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Addressing water scarcity in agriculture through small reservoir construction in Kashkadarya Province

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Abstract: This study explores the construction of small reservoirs (SRs) as a strategic solution to address water scarcity in Kashkadarya Province, Uzbekistan, where agricultural productivity is heavily dependent on irrigation. By utilising geographic information system (GIS) and remote sensing (RS) technologies, optimal locations for reservoirs were identified, focusing on improving the water availability for irrigation during critical periods. The research highlights the socio-economic and environmental benefits of SRs, including enhanced agricultural yields, increased employment opportunities, and reduced reliance on energy-intensive pumping stations. The findings indicate that the construction of an 18 Mm^3 reservoir in the Ayakchisoy River could supply water to 26.5 thousand hectares, thereby improving the region's resilience to climate variability. This approach offers a sustainable framework for managing water resources in arid regions, contributing to food security and economic stability.

Keywords: drought mitigation; rural livelihoods; water resource management; food security; socio-economic impact; irrigation; geographic information systems; agricultural productivity; climate resilience

Water scarcity and agricultural vulnerability in Uzbekistan. Uzbekistan, located in Central Asia, faces significant challenges due to its predominantly arid and semi-arid climate (World Bank 2020), which are further exacerbated by global warming and changing weather patterns, including rising temperatures, altered precipitation, and extreme weather events like floods and droughts (Toromade et al. 2024). These climate changes have serious implications for food security, especially as drought conditions are expected to increase, as shown by the standardised precipitation evapotranspiration index (Rakhmatova et al. 2024). Agriculture remains a vital component of Uzbekistan's economy, despite the ongoing industrialisation (FAO 2021), with a substantial portion of the population involved in farming. From 2010 to 2023, the agricultural sector's contribution to the national gross domestic product (GDP) showed a steady decline, dropping from over 30% to 21.62% by 2023 (Figure 1). Similarly, the sector's share of employment has decreased, indicating a shift towards other in-

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dustries. However, agricultural production across the country grew significantly, with regions like Karakalpakstan, Andijan, Bukhara, Jizzakh, Samarkand, and Fergana showing impressive gains. Kashkadarya Province also experienced notable growth, although it lagged behind some regions due to water scarcity and climate change impacts.

The heavy dependence on water resources, particularly for the irrigation of over 80% of agricultural land, makes Uzbekistan's agriculture highly vulnerable to both climate change and infrastructural developments (Pohl 2023; Sultonov and Muminov 2023). The country's annual water consumption has decreased from 64 km^3 in the 1980s to around 51–53 km^3 today, with 80% of this water sourced from transboundary rivers, complicating the water availability for irrigation due to upstream infrastructure projects (Wehrheim et al. 2008; Rakhmatullaev et al. 2011). This could potentially reduce the irrigated areas, leading to significant economic losses and increased unemployment, particularly in regions like Karakalpakstan and the Fergana Valley, where water shortages are more acute. Measures such as improving water consumption regulation, enhancing water and energy use efficiency, and investing in irrigation infrastructure projects like canals and pumping stations have been proposed to mitigate these challenges and ensure agricultural productivity and economic stability.

Water scarcity is a pressing issue in Uzbekistan, where regions experience varying degrees of water stress due to factors like geography, economic development, and infrastructure. Karakalpakstan, one of the most water-stressed areas, faces severe shortages due to its reliance on the Amu Darya and the desiccation of the Aral Sea, with limited success from international efforts to restore water levels (Kurbanbaev and Turlibaev 2024). In the Fergana Valley, despite its proximity to water sources, periodic shortages occur due to the high population density and agricultural demand, although investments in drip irrigation and more efficient systems have helped mitigate some of the

