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Comparative Assessment of the Mountainous River Basin in Kyrgyz-Kazakh Region of Central Asia with River Basins in Australia, Canada and USA

Akylbek Kurishbaev[1], Raushan Amanzholova[2], Dinara Adenova[3], Janay Sagin*[4], Diana Burlibayeva[5], Dani Sarsekova[6], Kuantar Alikhanov[7], Abay Serikkanov[8], Rebecca King[9]

[1]Kazakh National Agrarian Research University, Abay Avenue 8, Almaty, 050010, Kazakhstan
Email: rector@kaznaru.edu.kz | ORCID: https://orcid.org/0000-0002-0568-5964
[2]Kazakh-British Technical University, Tole Bi Street 59, Almaty 050000, Kazakhstan
Email: r_amanzholova@kbtu.kz | ORCID: https://orcid.org/0000-0001-9129-1074
[3]Institute of Hydrogeology, Satbayev University, Almaty, Kazakhstan
Email: d.adenova@satbayev.university | ORCID: https://orcid.org/0000-0001-7973-811X
[4]Kazakh-British Technical University, Tole Bi Street 59, Almaty 050000, Kazakhstan
Email: j.sagin@kbtu.kz | ORCID: https://orcid.org/0000-0002-0386-888X
[5]Institute of Geography and Water Security, Pushkin St 99, Almaty, 050010, Kazakhstan
Email: diana.burlibayeva@yandex.kz | ORCID: https://orcid.org/0000-0002-2385-8611
[6]Kazakh National Agrarian Research University, Abay Avenue 8, Almaty, 050010, Kazakhstan
Email: sarsekova.dani@kaznaru.edu.kz | ORCID: https://orcid.org/0000-0003-0537-4936
[7]National Academy of Sciences of the Republic of Kazakhstan, Shevchenko S., Almaty, 050010, Kazakhstan. Email: k.alikhanov.nas@gmail.com | ORCID: https://orcid.org/0000-0001-9514-7678
[8]National Academy of Sciences of the Republic of Kazakhstan, Shevchenko St., Almaty, 050010, Kazakhstan. Email: a.serikkanov.nas@gmail.com | ORCID: https://orcid.org/0000-0001-6817-9586
[9]Kazakh-British Technical University, Tole Bi Street 59, Almaty 050000, Kazakhstan
Email: r.king@kbtu.kz | ORCID: https://orcid.org/0009-0000-9098-9411
**Corresponding author*

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Abstract

Central Asia is among the most heavily affected regions worldwide by climate change and water shortages. Impacts include changes in precipitation patterns, more frequent temperature extremes and increased aridity causing a negative impact on agricultural production, food availability, and environmental security. To combat this threat, it is important to enhance information literacy among all water users. This can be done through awareness campaigns, blended learning by providing the proper Technical and Vocational Education and Training (TVET) programs and utilizing all available facilities. This will address relevant issues, such as miscommunication, complexities of transboundary water sharing issues, overexploitation of water resources, and poor flood-drought mitigation techniques. Proper and user-friendly lifelong blended learning for scientific information dissemination focusing water issues can provide stronger support to increase awareness among water users and decision policy makers. Worldwide, especially in North America and Australia, information literacy campaigns have proven successful. This strategy can be replicated in the Mountainous Kyrgyz-Kazakh Chu-Talas transboundary river basin. The issues concerning the Mountainous Kyrgyz-Kazakh Chu-Talas transboundary river basin is elaborated and compared with Australian, Canadian, and US river basin management programs. The foresight analysis is presented, as to what would be a rationale to improve water resources more sustainably in Central Asia. Methodologies, programs, technologies, communities-based river basin committees, snow-water collection with agroforestry, and basin-based water market opportunities were analyzed to assess potential applications in Central Asia region.

Keywords

Sustainability; Central Asia; Foresight; Water resources; River basin

Introduction

Water resources are complicated issues in Central Asia (CA), including the transboundary Kyrgyz-Kazakh Chu-Talas River Basin (CTRB) area. Many problems are related to the outdated water distribution system, poor Technical and Vocational Education and Training (TVET) support, lack of user-friendly database platforms, weak economic incentives for water recycling and flood water storage technologies like Flood-MAR[1] (Managed Aquifer Recharge), and lack of foresight encompassing the proper project preparation activities combining scientific research connected to the business planning.

Water distribution systems in CA lack proper transparency, and water saving incentives, including IT-based water monitoring with climate change and anthropogenic distractions prediction analysis (Mashtayeva *et al.*, 2016; Panichkin *et al.*, 2017). The CTRB, including surface-groundwater resources, are in permanent debates about the water usage in the area (ORDA, 2024; UNECE, 2021). The difficulties in determining the water balance of the basin result from the restricted cross-border collaboration of hydrologists, meteorologists, and hydrogeologists, local people, and farmers (Adenova *et al.*, 2023). The predominance of administrative control in the CTRB, without the local people's involvement in the decision-making process, creates complexities in the management of water resources. The CTRB water sharing disputes between Kazakhstan and Kyrgyzstan are cooked by the politicians and administrators belonging to these two countries.

The rural people and farmers who live and work in CTRB are not included in decision-making processes, thus preventing them from participating in efficient planning and water usage programs. Due to the lack of proper cooperation, the local people residing CTRB are unable to coordinate the planning and use the resources efficiently integrating proper communications with their neighbors (ORDA, 2024; UNECE, 2021). The proper modeling and calculations of water resources with prediction analysis are missing in context of CTRB. This is a reason why administrators from these two countries give the incorrect calculations about water volume, which farmers may use and, accordingly, they can plan their crop plantations and irrigation activities.

As an example, during the winter season of 2022-2023, the 2023-year prognosis of potential water volume, which farmers might use in the CTRB, was overestimated. Administrators presented optimistic water volume which could become available in 2023 during early springtime. The forecast by the CTRB Hydrometeorological Service reported the water inflow for the growing season (April-September) of 2023 was expected to be in the range of 474–727 million cubic meters, or 115% higher compared to the previous year, i.e. 2022. Considering the forecast, farmers were given optimistic plans for the growing season of 2023, when 222 million cubic meters of water were supposed to flow along the Shu River, and 520 million along the Talas River. On the contrary, due to low night temperatures in spring and early summer, the melting of glaciers was not intense. Therefore, the forecast by CTRB Hydrometeorological Service was not confirmed (Melnik, 2023).

[1] *California's Flood-MAR Hub. What is Flood-MAR?* Available online at: https://floodmar.org/ [accessed 3 December 2023].

The CTRB management is dominated by the administrative system without the local people's involvement. This management is run mostly relying on the basic supply transactions, when one supplier tries to convince another to achieve something in shortest time as much as possible, without a detailed analysis of the consequences. A proper forecast revealing what may happen in the future, and how these current momentary actions will affect the sustainability of the CTRB environment is missing. In this case study, one side, Kyrgyzstan was found trying to convince the other side, Kazakhstan, about the problems cropping up in context of water volume estimations. On the other hand, the water suppliers from Kazakhstan needed to take water immediately by diminishing the future planned shared amount of water (Airan, 2023; Nurmatov, 2023).

The CTRB residents, farmers and users of water are practically excluded from the decision-making process. How can they use water in their basin or in their region of residence? CTRB's local residents are excluded from the decision making process in the programs for efficient water use, climate change adaptation, water volume calculations with monitoring in their basins. Residents do not have adequate voice in the program to plan basin-based activities in coordination with other members of the CTRB. Inclusion of people's voices in decision making is the best strategy to make their shared basin more sustainable. The residents of CTRB lack access to comprehensive lifelong blended learning opportunities, which would include adapting to and mitigating climate change, planning resources in collaboration with family members, and minimizing disruptions for neighboring communities. Additionally, farmers in the CTRB lack adequate information regarding precipitation forecasts, including snow and rain, as well as understanding the water balance and flow within the basin.

Methodology

The research methodology is presented below in the graphical flowchart (Figure 1). The water resources planning and management in Kyrgyz-Kazakh Region is compared with the Australian, Canadian and US river basins. This study employed a comparative-descriptive methodology that delves into the intricacies of basin-based water resource system planning and management across global regions, including Australia, Canada, the USA, and the river basins of Kyrgyzstan and Kazakhstan. Subscribing the scholarly insights of Bathelt and Li (2020), the analysis adhered to a dual principle: comparing entities that share commonalities, and focusing on the salient attributes of each entity. By scrutinizing the existing literature, this study aimed to gauge the efficacy of basin management strategies and the economic viability of harnessing natural water resources within these basins. Deriving insights from literature review and collaborative brainstorming sessions within research group[2], the study identified strategic tools (see Figure 1) suitable for adaptation to the unique context of the Kyrgyz-Kazakh basins.

