

RESEARCH ARTICLE

TRANSBOUNDARY WATER RESOURCES MANAGEMENT: THE CASE OF CENTRAL ASIA

Chinara Adamkulova^a, Nelli Akyzbekova^b, Alla Imakeeva^c, Kishimzhan Zhakshylykova^d, Almagul Attokurova^e^aInternational University of Kyrgyzstan, Bishkek, Kyrgyzstan.^bInstitute of Management and Business named after A.A. Asanova, Kyrgyz National University, Bishkek, Kyrgyzstan.^cInstitute of Management and Business, Kyrgyz National University named after Jusup Balasagyn, Bishkek, Kyrgyzstan.^dKyrgyz State University named after I. Arabaev, Bishkek, Kyrgyz.^eKyrgyz National University named after Jusup Balasagyn, Bishkek, Kyrgyz.*Corresponding Author Email: adamkulova_chinara@edurns.com

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ABSTRACT

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Water plays a key role in sustaining life, promoting social equity, and eradicating poverty, yet the management of transboundary water resources is often accompanied by geopolitical challenges. This article examines issues related to access and governance of water resources in Central Asia, where river basins hold significant ecological and economic importance. The scope of water-related problems in the region, their geopolitical dimensions, existing legal frameworks for transboundary water management, and the potential of cooperative strategies for sustainable water resource management are analyzed. Special attention is given to the institutionalization of water conflicts, which have acquired an environmental dimension, as well as the development of approaches to assessing resilience and reducing water stress. The findings and recommendations presented in the article aim to contribute to the development of more effective solutions at local and regional levels.

KEYWORDS

Transboundary water resources management, climate change adaptation, inter-state cooperation, sustainable development, Central Asia, regional cooperation

1. INTRODUCTION

Water is a fundamental resource that sustains all living systems and is widely recognised as critical to achieving global peace, social equity and poverty eradication. The complex functioning of river systems necessitates complex policy, legal and infrastructural frameworks to ensure equitable access to and effective management of water resources. However, shared water bodies present a unique challenge to global resource management, often defying regional co-operation efforts, despite international appreciation of the principles and forums convened to address such issues. This challenge makes effective 'resource governance' the exception rather than the rule, especially in regions where river basins support diverse ecologies and livelihoods.

Historically, tensions around water management often reflect broader geopolitical dynamics. National security interests are often asserted against the economic opportunities of neighbouring countries, particularly in regions with overlapping historical claims to ecospace projected as sovereign territories. Nowhere is this interplay of resource management and geopolitics more evident than in transboundary water scenarios in Central Asia, a region where river systems not only underpin local ecology but are also critical factors in economic and political stability.

Central Asia occupies a unique position in world geopolitics due to its strategic location as a bridge between East and West, as well as a rich history of economic co-operation, cultural exchange and social interaction between Turkmen, Uzbeks, Kazakhs, Kyrgyz and Tajiks. The abundance of rivers in the upstream countries (Kyrgyzstan and Tajikistan) highlights

the critical importance of water resources for the downstream countries (Kazakhstan, Turkmenistan and Uzbekistan), which have historically been a source of both tension and co-operation. Today, the management of these shared waters remains fraught with difficulties due to competing national interests, ethnic tensions and historical grievances.

Despite numerous regional initiatives, transboundary water management in Central Asia remains contentious. Nationalist and geopolitical rivalries have overshadowed efforts to implement sustainable management practices, and water-related conflicts have taken on an 'ecological impetus', further institutionalising disputes and complicating their resolution. This article seeks to address these pressing issues by exploring the complexities of water governance in Central Asia and investigating innovative strategies for sustainable and cooperative management.

This article contributes to the academic discourse on water governance by offering a focused analysis of the unique challenges facing Central Asia. In contrast to existing studies that mainly look at global or bilateral water conflicts, this paper focuses on the geopolitical and ecological context of the region, emphasising the relationship between historical legacies and contemporary governance arrangements. The novelty of the study lies in the interdisciplinary approach that combines political, legal and environmental perspectives to propose workable strategies for sustainable transboundary water management.

Furthermore, the article emphasises the scientific importance of understanding water-related stresses and resilience in a region where conflicts over resources are both a manifestation and driver of wider geopolitical dynamics. By identifying gaps in existing legal frameworks,

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exploring the implications of regional water policy, and suggesting strategies for co-operation, this study offers valuable insights that can inform both policy development and future research. It aims to highlight ways to reduce water stress, increase resilience and promote regional cooperation in one of the world's most geopolitically significant but understudied areas.

The Republic of Kazakhstan, the Kyrgyz Republic, the Republic of Tajikistan, Turkmenistan, and the Republic of Uzbekistan constitute Central Asia, located at the heart of Eurasia and playing a crucial role in the water relations of the region. The ambition of these countries for stability and prosperity amidst global and regional adversities calls for a holistic approach to the development of water resources (Janusz-Pawletta and Gubaidullina, 2015).

2. LITERATURE REVIEW

The management of transboundary water resources, particularly in regions with complex geopolitical landscapes like Central Asia, has been extensively studied within the fields of environmental science, political geography, and international relations. This review summarizes the most relevant literature and highlights the contributions and gaps that this study aims to address.

