

Water Management in Turkestan Region

by

Anel Baken,
Bauyrzhan Zhomart,
Serzhan Katayev

Supervisor

Dr. Aliya Assubayeva

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Abstract

The problem of water scarcity is worldwide, with the increasing demand, population increase, and climate change, and therefore the water accessibility became one of the key priorities of Sustainable Development Goal 6. The natural availability of water, combined with infrastructure age, is putting an even greater strain on the water systems in Kazakhstan. In this background, there has been a fast urban growth in Turkestan, a semi-arid area in the southern side of Kazakhstan, with the population of the city growing by 42 percent between 2017 and 2024 (Bureau of National Statistics, 2024). Local authorities responded by initiating large-scale infrastructure projects, beginning in 2021, such as canal restoration, reservoir development, mechanized water transfer along the Syr Darya river.

This paper investigates (1) the measures that the Turkestan Administration has put in place to deal with water scarcity and (2) the perception of stakeholders on effectiveness of such measures. The data were gathered by a qualitative method, in which 25 semi-structured interviews were organized with the residents, farmers, enterprises, officials, and water-sector, environmental experts, supplemented by a document analysis and observation in the field. Results show there is modernization and conformity to national policy priorities, but the continued limitations in governance and implementation. Whereas authorities stress infrastructure successes and documented water savings, analysts and water consumers magnify massive physical losses, incomplete monitoring, lack of data transparency and institutional capacity gaps between agencies. The paper concludes that there is inadequate infrastructure-based solutions without governance, monitoring systems, and involvement of stakeholders.

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1. Introduction

1.1 Background and problem statement

Access to reliable and safely managed water resources is one of the global challenges. Increasing water demand, increasing population and climate change all together led to water scarcity around the world. Subsequently, the United Nations prioritized universal access to clean water and sanitation under Sustainable Development Goal 6. According to the UN World Water Development Report 2023, global water use has been increasing by about 1% per year for the past 40 years and is expected to grow at this rate until 2050.

Kazakhstan also faces increasing pressure on its water systems due to rapid urbanization, aging infrastructure, and declining natural water availability. The situation is further exacerbated by transboundary water factors, in particular, the implementation of the Afghan Kush-Tepa project on the Amu Darya River, which involves the redistribution of water flow in favor of the northern provinces of Afghanistan (Tsiryapkina, 2025). The expected reduction of water resources in the lower reaches of the Amu Darya increases regional water tensions in Central Asia and requires the basin States, including Kazakhstan, to accelerate the modernization of water management and transition to more economical methods of water use (Mustafabeyli, 2024). Within this national context, Turkestan region, which is also known with its aridity, stands out as one of the rapidly growing regions in the country. After Turkestan city's designation as a city of national significance in 2018, Turkestan region has experienced accelerated population growth, urban expansion, and rising tourism inflows (The Astana Times, 2024). If in 2017 the population of the city of Turkestan was 159,953, as of the beginning of 2024 the population is 228,030, which shows an increase of 42% (Bureau of National statistics, 2024). These developments have sharply increased the demand for both drinking and irrigation water, as shown in Figure 1.

Starting from 2021, the Region Administration has launched new comprehensive infrastructure projects and has taken a systematic approach to addressing water shortages. These include capital repair of the main canal, construction of new water reservoirs, and pumping water from the Syr Darya River through a mechanical canal. These measures are aimed at both modernizing old irrigation systems and creating sustainable reserves for long-term supply. Despite impressive technological progress and growing water savings, there is limited evidence on the actual effectiveness of implemented measures, as well as

a lack of information on how these measures affect and are perceived by the local population and key stakeholders.

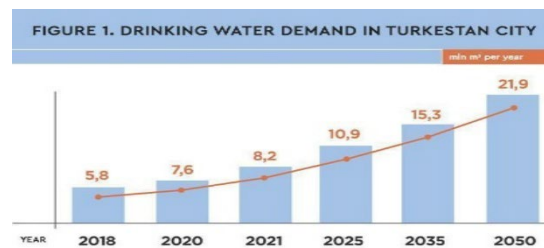


Figure 1. Drinking water demand in Turkestan city

Note. Data derived from Water resource provision in Turkestan region, by Turkestan Administration, 2021. Included as Appendix I.

Against this background, Turkestan region can be considered as a potential example of how effective water management is conducted in growing arid regions, which includes supplying the region with water for drinking needs, irrigation needs and creating a microclimate in the city, which implies its relevance for analysis and study in the context of sustainable water supply.

1.2 Research objectives/questions

Despite the fact that this region has already been studied, we aim to conduct a case study to further investigate the current ways of water resource mobilization and implementation of innovations in the Turkestan region (Argali, 2024; Arifjanov et al., 2024; Mustafayev et al., 2024; Zhumabaev et al., 2024). The region is actively seeking sustainable and innovative solutions to address critical water shortages.

Therefore, this study aims to address the following research questions:

1. What strategies and measures has the Turkestan Administration implemented to address water scarcity in the region?
2. How do stakeholders perceive the effectiveness of these measures?

The study used a qualitative methods approach, combining semi-structured interviews, document analysis, and field observations, to achieve a comprehensive understanding of the existing state of water resources and to assess the effectiveness of the implemented measures. The results show that, despite large-scale infrastructure modernization and accounting reforms are widely presented as progress, awareness and perceived benefits remain uneven among stakeholder groups. In particular, the study highlights gaps in communication, transparency, and the practical accessibility of support tools, with rural residents and small farmers reporting higher vulnerability and uncertainty

than urban users and large producers. These findings contribute to research linking “engineering” solutions to management potential and life experiences, and point to policy priorities, including greater stakeholder engagement, improved data monitoring and transparency, and more equitable mechanisms for financing and implementing water-saving measures.

1.3 Structure of the thesis

This thesis consists of 6 chapters: Chapter 1 - Introduction, which includes background and problem statement, research objectives/questions and the structure of the thesis; Chapter 2 - Literature review, which consists of part 1, 2 and theoretical framework; Chapter 3 - Methodology, which provides data, methods, analysis and the ethic of the study; Chapter 4 - Findings; Chapter 5 - Discussion; and Chapter 6 - Conclusion, which presents the research summary, practical implications, limitations of the study and suggestions for further research/policy recommendations.

2. Literature review

To systematically review the literature on climate change challenges and external influence in arid regions, the PSALSAR (Protocol, Search, Appraisal, Synthesis, Analysis, Report) framework was adopted (Mengist et.al 2020). It contains 2 research areas: 1) Climate and environmental context; 2) Water management technologies. In order to define the research scope of reviewed literature the PICOC (Population, Intervention, Comparison, Outcome, Context) framework was applied (see Table 1).

Table 1. Description of PICOC framework for four research areas.

Research areas	Research areas
Climate and environmental context	Population: Communities living in arid regions and environmental organizations; Intervention: Climate adaptation and mitigation strategies; Comparison: Climate change effects in arid regions; Outcome: Improved water security and resource management; Context: Turkestan, a semi-arid region in southern Kazakhstan with limited freshwater resources.
Water management technologies	Population: Water management technologies applied in arid regions; Intervention: drip irrigation, desalination, rainwater harvesting, and wastewater reuse; Comparison: Effectiveness, efficiency, sustainability of different technologies; Outcome: water security and mitigation of water scarcity; Context: Turkestan, a semi-arid region in southern Kazakhstan with limited freshwater resources.

2.1 Part 1. Climate and environmental context

In the context of understanding the climate change challenges and external influence in arid regions, and assessing their impact on water management in Turkestan, the following key questions were developed: 1) What are the primary climate change challenges that arid regions face? 2) How do external factors (e.g., international policies, foreign investments, technological interventions) influence climate adaptation efforts in Turkestan? 3) What strategies have been implemented in Turkestan to address climate change and resource scarcity?

Annually, the demand for water resources in industrial, agricultural and domestic sectors is getting higher leading to significant water scarcity particularly in arid and semi-arid regions. In addition to the growth of population, climate change also has its negative influence on changes of weather conditions. According to future climate scenarios (2054-2064), peak precipitation is predicted to shift from early summer to late spring, mainly due to earlier snowmelt caused by rising temperatures (Zhumabaev et al., 2024). These changes often lead to conflicts between water availability and increased demand during the peak summer months (Zhumabaev et al., 2024). Rising temperatures and less precipitation is having an impact on water resources and economic growth in Kazakhstan and Central Asia. Turkestan's climate variability is influenced by its inland location, mountainous terrain, and arid environment, leading to low rainfall, high evaporation, and inadequate moisture availability (Argali, 2024; Zhumabaev et al., 2024).

Several authors (Argali, 2024; Berndtsson & Tussupova, 2020; Mustafabeyli, 2024; Yapiyev, 2017; Zhumabaev, 2024) argue that ineffective water management and conservation policies are major contributors to ecological degradation and social instability. Argali (2024) highlights the need for integrated water management strategies, sustainable policies, and regional co-operation to combat the crisis. Whereas, Yapiyev et al. (2017) claims that increased irrigation and climate change have disrupted the fragile water balance in Central Asia basins. The authors highlight that transboundary water management approaches and advanced adaptation technologies could mitigate these issues.

Based on current challenges, various international donors and regional programs have contributed to assessing water resources in Central Asia. These efforts focus on developing strategies to mitigate the impacts of climate change and ensure water security in arid regions such as Turkestan. The study by Berndtsson & Tussupova (2020) emphasizes the importance of regional collaboration and international support in adapting to climate-related water challenges. However, not all authors agree with that, for example Mustafabeyli (2024) is skeptical about cooperation, highlighting national selfishness in water disputes.

In view of analyzed and explored articles, several limitations were identified: 1) lack of specific solutions made in Turkestan, most articles cover only Central Asia; 2) the role of local community, articles highlight policy failures and governance challenges, but they lack perspectives from local communities; 3) water quality, studies do not examine

the pollution, including the industrial and agricultural runoff as well as salinity issues, or groundwater contamination in Turkestan.