[2] The research group has included the diverse cross-disciplinary researchers and local people, farmers from the transboundary area of Kyrgyzstan and Kazakhstan. During the yearly forum of Kazakhstan and Kyrgyzstan scientists, the authors brainstormed about the cooperation and exchange of experience between the scientific communities of both the countries. The forum was dedicated to promoting the development of science, technology and education in the region, and for active discussion on current scientific issues and initiatives. Ministry of Science and Higher Education of the Republic of Kazakhstan, Ministry of Education and Science of the Kyrgyz Republic, National Academy of Sciences of the Republic of Kazakhstan under the President of the Republic of Kazakhstan, and National Academy of Science of Kyrgyz Republic have supported events of the forum.

To enhance the planning and management of water resources within the Kyrgyz-Kazakh basins, several key areas for improvement were delineated. These included bolstering emergency event modeling (capabilities and predictive tools), utilizing resources such as FEMA's HAZUS. Additionally, enhancing flood water management through tailored programs like Flood-MAR (Managed Aquifer Recharge), fostering transparency in agricultural management via the integration of unified GIS databases with tools like Soil Water Assessment Tools (SWAT) modeling, and optimizing snow-water collection methods through innovative agroforestry approaches.

Moreover, the study advocates for the implementation of basin-based water market programs to incentivize economic efficiency in water resource management. These methodologies and strategies will be expounded upon in subsequent sections, offering a comprehensive framework for advancing basin-based water resource planning and management practices.

Research questions Included:

1) How to improve the current situation in CTRB?
2) How can the CTRB residents and farmers be involved more in joint activities to make their life more sustainable?
3) How to incorporate experience of other countries, including the Canada-US river basins (RRBC, 2023) and Australia? Will they be reasonable to study for a comparative analysis?

Research Area

Kyrgyz-Kazakh Chu-Talas River Basin (CTRB)

The CTRB is one of the CA regional catchments that are shared by Kyrgyzstan upstream and Kazakhstan downstream (Figure 2). CTRB is formed by the basins of the rivers, Chu (Shu) and Talas. Both the rivers source the water from the mountains of Central Tien Shan in Kyrgyzstan at elevations exceeding 4,000 m above sea level (asl) and extend into lower altitudes to the steppes and deserts of Kazakhstan with elevations of about 400 m asl where hills terminate to a topographic depression forming shallow lakes (Figure 2).

The Chu basin receives more precipitation (up to 1,000 mm/year in the high mountains of Tien-Shan) than the Talas River (about 500 mm/year). Talas basin has higher population density (11%) and proportion (5.3%) of arable land (Yapiyev *et al.*, 2017, 2018, 2019, 2020). The Kyrgyz capital, Bishkek, having a population of just over 1 million, is in Chu River upstream area on its tributary, the Ala-Archa (GEF, 2019). Water consumption is dominated by irrigation accounting for over 90% of the basin water usage in the Kyrgyzstan zone of the CTRB (GEF, 2019).

The Canada-US River Basin Commission

The Red River, marking the boundary between North Dakota and Minnesota in the US, flows northward into Manitoba before reaching Lake Winnipeg in Canada. Running through the fertile Red River Valley, this 885 km (550 miles) long river frequently floods during the spring thaw, posing a threat to cities like Winnipeg of Manitoba in Canada;

Fargo, North Dakota; and Moorhead, Minnesota in the US. The Red River basin supports various important fish species such as channel catfish, walleye, and bigmouth buffalo. The Red River traverses the level terrain once occupied by the expansive glacial Lake Agassiz, which originated at the conclusion of the Wisconsin glaciation period from the melted ice of the Laurentide Ice Sheet. The gradual melting of this continental glacier gave rise to the formation of the lake. Across millennia, sedimentation occurred, depositing layers of soil at the lakebed. These lacustrine soils serve as the foundational soils of the present-day Red River Valley (RRBC, 2023). The Canada-US Red River Basin Committee (RRBC, 2023) coordinates water project programs (Figure 3), basin activities affecting cross-border river flows, water quality, and ecosystem well-being.

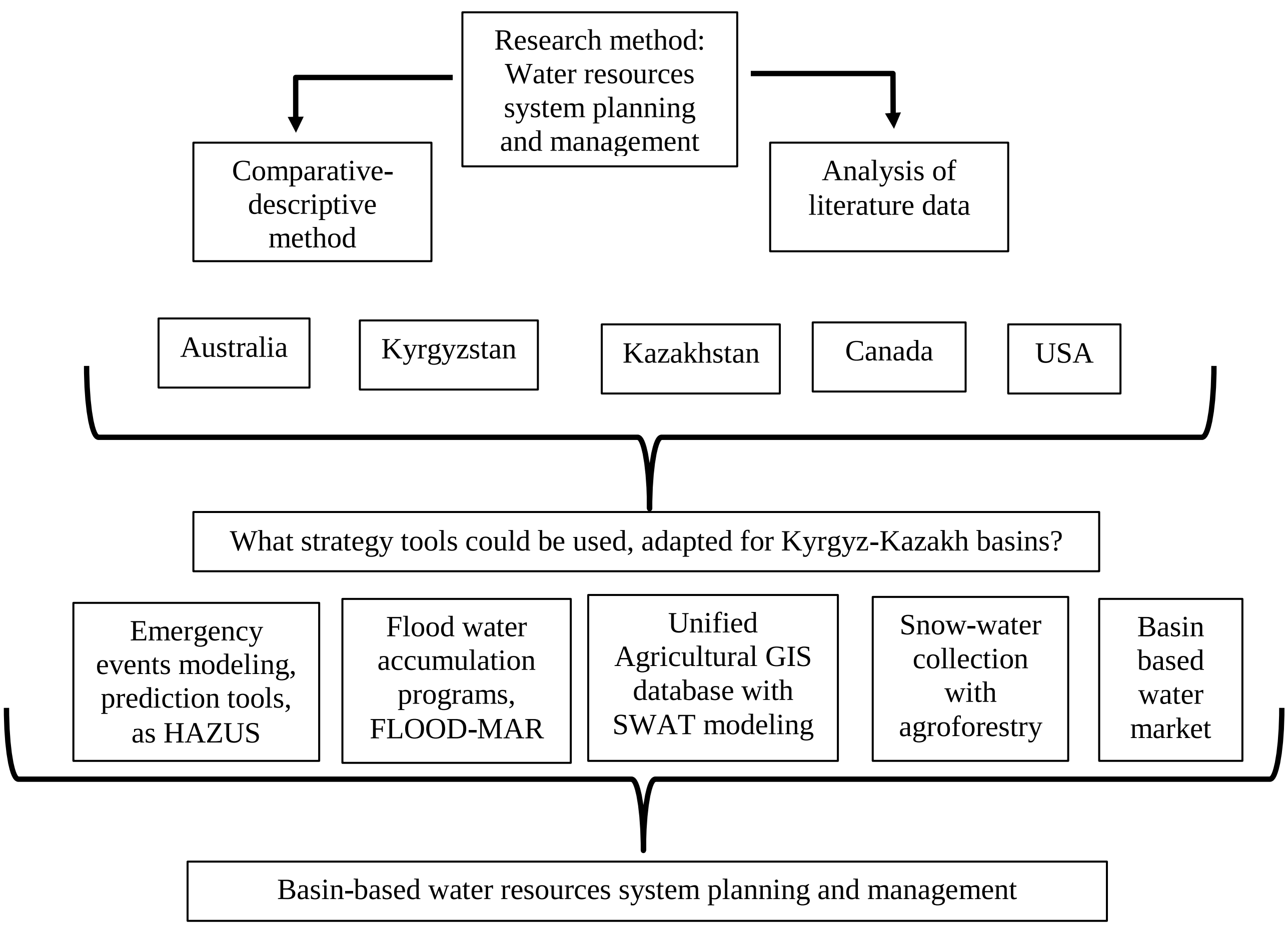

Figure 1: Block diagram of research methods: Kyrgyz-Kazakh basin-based water resources system planning and management comparison with Australia, Canada and USA