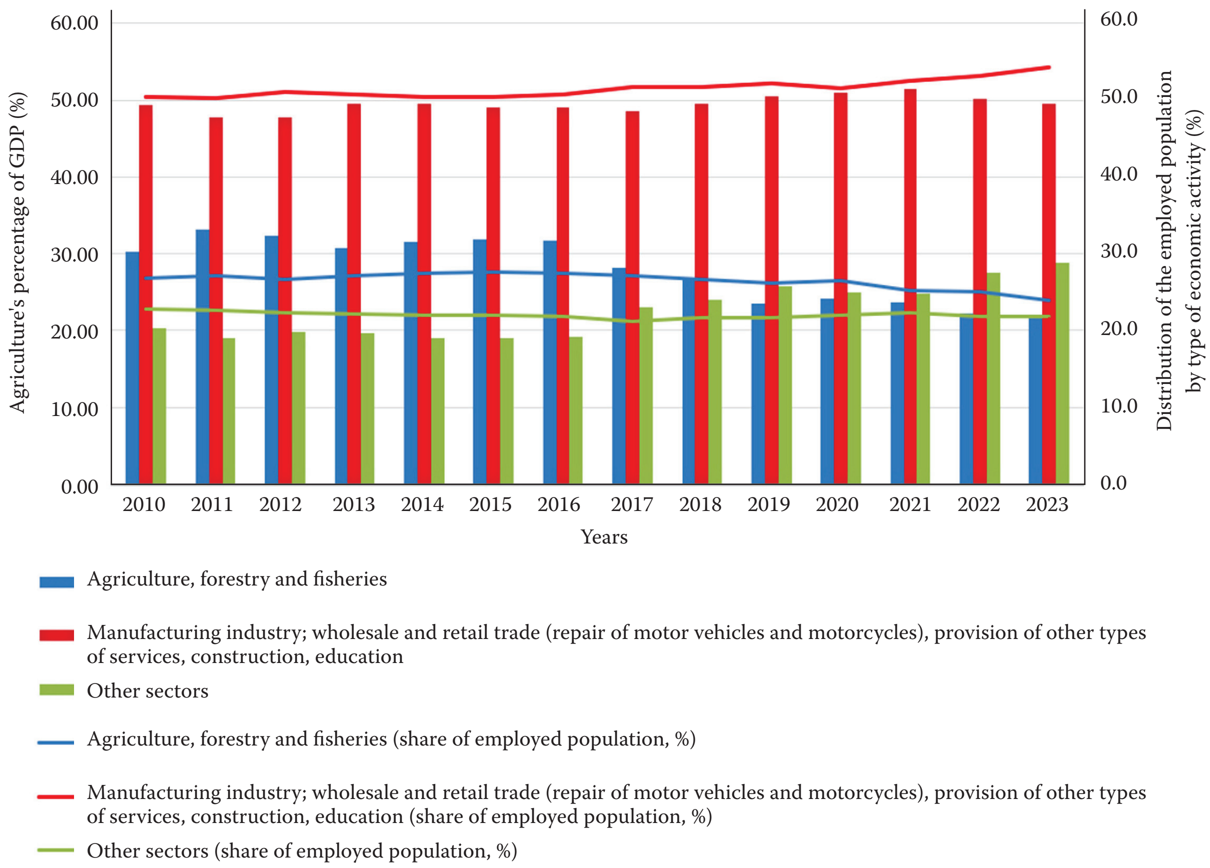

Figure 1. Share of agriculture and other sectors to the gross domestic product (GDP) and distribution of employment by economic activity (2010–2023)

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pressure. Southern regions like Kashkadarya and Surkhandarya experience intensified water scarcity during the summer months, despite the presence of large reservoirs. To address these challenges, Uzbekistan is focusing on implementing modern systems for regulating water consumption, improving the water and energy use efficiency, and establishing robust legal and institutional frameworks for better water management (Bekchanov et al. 2012).

Construction and importance of small reservoirs (SRs). The construction of SRs during drought is a justifiable and crucial water management strategy, especially in arid and semi-arid regions. SRs are vital for capturing and storing runoff during periods of high flow, which ensures water availability during dry seasons, significantly mitigating the effects of drought on agricultural productivity. In drought-prone areas, where water scarcity can severely hamper crop yields and food security, SRs provide essential irrigation resources. For instance, research highlights that SRs can enhance the agricultural productivity by up to five times, demonstrating their effectiveness in boosting local economies and food production during dry spells (Molénat et al. 2023; Colombo et al. 2024). Although SRs may reduce inflow to larger strategic reservoirs, potentially exacerbating hydrological drought propagation, their localised benefits in terms of water availability, agricultural productivity, and flood management outweigh these risks. A balanced approach that integrates SRs with other water resource management techniques, such as rainwater harvesting and recycled wastewater, can mitigate these potential downsides and ensure sustainable water use (Elmahdi 2024). The effective management and strategic construction of SRs, particularly in key catchment areas, can optimise the water storage and supply, reducing the vulnerability of agricultural systems to drought conditions. Several local and international experiences have demonstrated the successful implementation of SRs to address water scarcity, improve the agricultural productivity, and mitigate the impacts of droughts.

