooperation.

The SWOT analysis showed that the proposed educational program has a number of strengths, including the relevance and complexity of the approach. However, weaknesses were also identified, such as the need for funding and the possible difficulties of incorporating into existing educational structures.

Table 5 | SWOT analysis of the educational program

Strengths	Weaks	Opportunities	Threats
Relevance	Need for funding	Improved water management	Difficulties of implementation
A complex approach		Interaction with international partners	

Based on surveys and interviews with experts, the authors identified the following key competencies that should be included in the educational program:

- understanding of hydrological processes;
- knowledge of the principles of sustainable water management;
- knowledge of climate change adaptation measures;
- data-driven decision-making skills;
- possession of methods for monitoring and assessing the state of water resources;
- understanding of the legal framework for water management and international cooperation.

The proposed concept of the educational program includes the following elements:

- theoretical courses on hydrology, water management, climate change and legal regulation;
- hands-on activities including labs, modeling and data analysis;
- field work to observe and study the real conditions of water management;
- interaction with international experts and organizations through seminars and webinars;
- preparation of projects and case studies in the field of water management.

The analysis identified potential partners that can contribute to the implementation of the educational program, including universities, research institutes, government bodies and international organizations.

In this section, the results of the study were presented in a clear logical sequence. In the next section, we will discuss these findings and their implications for water management in Central Asia in the face of climate change.

The educational systems of the countries of Central Asia have also seriously deteriorated during the transition process. Creating national higher education systems has proven to be a difficult task: numerous inconsistent national reforms, insufficient funding for education and research, a gap between education and work in the 'real sector', low incentives for qualified professionals to teach and less than inspiring career opportunities for young people who have just graduated from higher education can be named among the problems generated by the difficult transition period.

With few exceptions, the existing higher education systems in the countries of Central Asia need significant improvements and comprehensive assistance to be able to meet the needs of the economy and public services, in particular the water sector, and improve the performance of their graduates. A comprehensive review of academic and scientific research related to water resources in the countries of Central Asia, prepared under the Central Asia Water and Energy Program (CAWEP) with the support of the World Bank, the European Union, the Swiss Development Cooperation and UKAID in 2019, indicates: 'One should recognize that with independence at the end of the 20th century, the demand for higher education increased in all countries of Central Asia, which was accompanied by rather low requirements for the quality of professional skills of specialists in many sectors of the economy'.

Political sovereignty and the liberalization of the legal field have opened wide opportunities for the creation of many universities, often without appropriate justification since the main purpose of their creation was commercial interest. For example, in the UK there are only 160 higher education institutions per 67 million citizens, in Kazakhstan there are 133 institutions (including branches in other cities) per 20 million people and in the Kyrgyz Republic with a population of 7 million people there are 64 different higher education institutions.

Since the beginning of the 1990s, the teaching staff and employees of universities and research institutes began to suffer first quantitative (expected), and then qualitative losses. In addition, if we take into account the significant increase in the number of university teachers hired to cover the needs of education, it turns out that this happened simultaneously with a decrease in the qualification requirements for teachers. Economic transformations in the countries of Central Asia and various ways of their political and economic development – from wide privatization (Kazakhstan, Kyrgyzstan) to a rigidly centralized system of state administration (Turkmenistan) – which aggravated disintegration processes in many areas of cross-border cooperation between countries and significantly weakened academic ties and academic mobility among the universities of Central Asia'.[3]

[3] https://documents1.worldbank.org/curated/en/199621582301598583/pdf/Review-of-Water-Related-Academic-and-Research-Capacity-in-Central-Asian-Countries.pdf

The role of higher education in translating political will into specific action

In recent years, regular consultative meetings of the presidents of the Central Asian countries are a convincing demonstration of the emergence of political will to strengthen regional cooperation on water resources. There are grounds for hope. The Joint Statement following the Consultative Meeting of the Heads of State of Central Asia in the Avaza National Tourist Zone (Turkmenistan) in 2021 puts water and energy at the center of a renewed climate for regional cooperation.