2.2 Part 2. Water management technologies

In the context of identifying the most effective water management technologies for arid regions, and assessing their practical applications in the conditions of Turkestan, following key questions were developed: 1) Which technologies are most effective for water management in arid regions? 2) How have these technologies been implemented in Turkestan? 3) What gaps exist in current research and practice?

Studies were selected based on predefined criteria to ensure relevance. Included works focused on empirical research documenting the implementation of water management technologies in arid zones, with particular emphasis on case studies from Central Asia or regions with comparable climatic conditions. Publications addressing cost-effectiveness, efficiency, and scalability of technologies were prioritized.

He et al. (2021) investigate the approaches to water demand reduction by considering improving water use efficiency through modern drip irrigation systems, water recycling and cultivation of new crop types, limiting population growth, and virtual water trading. Approaches to water supply are considered measures such as reservoir construction, groundwater utilization, and inter-basin water transfers. To find the appropriate solutions to the problem the authors consider different scenarios depending on the context of each city - groundwater exploitation may be feasible for cities where the water table has not declined significantly; for cities located in catchment basins that have seasonal water shortages and suitable topography, the construction of reservoirs has been identified as a potential solution; inter-basin water transfers can only be a solution if the neighboring basins are located in the same country, not more than 1000 km away (the distance of the longest water transfer project in the world), and do not experience water deficit.

Arifjanov et al. (2024) show how water-saving systems reduce water waste and improve irrigation, scaling to urban landscaping or agriculture in arid urban contexts in Central Asia. Abdelkareem et al. (2024) emphasize the importance of using remote sensing and GIS-based methods as key tools for identifying suitable areas for rainwater harvesting and supporting sustainable groundwater management. They found that these technologies can help to improve water resource monitoring and planning by providing more accurate identification of potential areas for rainwater harvesting and groundwater

extraction. Water recycling is discussed in Shemer et al. (2023) as an integral component of sustainable water management, discussed in the broader context of desalination as a key approach to reduce global water scarcity. Recycled water can serve as a sustainable source for various industries if it meets sanitary and environmental safety requirements. Membrane technologies, particularly ultrafiltration (UF) and reverse osmosis (RO), have played a crucial role in the production of high-quality recycled water by effectively removing dissolved solids, bacteria, viruses and organic contaminants. In addition, membrane bioreactors (MBRs) have become an effective alternative to conventional wastewater treatment, improving water quality and ensuring its safe reuse. In addition to the methods mentioned above, Yapiiev et al. (2017) describes innovative technologies that may be useful but have not been applied in Central Asia yet. One of them is Managed Aquifer Recharge (MAR). This technology allows water to be stored in underground aquifers and recharged when needed. This approach helps to avoid significant water losses due to evaporation, which are common in open water bodies. Another method is the use of coverings to reduce evaporation. This includes floating coverings such as “shade balls”, special coatings and chemical evaporation inhibitors. Floating solar panels are also a promising solution, which not only reduce water evaporation by 70%, but also generate electricity (Yapiyev et al. 2017).

While existing studies provide a comprehensive overview of water management technologies, a number of limitations and research gaps remain. Details of the literature search strategy, database selection, keyword combinations, quality assessment criteria, and thematic coverage across climate context, water management technologies, and governance and policy frameworks are provided in Appendix V.

Arifjanov et al. (2024) note the lack of more detailed soil characteristics when analyzing water management strategies. Furthermore, their works lack detailed information on the duration of irrigation, including the frequency of watering - daily, weekly, decadal or monthly. Technologies such as aquifer recharge (MAR) systems and sustainable groundwater use require groundwater level data. However, the implementation of such projects in Central Asia is hindered by the limited availability of such data in open sources, as well as the lack of local funding and engineering capacities. This is particularly confirmed by the lack of data on Central Asia on the MAR portal of the International Groundwater Resources Assessment Center (IGRAC). One of the key reasons for the lack of information is the policy of some countries in the region restricting the dissemination of groundwater data, which creates additional obstacles to the

development of scientific research in this area (Yapiev et al., 2017). Also, the mentioned studies lack the cost-benefit analysis necessary to assess the economic feasibility of implementing these technologies, their long-term sustainability and potential impact on water resources and ecosystems.

3. Methodology

This study aims to analyze and assess the measures taken by the Turkestan administration to manage water resources in the city and region in terms of their impact on reducing water losses and improving access to water resources in a semi-arid climate. The following questions have been developed to assess the measures taken: 1) How effective were the measures implemented by the Turkestan administration in managing urban and regional water resources? 2) How did the measures taken impact the work of farmers and small and medium-sized businesses? 3) What challenges did local residents face during the implementation of the measures taken? 4) What were the reasons for choosing these specific methods (e.g., drip irrigation) over alternative approaches? In order to address these questions, this study employs a qualitative research design.

The research is designed as a qualitative case study, offering an in-depth analysis of water resources management in Turkestan within its natural environment (Bryman, 2012). The case study includes elements of program implementation evaluation, with the aim of analyzing the actions already taken to enhance water supply and evaluating their effectiveness in the region.

Qualitative methods, particularly semi-structured interviews provide a deeper understanding of the perceptions and reactions of local people and stakeholders on how the applied measures on water in Turkestan influenced their daily lives and work. This approach is in accordance with descriptive design as it aims to describe current initiatives and existing practices. The chosen strategy was aimed at ensuring trustworthiness and validity of the data as the study uses methodologically proven data collection and analysis techniques (Bryman, 2012).

3.1 Research objectives

This study is based on a framework that views that water scarcity in Turkestan region is a result of an imbalance between limited water access, and further growing water

demand, shaped by arid conditions and climate change which reduce the water availability by lower precipitation and higher evaporation. Within this framework, approaches to address water scarcity are examined along two key dimensions: supply-oriented measures - seek to expand available water resources through constructions such as reservoirs, groundwater abstraction, and inter-basin water transfers; demand-oriented measures are aimed at minimizing water losses and improving efficiency by means of canal rehabilitation, the introduction of modern irrigation technologies, automation systems, and water reuse practices.

The framework further acknowledges that the actual performance of these measures is shaped by implementation conditions, including the availability of reliable data, the quality of monitoring systems, the state of infrastructure and institutional capacity. This perspective provides a structured basis for assessing water resource mobilization strategies in the Turkestan region and evaluating their effectiveness under arid conditions and increasing climate-related pressures.

3.2 Research design components

This paper examines water supply and water use in the city of Turkestan and Turkestan region which in the context of hydrological units located in Aral-Syr Darya river basin. This area contains a significant concentration of agricultural and industrial facilities that use water extensively. The city of Turkestan is administratively located inside the Turkestan area, which is geographically vast and environmentally diverse. Mustafayev et al. (2024) has identified six water-resource zones, each of which has its unique hydrological features and level of water consumption. There are Chirchik-Keles river basin, Arys river basin, River Basin of the South-Western slope of the Karatau ridge, River-Basin of the northeast slope of the Karatau ridge, Above the Shardara reservoir, Below the Shardara reservoir (See Figure 2.). Therefore, given this hydrological heterogeneity the purposive sampling strategy was used for the interviews based on selecting participants who have the key information and expertise. The data collection mostly concentrated on the city of Turkestan and its adjacent regions within the sub-river basin of the south-western slope of the Karatau Mountains. In addition, interviews were conducted in other parts of the Turkestan region to obtain a comparative and contextual perspective on water management practices in different areas.

Semi-structured interviews were conducted in person and online to assess the level of satisfaction with access to water resources and to study the impact of

implemented projects on water consumption by the population and economic activity in the Turkestan region. Three languages were used for the interviews – Kazakh, Russian, and English – depending on which was most convenient for the participants. Face-to-face contact allows respondents to feel less constrained, which contributes to more sincere and detailed answers compared to online interviews. Online interviews were conducted in cases where participants chose this format, or in cases involving international experts located outside Kazakhstan.

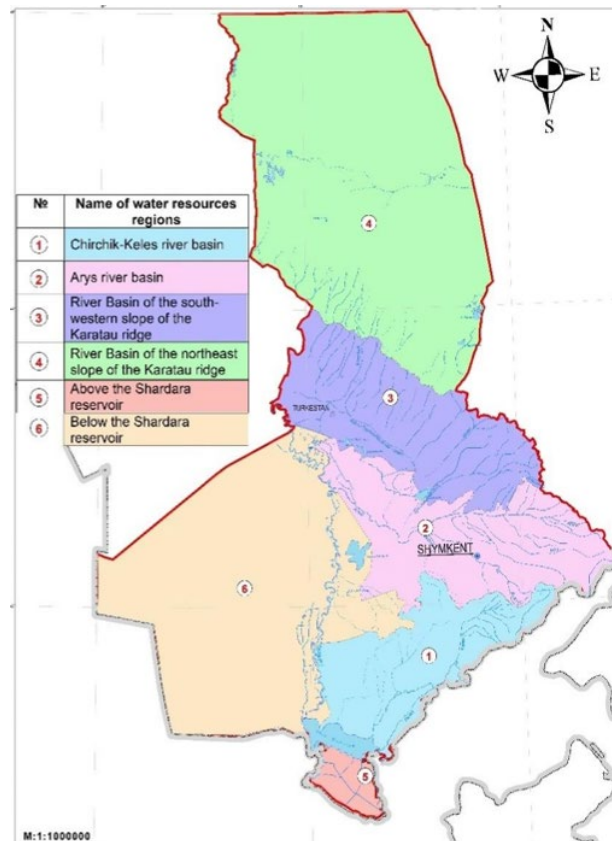


Figure 2. Distribution of six water-resource regions in the territory of the Turkestan region of the Republic of Kazakhstan.

Note. Taken from *Comprehensive assessment of water supply of the Turkestan region for the development of economic sectors and recreational tourism* (p.22), by Z. Mustafayev, I. Skorintseva, A. Toletayev, G. Aldazhanova, and A. Kuderin, 2024, *GeoJournal of Tourism and Geosites*, 52(1), 20–29.