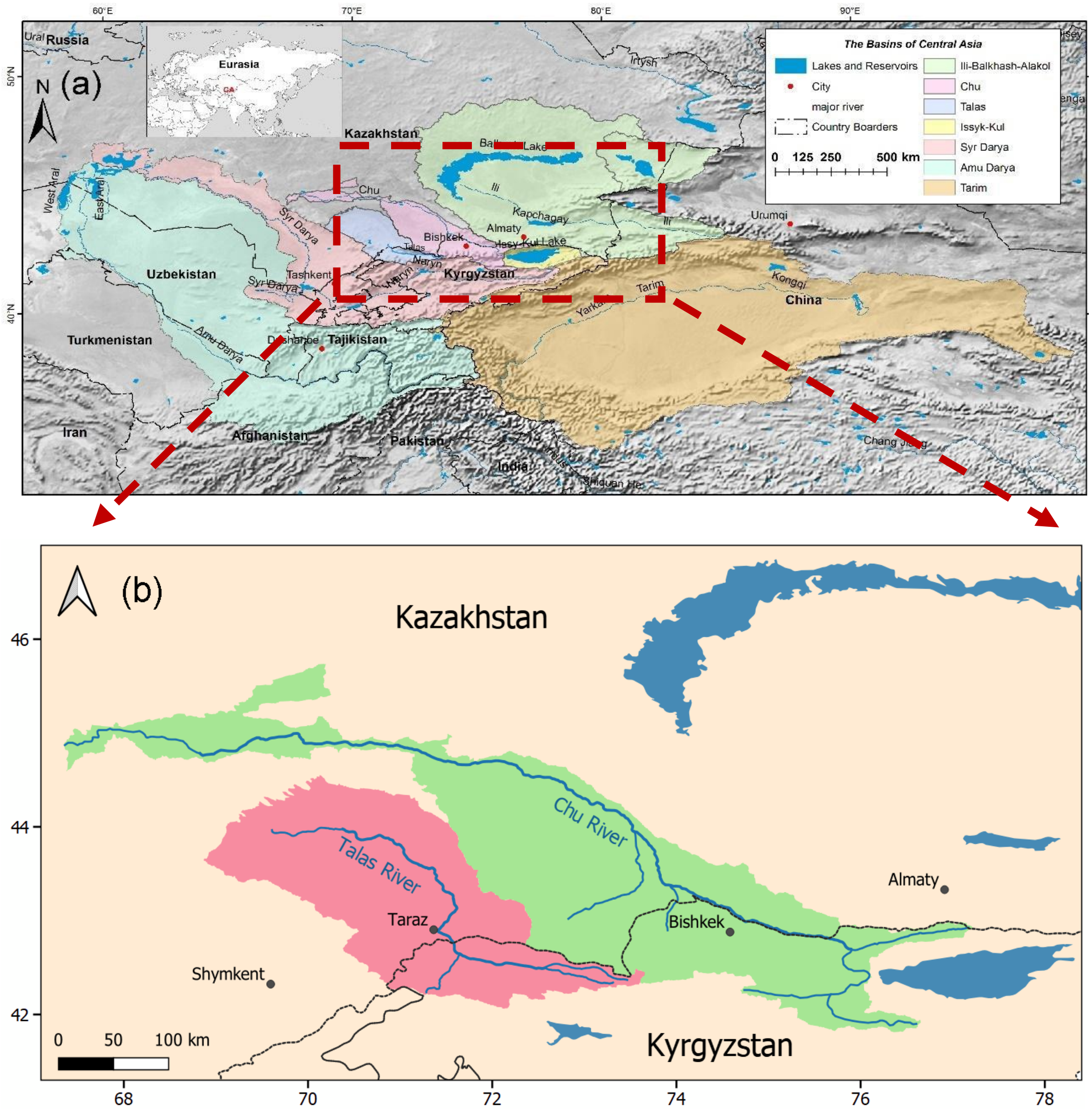

Figure 2: (a) South CA Basins. (b) Chu-Talas River Basin (CTRB)

Australian Murray-Darling River basin commission

The area of the Murray-Darling basin covers 1,062 thousand km^2, which is 14% of mainland Australia (Murray-Darling Basin Authority, 2001), in which about 60 thousand km^2 is the floodplain area, or circa 6% of the Murray–Darling River basin area. The Murray-Darling Basin has a diverse landscape, ranging from semi-arid ephemeral river systems in the north to highly regulated river systems in the south, fed by the runoff from Australian Alps. Most of the Murray–Darling River basin consists of extensive plains and low undulating areas, most of them are located at less than 200 m above sea level. A significant part of the catchment area is situated on peaks with the altitude ranging

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200-1,000 m. In the easternmost and south-eastern territories, there are hills with a height of more than 1,000 m (Figure 4) (David, 2001).

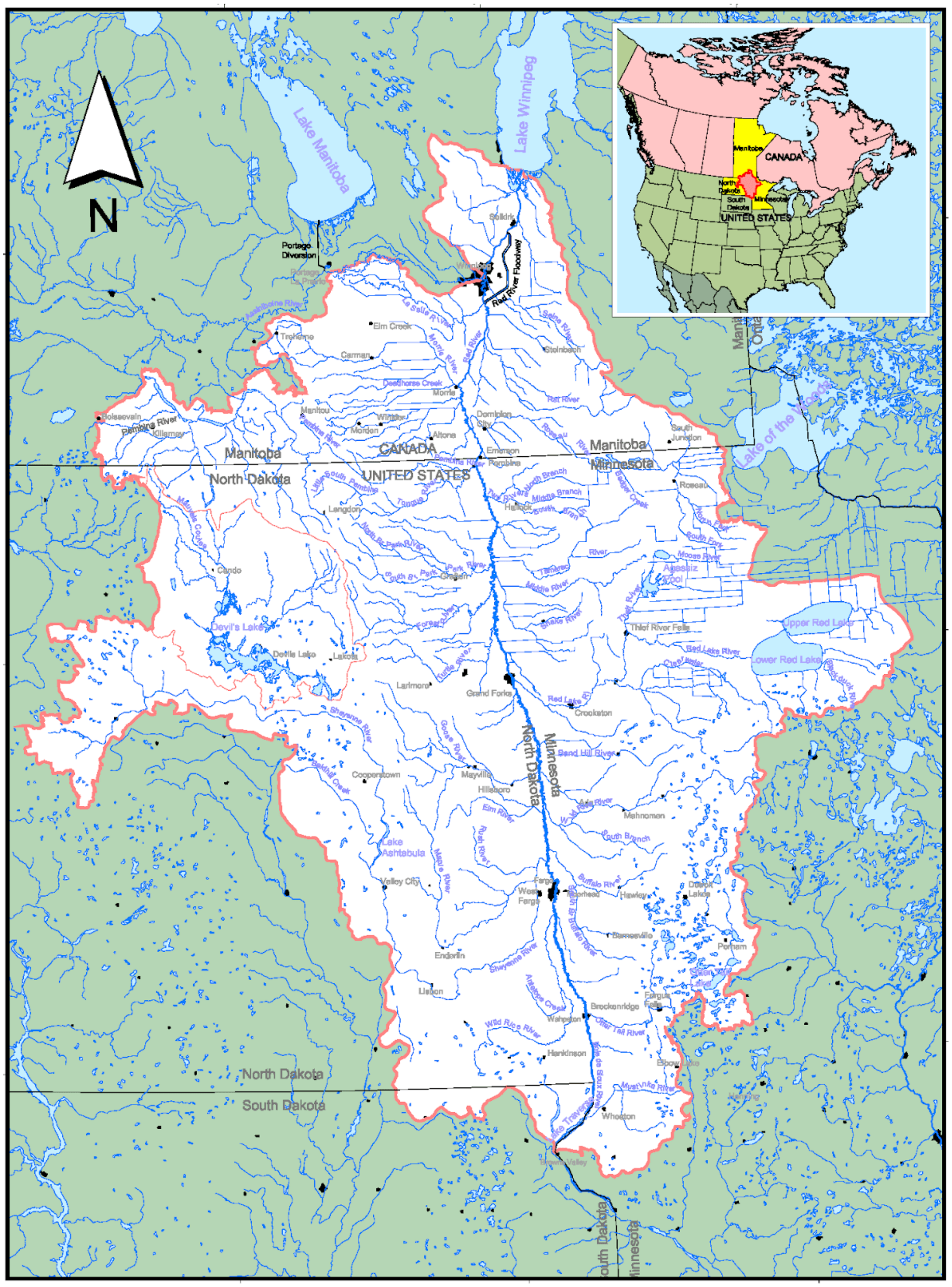

Figure 3: The Canada-US Red Riber Basin, marking the boundary between North Dakota and Minnesota in the US, flows northward into Manitoba before reaching Lake Winnipeg in Canada: the fertile Red River Valley, this 885 km (550 mile) long river frequently floods during the spring.

The climate of the Murray-Darling Basin is subtropical in the north, semi-arid in the west, and moderate temperate in the south. The average annual temperature varies between + 4 and + 11°C. The average temperature in the cold period ranges from -5°C to -10°C, and in the warm period from +16°C to + 20°C. Precipitation decreases from high rainfall in the summer period to lesser in winter period, and spatially from the north to the south. On the eastern side of the basin, the average annual precipitation reaches 1,500 mm. On the other hand, in the south, several months observe a fall season every winter on the peaks of the Great Dividing Range. The basin's western side is usually hot and dry, and the average annual precipitation is generally less than 300 mm (Australian Government Department of the Environment, 2016). The evaporation rate in the basin is high, with 94% of the precipitation falling in the basin being used by plants (transpired) or evaporated from land and surface waters (Vagapov, 2003; Vasilenko, 2012).