In Ghana and Burkina Faso, SRs have significantly enhanced the agricultural resilience to unpredictable rainfall by storing water during the rainy season for dry-season irrigation, increasing the local agricultural productivity by up to five times (Umukiza et al. 2023). China's extensive construction of over 6 700 SRs since the 1950s, particularly in Guangdong, has been crucial for rural water management by supplying water for agricultural and community needs and supporting rural industrialisation and local economic growth (Han and Dumont 2011). In India, SRs, referred to as tanks, are vital for water resource management in semi-arid regions, with research indicating that optimising their design and operation enhances efficient water allocation during dry periods, thereby maximising irrigation, supporting rural economies, and improving crop yields (Helweg and Sharma 1983). In Italy, the construction of SRs has nearly doubled over the past two decades to tackle seasonal water shortages in agricultural regions affected by drought, highlighting their crucial role in maintaining water availability during dry spells (Aminzadeh et al. 2024).

In Uzbekistan, SRs are integral to the country's strategy for managing water resources, especially in arid and semi-arid regions such as the Kashkadarya region, the Fergana Valley, and Samarkand. The country has accumulated valuable experience in constructing and using SRs to meet agricultural demands during the dry months while also mitigating the risks of floods during the rainy seasons.

Some prominent SRs in the Kashkadarya region include Dekhanabad (18.4 million m^3), Kalkama (9.5 Mm^3), Korabog (9.5 Mm^3), Langar (9.3 Mm^3), and Kizilsuv (9 Mm^3). These reservoirs serve dual purposes: they store irrigation water for crops during dry periods and help retain excess water during floods. This strategic use of SRs not only supports the agricultural productivity, but also ensures water availability in the arid zones of the country.

Research proposal. This study investigates the construction of SRs as a strategic and sustainable solution to mitigate water scarcity in Kashkadarya Province, a region particularly vulnerable to climate change and having limited water resources. The primary goal is to enhance the water availability for agricultural use, improve the irrigation efficiency, and ultimately boost the agricultural productivity in the region. In addition to technical aspects, the study explores the socio-economic impacts of the SR implementation, including the job creation in construction, maintenance, and farming sectors.

To achieve this, the study employs GIS and remote sensing technologies to determine the most suitable sites for SR construction. These tools enable

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the identification of optimal locations, the definition of hydrological and geographical parameters, and the assessment of other environmental and economic factors critical to the project's success.

This integrated approach not only promotes sustainable agricultural development, but also enhances the region's resilience to water-related challenges and supports long-term rural livelihoods.

MATERIAL AND METHODS

General information on the Kashkadarya Province. Kashkadarya Province, located in the south-eastern part of Uzbekistan, encompasses an area of 28 570 km^2. It is bordered by Surkhandarya Province to the east, Samarkand Province to the north, Bukhara Province to the northwest, and shares international boundaries with Turkmenistan to the south and Tajikistan to the northeast (Figure 2).

With an estimated population of 3 560 600 as of 2024, approximately 57% of the residents live in rural areas. Kashkadarya experiences an arid to semi-arid climate. Summers are typically hot, with temperatures often exceeding 35 °C (95 °F), while winters are mild with temperatures ranging between 0 °C to 10 °C (32 °F to 50 °F). The region receives limited rainfall, averaging around 200 to 300 mm per year. Most precipitation occurs during the winter months, and the dry conditions pose challenges for agriculture.

Agriculture remains a key economic driver for Kashkadarya, with output rising from 2.91 billion soms in 2010 to 39.92 billion soms in 2023, largely due to the production of cotton, wheat, and horticultural products (Figure 3).

From 2010 to 2023, Kashkadarya Province experienced significant growth in agricultural and livestock production, with the potato output doubling to 195 609 tonnes, vegetable production increasing from 321 472 to 559 256 tonnes, and fruit production more than doubling, while livestock farming also saw considerable expansion, with meat, milk, and egg production rising substantially; however, the region faces challenges in water management and climate adaptation, affecting cereal crop yields, particularly wheat.