The use of semi-structured interviews involves a combination of compulsory and open-ended questions, as well as gender and sociodemographic questions which will reveal more fully the opinions, attitudes and experiences of the participants. Semi-structured interviews were conducted using interview guides tailored to different categories of participants. The interviews with residents and farmers encompassed

inquiries regarding personal water access, daily water usage practices, and reported alterations in water availability and quality. In contrast, interviews with institutional actors concentrated on water management methods, policy execution, and institutional viewpoints about current water-related initiatives. List of interview questions and the coding criteria used for data analysis are provided in Appendix II (Interview Protocol and Coding Criteria). The stakeholder groups included in the qualitative interviews of the study are shown in Figure 3.

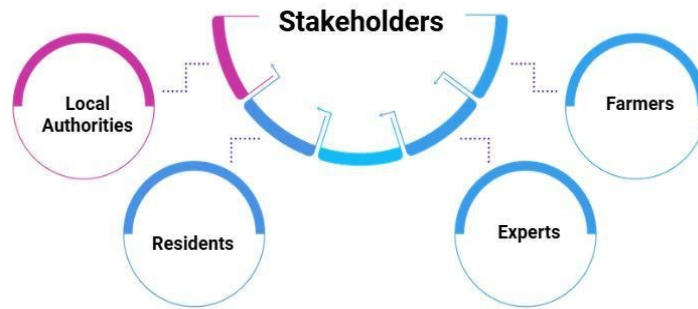


Figure 3. Stakeholder groups included in the qualitative interviews.

The study included interviews with:

- 7 Household representatives to determine their level of satisfaction with access to water and the impact of the implemented projects on domestic water consumption;
- 4 Representatives of enterprises and farms to assess the impact of water infrastructure modernization on their activities;
- 4 institutional stakeholders (a representative of the city administration and a representative of the regional water utility, Turan Su) were interviewed to obtain information on priorities, challenges, and the outcomes of implemented water-related programs;
- 10 Experts in the field of water resources, ecology and infrastructure to obtain a professional assessment of the effectiveness of the measures taken. The experts represented a wide range of institutional and professional backgrounds (see Appendix IV. Table of interviewees).;

Thus, the selection of respondents includes households with different levels of access to water, enterprises and farms that use water in their activities, professional experts in water management, representatives of urban management, as well as specialists

of specialized government agencies and research organizations involved in the process of water management and monitoring.

In addition to interviews, government documents were analyzed, including government reports, statistical data, and scientific literature on water resources management. These included the Water Code of the Republic of Kazakhstan and national policy documents such as the "Comprehensive Plan for the Development of the Water Sector of the Republic of Kazakhstan for 2024–2028," "Strong Regions – the Driving Force for National Development," and the "Concept for the Development of the Water Resources Management System for 2024-2030," as well as socioeconomic development plans for the Turkestan region and reports issued by the region administration. This analysis allowed for a systematization of data on state water policy and its impact on improving water supply.

3.3 Methods

The study used a qualitative methods approach, combining semi-structured interviews, document analysis, and field observations, to achieve a comprehensive understanding of the existing state of water resources and to assess the effectiveness of the implemented measures. Field observations were focused on the condition of key infrastructure in Turkestan region, including water treatment plants, reservoirs, hydrant systems and water distribution systems. Our observations allowed us to assess the current level of wear and tear on the facilities, their functionality, and identify potential weaknesses in management.

The qualitative analysis involved coding interview transcripts (Annex II) and analyzing government documents, enabling the identification of key themes related to stakeholders' perceptions of the effectiveness of water projects. The analysis was based on a structured approach with the aim of identifying general trends and individual perceptions of participants.

3.4 The ethic of the study

Written informed consent was obtained from all participants, with assurance of anonymity in both data collection and the presentation of results. Permission to conduct the study was obtained from the Nazarbayev University Research Ethics Committee (NU IREC) and the Nazarbayev University School of Public Policy on June 3, 2025. The study was conducted with methodological integrity, ensuring transparency in design, respect

for different points of view, and meticulous accuracy in data collection and analysis. The results are presented without distortion or selective omissions to ensure objectivity. Intellectual honesty is prioritized to properly attribute sources, protect against confirmation bias in analytical processes, and use the results exclusively to advance scientific knowledge and societal well-being. These principles are consistent with the ethical framework for policy research outlined in Booth et al. (2016) and aim to build trust between participants, institutions and the public.

4. Findings

This research investigated the evolving landscape of urban and agricultural water management in Turkestan, with a particular focus on governance capacity, sustainability, and stakeholder perspectives. Data were gathered through twenty two semi-structured interviews (Detailed list of interviewees see Appendix IV), document analysis, and field observations.

To ensure a logic and consistency, the research results are organized according to two key research questions and further organized by stakeholder groups. First, the part devoted to the strategies and measures that the Akimat of Turkestan is implementing to solve the problem of water scarcity. Second, to examine perceptions and assessments of the effectiveness of these measures by stakeholders.

1. What strategies and measures has the Turkestan Administration implemented to address water scarcity in the region?

Local authorities' perspective

Major infrastructure projects are being implemented in the region, which, when completed, will completely solve the problem of wastewater discharge and metering. Major repairs of the Turkestan main canal have been carried out: 59 km of canals are lined with concrete, 2.1 km are landscaped within Turkestan. This saves up to 60 million cubic meters of water annually. An automated water metering system from Rubicon Water has been implemented on the channel. (Press Service of the Akimat of Turkestan Region, 2024; Int 15).

The Kensai-Koskorgan-2 reservoir with a volume of 18.5 million cubic meters was built and put into operation, which provides an additional 31 million cubic meters of water per year. A water supply system is being built in Kentau with subsequent

replenishment of the Koskorgan reservoir (Akimat of Turkestan Region, 2025; Press Service of the Akimat of Turkestan Region, 2024).

In 2022, 1.3 billion tenge was allocated from the regional budget for the overhaul of the water body in the Otyrar district (Int 15). Current repairs of six water bodies in several districts of the region have also been carried out. In addition, 54 drainage channels with a total length of 141 km are being mechanically cleaned in the Maktaaral district, which will improve the reclamation condition of about 13 thousand hectares of land (Int 15).

If the projects are fully implemented, an additional 113 million m³ of water will be sent to the Bogen reservoir, which will solve the problem of irrigation water shortage in the territories adjacent to the city of Turkestan. Within the limits of the regional budget, repair works are carried out in districts and cities on priority water bodies. In 2024, 11 water bodies with a length of 43 km were overhauled at the expense of the regional budget, and 1,350 km of collector and drainage networks were mechanically cleaned for 6 projects. As a result, water supply was provided to 2.9 thousand hectares of land and the land reclamation status of 26.9 thousand hectares was improved (Int 15).

5.4 billion tenge is provided in 2025, major repairs of 13 water bodies with a length of 59 km and mechanical cleaning of 21.8 km of reservoirs for 1 project are carried out. As a result of the work, it is expected to improve the water supply of 7.7 thousand hectares of land. (Press Service of the Akimat of Turkestan Region, 2024).

Measures are also planned for the restoration of water bodies implemented with the involvement of funds from the Islamic Development Bank. As part of the first stage, 11 projects worth 63.2 billion tenge are being financed through the Kazsushar State Enterprise. As a result, 130 km of canals will be concreted and the water supply of 10.1 thousand hectares of land will be improved. It is also planned to finance 14 projects worth 73.6 billion tenge through the Turan Su enterprise. As a result, 166 km of canals will be concreted and the water supply capacity will increase by 53.3 thousand hectares of irrigated land (Int 15).



Figure 4. The irrigation canal (aryks) system of the city of Turkestan. Source: Authors

Design and estimate documentation (D&E's) is being developed for 120 projects, as well as for 157 projects through Kazsushar branches. To date, the D&E's is ready for 14 projects worth 41.4 billion tenge. In total, it is planned to overhaul 25 reservoirs, 269 channels with a total length of 4265.4 km. This will reduce the level of deterioration of water bodies from 76% to 50%, improve the water supply of 400 thousand hectares of irrigated land and ensure the annual production of additional agricultural products worth about 200 billion tenge (Int 15).

Also, a project has been developed to raise water from the Syr Darya River through a machine channel with pumping stations to form a reserve volume in case of dry periods. As part of the development of urban irrigation, systems of irrigation aryks, channels and hydrants with water supply to each district and house have been built and are functioning. This ensures an even distribution of water throughout the city (Int 15). Water from decorative and sports water bodies (artificially Shaga Lake, Grebnoy Channel) is used for irrigation. Up to 40% of the city's water is reused. Artificial lakes, green belts, and water mirrors have been built and continue to be built in the city to humidify the air. It is planned to further increase the areas of parks, squares, lawns and water bodies (Int 15).

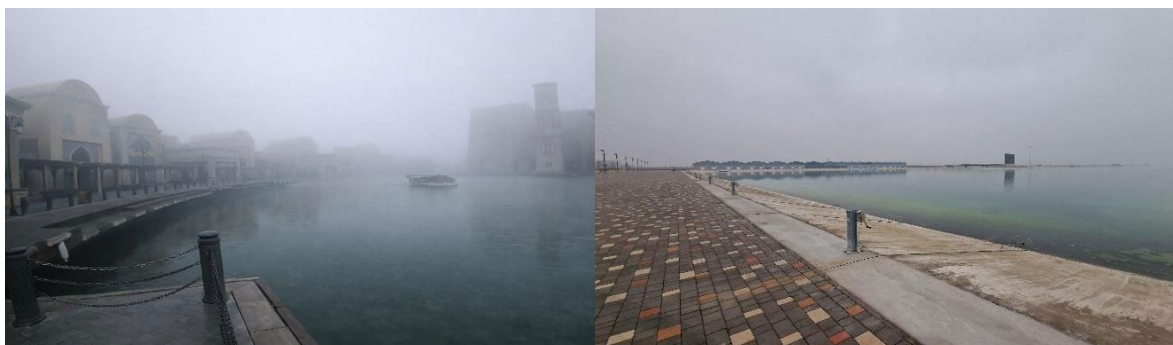


Figure 5. Caravan Saray and Grebnoy Canal. Source: Authors

A new production of drip irrigation equipment has been launched and is in operation. The company manufactures key components for water-efficient irrigation systems, including drip tape, polyethylene pipes, PVC hoses and a full range of fittings. Total investment of 650 million tenge, enabled 28 permanent jobs and a regional production base necessary to support modern irrigation technologies (Appendix III, Int 16).