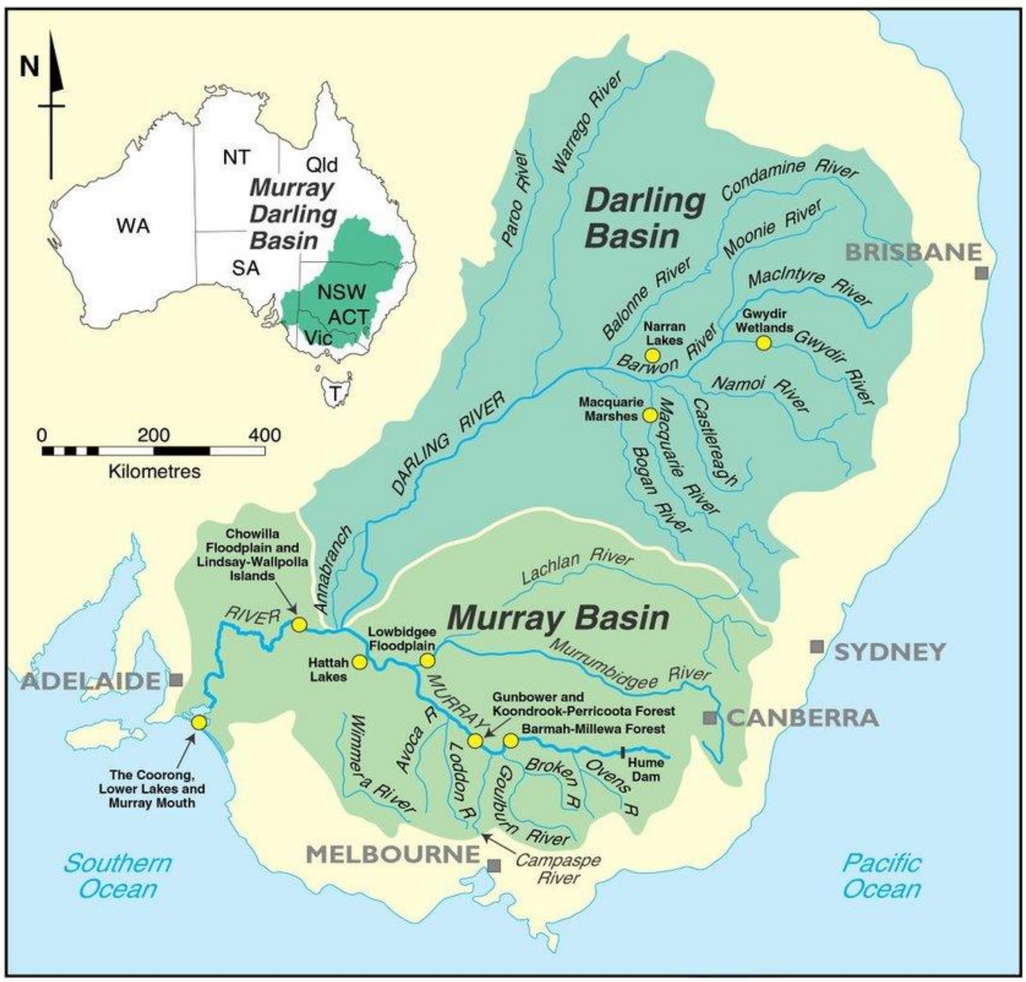

Figure 4: The Murray-Darling Basin (*Source:* Murray-Darling Basin Authority, 2023)

Climate change studies predict that the basin's climate is likely to become drier and more volatile in the future due to increasing concentrations of greenhouse gases in the atmosphere. Thus, in addition to more extreme droughts, there may be more extreme floods.

What Strategy Tools Can be Used for CTRB?

The challenges related to water resource in Central Asia (CA) present complex issues that necessitate careful diagnosis and strategic solutions. Like treating medical ailments, addressing these challenges effectively hinges upon accurate diagnosis, comprehensive monitoring of past trends, precise forecasting, and rigorous analysis of future scenarios. Success in any endeavor, be it a project or managing water resources, relies on a thorough understanding of the current situation, prudent resource assessment, and adept adaptation of technology to existing conditions. In the realm of Central Asia's water resource management, numerous obstacles stem from various factors. These include the lack of robust scientific support for professional project management, inadequate financial forecasting based on scientific principles, and a dearth of effective collaboration among relevant stakeholders. Furthermore, the absence of unified databases across key ministries in Kyrgyzstan and Kazakhstan exacerbates the issue. These ministries encompass areas such as emergency response, water management, agriculture, internal affairs, and industry. Addressing these challenges calls for a holistic approach akin to viewing the water resource system as an interconnected organism.

Central to this strategy is the establishment of a unified database platform integrating vital information on hydrometeorology, precipitation patterns, surface and groundwater dynamics, pollution sources, disease outbreaks, and water quality assessments. Such a platform would enable scientifically-informed financial assessments tailored to specific problem areas, mirroring successful practices observed in countries like Australia, Canada, and the USA. Many nations are increasingly adopting collaborative frameworks that unite researchers and integrate applied scientific programs in agriculture with disaster mitigation efforts. This convergence involves leveraging the expertise of insurance companies to address potential emergencies such as floods, droughts, fires, and earthquakes. By fostering interdisciplinary cooperation and embracing innovative approaches, Central Asian countries can navigate their water resource challenges more effectively, ensuring sustainable management practices for the future.

Emergency Events Modeling by Prediction Tools

The Canada-US unified Geographic Information Database of Emergency Modeling (FEMA’s HAZUS)[3] provides standardized tools and data for assessing the risk of earthquakes, floods, hurricanes, droughts and fires with economic analysis and scenarios for planning financial expenses in cooperation with insurance companies. The Ministries of Agriculture, Emergency Situations, Water Resources, and Irrigation (WRI) of Kazakhstan and Kyrgyzstan will be reasonable to adapt the HAZUS.

The economic benefit from the effectiveness of proactive actions is calculated by these basic principles, recommended by the main organization, including the UN and the US Federal Agency for Emergency Situations (FEMA). For every dollar invested in advance before an emergency, up to 10 dollars are saved by mitigation consequences of an emergency (NIBS 2023). As the expenses of climate change and anthropogenic disasters increase, the US FEMA is increasingly investing in proactive preparedness to respond effectively. Every

[3] *FEMA’s HAZUS Program provides standardized tools and data for estimating risk from earthquakes, floods, tsunamis, and hurricanes.* Available online at: https://www.fema.gov/flood-maps/products-tools/hazus [accessed 1 December 2023].

year for the past five years, more than 20 disasters have occurred in the United States, costing more than $20 billion (NIBS, 2020). FEMA's strategy is to become more forward-thinking rather than reactive. Climate change requires planning over decades in advance, but this was not FEMA's responsibility in the past. Now, US FEMA is intensively developing research work on modeling emergency scenarios for decades to come.

On the contrary, the Ministries of Emergency Situations of Kazakhstan and Kyrgyzstan do not have programs like the United States and Canada have, e.g. FEMA's HAZUS. With an investment of several million dollars in similar FEMA's HAZUS programs, the system can save tens of millions of dollars by mitigating the consequences of an emergency either in Kazakhstan, or in Kyrgyzstan.

Flood Water Accumulation Programs

In the programs accumulating drainage flood water using artificial groundwater recharge, application of MAR (Managed Aquifer Recharge) technologies are gaining popularity in many countries, including EU countries Canada and USA (TERESA, 2023)[4]. Dependence on surface water and the construction of reservoirs create environmental problems through evaporation, which leads to water loss. The USA and Canada, realizing their mistakes, reduced the amount of surface reservoirs and developed more Flood-MAR technologies for the use and replenishment of groundwater resources, with subsequent use of groundwater during droughts (Figure 4). In the American State of California, due to the intensifying water crisis, the government is encouraging the population and farmers to use more Flood-MAR technology with funding from grants and soft loans, ceasing support for the construction of dam reservoirs. The benefits and effectiveness of the implementation of Flood-MAR programs in increasing flexibility in water resource management and drought resistance, with regional self-sufficiency in increasing water supply and flood protection. Investments in Flood-MAR have high returns.

MAR provides valuable social benefits and promotes the conservation of groundwater resources (TERESA, 2023). There is no consensus on the appropriate method to estimate the social discount rate (SDR)[5] for social infrastructure projects. The two most used alternatives are the social rate of time preference (SRTP)[6] and the social opportunity cost of capital (SOC)[7]. SRTP is the rate at which a society is willing to save a unit of current consumption in exchange for more consumption in the future. Using this approach, recent UK SDR estimates have been in the range of 3.5–3.75%. (Freeman *et al.*, 2020). The US Council of Economic Advisers suggests testing the sensitivity of social infrastructure proposals using alternative discount rates, suggesting rates of 3% and 7% (White House, 2024). By using these social important investment approaches in the MAR technologies based on the credit rate of 3%, the MAR will fully pay back approximately in 30 years (Zheng *et al*., 2021).

[4] INOWAS, *Innovative Groundwater Solutions.* Available online at: https://inowas.webspace.tu-dresden.de/ https://www.fema.gov/flood-maps/products-tools/hazus [accessed 1 September 2023].
[5] https://www.mercatus.org/research/policy-briefs/social-discount-rate-primer-policymakers
[6] https://www.mercatus.org/system/files/moore_and_vining_-_mercatus_research_-_a_social_rate_of_time_preference_approach_to_social_discount_rate_-_v1.pdf
[7] https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2017/02/Working-Paper-182-Spackman-April-2018.pdf

At the same time, while analyzing the economic effect of Flood-MAR in terms of the rational use of budgetary funds for flood emergencies, according to the US Federal Emergency Management Agency (FEMA), for every dollar invested in advance before an emergency, up to $10 is saved on consequences of emergency situations (NIBS, 2020). At $10 million in flood costs, implementing Flood-MAR technologies could save $9 million with an initial upfront investment of $1 million in Flood-MAR. Moreover, the agricultural efficiency of Ag-MAR demonstrates that there is potential to increase regional recharge by 7–13%, to increase crop consumption by 9–12%, and to increase natural vegetation consumption by 20–30% (Levintal *et al.*, 2023). Ag-MAR has great potential to improve the long-term sustainability of water resources in agricultural regions (Levintal *et al.*, 2023). In Kazakhstan, the Ministries of Emergency Situations, Water Resources and Agriculture are disintegrated; each is a Ministry in itself. No cooperation programs like Flood-MAR do exist in Kazakhstan and Kyrgyzstan.