2.1 Integrated Water Resources Management (IWRM)

The concept of IWRM has been widely accepted as a framework for managing water resources sustainably. As noted by GWP (2000), IWRM promotes the coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising the sustainability of vital ecosystems. In Central Asia, authors like Wegerich and Warner (2010) have discussed the application of IWRM principles, but challenges persist due to the region's unique geopolitical dynamics and historical context. This study builds on their work by exploring the practical implementation of IWRM in the context of Central Asian river basins.

2.2 Geopolitical Dynamics and Water Management

Scholars such as have examined the geopolitical dimensions of water management in Central Asia, emphasizing how the legacy of Soviet-era water distribution policies continues to influence current interstate relations (Janusz-Pawletta and Gubaidullina, 2015). Their research highlights the persistent tension between upstream and downstream countries, particularly in the Syr Darya and Amu Darya basins. Our study contributes to this discourse by providing updated empirical data and analyzing recent developments in interstate cooperation.

2.3 Climate Change and Water Resources

The impact of climate change on water availability in Central Asia has been a growing area of concern. Studies have demonstrated that glacier melt and changing precipitation patterns are likely to exacerbate water scarcity in the region by (Sorg et al., 2012; Immerzeel et al., 2020). These findings underscore the importance of adaptive management strategies, which our research addresses by proposing specific climate adaptation measures within the IWRM framework.

2.4 Water Conflicts and Cooperation

The literature on water conflicts and cooperation in Central Asia, such as the work of often focuses on the potential for conflict over shared water resources (Zhiltsov et al., 2018). However, there is also significant research on cooperation mechanisms, as explored by the United Nations Economic Commission for (Europe, 2011). This study adds to the cooperative aspect by recommending the establishment of a Central Asian Water Resources Commission, aimed at facilitating dialogue and joint management efforts.

2.5 Technological Innovations in Water Management

Technological advancements, particularly in GIS and remote sensing, have revolutionized the monitoring and management of water resources. Authors like have discussed the role of such technologies in Central Asia, highlighting their potential to improve water use efficiency (Vinokurov et al., 2021). Our research leverages these technologies to provide a detailed analysis of water distribution patterns and their implications for policy-making.

2.6 Gaps in the Literature

While existing research provides valuable insights into various aspects of water management in Central Asia, there remains a lack of comprehensive studies that integrate these diverse perspectives into a cohesive framework for action. Specifically, there is a need for research that

combines technological, geopolitical, and environmental analyses to propose actionable strategies for sustainable water management in the region. This study aims to fill this gap by offering an integrated approach that addresses the complexities of transboundary water management in Central Asia.

3. METHODS AND MATERIALS

This study employs an integrated approach grounded in Integrated Water Resources Management (IWRM) principles, which emphasizes the coordinated development and management of water, land, and related resources. The methodology is structured across three analytical levels—macro, meso, and micro—allowing for a comprehensive examination of water resource management in Central Asia.

3.1 Data Collection

We utilized Geographic Information Systems GIS to map and analyze spatial data related to water distribution, infrastructure, and environmental factors across the Amu Darya and Syr Darya river basins. This technology enabled us to visualize changes over time and assess the impact of geographic and environmental variables on water management.

Semi-Structured Interviews: Interviews were conducted with key stakeholders, including government officials, representatives of non-governmental organizations (NGOs), and local community leaders. These interviews provided qualitative insights into the challenges and opportunities in transboundary water management, capturing diverse perspectives from different levels of governance.

Document Analysis: We reviewed and analyzed a wide range of policy documents, agreements, and reports related to water management in Central Asia. This included historical treaties, current water-sharing agreements, and international environmental assessments. The document analysis helped contextualize our findings within the broader policy framework.

GIS technology played a key role in our study in mapping and analyzing spatial data related to water resources in the Amu Darya and Syr Darya river basins. Specifically, we used GIS for the following purposes:

- **Hydrological and watershed management:** GIS was used to model river flows and analyze the impact of different water management scenarios. This analysis provided an understanding of how changes in river catchments influenced by land use and management practices affect water distribution and availability.
- **Infrastructure and Sanitation Mapping:** We mapped major water infrastructure such as dams, reservoirs and irrigation networks using mobile GIS software. This allowed us to assess the state of the infrastructure and identify areas where improvements are needed to improve water use efficiency and sanitation.

These GIS applications provided a sound basis for evidence-based decision-making, allowing us to visualize temporal and spatial changes in water resources and develop sound recommendations for sustainable management of transboundary water resources.

We conducted interviews with key stakeholders, including government officials, representatives of non-governmental organizations (NGOs), and local community leaders. These interviews provided qualitative insights into the challenges and opportunities in transboundary water management, capturing diverse perspectives from different governance levels. The information gathered was used to complement spatial data and identify areas where governance practices could be improved.