Irrigation system of the region. Kashkadarya Province plays a crucial role in Uzbekistan's water management policies, relying heavily on the Amu Darya River, which supplies approximately 75% of the region's water via 45 pumping stations along the Karshi main channel. The Zarafshan River

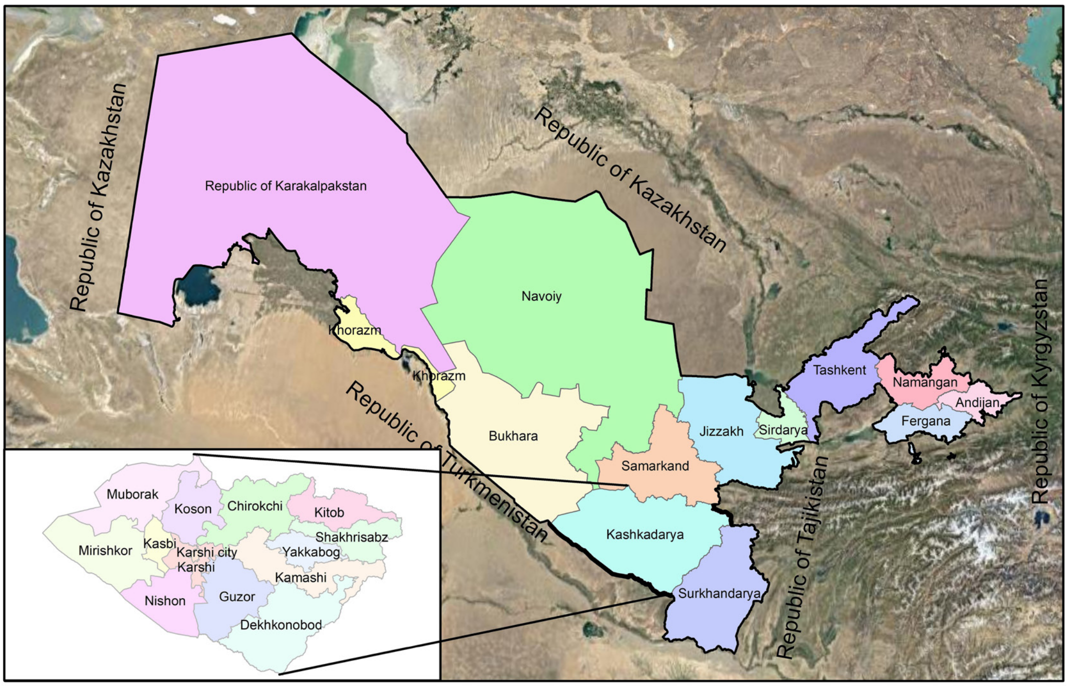

Figure 2. Location of Kashkadarya Province

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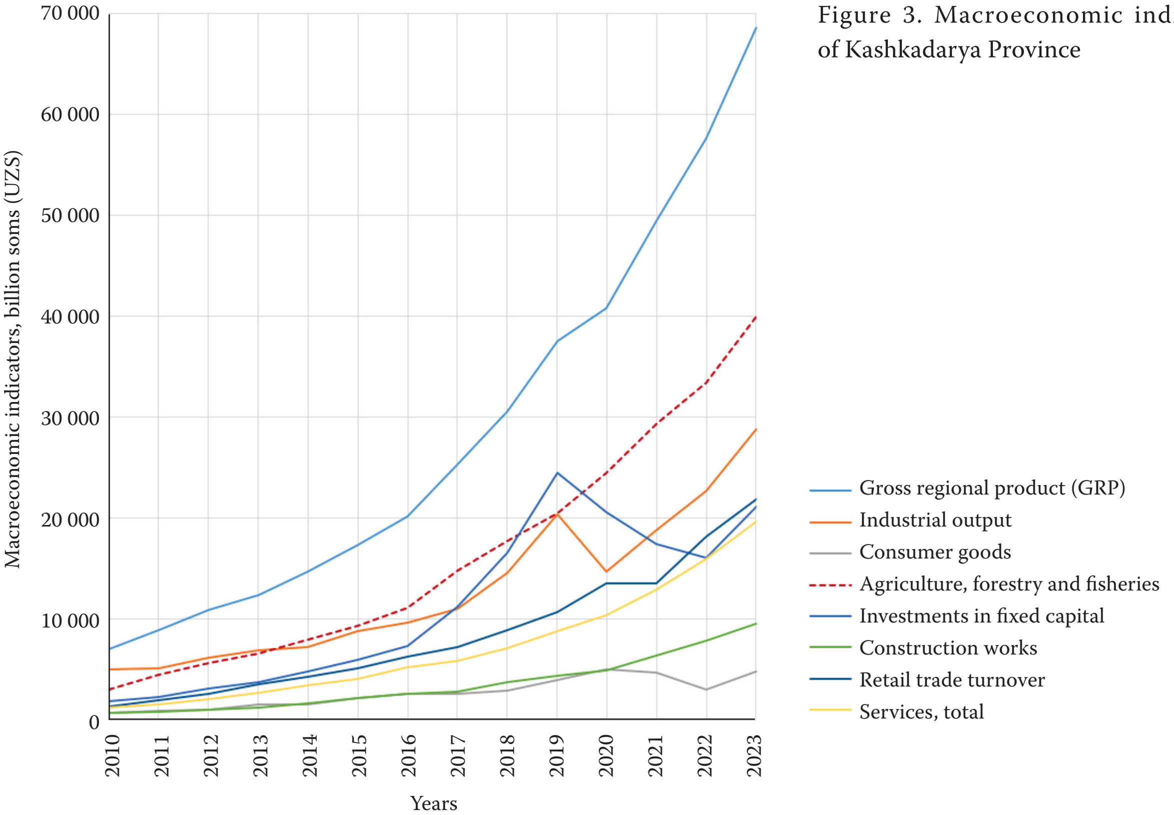