Unified Agricultural GIS Database with SWAT Modeling

The Canada-USA Department of Agriculture's SWAT Unified Geoinformation Database[8] (USDA, 2023) is utilized for soil and water resource monitoring with modeling of the quality and quantity of surface and groundwater and predicting the environmental impacts of land use, land management and climate change. SWAT (Figure 5) is widely used to assess and plan the soil erosion prevention and control, nonpoint source pollution control, and regional watershed management (Sagin *et al.*, 2016, 2017; Sagintayev *et al.*, 2011, 2015).

Modeling tools simulate the functioning of ecosystems and their interactions with human activities to help make decisions and evaluate management strategies. This leads to informed decisions that balance human development and environmental protection. Among these models, the Soil and Water Assessment Tool (SWAT) stands out for its ability to model a variety of biophysical processes that may be associated with the provision of ecosystem services (ES). SWAT has been successfully used to assess ecosystem services, further helping to translate SWAT results into monetary terms, as the FEMA's HAZUS does in disaster response cases. Both the modeling programs are available as a geoinformation platform having GIS data processing system and uniform GIS standards. In addition to the fact that SWAT can be used in tandem with US FEMA's HAZUS disaster management, SWAT promotes more efficient planning and use of water resources with analysis of soil receiving fertilizer inputs at a particular water quality. SWAT allows farms to optimize costs by up to 70% through preparing models for optimal land use conversion for all crops and rangelands. It can be used by analyzing the net present value of 10-year farm profits and load reduction, coupled with the cost-effectiveness ratios (Liu *et al.*, 2019). If, for example, farmers' expenses are about $10,000, then with the effective use of SWAT modeling technologies, expenses can be optimized up to 70%, or $7,000, and the farmer will need to spend a smaller amount of about $3,000.

In Kazakhstan, there are no agricultural modeling programs like the modeling programs of the US Department of Agriculture SWAT.

[8] WEG Model Development, *Canadian Version of Soil and Water Assessment Tool (CanSWAT).* Available online at: https://geg.uoguelph.ca/weg-model-development [accessed 28 September 2023].

Community Based River Basin Committees

The Canada-US programs for scientific collaborative management of transboundary river basins, e.g. Saskatchewan River Basin, Global Institute for Water Security, Canada-US Red River Basin Commission (RRBC, 2023), are good candidates to investigate for potential adaptation in Kyrgyz-Kazakh CTRB. Community based committees should be created in river basin areas, together with neighboring countries. Possible applications include ownership of water resources and reservoirs, mutual responsibility for maintenance, financing and security, and maintaining a unified geoinformation database for modeling emergency situations. Platforms such as FEMA's HAZUS can be used for assessing the risk of earthquakes, floods, droughts, and water accumulation (Flood-MAR). The Kazakh Academy of Science, together with the Ministries of Agriculture and Emergency Situations, can strengthen the work of basin committees (Figure 1, 2) with the involvement of scientists. A pilot program of research for the CTRB, consisting of two regions of Kyrgyzstan (Chu and Talas) as well as Zhambyl region of Kazakhstan, in cooperation with basin committees and Water Security Institutes of Canada-USA, can be developed (Water for Food, 2023).

National Academy of Kazakhstan/Kyrgyzstan scientists could establish programs of research, training, and participation in conferences jointly with Canada-USA. Basin management through basin committees makes it possible to manage the water resources of river basins more effectively by residents, farmers, and local organizations in the river basin. As a result, emergency risks are reduced, and water consumption per unit of grown product becomes more predictable. The expensive bureaucratic system of administrative (ministerial) management is eliminated, and water resources are managed by basin's water users. Efficient use of water resources allows farmers in the basin to plan better. Incomes have increased several times with the same volume of water used per unit of grown product through the coordinated use of forecast programs, such as FEMA's HAZUS, Flood-MAR, and SWAT. The path to sustainable development hinges on minimizing the expenses associated with cumbersome bureaucratic administrations and adopting contemporary technologies. This transition involves granting ownership of resources to local residents and users of water within the basin. Additionally, it entails overhauling water rights through market-oriented environmental programs, thereby fostering opportunities for natural restoration of water resources.

Snow-Water Collection with Agroforestry

The Canada-USA Ministries of Agriculture have spearheaded scientific initiatives aimed at augmenting forest cover. One key aspect involves compelling land users to undertake the planting and maintenance of forests along reservoirs, extending to the width of these reservoirs. This strategic approach also encompasses areas crucial for snow-water retention. Investigating the potential adaptation of such programs for the Kyrgyz-Kazakh Central Transboundary River Basins (CTRB) holds promise for bolstering regional resilience. Furthermore, the promotion of programs integrating forest plantations for snow-water retention with Flood-MAR (Managed Aquifer Recharge) technologies in the USA and Canada is gaining momentum. These initiatives come with comprehensive guidance, advanced training programs in colleges, and grant systems designed to incentivize the farmers. Studies suggest that the combined utilization of forest plantations in agricultural landscapes can elevate overall productivity by up to 30% compared to conventional crop cultivation methods (Wilson and Lovell, 2016).

The financial benefits of agroforestry practices manifest in various forms. Firstly, there are direct outputs derived from the tree and shrub components. Secondly, there is indirect productivity enhancement attributable to these components. Thirdly, there is a reduction in external factors, facilitated by the support of trees and shrubs (Agriculture and Agri-Food Canada, 2010). Moreover, agroforestry systems yield enhanced ecosystem services, including heightened resilience, increased biodiversity, carbon sequestration, and improved water quality. Notably, the integration of snow-water retention techniques with Flood-MAR technologies ensures a more stable and predictable water supply, further amplifying the ecological and economic benefits of agroforestry practices in the region.

Groundwater Resources – Geological Hydrogen

Numerous countries are currently engaged in "white" hydrogen exploration, akin to a modern-day gold rush. This fervor extends to regions like the German-French border, which boasts the world's largest underground reserves of "white" hydrogen. On the territory of the transboundary Moselle-Saar River basin, where coal mines abandoned more than 20 years ago, are located large volumes of natural geological “white” hydrogen, discovered with an estimated volume of up to 250 million tons (Bettayeb, 2023). It is important for underground hydrogen “factories” to replenish water for the physico-chemical oxidative processes of serpentinization, the process for hydrogen production underground (Ellis, 2023; Hand, 2024). Kazakhstan, or Central Asia as a whole, does not have “white” hydrogen exploration activities and does not have the “gold rush” programs dedicated to underground geological “factories” identifications. Central Asian countries may expand cooperation in efficient use of groundwater resources together with keeping sustainability of natural geological “white” hydrogen production (Figure 5). Such programs can improve regional cooperation. This program can be connected with the NEXUS-water, food, energy activities.

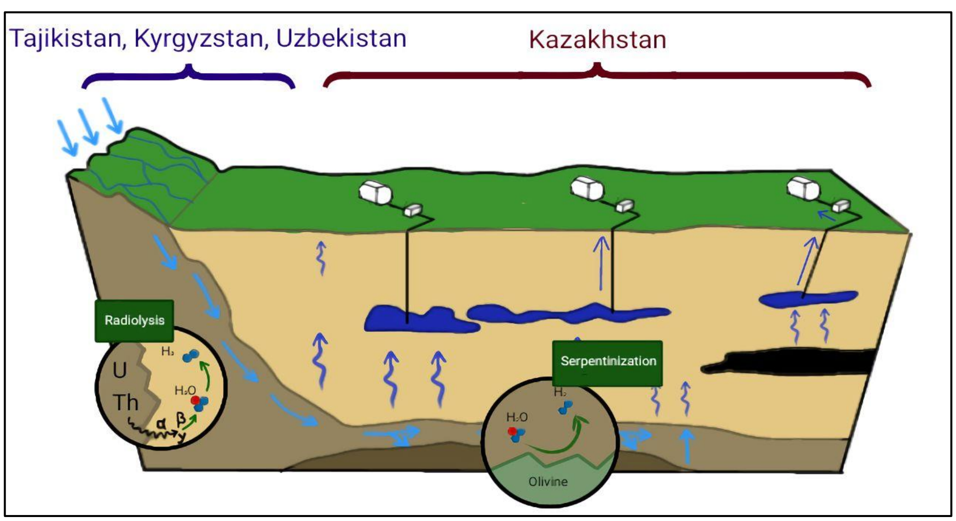

Figure 5: The diagram exhibits a potential of Central Asian countries for cooperation in groundwater resource use to prospect natural geological “white” hydrogen production (adapted from Ellis, 2023; and Hand, 2024)