We reviewed and analyzed a wide range of policy documents, agreements, and reports related to water management in Central Asia, including:

- **International Treaties and Agreements:** Historical and contemporary water-sharing treaties between Central Asian countries. This analysis helped assess the effectiveness of current cooperation mechanisms and pinpoint areas needing enhancement.
- **National Water Management Policies:** Legislative frameworks and strategies within individual countries, providing a basis for understanding internal regulatory structures and identifying discrepancies in the transboundary context.
- **Reports from International Organizations:** Documents detailing climate change impacts on regional water resources and recommendations for sustainable management. These sources were essential for contextualizing our findings and formulating adaptive governance strategies.

3.2 Data Analysis

Quantitative data on water availability, usage patterns, and climate variables were subjected to statistical analysis. We employed trend analysis to identify long-term patterns and potential future scenarios in water availability and distribution.

We evaluated existing water management policies and interstate agreements using a combination of qualitative content analysis and comparative analysis. This allowed us to assess the effectiveness of current governance structures and identify gaps that need to be addressed to improve cooperation and adaptation strategies.

We used trend analysis to evaluate long-term changes in water availability and usage across the Amu Darya and Syr Darya river basins. This method involved analyzing time-series data on hydrological parameters, such as river flow rates and reservoir levels, to identify patterns and forecast future trends. The analysis helped us understand the impact of climate change and human activities on water resources.

Utilizing GIS, we conducted spatial analysis to assess the distribution and variability of water resources. This included evaluating the geographic spread of water infrastructure and identifying areas most vulnerable to droughts or floods. Spatial patterns were statistically analyzed to pinpoint hotspots that require targeted management interventions.

We conducted qualitative content analysis of policy documents and interview transcripts to identify recurring themes and evaluate the effectiveness of existing governance frameworks. This method allowed us to extract meaningful insights from textual data and compare governance practices across different countries.

We assessed the success of current water management strategies based on their ability to maintain sustainable water levels and prevent resource depletion. Criteria included the consistency of water flow and the infrastructure's capacity to support agricultural and urban needs.

The impact of proposed and existing policies on regional water security was evaluated. Metrics included the reduction in water-related conflicts and the improvement in equitable water distribution among riparian states.

We used criteria such as the adaptability of water management systems to climate variability and the implementation of climate-resilient infrastructure. Success was measured by the reduction in the vulnerability of communities and ecosystems to climate extremes.

The level of stakeholder involvement in water governance and the coherence of policies across national and regional levels were assessed. Effective policies were those that facilitated collaboration, knowledge sharing, and conflict resolution among stakeholders.

3.3 Theoretical Framework

Our analysis is grounded in contemporary governance theory, with a focus on the application of IWRM principles in transboundary contexts. The theoretical framework incorporates elements of political ecology, which examines the relationships between political, economic, and social factors in environmental management. This approach facilitated a holistic understanding of the challenges and potential solutions for water resources management in Central Asia.

3.4 Validation of Findings

To ensure the robustness of our results, we employed triangulation by cross-referencing findings from GIS analysis, interview data, and document analysis. This multi-method approach enhanced the validity of our conclusions and provided a more nuanced understanding of the complex dynamics at play in transboundary water management.

4. RESULTS

4.1. Historical and Geographical Context for the Development of the Region

Central Asia has significantly influenced the economic, historical, cultural, and intellectual landscape of the modern world for many centuries. Positioned in the center of Eurasia, the region comprises highlands, steppes, barchan deserts, and saline semi-deserts, which dictate a hot and dry climate in summer and cold, windy conditions in winter, underscoring a unique reliance on freshwater sources. The lack of river systems for water communication with major trade centers means the region is isolated from oceanic and maritime links. This isolation has historically concentrated economic activities around oases, intermountain valleys, and foothills, while vast steppes and deserts were occupied by nomadic pastoralists of initially Iranian and later Turkic descent. The recorded history of Central Asia stretches back 3000 years, with the first urban

settlements emerging in the second millennium BC, though the region's past extends several millennia further. It was home to ancient states and notable cultural and historical regions like Margiana, Bactria, Sogdiana, Fergana, and Khorezm. A millennium ago, the development level and scale of economic and cultural activities were so significant that this era is rightly termed the "Golden Age of Central Asia". The approach to production and agriculture in Central Asia was extensive and reliant on irrigation. Most major cities were situated near isolated oases, divided from each other by deserts or steppes. A network of underground and surface canals, dams, and reservoirs was engineered to channel water across distances. According to Frederick Starr, a leading contemporary researcher of Central Asia, no civilization has matched the efficiency and complexity of Central Asia's irrigation systems (Nag et. al., 2016). The construction and maintenance of large-scale irrigation systems, such as the one in Merv (present-day Turkmenistan), demanded considerable human resources. Central Asia's strategic position as a junction of the shortest routes connecting all four major economic and cultural zones of Eurasia at the time - the Middle East, Europe, India, and China - made it a unique region through which trade caravans passed for three millennia.

4.2. Population and Economy of Central Asian Countries

Before delving into the intricate issues of water resource management in Central Asia, it is essential to understand the region's unique characteristics and the origins of these pressing concerns. A glance at the current dynamics reveals that Central Asia is undergoing a transformative phase. Since achieving independence from the Soviet Union in the early 1990s, the region's states have encountered various developmental hurdles, including political instability, corruption, and infrastructural limitations. However, the past decade has marked a notable shift towards progress, with Central Asian nations enhancing regional collaboration to forge a stable and thriving future.