Figure 3. Macroeconomic indicators of Kashkadarya Province

provides about 5% of the water supply, highlighting the importance of multiple water sources for regional water security, while the remaining 20% comes from local rivers, including the Kashkadarya River and its tributaries, which are vital for local irrigation (Abdivalievich 2024). The province manages 514 114 ha of irrigated land, comprising 293 959 ha of non-saline land and 220 155 ha of saline land, further classified into 176 540 ha with weak salinity, 34 866 ha with medium salinity, and 8 749 ha with strong salinity.

Kashkadarya Province has an extensive irrigation system managed by the Amu-Kashkadarya Irrigation Systems Basin Administration and its affiliated organisations. The region maintains 253 canals extending 2 471 km, of which 1 577.3 km are concrete-lined, 16 km are tray canals, and 877.7 km are open earth channels. The system includes 3 603 hydrotechnical structures, comprising 2 024 hydroposts, 40 dukers, 44 aqueducts, and other structures. The irrigation network spans a total of 20 449 km, with 2 205.7 km of concrete-lined channels, 6 236.5 km of channels, 864 km of pipelines, and 11 143.4 km of earthen channels (Figure 4).

The region also boasts significant water storage facilities, including large reservoirs such as Talimarjon (1 500 Mm^3), Chimkurgan (500 Mm^3), Pachkamar (260 Mm^3), Hisorak (170 Mm^3), Kamashi (25 Mm^3), in addition to 8 smaller reservoirs and 9 large hydrocells.

In 2003, the Amu-Kashkadarya Irrigation Systems Basin Administration (IBSA) was established to manage water resources using a basin approach, replacing the regional framework of the previous Kashkadarya Provincial Water Administration. Under the Amu-Kashkadarya IBSA, five Irrigation System Departments (ISDs) were formed, including the Karshi Main Canal, Mirishkor, Aksuv, Eskianhor, and Yakkabog-Guzor ISDs, along with the establishment of a pumping station and energy department and a reclamation expedition. The water supply to each ISD varies, with the Karshi Main Canal and Mirishkor ISDs receiving water from the Amu Darya River via the Karshi Main Canal, the Eskianhor ISD getting its supply from the Zarafshan River through the Eskianhor Canal, the Yakkabog-Guzor ISD sourced from the Guzordaryo River and associated reservoirs, and the Aksuv ISD, which is the primary focus of this research, obtaining its water from the Aksuv and Kashkadarya rivers.