Translating high-level political will into action is critical to achieving long-term water sustainability. Preparing and conducting the complex interdisciplinary, intersectoral and intercountry dialogues needed to strengthen regional cooperation on water requires a new generation of highly qualified water management experts and water diplomats. In addition to water engineers, Central Asian countries need to train managers and diplomats who have in-depth knowledge of the economic, financial, institutional, legal and political aspects of water management, in addition to knowledge of technical issues and environmental considerations. It is also necessary to develop critical thinking abilities and teach basic social science skills. As an elective, modules on conflict management, relevant geopolitical and geo-economic processes and an introduction to multilateral diplomacy at international forums and organizations on climate and green development should be offered. In connection with the above circumstances, the idea of the project arose – the creation of a master's program for the training of water management experts and water diplomats.

General goals of the project

The experts involved in the project will update and introduce innovative elements into existing curricula or create new innovative curricula for MA/MSc programs inspired by the best European experience and practices and adapted to regional conditions and requirements. The project will enable the universities of Central Asia to develop high-quality programs to train a new generation of managers and decision makers for the water sector with the support of EU partner universities, local and international organizations and stakeholders.

Needs analysis

The educational systems in Central Asia have suffered greatly from the transition, and especially the social sciences (required for teaching water management and diplomacy) are still very weak (see Arnell 2004; Adamkulova 2022; Hadri *et al*. 2022). During the Soviet era, methodological and theoretical pluralism, as well as independent empirical research, were not part of the curriculum. Also, while technical disciplines such as hydraulic engineering were well connected to global academic discourses, the social sciences were not (Brown & Lall 2006). Therefore, knowledge about the social, political and economic aspects of water management is much less than about the technical ones. However, in the light of new approaches to water resources management and governance, such as IWRM, basin management or nexus approaches, the skills of coordination, conflict resolution and participatory decision-making are essential.

The two-year research program 'Water as a driving force for sustainable recovery: economic, institutional and policy aspects of water management in Central Asia', implemented with the joint support of Corvinus University Budapest (CUB), SDC's Blue World Central Asia initiative, Stockholm International Water Institute and the Regional Environmental Center Central Asia, which has brought together more than 100 leaders, experts and researchers from the region so far, recommends increased investment in human development as a significant contribution to achieving resilience to climate change and the resulting water stress.

As explained in the World Bank survey of academic and research capacity in the field of water resources in the countries of Central Asia in relation to Tajik universities,[4] 'there is a need for a radical revision of the curricula in almost all of the above-mentioned universities', and further: it is necessary to 'improve the quality of university management, the content of curricula, faculty, organization of the educational process, research and innovation, international cooperation, information and methodological support, educational technologies and tools, social, educational and extracurricular activities' (World Bank 2014). These recommendations are also relevant for other Central Asian countries. Indeed, the section on Uzbekistan establishes, among other things, the following requirements 'for economic and organizational and managerial competencies:

- fundamentals of economic knowledge, scientific understanding of management, marketing, finance, etc.

[4] Krasznai 2021, 99.

- knowledge and understanding of the goals and methods of state regulation of the economy, the role of the public and private sectors in the economy'.

The document also notes that 'cooperation between the academic institutions of the countries of Central Asia is insufficient, which hinders the development of academic mobility of students and scientific personnel'.[5]

Strengthening human capacity building is seen as a sine qua non for bridging the growing gap between investment needs and available resources, which seriously hampers the efforts of Central Asian countries to build climate resilience and achieve long-term water security. As a result of the one-sided qualification and training of experts, the 'engineering approach' continues to dominate. Due to the lack of human potential, the development of a comprehensive economic basis for regional cooperation on water remains difficult to achieve, which hinders the achievement of rational and efficient use of common transboundary water resources through mutually beneficial interstate cooperation.

RESULTS AND DISCUSSION

Water management in Central Asia has long been the subject of research by many scientists such as Cooley *et al.* (2013) and Cooley *et al*. (2011), who drew attention to the complexity of managing transboundary water resources in the face of climate change. Much of the earlier research has focused on policy and infrastructure aspects, while our research focuses on the value of educational programs.

One of the key findings is the identification of the competencies that are required for professionals in water management. This reflects the importance of having well-trained professionals able to adapt and apply management strategies in the challenging environment of climate change.