The five sovereign states of Central Asia—Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan—span over 4 million square kilometers in the heart of the expansive Eurasian continent. Over three decades' post-independence, these countries have navigated a complex journey towards integration into the global economy. This period has been characterized by the development of regional cooperation and the strengthening of economic ties with major neighboring economies, such as China and Russia. For a more detailed comparative analysis, let us examine the statistical data concerning the Central Asian countries. According to the Real Time World Statistics portal, as of January 21, 2024 the combined population of the Central Asian countries stands at approximately 78.3 million with their collective territory measuring nearly 4 million square kilometers (Worldometers, 2024),. The Gross Domestic Product (GDP) of these nations collectively amounts to USD 384.96 billion (World Bank Group 2024). The proportion of these indicators can be seen more clearly in the figure 1.

Table 1: The structure of the CA population	
Country	Population (persons)
Kazakhstan	19744241
Kyrgyzstan	6735347
Tajikistan	10143543
Turkmenistan	6516100

Source: created by author by (Worldometers, 2024)

For a more visual picture of the population structure of the Central Asian countries, we have constructed a structural diagram based on the data from the population.

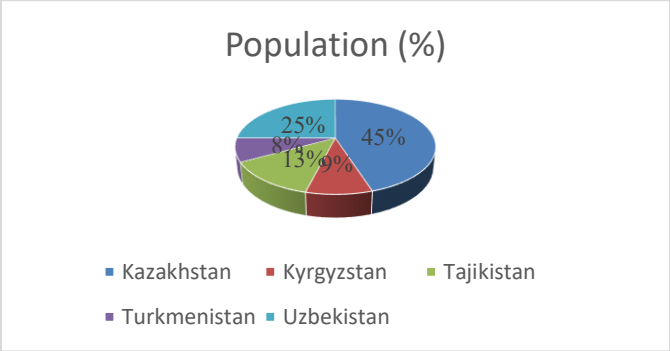


Figure 1: The structure of the CA population

Source: created by author by (Worldometers, 2024)

Further we analyzed the data on the territory of the Central Asian countries and revealed that the largest territory in Kazakhstan - 2 724 000 km², and the smallest - in Turkmenistan – 488 100 km² (Table 2).

Table 2: The structure of the CA territory	
Country	Territory, km ²
Kazakhstan	2724000
Kyrgyzstan	191300
Tajikistan	142600
Turkmenistan	488100
Uzbekistan	448969
Total	3994969

Source: created by author by (Worldometers, 2024)

On the structural diagram of territory distribution, we would like to demonstrate how unevenly it is distributed among the countries, as Uzbekistan has the largest population, but its territory is much smaller than that of Kazakhstan (Figure 2).

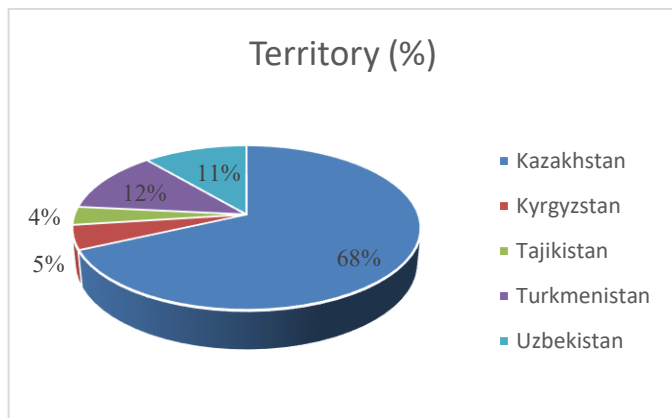


Figure 2: The structure of the CA territory

Source: created by author by (Worldometers, 2024)

Finally, we have made a comparative analysis by GDP volume between the Central Asian countries based on the data in Table 3. (World Bank Group, 2024)

According to the data in Table 3 we see that the largest volume of GDP is produced in Kazakhstan (\$261,421,121,085.57), the second place in GDP production belongs to Uzbekistan, the third place is occupied by Turkmenistan. These three countries have large oil and gas reserves. Kyrgyzstan and Tajikistan close the list, practically at the same level of GDP volume. These two countries are located mainly in mountainous areas and do not have large oil and gas reserves.

If we graphically depict data on the GDP volume of the Central Asian countries, we will see more clearly how small a share belongs to Kyrgyzstan and Tajikistan.