Site selection and purposes. This study analyses various factors influencing the selection of the

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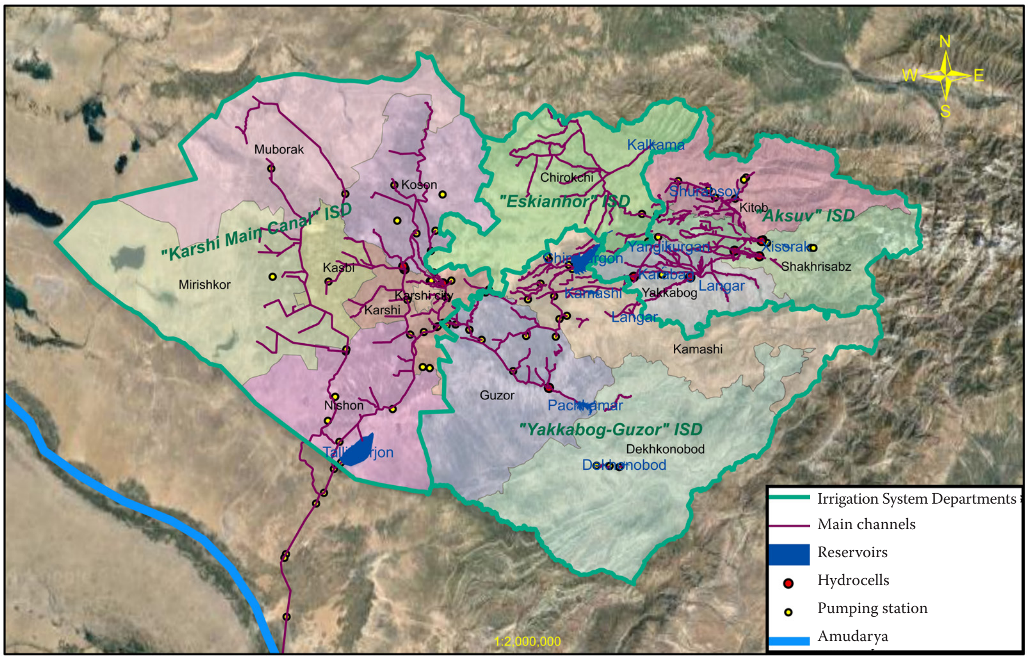

Figure 4. Irrigation system of Kashkadarya Province

sites for constructing the proposed SRs, including water scarcity, agricultural land area, population density, required water storage capacity, and the anticipated benefits of the SR construction. These factors are critical for ensuring that the selected sites effectively address local water needs, enhance agricultural productivity, and promote sustainable water resource management in the region.

As a result of the analysis, Aksuv ISD was selected. The Aksuv ISD primarily supplies water to four districts: Kitab, Shahrisabz, Yakkabog and Chirakchi, drawing from key water sources, in-

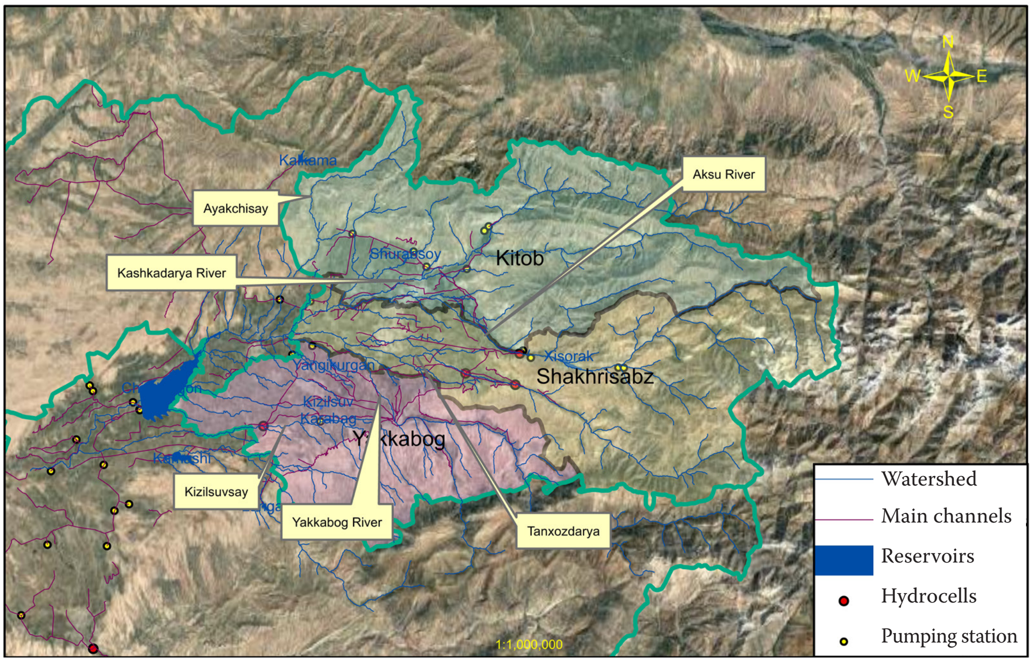

Figure 5. Aksuv Irrigation System Departments

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cluding the Kashkadarya, Aksuv, Tankhoz, and Yakkabog rivers, as well as several smaller streams and Eskianhor Canal. The Hisorak Reservoir, with a capacity of 170 million m^3, along with other SRs, plays a crucial role in water collection for agricultural use during the growing season.