Based on the results, we can conclude that cooperation between various institutions and organizations is a key factor in the creation and implementation of an effective educational program. This is in line with the work of Bernauer & Siegfried (2012) who stressed the importance of regional cooperation in water management in Central Asia.

Of particular importance is the observation that the educational program should include practical elements such as field work and case studies. This can provide students with the opportunity to apply theoretical knowledge in practice, which is important for real conditions of working with water resources.

Surprisingly, it turned out that some potential partners expressed concerns about possible financial and organizational difficulties in implementing the program. This indicates the need for careful planning and the possibility of attracting additional sources of funding.

The results confirm the initial hypothesis that the development and implementation of an educational program in the field of water management can help to increase the resilience of Central Asia to climate change.

In general, this study reveals a number of important aspects related to education and water management and suggests concrete steps to implement an educational program in Central Asia, taking into account climate change.

When analyzing existing approaches to water management in Central Asia, the work of Sorg *et al.* (2012) focused on the impact of climate change on water resources in the region. In contrast to this work, our study focuses on the role of education in building resilience to climate change. This shows that the issue of water resources management in Central Asia is multifaceted and requires an integrated approach.

The results of our study indicate the possible positive impact of educational programs on local communities. Training of professionals capable of developing and implementing effective water management strategies can improve the adaptation of local communities to climate change and reduce the risks associated with water scarcity.

It is important to pay attention to ways of further development of the program. Based on the results, we propose to strengthen ties with international organizations and educational institutions for the exchange of knowledge and experience. It is also worth considering the introduction of innovative technologies in the educational process, such as distance learning and the use of modern simulators to simulate various scenarios of climate change.

As a result of our research, the importance of education in managing water resources in Central Asia, considering climate change, becomes apparent. Increasing the competence of specialists, cooperation with various stakeholders and the introduction of practically oriented elements in the educational program can become the basis for creating a more sustainable and climate-adapted water management system in the region.

[5] Krasznai 2021, 101.

Update existing or develop new curricula for universities in Central Asia to help train a new generation of water management experts and water diplomats with the support of CUB in collaboration with IHE Delft (UN-IHE), University of Bergamo (UB), The German-Kazakhstan University (DKU) and the University of Reims (URCA) will provide significant advantages in a number of areas:

- Revised or new training materials will balance the concerns and interests of each country and convincingly describe the benefits of innovative green approaches and regional water cooperation.
- A comprehensive and open discussion of key strategic issues in the region by students of partner universities would help to strengthen the culture of open democratic scientific debate and civil society participation.
- The development of coherent, harmonized curricula for universities in all five countries will facilitate student mobility between Central Asian universities and their EU partner institutions.
- By integrating research and discussions on regional water management issues into the Master's programs and the regional continuing professional development and research program, the universities of Central Asia and their European partners will create a broad network for research and scientific innovation.

The new courses will increase employability and open attractive career opportunities for graduates who will be able to combine work in the water sector with assignments in other government sectors such as ministries of foreign affairs, the economy or the environment, in the private sector, regional organizations and institutions, with work for abroad, in specialized UN agencies or other international organizations and development partners. The water sector will once again be able to attract the brightest and most motivated young people.

The project aims to develop new innovative curricula or reform and introduce innovative elements into existing curricula, providing two areas of specialization at the MSc level (water management and water diplomacy) and strengthening links between higher education and the economy and society. Updated or new curricula will place more emphasis on developing critical thinking skills, reading and working with academic texts and approaches, and introducing more interactive learning, as it will be difficult to make the proposed new courses effective without addressing existing shortcomings. Developing new, innovative curricula and starting the accreditation process within three years is an ambitious and challenging, but still doable task.

CONCLUSION

Updated or new master's curricula and the regional Continuing Professional Development and Research Program will actively engage the business community and leading economic research institutions to provide knowledge tailored to the needs of the private sector.

A new generation of managers and decision makers (as well as businessmen) with deep knowledge of the economic and financial aspects of water management will play an important role in attracting private investment in the modernization, maintenance and operation of the region's vast water infrastructure, which is now almost entirely owned by governments. They could actively participate in the development and implementation of structural and institutional reforms of the economy that would improve the business and investment climate and thus help attract private investment in the water sector.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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