In Figure 3. it can be seen that the share of gross domestic product in upstream countries is only 6,00%, while the share of GDP in downstream countries is 94,00% (World Bank Group, 2024)

Table 3: The structure of the CA GDP	
Country	GDP
Kazakhstan	\$261421121085,57
Kyrgyzstan	\$13987627908,84
Tajikistan	\$12060602008,85
Turkmenistan	\$59887334844,07
Uzbekistan	\$90889149306,73
Total	\$438245835154,05

Source: created by author by (World Bank Group, 2024)

In summary, it should be noted that the countries of Central Asia demonstrate significant differences in geographical location, including the

division into upstream and downstream countries. Moreover, there are stark differences in demographic characteristics: Uzbekistan is the most densely populated country in the region, accounting for 44% of Central Asia's total population. Economic development also varies: Kazakhstan leads with a GDP that accounts for 58% of the region's total GDP. Meanwhile, Kyrgyzstan and Tajikistan, located in the upstream and predominantly mountainous areas (80-90% of the territory), lag in economic development, their combined GDP making up only 6% of the region's total GDP (Figure 3).

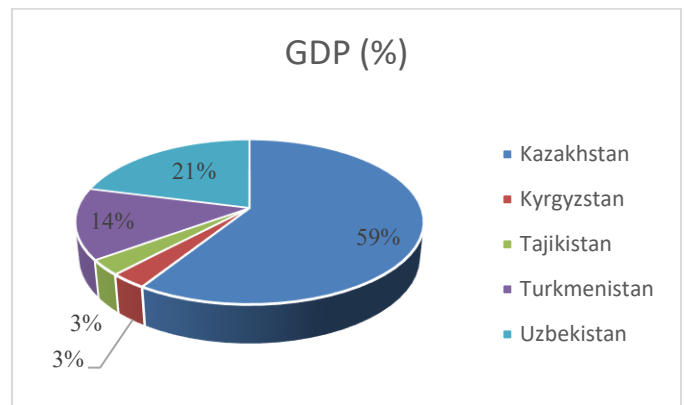


Figure 3: The structure of the CA GDP

Source: created by author by (World Bank Group, 2024)

Given these circumstances, it logically follows that upstream countries (Kyrgyzstan and Tajikistan) lack the economic resources to maintain and create new technical structures for water conservation during the winter period. Downstream countries (Kazakhstan, Turkmenistan, and Uzbekistan), having much more economic resources and being more interested in obtaining water during the summer period, should invest in the reservoirs and hydropower stations of Kyrgyzstan and Tajikistan. Only joint efforts in the reconstruction of water facilities will allow for the efficient use of water resources (Adamkulova and Aitbaev, 2023).

4.3. Water Distribution in Central Asia

Water, the crux of life, has historically been a catalyst for numerous disputes. History is replete with struggles over water access in regions like the Tigris-Euphrates, Nile, and Jordan river basins. In Central Asia, while armed conflicts specifically over water have yet to occur, the unregulated exploitation of water resources poses a significant threat to regional stability. These challenges extend beyond the mere provision of drinking water and irrigation; they encompass the economic aspects of water usage, particularly in sectors like cotton cultivation and hydroelectric power production. Consequently, effective management of water resources is critical for maintaining both social and political harmony within the Central Asian republics.

The lack of a regulated water distribution system for major Central Asian rivers, such as the Amu Darya and Syr Darya, presents a grave concern, undermining the region's stability. Despite receiving international attention and support, the countries involved have struggled to reach a consensus on water sharing agreements. At the heart of this issue is the uneven allocation of water resources among the five nations, a situation compounded by their shared geographical features and historical connections.

A pressing issue in water distribution involves the Amu Darya and Syr Darya rivers, which are integral to the Aral Sea basin. This basin spans large areas of southern and southeastern Kazakhstan, most of Kyrgyzstan, nearly all of Uzbekistan and Tajikistan, as well as portions of Turkmenistan, northern Afghanistan, and parts of Iran. The Amu Darya, Central Asia's longest river, originates from the Panj and Vakhsh rivers at the Afghanistan-Tajikistan border. It traverses Afghanistan and Turkmenistan before re-entering Uzbekistan, ultimately flowing into the Aral Sea. The Amu Darya stretches for approximately 2,540 kilometers. The Syr Darya, together with its major tributary, the Naryn, extends over 3,019 kilometers. Both rivers derive their flow from the melting glaciers and snow in the Central Asian mountain ranges, underscoring the interconnectedness of the region's water system.

This region possesses adequate water resources; yet, due to the complex interplay of topography that frequently aligns with national boundaries, the distribution of water is markedly uneven. Notably, 87% of the water within the Aral Sea basin originates from the mountainous terrains of Kyrgyzstan, Tajikistan, and Afghanistan, while 83% of these resources are

consumed across the steppes and deserts of Uzbekistan, Turkmenistan, and southern Kazakhstan, areas virtually devoid of indigenous water supplies (United Nations Economic Commission for Europe, 2011).

Beyond the rivers, Central Asia is home to several distinct water systems unaffiliated with the Aral Sea basin. For instance, southeastern Kazakhstan is part of Lake Balkhash's basin, fed by the Ili River, which begins in China and flows into Kazakhstan. Regions north of Balkhash fall within the Irtysh River basin, traversing Kazakhstan to join the Ob River in Russia. Additionally, Kyrgyzstan boasts Lake Issyk-Kul, a self-contained water system, and in its eastern part lie rivers contributing to the Tarim River system that extends into China.

Despite the regional abundance of water, its utilization does not uniformly satisfy the demands of all countries involved. The majority of water resources are dedicated to irrigation and industrial purposes in nations where water access is inherently restricted. This disparity fosters further strain and discord among states striving to secure water for their economic needs and populations.