Basin Based Water Market

Like many countries, including Central Asia, Australia is prone to floods and droughts. The recurring cycle of floods and droughts in the Murray-Darling River basin with the necessity to improve resource management and to mitigate environmental degradation has led Australia to urgent reforms in their water management system. The adopted Australian reforms are considered a global breakthrough in the field of environmental management. The reforms were promoted in 4 key areas:

1) Transformation of the water distribution inside the basin. Australia has moved from the old method of allocating water resources with limited environmental restrictions to a new flexible market-based system. Australia has established limits on the total water use in catchment basins and provided economic value for individual right holders of water resources within the basin.
2) Improving environmental management. Australia has legally fixed the limits of water volume taken from the basin, thus guaranteeing stable water use in the future.
3) Reforming the pricing of water supply services. Australia has introduced a pricing regime based on the volume of water consumption and reimbursement for efficient water use.
4) Modernization of the mechanism of providing services for water users. Australia has divided water resources management functions establishing service standards, and implementing measures to comply with regulatory requirements. Australia optimized water resource administrative organizations with service provision and financial efficiency improvement. All data related to surface- groundwater use and movement is made transparent and available at any time to all people. In irrigation areas, the management of the basin's water resources has been transferred to local authorities under personal responsibility so that everyone can contribute to decision-making ensuring a balance between water prices and the level of service (Jane, 2016). Governmental administrative and ministerial management are significantly reduced in Australia.

Australian basin-based water market system will be reasonable for the Central Asian region to investigate, to study. How potentially this approach may improve the current water crisis issues in Central Asia? Of course, it will be complicated to implement a same approach for the whole Central Asia region, for all five Central Asian (Kyrgyzstan, Kazakhstan, Uzbekistan, Tajikistan, and Turkmenistan) countries. These countries already spend dozens of years trying to improve situation with the Aral Lake basin to shrink disasters without success. Afghanistan now is building a huge canal to take water from the Amu Darya River, which is a sub-basin of the Aral Lake basin. So, the Central Asia region is moving to the many water disasters. The more efficient sustainable approaches should be implemented to improve the current water status. Kyrgyzstan and Kazakhstan are similar in their administrative systems, and their local people are well connected. Economically, these two countries are also well connected. Hence, proposing the same water market approach CTRB river basin can be manageable. However, proper training and capacity building programs will be necessary to set up, preferably, in cooperation with Australian water experts.

Discussion: Basin-Based Water Resources System

Central Asian countries, including Kyrgyzstan and Kazakhstan, have systemic problems in their water resource management. Central Asian countries miss a well-integrated user-friendly and transparent database platform through which local people can understand water management procedures. The local people within the Central Asian basins are excluded from decision-making activities. Discrepancies in water resource indicators and the lack of objectively reliable information reflecting the surface groundwater resources status create complexities for local people. Central Asia lacks consistent water resources management, and the ministerial administrators' interventions confuse many people. Moreover, proper scientific support is also absent in water resources linking with well-connected TVET programs (Baykhozha, 2023).

The water resource information database with related water management facilities in Kazakhstan is privately owned by "Kazgiprovodkhoz". The state water cadaster certification is not publicly available. Water management facilities lack proper monitoring systems. One water distribution organization, "Kazvodkhoz", is responsible for the two competing tasks: a) the general water facilities constructions, and water monitoring tools installation; b) quality control of construction, and certification programs. While delivering the services, the "Kazvodkhoz" and its branches combine two competing responsibilities as a customer and a contractor (Kharlamov, 2019).

Currently, 60-70% of the water consumed is used for irrigation in Kazakhstan, with a considerable water loss; more than half of the irrigation water is lost due to inefficient irrigation systems (Ilyasov, 2023). Efficient water resource programs reduce the impending environmental problems together with optimizing the existing management methods having an increased economic benefit for the people. Such programs also involve the local people in the decision-making process on the pattern of RRBC (2023) and the Murray-Darling River basin of Australia.

Agriculture in Central Asia, including Kyrgyzstan and Kazakhstan, is also inefficient with considerable water consumption, compared to Australian agriculture. The industry and public utilities of Kazakhstan pollute the environment making the water quality worse. The significant water volume is taken by heavy industry in Kazakhstan. After industrial use, the polluted water is often discharged back into the streams adding further to the environmental toxicity. The interests of large industries are on higher priority in Kazakhstan than the interests of the people in the rural regions (Burlibayev, 2014). Kyrgyzstan and Kazakhstan have similar issues with water resources, flood-drought problems with a necessity to improve the water efficiency, to set up more water sustainability programs.

Experience of the Canada-US Red River Basin Commission

The Canada-US Red River Basin Commission (RRBC) oversees the implementation of flood-and drought related issues, including financial, efficient use of water resources. Local residents, farmers, and First Nations people living in the three US states of Minnesota, North and South Dakota and the Canadian province of Manitoba are actively involved in the implementation of projects for the efficient use of water resources. Civil societies organizations involved in the protection of nature, flora and fauna also actively participate in water resource management. Water technicians are affiliated with the projects, and they have strong local capacity of managing their water resources with financial and technical inputs. Permanent lifelong blended training related to water issues are provided to everybody in the Canada-US river basin. The rural regional libraries are used intensively for regular meetings, seminars, and planning activities (RRBC, 2023).

The RRBC maintains all databases, open and accessible to everyone. Information about each project and the group leading the project is available freely on an open access website. For example, in the basin, residents and farmers decided to take LIDAR (Light Detection and Ranging)[9] Remote Sensing with high-resolution images of 50 cm to create topographic maps, digital elevation models, land planning for farmers, modeling floods and droughts. Accordingly, $5 million were spent on this, with a contribution of $3 million from local farmers and $2 million from the provincial administration. As a result, the open access LIDAR data is available for everybody to download. Moreover, training programs on the use of LIDAR is also given to everyone, with modeling programs on climate change forecasting and adaptation. For the effective use of accumulation of drainage and flood waters, the Basin Committee uses intensive modeling and, in consultation with farmers in Canada and the USA, determines the locations where it will be optimal to create small reservoirs for replenishing underground aquifers. Such a modeling is done through the Flood-MAR programs operating in California.

Experience of Australian Basin System

Australia has a well-developed agrarian farming support system with a personalized service system in the remote rural areas, including territories of Indigenous aboriginal people, with regulated attention to the protected wetland system. The current Australian policy was initiated in the 1990s. Since 2000, the water consumption per crop cultivation has decreased rapidly. Over 10 years, the water use indicator has reduced by 2.5 times. At the same time, the agro-production output has not undergone significant changes in Australia. The gross income from the agro-business has continued to grow in Australia. On the other side, Kazakhstan is missing such an efficient water consumption program; the agro production output is directly related to the consumed volume of water. Agriculture is continuously facing resource depletion, swamp formation, and land desertification. The interests of big industries are on the priority in Kazakhstan. Small farms in remote rural regions of Kazakhstan are poorly supported. The facilities giving information about surface and groundwater network are not user friendly and are not accessible to ordinary people in Kazakhstan.

In the Murray-Darling basin of Australia, the yield of products shows small fluctuations due to the presence of a detailed branched web of water supply to every resident, farmer and agricultural producer in rural regions. The system of surface and underground water resource facilities is interconnected, and all the data are transparent and accessible to everybody in Australia. People have more incentives to use water more efficiently. Even in water crisis periods, farmers may purchase water from those who have used water more efficiently, or have recycled the water, in Australia. People have more incentives to collect water during the flood seasons and upon heavy precipitation, and to develop

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[9] *Light Detection and Ranging - Remote Sensing.* Available online at: https://www.neonscience.org/resources/learning-hub/tutorials/lidar-basics [accessed 15 September 2023].

underground managed aquifer recharge (MAR) to reduce water losses due to evaporation. This strategy allows the mitigation of natural disasters and floods by storing water with low losses, and using water during droughts.

In Kazakhstan, the attitude to ownership rights over energy and water resources are completely different. The owners of energy resources and industry are a small group of people. Water resources are considered less valuable in comparison with energy resources and industry activities. The ownership of water resources is practically absent and poorly regulated in Kazakhstan. On the contrary, water in Australia is an asset and a mean of earning money. In Australia, every citizen has the right to own a certain amount of water resource. The water of the typical basin is the property of every person who lives in its catchment area. Each resident has the right to a certain amount of water. It becomes rational for engineering companies to build water facilities to preserve water resources during floods, to protect water and then to offer the collected water in the market to those regions where there is demand.