The production line includes several workshops equipped with extruders, winding machines, injection molding presses and pipe forming plants. The annual production volume reaches 183,960 km of drip tape, 5,256 km of polyethylene pipes, 2,117 km of PVC hoses and up to 3,000 fittings, which ensures stable local supplies and reduces dependence on imported irrigation equipment. The availability of domestically produced components reduces the operating costs of agricultural enterprises and accelerates the transition to water-efficient farming methods (Appendix III, Int 15, 16).

The launch of this facility strengthens the technological basis of water-saving measures in the Turkestan region. By providing farmers and municipal enterprises with affordable and high-quality drip irrigation systems, the plant directly supports broader regional goals to improve irrigation efficiency and adapt agricultural production to growing water scarcity (Int 15, 16).



Figure 6. Kazakhstan factory for the production of sprinkler systems. Source: Authors

However, it should be noted that when respondents were asked directly whether sprinkler or drip irrigation systems were being purchased in the Turkestan region and who their main users were, they gave an evasive answer, stating that the main and in practice only purchasers of such equipment were farmers from the Zhambyl region. This response points to a potential gap between the formal availability of local irrigation technologies and their actual use by agricultural producers in the Turkestan region itself.

Experts' perspective

Expert interviews indicated a fragmented degree of knowledge about the water management measures taken by the Turkestan administrations. The coverage, applicability, and technical merit of the proposed measures were largely validated by a variety of experts, especially those who are directly involved in the design, planning, or implementation of these initiatives. These experts emphasized that infrastructure modernization, canal concreting, reservoir construction, and the introduction of automated water accounting systems are necessary and timely responses to chronic water scarcity in the region (Int 6, 12, 23).

However, another group of experts demonstrated limited or complete lack of awareness of specific measures currently being taken. Some of the respondents could not identify particular projects or were not aware of the nature and goals of the current activities. This is an indication of a lack of communication and transparency, even within professional groups. The disparity in expert opinions is an indication of a problem in governance, especially concerning the distribution of information and participation in the planning and implementation of water management activities. (Int 1, 2, 3, 4, 5, 7, 8)

Residents' perspective

Interviews with residents of Turkestan and the surrounding region indicate a general lack of awareness regarding the extensive and long-term water management initiatives undertaken by local authorities. Most respondents reported that they had heard that “some measures” were being undertaken to address water scarcity, however, they were unable to identify specific projects, policies, or infrastructure investments. For residents living in the city, water management remains a distant issue that does not attract much attention unless there are disruptions to the daily water supply (Int 9, 10, 11, 17, 18)

In contrast, residents of Turkestan region more directly affected by water scarcity demonstrate greater awareness of short-term and local measures. These respondents more often mentioned specific actions taken by local authorities, such as hiring contractors to drill wells to extract groundwater in order to ensure water supply during periods of shortage. However, even in these areas, awareness is mainly limited to emergency or directly observable measures, while knowledge of broader regional strategies is lacking. (Int 19, 20).

Farmers' perspective

Interviews with farmers also show that awareness of specific and comprehensive water management measures implemented by local authorities is equally low. Neither small nor large farmers were able to name specific projects, programs, or infrastructure initiatives aimed at addressing water scarcity. For all respondents, information on water management at the regional level remains vague and unsystematic (Int 13, 14, 21, 22).

At the same time, farmers from both groups indicated awareness of governmental subsidies for acquiring sprinkler irrigation systems. This was the only measure consistently mentioned across interviews. However, none of the farmers surveyed, whether large or small, reported having applied for or received these subsidies, nor were they familiar with the procedures or conditions required to obtain them (Int 13, 14, 21, 22).

Overall, farmers' awareness appears to be limited to general and secondary information, without direct involvement in specific policy instruments or water conservation programs. This indicates that existing measures, even if formally introduced, have limited visibility and reach among agricultural water users.

2. How do stakeholders perceive the effectiveness of these measures?

Local authorities' perspective

In 2025, due to the dry weather conditions and lack of precipitation, there was an acute shortage of irrigation water in the region. However, the measures taken in the Turkestan region the area of agricultural crops increased by 34 thousand hectares and amounted to 907 thousand hectares. The area of cotton was increased by 38 thousand hectares and brought to 145 thousand hectares. The growth of acreage was achieved through the introduction of water-saving technologies on 50 thousand hectares. To date, all acreage in the canal area is fully supplied with irrigation water (Int 15).

According to Interview 15, for environmental purposes, water is discharged in a volume of 5 m³/sec. The annual water supply limit is 984.6 million m³, 667.1 million m³ (68%) has actually been supplied, and the number of storage facilities is 4251. The water supply was carried out according to an approved schedule agreed with the akimats of the districts and farms, using priority. The growing season has been completed in the normal mode, the death of crops is not allowed (Int 15).

Experts' perspective

Experts' perception of water management measures in the Turkestan region vary significantly, reflecting the heterogeneity of professional views and experience in interacting with ongoing initiatives.

Respondents (Int 6, 12, 23, 24, 25) generally positively assess the measures taken by the regional authorities. In their opinion, modernization of the water infrastructure, concreting and restoration of irrigation channels, construction and reconstruction of reservoirs, as well as the introduction of automated water metering systems are necessary and justified steps in conditions of sustainable water scarcity. These experts consider the ongoing projects as a logical continuation of the state policy in the field of water security and consider them potentially effective in reducing water losses and improving the manageability of water distribution in agriculture.

At the same time, other experts are critical of the measures being implemented, pointing out their limited effectiveness and the presence of deep institutional and technical problems. Despite over a trillion KZT invested in Kazakhstan's water infrastructure between 2013 and 2022, the country continues to lose approximately 5.2 km³ of water annually due to deteriorated networks. Local authorities report ongoing rehabilitation of canals repairing and cleaning, however physical wear remains above 50

%. (Supreme Audit Chamber of the Republic of Kazakhstan, 2023; Tengrinews.kz, 2025; Int 4; 12).

Experts noted that many canals, including major ones such as the Turkestan Main Canal, were designed decades ago for different crop patterns. Their unlined sections cause filtration losses approaching 40% (Int 4). Although the authorities are still undertaking concrete lining, the respondents questioned the cost-effectiveness of the method by suggesting other technologies like polymer or mastic linings, which would have been less costly (Int 12).

Although large reservoirs offer some seasonal balance, they also cause high evaporation rates of up to 1,000 mm per year in the region's climate (Int 2). Experts also recommended that smaller systems like infiltration basins, groundwater recharge areas, and underground channels would offer a better balance between water supply and ecological sustainability (Int 2, 4, 7, 8).

Experts pointed out that most hydrological observation is still done manually. The observation is done using simple equipment, and the data is recorded on paper (Int 8). The lack of a comprehensive digital platform or a hydrological database makes it impossible to coordinate the efforts of the various institutions. Inconsistencies continue to exist between the documented information and the reality on the ground, and illegal pumping continues to be common (Int 4, 8). Interviewees noted that upstream withdrawals and illegal irrigation practices, including a “black market” in water, distort both supply accounting and pricing mechanisms (Int 4).

Respondents agreed that without transparent and continuous monitoring supported by digital meters, satellite data, and automated regulators planned efficiency gains will remain largely declarative (Int 4, 5, 6, 7, 8, 12, 23). The results show a high level of fragmentation between national, basin, and local levels. Basin councils, although designed as a participatory mechanism, do not have the power to implement allocation and penalize overuse. Their functioning is also hampered by low budgets, outdated job descriptions, and a lack of public participation (Int 4, 7, 8).

Human resource shortages were found to be a common thread running through all the interviews. The water sector is unable to retain and hold on to competent engineers, hydrologists, and technicians. Low pay, an aging workforce, and a lack of technical education in water engineering were found to be major hurdles. The loss of institutional memory from previous generations is also creating a situation where there is a reliance on foreign consultants and international agencies for project design (Int 7, 8).

Performance indicators are also designed to favor short-term outcomes such as kilometers of roads repaired and the number of reservoirs built, as opposed to long-term outcomes such as water loss reduction and efficiency gains. This creates a perverse incentive system that is not conducive to innovation and a change in management practices (Int 7).

Dependence on external funding sources is a concern for sustainability. The water rehabilitation project in Turkestan is largely funded by external sources, mainly the Islamic Development Bank. (Int 12) The initial investment phase (2025-2027) will see 136.8 billion KZT channeled into 25 projects, while a second phase will see over 680 billion KZT directed at 277 projects. (Int 15) Repayment of loans is tied to agricultural income, which is subject to climate change and declining groundwater resources. (Int 12) Small-scale farmers have been especially hard hit in securing funding, often due to collateral or administrative issues. (Int 14, 21, 22) There was a concern that the focus on major infrastructure development at the expense of maintenance and monitoring would simply re-establish cycles of dependency when external funding dries up. (Int 4, 12).

The water system of Turkestan is closely connected with the transboundary river flows of the Syr Darya Basin, which makes it susceptible to upstream management practices (Int 7, 15). The respondents reported about the persistent imbalance between water supply and demand: while the irrigated area is being expanded, the transboundary river inflows from neighboring countries are unstable because of the poor coordination and climate change (Int 5, 7, 8).