The Aksuv ISD area was divided into four zones for the research work: A, B, C, and D, each distinguished by its water supply (Figure 5). Area A mainly corresponds to the territory of Yakkabog District, where the presence of the Yakkabog River, along with several streams and SRs, ensures a relatively better water supply compared to other areas. Area B covers Shahrisabz District and benefits from a superior water supply, as it is fed by the Aksu and Tankhoz rivers and the Hisorak Reservoir, making it the best-supplied area among the four zones. Area C corresponds to Kitab District, where the water supply is relatively good, being located at the headwaters of the Kashkadarya River and receiving additional water from the Hisorak Reservoir via the Anhor (Dam) Canal. Area D, also part of Kitab District, experiences a lower water supply due to its higher elevation along the Kashkadarya River, which limits the water availability compared to the other areas.

The water supply in Area D is highly complex, primarily relying on the Pakhtakor and Zarafshan pump stations (PSs). The Pakhtakor PS draws water from the Eskiankhor Canal, which draws water from the Zarafshan River, while the Zarafshan PS sources water from the Anhor (Dam) Canal, supplied by the Hisorak Reservoir. This intricate system introduces unique challenges, including dependency on multiple water sources and an extensive pumping infrastructure, which can result in operational difficulties and inefficiencies. Due to these complexities, Area C was selected as the research focus to address the region's specific water supply challenges.

The purpose of constructing SRs in Area D is to supply water without relying on the two existing pumping stations, thereby improving the water supply efficiency and saving energy. However, there are limited options for selecting a suitable location for this reservoir. The only viable choice is the Ayakchisoy River, a tributary of the Kashkadarya River, making it the most appropriate site to enhance the water supply in Area D. Ayakchisoy is a tributary of the Kashkadarya River, and floods are observed in the spring. The average annual flow of the Ayakchisoy is 50.0 Mm^3.

The climate analysis of the Ayakchisoy River, as shown in Figure 6, reveals significant trends in temperature and precipitation over two distinct periods: 1983–2002 and 2003–2022. The data indicate a marked increase in the average monthly

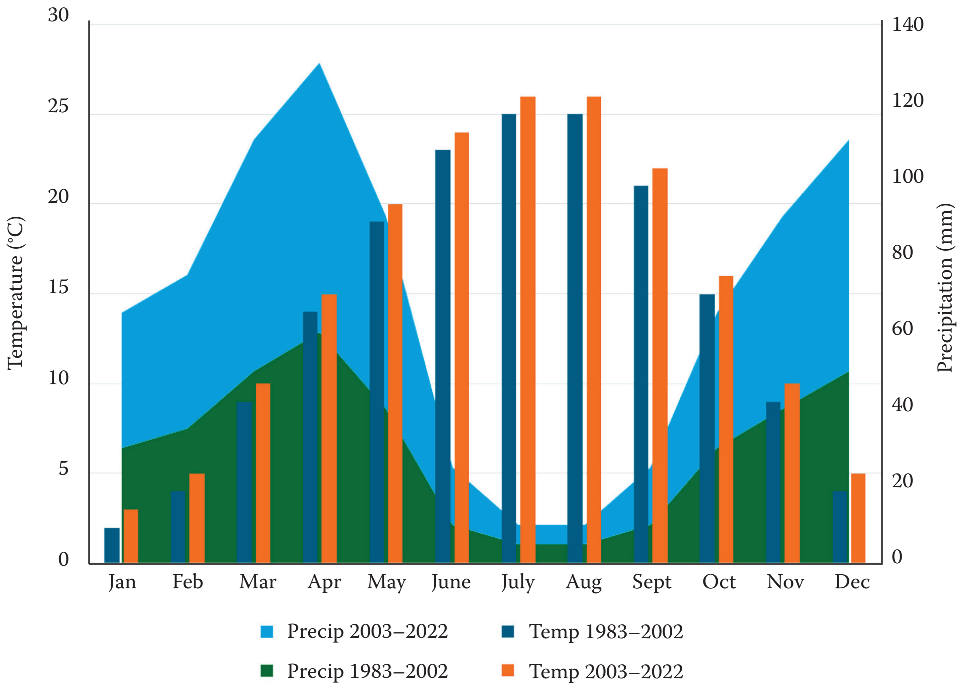

Figure 6. The dynamics of precipitation and temperature in the region – Area D (source: climatecharts.net)