The pathway to effective water management in Central Asia lies in collaboration and united efforts from all concerned parties. It necessitates the formulation of unified water usage strategies, the regulation of river flows, and the establishment of mechanisms for conflict resolution. Such a comprehensive approach is vital for the sustainable development of the region and for averting potential conflicts in the future.

This entire region has a sufficient amount of water resources; however, due to variations in relief, which often coincide with state borders, water is distributed extremely unevenly. For example, 87% of the water in the Aral Sea basin is formed in the mountains of Kyrgyzstan, Tajikistan, and Afghanistan, whereas 83% of these water resources are used in the steppes and deserts of Uzbekistan, Turkmenistan, and southern Kazakhstan, where there are practically no own water supplies.

Table 4: Water resources of the Aral Sea basin						
Country	Amudarya		Syrdarya		Total	
	Km3	%	Km3	%	Km3	%
Kazakhstan	-	-	4.50	12.12	4.50	3.89
Kyrgyzstan	1.90	2.42	27.40	73.77	29.30	25.35
Tajikistan	62.90	80.17	1.10	2.96	64.00	55.36
Turkmenistan	2.78	3.54	-	-	2.78	2.40
Uzbekistan	4.70	5.99	4.14	11.15	8.84	7.65
Afghanistan	6.18	7.88	0.00	0.00	6.18	5.35
Total	78.46	100.00	37.14	100.00	115.60	100.00

Indeed, although Afghanistan is not part of Central Asia, its territory is located in the Amu Darya river basin. The country plans to construct a canal that would divert up to one-third of the river's water volume. Such actions could lead to a deficit of irrigation water in Uzbekistan, Tajikistan, and Turkmenistan during the hot summer months. The Kosh Tepa canal is expected to be 285 kilometers long, 100 meters wide, and about 8.5 meters deep. Upon completion, the canal will supply water to three northern districts of Afghanistan, allowing the country to use no less than one-third of the Amu Darya's water. Uzbekistan fears that this will lead to a critical reduction in access to water resources (Current Time TV. 2023, April 7/ Afghanistan builds a canal.). It is in this context that Afghanistan is mentioned in the discussion of regional water resources.

In addition to rivers, there are a number of other water systems in Central Asia that are not connected to the Aral Sea basin. For example, southeast Kazakhstan belongs to the basin of Lake Balkhash, formed by the Ili River, which originates in China and flows into Kazakhstan. Some areas north of Balkhash are part of the basin of the Irtysh River, which flows through Kazakhstan and discharges into the Ob River in Russia. In addition, Kyrgyzstan has Lake Issyk-Kul, which forms an independent water system, and in the eastern part of the country there are rivers that are part of the Tarim River system that flows to China.

Despite the availability of sufficient water in the region, its use does not always meet the needs of all countries. Most water resources are used for irrigation and industry in countries where access to water is limited. This creates additional tensions and conflicts between states seeking to provide water for their economies and populations.

Effective water management in Central Asia requires cooperation and concerted action by all stakeholders. This includes developing common strategies for water use, regulating river flows and establishing conflict resolution mechanisms. Only such an approach can ensure sustainable development of the region and prevent possible conflicts in the future.

4.4. The Complex Legacy of the Soviet Era

The challenging climate of Central Asia necessitated the adoption of irrigation for viable agriculture on its plains, fostering the development of intricate systems for water resource management and communal cooperation. However, this equilibrium was disrupted during the Soviet era, with the advent of collectivization and the centralization of the water economy, primarily aimed at bolstering cotton production. These policies led to significant adversities for both agriculture and society at large.

The construction of dams in the upstream sections of major rivers and the expansion of irrigation in the downstream areas precipitated numerous regional issues, such as the degradation of arable land and a reliance on external food supplies. The management of water resources and electricity generation was centralized under Moscow's control, frequently giving rise to tensions and disputes among the Central Asian republics.

By the mid-1980s, the drawbacks of prioritizing cotton cultivation became unmistakably apparent, manifesting in economic and environmental distress. The mismanagement of water resources resulted in inefficiencies and grave ecological repercussions, notably the desiccation of the Aral Sea. The authorities' attempts to mitigate these issues by diverting water from other regions were not only costly but also environmentally negligent (Zhiltsov et. al., 2018).

By the twilight of the Soviet era, the allocation and utilization of water resources in Central Asia were marked by inefficiency, culminating in a multifaceted crisis encompassing political, economic, and ecological dimensions. The dissolution of the Soviet Union and the consequent emergence of new republics in Central Asia further complicated the hydrological landscape. Many rivers and water bodies became bisected by international borders, which were not considered in the design of existing hydraulic infrastructure. Efforts by Moscow to balance the diverse interests of the newly sovereign states often exacerbated tensions and conflicts. The established system of water allocation quotas, with its narrow focus on cotton production metrics, proved to be politically, economically, and environmentally unsustainable.

In summary, water management issues emerged as a paramount challenge for Central Asia by the end of the Soviet period, underscoring the need for a holistic and sustainable approach to resource governance and interstate conflict resolution.