Despite the new regulations in the 2025 Water Code, which give priority to ecological river flows, best available technologies, and obligatory water use plans, the process of their implementation at the basin level is slow (Int 7). The respondents also mentioned that the transboundary agreements are usually seasonal and informal, which makes it difficult for farmers to predict the availability of water resources during the most important periods of plant growth (Int 4, 7). The absence of data transparency hampers the negotiation position of Kazakhstan. Some experts pointed out that the upstream countries have more up-to-date hydro-meteorological data and better research connections with international organizations, which gives them an advantage in transboundary negotiations (Int 2, 4, 7, 8).

Critics pointed out that the dominant approach emphasized the “blue water” component, surface and groundwater, to the neglect of the “green water” component, soil moisture and evapotranspiration, which represents the largest part of the hydrologic cycle in arid environments. The existing legal system emphasizes rational use and technical

control but does not have provisions for ecosystem restoration and soil-water balance management. (Int 5, 7). Respondents argued that without integrating green-water accounting and ecological flows into planning, Turkestan risks depleting its natural resilience. Modern concepts such as Managed Aquifer Recharge (MAR), bank filtration, and the use of treated wastewater for irrigation are known among experts but rarely operationalized in regional policy (Int 2, 5, 7).

Farmers' perspective

Interviews with farmers of various scales, along with indirect evidence from the media and expert commentary, reveal a complex and ambiguous picture of how the local government's water management measures are perceived. A representative of a large greenhouse complex gave a very positive assessment of the changes in the region's water infrastructure, stressing that the modernization of networks and new measures by the Akimat have significantly simplified access to water and increased the stability of supplies. (Int 13). According to him, the organization of water supply at the enterprise works without interruptions and ensures the predictability of the production cycle, which directly increases the efficiency of the greenhouse economy. He noted that in recent years, the water supply system has become more reliable: pressure has improved, the number of technical failures has decreased, and the response rate of utilities has increased. The company does not experience any serious difficulties with access to water, and the current conditions, according to him, make it possible to plan production with a high level of confidence. He mentioned the introduction of drip irrigation technologies, the expansion of the use of purified process water and the continuation of digitalization of accounting as promising areas for further development, but stressed that existing measures already create comfortable conditions for the operation and growth of the enterprise. Overall, his assessment boils down to the fact that the akimat's water management policy has become one of the key factors in the sustainability and efficiency of the greenhouse complex.



Figure 7. Large greenhouse complex in the Turkestan region. Source: Authors

However, a farmer of a small farm (Int 14) gave a negative assessment of the current situation with water supply, emphasizing that changes in infrastructure are either not felt at his level, or have led to additional difficulties. According to him, the organization of water supply on a small farm remains unstable: the pressure often drops, the water supply is irregular, and this directly reduces yields and makes planning almost impossible. He notes that the water supply system has deteriorated rather in recent years: periods of interruptions have become longer, and responses to appeals to the relevant services have been slower. The farmer reports constant difficulties with access to water both for irrigation and for minimal production needs, which is becoming the main risk factor for his farm. Among the most pressing problems, he highlights the lack of a transparent water supply schedule, poor infrastructure preparation for summer peaks, and uneven distribution of resources between large and small farms (Int 14). When asked what could be done to better the situation, the respondents point out that there is a dire need for proper control over water supply, faster repair work in the water supply network, and proper prioritization that considers the requirements of small farmers (Int 14, 21, 22). In addition, as reported by an environmental journalist, farmers are increasingly faced with uncertainty because of the depletion of groundwater, irregularities in irrigation timings, and a lack of institutional support.(Int 4).

In many irrigation zones, low water pressure and canal degradation limit supply reliability. Farmers are frequently forced to resort to the use of pumps or make “side deals” in order to get water access during peak periods. There are also reports about the continued existence of “side deals” or unofficial payments for access to canal water (Int 4, Tengrinews, 2025).

There is also a noticeable change in the type of crops being grown. High-value but water-demanding crops like tomatoes, rice, and eggplants are gradually being replaced by drought-tolerant crops like lucerne and fodder crops. This is a good strategy

in that it ensures that productivity is maintained at the lowest levels, but it is not very profitable (Tengrinews, 2025). Finances are also a problem for small farmers. The lack of well-supported programs and delays in implementing drip-irrigation subsidies further discourage efficiency improvements. As a result, farmers increasingly depend on short-term coping strategies rather than long-term modernization (Int 14, 21, 22, 24, 25; Tengrinews, 2025). Simultaneously, both big and small farmers were unaware that Kazakhstan had a domestic facility manufacturing domestically created sprinkler irrigation systems, highlighting inadequate diffusion of knowledge regarding national water-saving technology among end users (Int 14, 15, 21, 22).

Residents' perspectives

Interviews with residents indicate substantial differences between urban flats and private residences. Residents in high-rise buildings often benefit from a reliable and uninterrupted water supply, but residents of single homes sometimes struggle with low water pressure and are necessitated to invest in pumps at their own cost to meet essential household requirements. (Int 9, 10, 11, 17, 18). Notably, when asked directly about water pressure, many urban respondents admit that it is insufficient, however, when assessing the overall situation and government measures, they often respond positively and submissively, which can be characterized by the phrase “Shukir, shukir, bari jaksy (Thank God, everything is fine)”. This, surprisingly, reflects a form of adaptive optimism, in which structural deficiencies are normalized rather than openly challenged. The majority of respondents report overall satisfaction with water quality for household use, nonetheless, they prefer to buy bottled water for drinking, reflecting ongoing distrust in the safety of tap water. This behavioral trend indicates that enhancements in supply continuity have not been paralleled by corresponding increases in public trust.



Figure 8. Resident of Turkestan. Interviewee 18. Source: Authors

Affordability issues remain acute. Residents without individual meters are charged fixed rates that may exceed actual consumption, whereas those with gardens pay considerably more during summer months. Some households circumvent high costs by using public street columns for irrigation, reflecting both informal adaptation and weaknesses in enforcement. (Int 17, 18, 19, 20).

In addition, residents of the region complain that the expansion of large commercial greenhouses has led to increased water abstraction, causing periodic water shortages and reduced water pressure in nearby settlements. These complaints exacerbate the perception of unequal access to limited water resources and competition for them between agricultural enterprises and local communities (Int 19, 20).

Residents of the region are generally cautious and critical of the measures taken by the authorities. Rural residents acknowledge that temporary measures help to avoid a complete shutdown of water supply and are seen as necessary emergency assistance. However, these measures are widely perceived as forced and short-term, failing to address the root causes of unstable water supply. Residents express concern about the lack of clear explanations for the sharp decline in groundwater levels and the lack of a transparent timetable for implementing long-term solutions. This creates a sense of instability and dependence on external assistance, which undermines confidence in the water supply system's ability to meet future needs, despite the official involvement of the state (Int 19, 20).

Despite these challenges, many citizens acknowledge improvements in urban greenery, public infrastructure, and general living conditions compared to a decade ago, when water supply was intermittent and restricted to specific hours. (Int 9, 10, 11, 17, 18).

Document analysis

An analysis of key strategic and regulatory documents shows that water management measures in the Turkestan region are generally consistent with national policy, but their practical implementation is accompanied by systemic constraints.

The Concept for the Development of the Water Resources Management System for 2024–2030 provides the transition to basin management, infrastructure modernization, reduction of water losses, and digitization of metering. The projects being implemented in Turkestan directly reflect these priorities. At the same time, the Concept itself acknowledges the problems of fragmented management, outdated data, and weak monitoring, which coincides with the criticism of experts in the study.

The Comprehensive Plan for the Development of the Water Sector of the Republic of Kazakhstan for 2024-2028 specifies targets through quantitative indicators and significant funding, including reducing irrigation losses and expanding water-saving technologies. However, the focus of the indicators is primarily on physical volumes of work (km of canals, number of facilities) rather than actual results (water availability, uniformity of distribution), which partly explains the discrepancy between official reports and the perception of measures by farmers and the population.

An analysis of the document National Project “Strong Regions – Driver of the Country's Development” showed that water supply and sanitation issues are considered primarily as part of basic infrastructure and quality of life, rather than as an element of specialized water policy. The project sets targets for achieving 100% access to water supply in cities and rural areas by 2025, reducing the wear and tear of engineering networks, and increasing public satisfaction with services. However, the logic of the project is focused on territorial equalization and physical expansion of infrastructure, with a predominance of quantitative indicators (coverage, kilometers, percentages), without detailed reference to water resource sustainability, loss reduction, or adaptation to climatic aridity. This partly explains why formal improvements in water accessibility indicators can coexist with persistent local shortages, uneven distribution, and low confidence among farmers and rural residents.

The 2025 Water Code introduces significant reforms: ecological flow protection, bans on new dams on small rivers, strengthened monitoring, and mandatory reuse in industry from 2027 onward. In agriculture, it promotes gradual consumption reduction, water-saving technologies, and the creation of irrigation cooperatives. These provisions align with Kazakhstan’s commitments under UN water conventions and the national

vision of “water security” encompassing scarcity protection, pollution control, and ecosystem preservation.

However, the translation of these provisions into practice will depend on institutional capacity at local levels. As one expert noted, “laws are improving faster than the institutions that must enforce them.” (Int 7).

The analysis of the documents shows that requirements for the mandatory introduction of water-saving technologies, protection of ecological flows, preparation of water use plans, and restrictions on the construction of dams on small rivers are forming a new framework for water resource management that will significantly affect current practices in Turkestan. In agriculture, it promotes gradual consumption reduction, water-saving technologies, and the creation of irrigation cooperatives. These provisions align with Kazakhstan’s commitments under UN water conventions and the national vision of “water security” encompassing scarcity protection, pollution control, and ecosystem preservation.

Nevertheless, the results of the study show a gap between regulatory provisions and their implementation at the local level, particularly in terms of informing water users and the actual involvement of stakeholders.