Basin System in Kazakhstan and Central Asia

In Kyrgyzstan/Kazakhstan, as well as in Central Asia as a whole, there is no concept of ownership of water resources by the ordinary people of a particular basin. In Central Asia, there is no incentives to restore or keep water, resulting into each resident uses as much water as he/she deems appropriate. Water is underestimated as a resource. Ordinary people do not have incentives for saving water out of its efficient usage. Creating conditions for ordinary people to earn money by saving water will catalyze more efficient use of the water resources in Central Asia. Moreover, each country carries significant expenses for governmental administration, including large budgets for the emergency agencies. This whole administrative system exhibits limited productivity. At the same time, the public resources need to be redistributed to spend on the training of technical specialists, hydrologists, and hydrogeologists (Adenova *et al.*, 2023; Baykhozha, 2023).

Conclusion

Effective water management systems in Central Asia are vital for sustainable development. This can be achieved by implementing a few successful examples of other countries' successful strategies. Replicating successful models can improve the complex current situation in the transboundary CTRB area. Due to the overwhelming administrative control in the CTRB, farmers who live and work in rural areas are excluded from decision-making processes, making it next to impossible for them to take part in efficient planning and democratic water usage initiatives. To increase the sustainability of water resources in Central Asia, it is important to strengthen the transparency of the river basins economy. The local people should be involved in solving their problems by providing them with high-quality secondary technical education on the use of common database platforms with user-friendly software, alongside technical and financial education.

It would be advisable to explore adaptive tools and technologies, such as FEMA's HAZUS, Flood-MAR, and water market approaches, for Central Asian regions. This includes technical and financial assessment and analysis of the risks of earthquakes, floods, hurricanes, droughts, fires. A user-friendly monitoring system can improve communities' resilience. Moreover, it is important to involve the local people and farmers in solving their problems concerning the river basin issues, while subscribing the ideas from the example of Australia, Canada, and the USA. Geospatial information technologies, such as Google Earth Engine (GEE), can assist in monitoring land and water resource usage. Integrating these tools with existing financial programs can significantly expand its effectiveness. This technology can enhance economic efficiency through implementing proactive actions, such as preparing for emergencies; these proactive measures have the potential to save 10 dollars for every dollar invested pre-emergency.

Many problems in the projects are associated with the factors of weak scientific support extended to professional project management of water resources, weak scientific forecast of financial expenses, and absence of unified databases. Many departments of the ministries in Central Asia, including those that manage emergency situations, water, agriculture, economy, internal affairs, and industry, are disconnected and compartmentalized. It would be helpful to develop a unified platform for hydrometeorology of precipitation, movement of surface-groundwater, consumer points, scientific assessment of financial costs, and prediction of problems. Interdisciplinary cooperation is required to improve the sustainability in Central Asian region. Water-saving technologies and innovations, as well as a transition to integrated basin-wide management, can mitigate the growing scarcity of water resources in Central Asia.

Central Asian countries are vulnerable to climate change, disruptions in global and regional water cycles, transboundary non-cooperation, and exploitative water-intensive industries. In Kazakhstan, if current policies continue, available water resources may be reduced by 30-50% by 2030, which will entail significant restrictions in food production, apart from drinking water limitations and ecosystem degradation. In these conditions, the transition from conflicting water supply systems to joint basin management is important, in addition to inclusion of innovations and water-saving technologies. A sustainable approach to lifelong blended learning, tailored for ease of use, can effectively disseminate scientific information about water issues. Scaling up such initiatives would greatly enhance awareness among both water users and policy makers.

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Reference

Adenova, D., Tazhiyev, S., Sagin, J., Absametov, M., Murtazin, Y., Trushel, L., Miroshnichenko, O. and Zaryab, A. (2023). Groundwater Quality and Potential Health Risk in Zhambyl Region, Kazakhstan. *Water*, 15: 482. DOI: https://doi.org/10.3390/w15030482 .

Agriculture and Agri-Food Canada (2010). Shelterbelts Design Guidelines for Farmyard, Field, Roadside, Livestock, Wildlife, and Riparian Buffer Plantings on the Prairies. Agriculture and Agri-Food Canada, Agri-Environment Services Branch, Agroforestry Development Centre, Saskatchewan, Canada. Available online at: https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/epw10940/$FILE/Shelterbelts_Design_and_Guidelines.pdf [accessed 20 December 2023].

Airan (2023). What's happening on the border with Kyrgyzstan? Kazakhstan won't let trucks through. Drought in the south, geopolitics. A video by Airan (in Russian). Available online at: https://youtu.be/Z31qTmL8Hhk?si=Bqk2Vxb-u-gI2V0 [accessed 21 December 2023].

Australian Government Department of the Environment (2016). Directory of Important Wetlands in Australia. Available online at: https://www.mdba.gov.au/climate-and-river-health [accessed 10 December 2023].

Baykhozha, Z. (2023). Breach of the dam of the Sardoba reservoir. After the flood: why Kazakhstan cannot protect its interests in the water sector. *Central Asia Monitor*, 12 May 2020. Available online at: https://camonitor.kz/34807-posle-potopa-pochemu-kazahstan-ne-mozhet-zaschitit-svoi-interesy-v-vodnoy-sfere.html [accessed 5 December 2023].

Bathelt, H. and Li, P. (2020*)*. Building Better Methods in Economic Geography. *Zeitschrift für Wirtschaftsgeographie*, 64(3): 103-108. DOI: https://doi.org/10.1515/zfw-2020-0014

Bettayeb, K. (2023). A gigantic hydrogen deposit in northeast France? CNRS News, 26 July 2023. Available online at: https://news.cnrs.fr/articles/a-gigantic-hydrogen-deposit-in-northeast-france [accessed on 12 January 2024].

Burlibayev, M. (2014). Introduction of Ertis - the main factor of sustainable development of the regional ecosystem. In: Burlibayev, M., Kuts, S. I., Fashchevsky, B. V. *et al*. (eds.), Flooding of the Ertis floodplain is the main factor in the sustainable development of the river ecosystem Almaty: Khaganate Book, 395 pp.

David, B. (2001). The Murray-Darling Basin. Balancing the priorities of agriculture and the environment. Teacher guide and lesson plans for lower secondary. Melbourne: Melbourne: Education Services Australia, p.61-63. Available online at: https://gtaq.com.au/Resources/Documents/murray-darling-basin-teacher-kit.pdf [accessed on 10 April 2024].

Ellis, G. (2023). *The Potential for Geologic Hydrogen for Next-Generation Energy*. USGS, 13 April 2023. Available online at: https://www.usgs.gov/news/featured-story/potential-geologic-hydrogen-next-generation-energy [accessed on 10 April 2024].

Freeman, M.C. and Groom, B. (2020). A social discount rate for measuring global heritage sub-seabed resource wealth: A report to the International Seabed Authority. Report by University of York, University of Exeter and LSE, UK. Available online at: https://www.isa.org.jm/wp-content/uploads/2022/12/Freeman-Groom-and-Turk-2020-Social-Discount-Rates-Post-Review.pdf [accessed on 15 January 2024].

Garcia, X. (2023). Using the Soil and Water Assessment Tool (SWAT) to quantify the economic value of ecosystem services. *River*, 2: 173–185. DOI: https://doi.org/10.1002/rvr2.47.

GEF (2019). Transboundary diagnostic analysis in the river basins of Chu and Talas. Chu-Talas Transboundary Commission Project report. Global Environmental Facility, The World Bank, Washington, DC. Available online at:

https://www.gefieo.org/sites/default/files/documents/projects/tes/5310-terminal-evaluation.pdf [accessed 2 December 2023].

Hand, E. (2024). Hidden Hydrogen: Does Earth hold vast stores of a renewable, carbon-free fuel? *Science*, 379(6633). DOI: https://doi.org/10.1126/science.adh1460

Ilyasov, R. (2023). Acute water shortage may occur in Kazakhstan in 20 years. TENGRI News, 19 November 2019. Available online at: https://tengrinews.kz/kazakhstan_news/ostraya-nehvatka-vodyi-vozniknut-kazahstane-20-let-384390 [accessed 2 September 2023].

Jane, D. (2016). The Australian Water Reform Journey. An overview of three decades of policy, management, and institutional transformation. Australian Aid and Australian Water Partnership. ISBN 978-1-921543-14-2. Available online at: https://waterpartnership.org.au/wp-content/uploads/2016/08/AWN-Australian-Water-Reform-Journey.pdf [accessed 3 September 2023].

Kazgiprovodkhoz Institute (2011). *The scheme of integrated use and protection of water resources of the Irtysh River basin in the territory of the Republic of Kazakhstan.* Book 1 "Summary note". Water protection complex, pp. 17-19, 65, 99.

Kharlamov, K. (2019). Kazakhstan's water resources are under threat. Atameken Business, 24 August 2019. Available online at: https://inbusiness.kz/ru/news/vodnye-resursy-kazahstana-pod-ugrozoj [accessed 5 September 2023].

Levintal, E., Maribeth, L., Kniffin, Y. G., Marwaha, N., Murphy, N. and Dahlke, H. (2023). Agriculturally managed aquifer recharge (Ag-MAR)—a method for sustainable groundwater management*:* A review. *Critical Reviews in Environmental Science and Technology*, 53(3): 291-314, DOI: https://doi.org/10.1080/10643389.2022.2050160 .