4.5. An Insoluble Problem or a Lack of Political Will?

Upon gaining independence, the five Central Asian republics were faced with the challenge of delineating state borders amongst themselves. What were previously administrative boundaries within a single country became international borders, with major rivers now crossing several states. This led to the division of residential areas, infrastructure, and irrigation systems, making the issue of water resource distribution an international concern.

The Soviet water management system, which was centralized and heavily focused on cotton production, was no longer applicable to the new realities. Each republic started to defend its interests, leading to tense negotiations and conflicts. Mountainous republics such as Kyrgyzstan and Tajikistan demanded more water, while the downstream states, particularly Uzbekistan and Turkmenistan, resisted these demands. They refused to exchange water for cheap energy and insisted on payment, which led to protests and forced the mountainous republics to look for alternative energy sources.

These dynamics have transformed water issues into a matter of political maneuvering between the republics. However, the absence of qualified policy experts and a lack of political will among the leaders of these republics have complicated the resolution of conflicts and cooperation. As a result, despite numerous agreements signed and institutions created to regulate water issues, many agreements remain unfulfilled, and established institutions are not functioning effectively.

Despite active political efforts and attempts to address water problems, the absence of will and cooperation among the republics hinders the effective resolution of these issues.

4.6. Non-compliance with Agreements

A significant moment in addressing water issues in Central Asia was the signing of the agreement on February 18, 1992, in Almaty by all five

Central Asian states. This agreement was intended to preserve the existing system of water distribution inherited from the Soviet period until new rules based on international norms could be developed. However, new rules have yet to be formulated.

Among the numerous other agreements, it is crucial to highlight the 1998 agreement signed by Kyrgyzstan, Uzbekistan, and Kazakhstan (later joined by Tajikistan) on the joint use of water and energy resources in the Syr Darya river basin. This area had a high conflict potential due to Kyrgyzstan's ability to regulate the flow of the Naryn River, a source of the Syr Darya. Despite the signing of the agreement, its provisions have not been effectively implemented and are considered ineffective (Adamkulova and Aitbaev, 2023). No agreements have been reached to regulate water resources in the Amu Darya river basin effectively. Tajikistan lacks hydraulic structures that can significantly influence the flow of the Amu Darya, as the majority of the water is controlled by the Nurek Dam, which regulates the Vakhsh River, contributing only about 25% of the total flow of the Amu Darya.

The only truly functioning agreement is between Kazakhstan and Kyrgyzstan, regulating the maintenance costs of hydraulic structures on the Chu and Talas rivers. However, the water volumes in these rivers are minor compared to the Amu Darya and Syr Darya. While new negotiations on energy compensation are held annually, their outcomes are not publicly disclosed, making it challenging to assess their effectiveness or to develop concrete plans based on these agreements. Instead of interstate regulation, agreements are often reached at the local level (Water resources of Central Asia and their use 2016).

Although water resource distribution still operates under the 1992 agreement, based on Soviet-era rules, its effectiveness is questionable. The prospects for adopting new rules at the regional level remain unclear. However, developing new regulations will become an increasingly complex task in the face of climate change, rising water demands, and the pursuit of peaceful regional development.

The political leadership in water development matters must particularly manifest itself in strategic planning, anticipating changes, and especially in assessing destabilizing factors such as changes in population size and distribution, climate change and its impact on resources and water consumption, shifts in the structure and development of water-intensive industries, and the dynamics of market mechanisms (prices, global influences, etc.). It is crucial to understand that the complexity of infrastructure and the multitude of stakeholders in the water sector—encompassing virtually all of society from water management authorities to consumers—makes it impossible to achieve quick, fundamental solutions to water management issues in a short time. This requires time and resources, hence, a clear political vision, particularly with respect to the use of transboundary waters. Additionally, it is essential to consider and anticipate the behavior of neighboring states, aiming above all to clearly define it through international agreements, joint plans, and most importantly, coordinated, harmonious, and friendly actions that comply with international law and behavioral norms.

5. DISCUSSION

The findings of this study provide crucial insights into the complexities of transboundary water management in Central Asia. This section discusses the implications of these findings in the context of existing literature, the challenges faced by the region, and the potential pathways for future development.

The study confirms the effectiveness of IWRM as a framework for managing shared water resources in a region characterized by geopolitical tensions and environmental challenges. While previous studies have emphasized the theoretical benefits of IWRM, this research provides empirical evidence of its practical application in the Amu Darya and Syr Darya river basins (Wegerich and Warner, 2010). The successful integration of geographic information systems (GIS) into IWRM practices demonstrates the potential of technology to enhance data-driven decision-making processes.

The geopolitical dynamics of Central Asia significantly influence the management of transboundary water resources. The study's findings align with observations regarding the lingering effects of Soviet-era water distribution policies (Janusz-Pawletta and Gubaidullina's, 2015). However, this research adds a contemporary perspective by analyzing recent interstate agreements and highlighting the ongoing challenges in achieving equitable water distribution among the Central Asian republics. The analysis suggests that while political will is essential, the lack of effective enforcement mechanisms remains a critical barrier to successful cooperation.