Overall, the documents form a consistent and logical framework for water policy, but the identified gap between strategic goals and local practice helps explain the heterogeneous and often critical assessments of the effectiveness of measures by different groups.

5. Discussion

The study set out to answer two research questions:

- What strategies and measures the Turkestan Administration has implemented to address water scarcity?
- How do stakeholders perceive the effectiveness of these measures?

The findings of the study show that water management in the Turkestan region has predominantly been characterised with massive and infrastructure-based interventions. In 2021, the local authorities began focusing on canal restoration, building reservoirs, alongside investments in water transfer and monitoring systems. These solutions are well in line with the national water policy documents and manifest an orientation toward water scarcity as a major technical and engineering issue.

One of the major findings of this study is that systemic water management inefficiency has not been addressed simply by technological and infrastructural interventions. Excessive amounts of physical losses, the lack of monitoring power, disjointed institutional roles, and poor stakeholder engagement still restrict the success of investments. The findings and analyzed literature review confirm that water shortage in arid regions is most likely to be influenced not only by lack of resources, but rather governance breakdown, data gaps, and institutional capacity constraints (Argali, 2024; Berndtsson & Tussupova, 2020; Molden, 2019).

While local authorities frame water scarcity primarily as an engineering problem, the empirical evidence suggests that infrastructure expansion without parallel improvements in governance, monitoring, and institutional coordination delivers limited long-term benefits. This supports Molden's (2019) argument that many water shortages stem from management failures rather than absolute physical scarcity.

Regarding Research Question 2, the findings show clear divergence in how effectiveness is perceived by stakeholders. While authorities tend to evaluate success through completed projects and efficiency indicators, users and experts emphasise reliability of access, fairness of distribution, data transparency, and trust in institutions. This difference in perceptions explains why reported improvements do not always translate into higher user satisfaction or perceived water security.

In addition, data collection in the Turkestan region itself proved challenging. Regional stakeholders demonstrated limited responsiveness to remote communication, making in-person engagement essential for establishing trust in order to conduct interviews. This requirement necessitated repeated field visits to Turkestan, requiring

additional time and financial costs. While these limitations do not undermine the overall findings, they highlight structural barriers to research access and transparency in regional water governance and underscore the need for more systematic data-sharing mechanisms.

5.1 Suggestions for further research and policy development

Future research could build this study by strengthening the evidence base by expanding both its empirical coverage and analytical methods. First, future studies should include farmers from other irrigation and water-use zones across the Turkestan region. This would allow comparative analysis of water access and adaptation of strategies across different hydrological and institutional contexts.

Second, engaging representatives of international financing institutions, particularly the Islamic Development Bank, would provide deeper insight into the design, monitoring, and sustainability of externally funded water infrastructure projects, as well as their alignment with local needs.

Third, the collection of quantitative data should complement qualitative findings. Online surveys among urban residents and rural users could systematically assess water quality, affordability, and accessibility. Such data would help validate interview-based findings and identify broader patterns in service delivery outcomes.

Fourth, future research should specifically examine adoption barriers for water-saving technologies. In particular, interviews with farmers in the Turkestan region could explore why locally produced sprinkler and drip-irrigation systems are not widely adopted, despite their uptake by farmers in neighboring regions such as Zhambyl. Investigating factors such as price, trust in domestic production, access to subsidies, technical support, and information asymmetries could reveal important policy and market failures.

Finally, the integration of econometric methods would significantly enhance policy evaluation. Regression analysis could be applied to assess the relationship between infrastructure investments and changes in water availability, irrigation efficiency, and agricultural productivity, as well as to evaluate the cost-benefit performance of implemented measures.

5.2 Policy implications

Building directly on these findings, the policy implications focus on addressing the identified gaps between infrastructure delivery, governance performance, and user experience.

First, there is a clear need to strengthen communication and outreach strategies. The fact that even water-sector specialists were largely unaware of ongoing reforms and infrastructure projects indicates weak information dissemination. Improving transparency, stakeholder engagement, and public communication could enhance trust and encourage the adoption of water-saving practices.

Second, access to financing remains uneven. Small and medium-sized farms face significant barriers due to bureaucratic procedures, collateral requirements, and limited awareness of available support programs. Simplifying administrative processes, expanding targeted subsidies, and improving financial literacy could help ensure more equitable access to modernization efforts. Together, these measures would not only improve the effectiveness of existing investments but also contribute to more inclusive and sustainable water management outcomes.

In this regard, the study contributes to existing literature by combining governance analysis with stakeholder perceptions, offering an empirical illustration of how infrastructure-led reforms translate into uneven outcomes at the user level.

5.3 Limitations of the study

There are a number of limitations of this study.

To begin with, there was limited access to the institutional data and stakeholders. Other organizations which were contacted on a national level did not respond to the formal requests and did not take part in the interviews. Consequently, there was a limitation in the range of the institutional analysis to include the views of some of the key regulatory and control institutions.

Second, the qualitative character of the study and a rather limited amount of interviews limit the ability to generalize the results. Although the case study method offered an opportunity to deeply explain the perception and experience, it cannot give statistically representative conclusions about the whole region.

Third, the Turkestan region is a place that needed a lot of personal interaction to collect data, as not many people responded to remote communication. The limited

resources and time limitation were the factors that only limited the scope of the fieldwork and involving the other stakeholder groups.

These weaknesses do not compromise the validity of the findings and indicate more general structural concerns regarding transparency, the availability of data and institutional openness regarding regional water management.

Conclusions

This Master project explored water management in the Turkestan area in the circumstances of active urbanization, agricultural development, and the growth of the climate pressure. The study was done using a qualitative case study approach where the measures taken by the local authorities to deal with the issue of water scarcity were analyzed as well as how these measures were perceived by users and stakeholder groups. The summarized findings are presented in the form of conclusions which will outline the key results, will describe their impact on the practical as well as will explain the limitations of the conducted research, and will suggest the direction of the future research and policy.

By addressing both policy measures and stakeholder perceptions, the study directly responds to the research questions and highlights the gap between formal reforms and lived water-use realities. To sum up, the water management in the Turkestan region is at a very critical crossroads. Although there have been considerable advancements in resources mobilization and modernization of infrastructure, how water is going to be secured over the long-term will be in relation to the capacity to transfer the formalities of reforms to effective, inclusive, and transparent governance practices. Good lessons can be learned in the Turkestan region case to other arid and fast rising regions that sustainable water management is not just a question of infrastructure development and design, but it is an issue of governance cooperation.

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Appendices

Appendix I.

Water resource provision in Turkestan region [Presentation]. Turkestan Administration, (2021). Provided by request.

Work conducted to ensure drinking water for Turkestan guarantees supply until 2042.

Reserve of the utilized source – Myrgalymsey field: 661.5 million m³

(Calculation: $86.4 * 365 * 21 = 661.5$, until 2042).

Table 2. City's drinking water demand

Year	Water demand (million m³/year)
2018	5.8 million m ³ /year
2020	7.6 million m ³ /year
2021	8.2 million m ³ /year
2025	10.9 million m ³ /year
2035	15.3 million m ³ /year
2050	21.9 million m ³ /year (includes 1.5 million visitors annually).

Additional reserves of explored drinking water sources

Reserve name	Reserve volume (million m³)
Biresek-Khantagi	728
Karachik	552
Ikansu-Ktai	1,277

Total	2,557
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Water supply system development

Parameter	Value
Increase in reservoir capacity	64% (46,000 m ³)
Total reservoir capacity	72,000 m ³
New supply networks	+49 km
New intra-city networks	+334 km
Reconstructed intra-city networks	201 km (26% of 2,078 km total)
Total built/reconstructed (2019-2021)	535 km

Irrigation needs for green spaces by 2035

Category	Area (hectares)	Irrigation need (million m ³ /year)	Notes
Urban parks and squares	485	4.6	2.5x growth since 2019
Prospective need	+400	8.5	Additional green spaces planned
Turkestan's green belt	13,000	57.7	3,000 non-irrigated, 10,000 irrigated
Residential area greenery	2,071	17,5	
Total	5,239	83.7	23% of the city's total area (22,370 ha)

Water demand for irrigation and other use

Category	Water demand (million m ³ /year)
Irrigation (green spaces), 5,239 ha	83.7
Water bodies	5.45
Agro belt, 11,074 ha	79.6
Overall demand	168.7

Appendix II. Interview protocol and coding criteria

Table 3. Semi-structured interview protocol for water security assessment

Target group	Purpose of the interview	Main questions	Open-ended questions
Households	To operationalize the level of satisfaction with access to water, perception of implemented measures and the impact of infrastructure changes on daily life.	1. How do you assess the current access to drinking water in your home? 2. How has the quality or availability of water changed since the implementation of new measures? 3. How do you estimate the cost of water (rates) and how affordable is it for your household?	1. Please describe how you usually get water in your home. 2. How convenient is it for you and your family? 3. Tell us about any changes that have occurred recently in the quality or availability of water. How has it affected your life? 4. What solutions do you think could significantly improve the water supply in your place? 5. Have you faced any challenges with your water supply? If yes, please describe. 6. Have you had any health problems related to drinking water quality (e.g., cases of

			gastrointestinal illness) in the past year?
Enterprises and farmers	To operationalize the impact of the measures taken on their performance, identify the main problems and needs.	1. How have changes in water infrastructure affected your activities? 2. Have you faced difficulties in accessing water for production or agricultural needs? 3. What measures, in your opinion, can improve water supply in the region?	1. How is the water supply organized at your enterprise (farm) and how does it affect your work? 2. What changes in the water supply system have you experienced in recent years? How have they affected the efficiency of your business? 3. What innovations could help use water more efficiently at your facility? 4. Do you experience water-related problems and, if so, which problems are of most concern to you?
Experts	Obtain professional opinion and evaluation of current measures and proposals for further improvement of water resources management.	1. How successful do you consider the implementation of infrastructure projects such as the construction of reservoirs, channel bed lining? 2. What innovations do you consider most	1. How would you characterize the current situation regarding water resources in Turkestan? What do you consider to be the most acute problems? 2. Which measures have been most successful or ineffective in recent years and why?

		promising to improve water supply?	3. What innovations do you consider most promising to improve water supply? 3. How do you assess the prospects of innovation implementation in arid regions of Central Asia? 4. How do you assess the level of involvement of local communities and businesses in water management processes?
City Administration	Obtain information on priorities, challenges and results of the implemented programs	1. What key results have been achieved through water management measures? 2. What challenges are encountered in implementing water management programs? 3. How are the results of interaction with local residents and businesses assessed?	1. How do you assess the current situation with water supply in Turkestan? What achievements can the city be proud of? 2. What directions or projects should be prioritized for sustainable development of the city's water sector? 3. How is the effectiveness of water management measures monitored? What indicators are used? 4. What measures are included in long-term plans to address climate

			change and population growth?
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In order to systematize and structure the collected data, the following criteria for coding interview responses were developed.