Liu, Y., Guo, T., Wang, R., Engel, B., Flanagan, D., Li, S., Pijanowski, B., Collingsworth, P., Lee, J. and Wallace, C. (2019). A SWAT-based optimization tool for obtaining cost-effective strategies for agricultural conservation practice implementation at watershed scales. *Science of The Total Environment*, 691: 685-696. DOI: https://doi.org/10.1016/j.scitotenv.2019.07.175 .

Mashtayeva, S., Liyun, D., Tao, C., Sagintayev, Z., Sadvakasova, S., Kussainova, M., Alimbayeva, D. and Alynbekova, M. (2016). Spatial and Temporal Variability of Snow Depth Derived from Passive Microwave Remote Sensing Data in Kazakhstan. *Journal of Meteorological Research (JMR)*, 30(6): 1033-1043, DOI: https://doi.org/10.1007/s13351-016-5109-z.

Melnik, L. (2023). How to fill the riverbeds? Zero.Kz, 11 August 2023. Available online at: https://ztgzt.kz/amp/kak-napolnit-rusla/?fbclid=IwAR132P5_8IKPAn97MtHbsRfEjZ0CgWkRyb6xOvAF4wJfVf0xSK-OONw4vOA [accessed 10 September 2023].

Murray-Darling Basin Authority (2001). Murray-Darling River Systems and Basin. Student and Teacher Murray River Project Information. Available online at: http://www.murrayriver.com.au/about-the-murray/murray-darling-basin/ [accessed 18 September 2023].

Murray-Darling Basin Authority (2012). Annual Report 2011-2012, Canberra, 2012, chapter 4 – River Murray operation assets. Available online at: https://www.mdba.gov.au/sites/default/files/archived/annualreports/2011-12/index.html [accessed 16 September 2023].

Murray-Darling Basin Authority (2023). Landscape. Available online at: https://www.mdba.gov.au/discover-basin/landscape/climate [accessed 17 September 2023].

NIBS (2020). Mitigation Saves: Mitigation Saves up to $13 per $1 Invested. Available online at: https://www.nibs.org/files/pdfs/ms_v4_overview.pdf [accessed 19 September 2023].

Nurmatov, E. (2023). There is almost no water in the Kirov Reservoir. Kyrgyzstan stopped supplying water to Kazakhstan. Radio Azatyk, 15 August 2023. Available online at: https://rus.azattyk.org/a/32548459.html [accessed 22 September 2023].

ORDA (2024). Ditches, ponds and good education will save from floods. ORDA News, 3 April 2024. Available online at: https://orda.kz/ot-navodnenij-spasut-aryki-prudy-i-horoshee-obrazovanie-uchenyj-384524/ [accessed 3 April 2024].

Panichkin, V., Sagin, J., Miroshnichenko, O., Trushel, L., Zakharova, N., Yerikuly, Z. and Livinskiy, Y. (2017). Assessment and forecasting of the subsurface drain of the Aral Sea, Central Asia. *International Journal of Environmental Studies*, 74(2). DOI: https://doi.org/10.1080/00207233.2017.1280321.

RRBC (2023). Three States, One Province, Two Countries, One Red River Basin. Red River Basin Commission, Winnipeg, Canada. Available online at: https://www.redriverbasincommission.org/ [accessed 21 December 2023].

Sagin, J., Adenova, D., Tolepbayeva, A. and Poryadin V. (2017). Underground water resources in Kazakhstan. *International Journal of Environmental Studies*, 74(3). DOI: https://doi.org/10.1080/00207233.2017.1288059 .

Sagin, J., Salybekova, V., Kalitov, D., Zavaley, V. and Rakhimov, T. (2016). Numerical Modeling of the Intensification Processes of Groundwater Treatment for Hexavalent Chromium Using In Situ Technology. *Journal of Environmental Hydrology*, 24. Available online at: http://www.hydroweb.com/journal-hydrology-2016-paper-4.html [accessed 21 March 2024].

Sagintayev, Z., Sizo, A., Wheater, H., Jardine, T. and Lindenschmidt, K.E., (2015). A Water Coverage Extraction Approach to Track Inundation in the Saskatchewan River Delta, Canada. *International Journal of Remote Sensing*, 36: 764-781. DOI: https://doi.org/10.1080/01431161.2014.1001084.

Sagintayev, Z., Sultan, M., Khan, S.D., Khan, A.S. and Mahmood, K. (2011). Remote Sensing Contributions to Hydrologic Modeling in Arid and Inaccessible Watersheds, Pishin Lora Basin, Pakistan. *Journal of Hydrological Processes*, 26(1). DOI*:* https://doi.org/10.1002/hyp.8114

Sagintayev, Z., Yerikuly, Z., Zhaparkhanov, S., Panichkin, V., Miroshnichenko, O. and Mashtayeva, S. (2015). Groundwater inflow modeling for a Kazakhstan copper ore deposit. *Journal of Environmental Hydrology*, 23: 9. Available online at: http://www.hydroweb.com/journal-hydrology-2015-paper-9.html [accessed 21 March 2024].

USDA (2023). SWAT - Soil and Water Assessment. Tool. USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research, part of The Texas A&M University System. Available online at: https://data.nal.usda.gov/dataset/swat-soil-and-water-assessment-tool [accessed 27 September 2023].

TERESA (2023). Urban water management: German expertise for Kazakh cities. Available online at: https://www.teresa.inowas.com/ [accessed 29 September 2023].

UNECE (2021). Transboundary cooperation in Chu and Talas River basin. Available online at: https://unece.org/environment-policy/water/areas-work-convention/transboundary-cooperation-chu-and-talas-river-basin [accessed 30 September 2023].

Vagapov, R.I. (2003). Water management balance in the Irtysh River basin. DGP "Scientific Research Institute of Water Management", Taraz, Kazakhstan.

Vasilenko, V. (2012). Problems of water resources use in the Ob–Ortysh basin. Institute of Economics and Industrial Production Organization SB RAS, Novosibirsk, Russia, p. 35.

Water for Food (2023). Daugherty Water for Food Global Institute. Available online at: https://waterforfood.nebraska.edu/ [accessed 25 October 2023].

White House (2024). Valuing the Future: Revision to the Social Discount Rate Means Appropriately Assessing Benefits and Costs. The White House, 27 February 2024. Available online at: https://www.whitehouse.gov/cea/written-materials/2024/02/27/valuing-the-future-revision-to-the-social-discount-rate-means-appropriately-assessing-benefits-and-costs/ [accessed on 10 April 2024].

Wilson, M.H. and Lovell, S.T. (2016). Agroforestry — The Next Step in Sustainable and Resilient Agriculture. *Sustainability*, 8(6): 574. DOI: https://doi.org/10.3390/su8060574

Yapiyev, V., Sagintayev, Z., Inglezakis, V.V.J.V., Samarkhanov, K. and Verhoef, A. (2017). Essentials of Endorheic Basins and Lakes: A Review in the Context of Current and Future Water Resource Management and Mitigation Activities in CA. *Water*, 9(10): 798. DOI: https://doi.org/10.3390/w9100798.

Yapiyev, V., Samarkhanov, K., Tulegenova, N., Jumassultanova, S., Verhoef, A., Saidaliyeva, Z., Umirov, N., Sagintayev, Z. and Namazbayeva, A. (2019). Estimation of water storage changes in small endorheic lakes in Northern Kazakhstan. *Journal of Arid Environments*, 160: 42-55. DOI: https://doi.org/10.1016/j.jaridenv.2018.09.008.

Yapiyev, V., Skrzypek, G., Verhoef, A., Macdonald, D. and Sagintayev, Z. (2020). Between boreal Siberia and arid CA–Stable isotope hydrology and water budget of Burabay National Nature Park ecotone (Northern Kazakhstan). *Journal of Hydrology: Regional Studies*, 27. DOI: https://doi.org/10.1016/j.ejrh.2019.100644.

Yapiyev, V., Sagintayev, Z., Verhoef, A., Kassymbekova, A., Baigaliyeva, M., Zhumabayev, D., Malgazhdar, D., Abudanash, D., Ongdas, N. and Jumassultanova, S. (2017). The changing water cycle: Burabay National Nature Park, Northern Kazakhstan. *WIREs*, 4(5): e1227. DOI: https://doi.org/10.1002/wat2.1227.

Zheng, Y., Ross, A., Villholth, K. and Dillon, P. (eds.) (2021). Managing Aquifer Recharge: A Showcase for Resilience and Sustainability. UNESCO-IAH Publication. Available online at: https://unesdoc.unesco.org/ark:/48223/pf0000379962 [accessed on 10 April 2024].

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*A.1*	*A.2*	*A.3*	*A.4*	*A.5*	*A.6*	*A.7*	*A.8*	*A.9*
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Collected the data	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Supervision	Yes	No	No	No	No	No	No	No	No
Project Administration	Yes	No	No	No	No	No	No	No	No
Funding Acquisition	Yes	No	Yes	No	No	Yes	No	No	No
Overall Contribution Proportion (%)	15	12	12	11	10	10	10	10	10

A = Author

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Research involving human bodies or organs or tissues (Helsinki Declaration)
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The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

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