The impact of climate change on water availability in Central Asia cannot be overstated. This study's findings support the work by demonstrating the tangible effects of changing climate patterns on the region's water resources of (Sorg et al., 2012; Immerzeel et al., 2020). The proposed climate adaptation strategies, including the establishment of a Central Asian Water Resources Commission, are crucial for mitigating the adverse effects of climate change. These recommendations are intended to foster regional collaboration and proactive planning, which are essential for the sustainable management of water resources in the face of climate uncertainties.

Despite numerous agreements and initiatives aimed at fostering cooperation, the Central Asian republics continue to face significant challenges in managing their shared water resources. The study identifies key obstacles, including the lack of transparent data-sharing mechanisms, political distrust, and infrastructural limitations. However, the research also highlights opportunities for progress, such as the adoption of advanced water conservation technologies and the potential for joint investment in infrastructure projects. The discussion emphasizes that regional cooperation is not only possible but necessary for ensuring water security and sustainable development in Central Asia (Krasznai, 2021).

This study contributes to the existing literature by providing a comprehensive analysis that integrates geopolitical, environmental, and technological perspectives on water management in Central Asia. The findings offer practical recommendations for policymakers and stakeholders, aiming to bridge the gap between theory and practice. Future research could further explore the role of international organizations in facilitating cooperation and the potential impact of emerging technologies, such as remote sensing and artificial intelligence, on water management practices. The discussion section underscores the importance of integrated approaches to managing transboundary water resources in Central Asia. By addressing the geopolitical, environmental, and technological dimensions of water management, this study offers a holistic framework for understanding and addressing the challenges facing the region. The recommendations provided aim to enhance regional cooperation, improve water resource management, and promote sustainable development in Central Asia.

6. CONCLUSION

Water resources management in Central Asia, while challenging, is not insurmountable. However, relying on outdated Soviet-era principles is unlikely to provide a comprehensive regional solution, as water issues are closely intertwined with the political, social and economic transformations in the region. Addressing these challenges requires time, patience and a renewed commitment to co-operation and innovation.

Our research on transboundary water management in Central Asia has highlighted the urgent need for greater co-operation and integrated strategies to address pressing issues such as climate change, water scarcity and inter-state disputes. Despite some progress, significant gaps remain in the implementation of sustainable management practices. To address these gaps, this paper offers several practical recommendations:

1. Establish a Central Asian Water Commission: To promote regional co-operation, a governing body responsible for controlling water allocation, resolving disputes and developing climate adaptation strategies should be established. Such a body would provide a platform for joint decision-making and equitable allocation of resources among riparian states. It should be noted that the existing IFAS body could not become a platform for productive co-operation because Kyrgyzstan temporarily stopped its membership due to disagreements.
2. Adopt water-saving irrigation practices and modernise infrastructure: States should give priority to modernising irrigation practices and infrastructure to improve water use efficiency and reduce wastage. These measures will not only increase agricultural productivity but will also help to conserve water in the face of increasing water scarcity.
3. Climate adaptation strategies: Given the significant impact of climate change on water availability, there is a need to coordinate regional efforts to develop and implement climate adaptation measures. This includes monitoring water resources, predicting climate impacts and integrating adaptive practices into water management policies.

Developing an integrated approach to transboundary water resources management is not only necessary, but also critical to addressing existing challenges and unlocking opportunities for sustainable development across the region. Effective water resources management has indirect benefits, including increased agricultural productivity, improved livelihoods and enhanced regional stability.

The following additional measures are recommended to achieve this objective:

Reform of legal instruments: Governments and stakeholders should actively promote the development of a robust international legal framework and reform of national legislation governing transboundary water management. The priorities of this framework should be sustainability, equitable access and prevention of environmental degradation.

Strengthen regional co-operation: Regional co-operation is vital to mitigate water disputes and ensure equitable benefit sharing. International organizations, politicians and civil society must engage in negotiation processes to build informed consensus to foster cooperation and reduce tensions.

By pooling resources, experience and expertise, Central Asian countries can co-operate to create innovative and sustainable solutions to common water problems. Strengthening these efforts will provide greater security for the people of the region, whose livelihoods and well-being depend heavily on the effective management of these vital resources.

Through these measures, Central Asia will be able to move towards a more sustainable and cooperative water management system that ensures the sustainable use of transboundary water resources for future generations. This vision of regional integration and sustainable management is necessary not only for the conservation of natural resources, but also for the promotion of peace, stability and prosperity throughout the region.

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AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Alla Imakeeva. Kishimzhan Zhakshylykova and Almagul Attokurova contributed to data analysis, methodology. The first draft of the manuscript was written by Chinara Adamkulova, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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DATA AVAILABILITY

The datasets collected and analyzed during this study are publicly available in the following sources:

Documents related to water agreements between Central Asian countries: <http://www.icwc-aral.uz/statute1.htm>

Economic and demographic data for Central Asian countries can be accessed via the World Bank: <https://data.worldbank.org/>

Additional population and GDP data are available on Worldometer: <https://www.worldometers.info/>

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