Appendix III. Data Sheet: Water-Saving Pipe Production Facility

Total Cost: 650 million KZT

Number of jobs: 28

Production Line Capacity:

183,960 km — Tape-type irrigation pipe

5,256 km — Polyethylene pipe

2,117 km — PVC hose

Table 4. Description of Workshops and Equipment

№	Name	Size / Diameter	Capacity (m per year)	Project cost (million KZT)
1	Tape pipe workshop	1000 mm	183,96	95.8
2	Polyethylene pipe workshop	90 mm	5,256	62.3
3	Fitting production workshop	63 mm	3	76.6
4	Fitting injection-press line	110 mm	1	73.8
5	PVC hose workshop	25 mm	2,117	59.6
—	TOTAL	—	—	327.7 million KZT

Description of Workshops and Equipment

Tape Pipe Production:

- Equipment: extruder, winding machine
- Production capacity: 183,960 m/year
- Product: water-saving irrigation tape (0.15–0.6 mm)
- High demand in agriculture

PVC Hose Production:

- Material: PVC
- Diameter: 25 mm
- Capacity: 2,117 km/year

Polyethylene Pipe Production

- Diameter: 16–90 mm
- Capacity: 5,256 km/year

Fitting Production

- For household and agricultural water supply systems
- Products: tees, elbows, couplings
- Injection-press equipment
- Capacity: 1,000–3,000 units/year

Data provided by Turkestan region Administration: “TURAN SU” State Enterprise Passport

Mission and Functions:

Maintenance, operation, repair, and reconstruction of state-owned water management systems and structures, as well as ensuring their safety.

Assets on the Enterprise Balance Sheet;

- 3 water facilities (hydraulic units)
- 3 main canals
- 20 reservoirs
- 1 administrative building
- 3 production and technical bases
- 81 units of various machinery
- 107 water management structures
- 439 employees

Appendix IV.

Table 5. Interviewees

Inter view er No	Occupation	Expertise	Gender	Forma t	Date
1	Expert	Senior economic and environmental policy expert	Male	Offlin e	June 2025
2	Expert	Hydrologist, Earth and Environmental Scientist	Male	Offlin e	June 2025
3	Expert	International project manager in the field of water governance and peacebuilding	Male	Online	August 2025
4	Expert	Journalist and investigator specializing in water issues;	Male	Online	August 2025
5	Expert	International Urban Infrastructure specialist;	Female	Offlin e	Septemb er 2025
6	Expert	Engineer of the Turkestan Region Dewatering System Project (Kantau city)	Female	Online	Septemb er 2025
7	Expert	Independent international expert coordinating a regional platform on water resources management and climate change	Male	Online	Septemb er 2025
8	Expert	Energy and Water Specialist	Male	Online	Septemb er 2025
9	Household	Citizen of city Turkestan	Male	Online	Septemb er 2025
10	Household	Citizen of city Turkestan	Female	Online	Septemb er 2025
11	Household	Citizen of city Turkestan	Male	Online	Septemb er 2025
12	Expert	Water-sector Consultant specializing in technical and economic feasibility studies for public infrastructure projects in Turkestan Region;	Male	Online	Septemb er 2025

13	Farmer	Large Greenhouse	Male	Offline	December 2025
14	Farmer	Small Farm	Male	Offline	December 2025
15	Local Authority	Akimat Representative	Male	Offline	December 2025
16	Local Authority	Turan-Su Representative	Male	Offline	December 2025
17	Household	Citizen of city Turkestan	Male	Offline	December 2025
18	Household	Citizen of city Turkestan	Male	Offline	December 2025
19	Household	Citizen of Turkestan region	Female	Offline	December 2025
20	Household	Citizen of Turkestan region	Male	Offline	December 2025
21	Farmer	Small Farm	Male	Online	December 2025
22	Farmer	Small Farm	Male	Online	December 2025
23	Expert	Hydraulic Engineer, author of the major overhaul project for the Turkestan Main Canal;	Male	Online	December 2025
24	Authority	Ministry of Water and Irrigation representative	Male	Offline	December 2025
25	Authority	Ministry of Water and Irrigation representative	Male	Offline	December 2025

Appendix V. Literature review

Climate and environmental context

The article search strategy was conducted using three academic databases: Google Scholar, Scopus, and scientific journals. Primary search terms included keywords, such as “climate change”, “Central Asian water management”, and “Turkistan”. Secondary terms were “arid regions”, “water scarcity” “water discharge”, “Turkistan” “Turkestan”.

Filters were applied accordingly to limit publications to peer-reviewed articles published between 2000 and 2025 in English and Russian languages. An example search string combined these terms as follows: (“climate adaptation” OR “climate change”) AND (“Turkestan” OR "Turkistan" OR “Central Asia”). The Voyant Tools service was used to analyze the selected articles and to form a word cloud to visualize key terms.

Quality Assessment. To assess the reliability of the selected studies, two key questions were considered:

1. Does the study provide a clear analysis of climate change challenges and adaptation strategies in arid regions?
2. Are external influences explicitly considered in relation to water security and resource management?

Water management technologies

The article search strategy was conducted using three academic databases: Google Scholar, Nazarbayev University Library, and Scopus. Primary search terms included keywords such as “water management technologies”; “arid regions”; “water scarcity” and “sustainable water use”. Secondary terms was “Turkestan”; “Turkistan”, “Turkestan Kazakhstan,” “Central Asia water management”; “drip irrigation” and “sprinkled irrigations”. Filters were applied to limit publications to peer-reviewed articles published between 2000 and 2025 in the English and Russian languages. An example search string combined the following terms: (“water management technologies” OR “sustainable water use”) AND (“arid regions” OR “water scarcity”) AND (“Turkestan" OR "Turkistan”). The Voyant Tools service was used in analyzing articles to form a word cloud. Also, the search method involved analyzing the Reference list in relevant articles.

Quality Assessment. To assess the reliability of the selected studies, the analysis asked following key questions:

1. Does the study clearly describe the technology’s effectiveness and limitations?
2. Are implementation challenges (e.g., financial, technical, social) explicitly addressed?

3. Is the methodology replicable in Turkestan's specific socio-environmental context?

Governance and policy frameworks

To ensure methodological rigor, this chapter source search also developed using Google Scholar, Nazarbayev University Library and Scopus databases, with primary keywords: “water governance”, “Aral-Syr Darya Basin regulation”, “Central Asia water policy”, “transboundary water conflict” and secondary keywords: “Turkestan Kazakhstan”, “institutional frameworks”, “Aral Sea crisis”, “Central Asia international water agreements”.

Quality Assessment. To assess the reliability of the selected studies, the analysis include following key questions:

1. Does the source clearly describe governance mechanisms (e.g., laws, regulations, institutions)?
2. Have the power dynamics or stakeholder roles been analyzed?
3. Is the study's context relevant to Turkestan?

The Aral-Syr Darya basin in which the city of Turkestan is located, the most important water source for Central Asia, has historically determined the system of water resources management in Turkestan city and neighboring areas. Water resources management in the Syr Darya basin has a long history of centralized governance. In the late 19th century, the first major irrigation projects for agricultural development were implemented under Tsarist rule in Russia (Xenarios, 2019). This centralized approach intensified during the Soviet era, when Moscow planned and distributed water among the Central Asian republics without regard to the new state borders. Massive irrigation canals and reservoirs were built to expand cotton crops and support agriculture in arid zones. The Soviet strategy considered the Aral-Syr Darya basin as a whole: the upper districts (Kyrgyzstan and Tajikistan) discharged water in summer to irrigate the lower districts (Kazakhstan, Uzbekistan, Turkmenistan), and in return they supplied fuel or electricity to the upper districts in winter. Management was top-down: water quotas for each republic were set centrally, and local water management in the region had little influence beyond the implementation of these allocations. While this system allowed for extensive irrigation development, it completely ignored environmental sustainability and local

needs, contributing to problems such as the Aral Sea crisis (Janusz-Pawletta & Gubaidullina, 2015; Teasley & McKinney, 2011; Micklin, 2007; Xenarios et al, 2019). After the collapse of the Soviet Union in 1991, the Syr Darya basin was divided between four independent states - Kazakhstan, Uzbekistan, Kyrgyzstan and Tajikistan.

The once unified system of governance fragmented as each country now pursued its own interests. In order to preserve the previous arrangements, the new states attempted to conclude temporary agreements. In February of 1992 The Almaty Agreement established a regional framework for water sharing. This agreement created the Interstate Commission for Water Coordination (ICWC) to continue to allocate water between states, aiming for continuity in water sharing. However, without the strong central authority of the Soviet state, enforcement became difficult (Dukhovny & Sokolov, 2003; Xenarios, 2019). Through the 1990s, additional declarations and institutions were formed (e.g. the Kyzylorda Agreement (1993) establishing the International Fund for Saving the Aral Sea, and the Nukus Declaration (1995) on sustainable development), but many of them remained declarative. In 1998, an important multilateral agreement on the Syr Darya was signed, often referred to as the “Bishkek Agreement” on the Syr Darya. Officially called the “Agreement between the Government of the Republic of Kazakhstan, the Government of the Kyrgyz Republic and the Government of the Republic of Uzbekistan on the Use of Water and Energy Resources of the Syrdarya River Basin”. It defined how Kyrgyzstan, Uzbekistan, Kazakhstan (and later Tajikistan) would share water resources and energy production. The 1998 Syr Darya Agreement initially helped formalize cooperation, but its implementation soon led to problems. Downstream countries often failed to provide promised payments for fuel or electricity to Kyrgyzstan, especially in wet years. Feeling deceived, Kyrgyzstan began unilaterally releasing excess water in winter for hydropower, leading to downstream flooding in winter and water shortages in summer. This cycle revealed the weaknesses of the agreement - it did not take into account multi-year hydrological variability and did not fully compensate for water storage services in the reservoirs. As a result, the effectiveness of the 1998 Bishkek agreement has diminished.

In Kazakhstan, water resources management is organized both at the national level and by basin. The newly established Ministry of Water Resources and Irrigation of the Republic of Kazakhstan determines policy and allocates water quotas within the country, while Water Basin Inspection manages water at the river basin level. Turkestan city, located in the Aral-Syr Darya basin, is under the control of the Aral-Syr Darya Basin Inspectorate for Regulation of Water Resources Use and Protection. At the local level,

water allocation between farms and cities is handled by city and regions (Oblast) administrations. However, since the Syr Darya is a transboundary river, national efforts are intertwined with regional institutions. Kazakhstan must coordinate with its neighbors to ensure water security in Turkestan, especially during dry seasons.

At the regional level, the Interstate Commission for Water Coordination (ICWC) is the key body established by the Central Asian states for joint transboundary water management. The ICWC consists of high-ranking water officials from each country and meets to make decisions on water allocation from the main rivers (Syr Darya and Amu Darya) in each growing season. Within ICWC, executive agencies - Basin Water Organizations (BWOs) "Syr Darya" and "Amu Darya" were established in the early 1990's. The BWO "Syr Darya", headquartered in Uzbekistan, is responsible for the day-to-day regulation of the Syr Darya waterflow: it manages key control points and reservoirs along the river (except for upstream dams, which are under the jurisdiction of Kyrgyzstan and Tajikistan), and controls water supply to each country according to agreed shares. Nominally, these institutions are part of the International Fund for Saving the Aral Sea (IFAS), which aims to promote cooperation to save the Aral Sea and manage the basin's resources.

Despite this institutional framework, governance problems do exist. Legally, existing agreements are outdated and not always supported by enforceable protocols. For example, the 1992 Almaty Agreement and related documents established principles but lacked reliable compliance mechanisms - today they are often seen as declaratory and in need of modernization. There is no supranational body that can forcibly allocate water or penalize non-compliance; the ICWC operates on the basis of consensus and goodwill. This leads to enforcement problems: if one country exceeds its water quota or fails to meet energy compensation, there is little the other countries can formally do except negotiate. Coordination among the four states is also difficult due to their overlapping interests and power asymmetries. In addition, the Syr Darya's legal framework does not cover all aspects - for example, groundwater and environmental flow needs are poorly considered, and Afghanistan (a potential player of the basin) is not involved in the agreements. In general, despite the existence of institutions (ICWC, BWOs, IFAS) and Kazakhstan's own internal structure, the overall governance structure is challenged by limited legal provisions, overlapping powers and the need for better integration between local, national and basin management.

Effective water management depends on governance reforms and cooperation between stakeholders, crucial for Turkestan to handle systemic inefficiencies and support sustainable urban development. Experts suggest using integrated frameworks like Integrated Water Resource Management to balance competing needs and encourage cooperation among all parties (Berndtsson & Tussupova, 2020). Problems such as outdated policies and weak agreements in Turkestan showed the need for stronger laws and better coordination to manage shared water resources (Janusz-Pawletta & Gubaidullina, 2015; Teasley & McKinney, 2011). Molden (2019) discusses that many water shortages are caused by poor management rather than a lack of resources, emphasizing that even the introduction of new water saving technology to increase water availability will not solve the problem without competent management.

Despite the breadth and depth of existing research articles, the existing literature does not answer the following questions and exposes the following research gaps. First, there is limited data on how local institutions such as local administrations and agencies implement national policies or involve communities in decision-making processes, leaving a gap in understanding the dynamics of grassroots governance. Research on how local governance structures in Turkestan adapt and implement broader national and basin-wide water policies in open sources is barely absent. Most academic studies examine water governance at the interstate or national level. However understanding the dynamics of local governance is critical to obtain a complete picture of water management in Turkestan city. Secondly, despite the “Gender” principle of Integrated Water Resources Management (IWRM), gender inequalities persist in Turkestan’s water management. Women's role in water management in Turkestan city is often ignored, despite their disproportionate responsibility for water harvesting in times of water scarcity. Thirdly, while climate resilience is widely addressed in national strategies and the newly adopted Water Code of the Republic of Kazakhstan, localized plans tailored to the recurrent droughts and arid conditions of Turkestan are absent. Fourth, there is insufficient data on how effective existing water allocation agreements are in practice, especially under conditions of seasonal water scarcity. For example, agreements such as the 1998 Bishkek Agreement set specific conditions, but there is little transparency and analysis of compliance: How often agreed water release schedules were followed? Did farmers in Turkestan receive their full share of water in dry years? How often compensations (fuel, electricity) were delivered as promised? Such assessments are scarce, making it difficult to draw lessons from the successes or failures of past agreements. More detailed empirical

studies and monitoring data on river flows, water use, and treaty compliance would help assess whether these framework agreements succeeded in alleviating water scarcity or whether informal arrangements prevailed instead. Finally, research on transboundary water governance has largely focused on state-level conflicts, ignoring the role of subnational actors such as Turkestan farmers, NGOs, and local cooperatives in shaping transboundary water governance.

Case studies and regional best practices

The article selection process involved Google Scholar, Scopus, and Nazarbayev University Library, with filters applied to peer-reviewed publications (2000-2025) in English and Russian. The Voyant Tools service was used to analyze key themes across selected studies.

Quality Assessment. To assess the reliability of the case studies, the following key questions were considered:

1. Does the study provide empirical data on water management outcomes?
2. Are the strategies and approaches clearly analyzed?
3. Are the proposed strategies adaptable to Turkestan's socio-environmental conditions?

One of the most relevant studies is by Zhumabaev et al. (2024), who examine water governance in Southern Kazakhstan, highlighting the critical role of local participation in improving resource efficiency. Their research shows that traditional, centralized water management models struggle to respond to climate variability, whereas community-based approaches enhance adaptability. In our case in Turkestan, where outdated infrastructure and inefficient distribution systems lead to high water losses, decentralizing management and involving local farmers and urban planners in decision-making could lead to more responsive and sustainable water use.

Berndtsson & Tussupova (2020) focus on infrastructure modernization and Water-Sensitive Urban Design (WSUD), advocating for rainwater harvesting, wastewater reuse, and smart irrigation technologies. Their findings suggest that in arid cities, integrating WSUD principles reduces pressure on freshwater sources and enhances long-term urban resilience. Given that Turkestan faces significant water losses due to outdated

supply networks, upgrading irrigation systems and implementing wastewater treatment could radically improve efficiency.

One of the most pressing concerns for Turkestan is transboundary water security, particularly regarding the Syr Darya River. Teasley & McKinney (2011) propose a hydro-economic model for water-sharing in the Syr Darya Basin, demonstrating that data-driven, coordinated management can reduce economic losses and ecological degradation. Their model suggests that if upstream and downstream users align water release schedules with seasonal needs, both agricultural and urban demands can be balanced more effectively. Applying similar data-driven forecasting and adaptive allocation mechanisms in Turkestan could prevent shortages during peak demand periods.

However, regional water cooperation is often complicated by geopolitical factors. Mustafabeyli (2024) analyzes the Afghan Kush-Tepa Canal, a major infrastructure project that could divert significant water flows from the Amu Darya River, indirectly affecting Syr Darya allocations. While this canal is not directly linked to Turkestan's water supply, it illustrates how upstream projects can reshape Central Asia's entire hydrological balance. Given Kazakhstan's reliance on shared water sources, strengthening diplomatic efforts within regional water agreements is essential to safeguard Turkestan's water security.

Technological advancements also play a crucial role in sustainable water management. Abdelkareem, Mansour & Akawy (2024) highlight the importance of remote sensing and GIS technologies in groundwater monitoring and rainwater harvesting. Their study emphasizes that mapping water resources in real-time allows for more precise allocation and conservation planning. Given that Turkestan faces seasonal water variability, integrating GIS-based decision-making could significantly improve water-use efficiency.

Shemer, Wald & Semiat (2023) focus on water recycling and membrane filtration technologies, emphasizing the role of ultrafiltration (UF) and reverse osmosis (RO) in producing high-quality recycled water. While desalination is not a viable option for landlocked Turkestan, expanding wastewater treatment and reuse systems could help reduce reliance on freshwater sources and improve resilience during drought periods.

The combined findings from these studies suggest that Turkestan's water management strategy should integrate three key elements: Decentralized, community-driven governance, shifting from rigid top-down structures to more adaptive and participatory models; Infrastructure modernization, with a focus on WSUD principles,

smart irrigation, and wastewater reuse; Transboundary cooperation, ensuring that regional agreements account for geopolitical challenges and hydrological interdependencies. By combining policy reforms, technological solutions, and regional coordination, Turkestan can strengthen its long-term water resilience in response to climate change and growing urban demand.

Limitations

Excluded materials contained book chapters, studies unrelated to arid environments, and gray literature (e.g., unpublished reports, conference abstracts). Also among the excluded materials were sources that confused Turkestan with Turkmenistan or used incorrect wording, such as “the Turkestan countries”, not related to the city of Turkestan