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temperatures during the latter period, especially peaking in the summer months, suggesting a warming trend that could affect the water availability and agricultural practices in the surrounding areas.

Conversely, the precipitation levels showed a decline in the latter period, with the total rainfall generally higher in 1983–2002 compared to 2003–2022, indicating potential challenges in water resource management, as reduced rainfall may exacerbate water scarcity. This combination of rising temperatures and decreasing precipitation highlights the need for adaptive strategies to mitigate the impacts of climate change on the Ayakchisoy River ecosystem and the agricultural systems that depend on its water resources. This is another reason to build SRs in the area.

GIS and RS data. To effectively determine the optimal parameters for the proposed reservoir and assess the suitability of the site, the study employed advanced GIS and RS data. These tools enabled the integration of spatial data, terrain analysis, and site-specific factors that are crucial for reservoir planning and management.

The study utilised a Digital Elevation Model (DEM) derived from the Shuttle Radar Topography Mission (SRTM), which is a product of radar-based remote sensing conducted by National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA). Specifically, we used the SRTM 1 Arc-Second Global DEM, downloaded from the United States Geological Survey (USGS) database. This DEM offers a spatial resolution of approximately 30 m and has a reported vertical accuracy of around ± 16 m, depending on the terrain complexity and vegetation cover.

The SRTM DEM captures the Earth's topography using interferometric synthetic aperture radar (InSAR) technology, making it a reliable source for elevation data in medium-resolution geospatial studies. The dataset al.owed for the detailed modelling of the spatial extent and potential storage capacity of the proposed reservoir sites.

The DEM was processed in ArcGIS to extract key terrain parameters such as the elevation, slope, visibility, and surface area, enabling a 3D analysis for the accurate assessment of the reservoir storage capacity and site suitability.

The tool calculates the storage area and volume capacities for an input surface raster using customisable stage elevations, applies a mask for location limitation, and generates a comprehensive report that includes tool parameters, study area maps, and cumulative storage capacity tables and graphs, while ensuring accuracy through the use of a z-factor to account for differences in the surface z units compared to the x, y ground units.

RESULTS AND DISCUSSION

Spatial model of the RS. In the water reservoir design, methods such as field surveying or using topographic maps can yield high-accuracy terrain data, but they are time-consuming and labour-intensive. To effectively determine key reservoir parameters, various technologies and methodologies can be employed. GIS and RS data are crucial for assessing the surface area and volume, as demonstrated in the development of water surface area-storage capacity relationships using empirical models and DEM (Bakiev et al. 2022). A DEM model of the reservoir area was obtained from the USGS database and analysed using ArcGIS software (Figure 7). In selecting a site, factors such as residential areas, public buildings, cultivated land, and other considerations were considered to determine the most optimal location.

Determining the reservoir parameters. The graph shown in Figure 8 illustrates the relationship between the reservoir's storage capacity (X-axis, in million m^3 – Mm^3) and the water surface elevation (Y-axis, in m above sea level – m a.s.l.). This curve provides insight into the geometry of the reservoir. At the bottom, the reservoir is narrow (such as in a gorge or depression), which causes the water level to rise rapidly with a small increase in volume. As the elevation increases, the reservoir widens, and a greater volume of water is required to raise the water level further. In addition, this graph is useful for calculating the reservoir volume based on the water level, planning the reservoir filling and drawdown operations, and determining the water surface elevation in the hydrological modelling.

At an elevation of 830 m, the reservoir reaches its maximum storage capacity of 18.47 Mm^3 and surface area of 0.94 km^2, highlighting a non-linear relationship between the elevation and volume. The capacity increases significantly at higher elevations, while it gradually decreases to zero at the 770 m base level. The 830 m elevation is chosen as the optimal maximum level, balancing the storage potential and construction cost efficiency.

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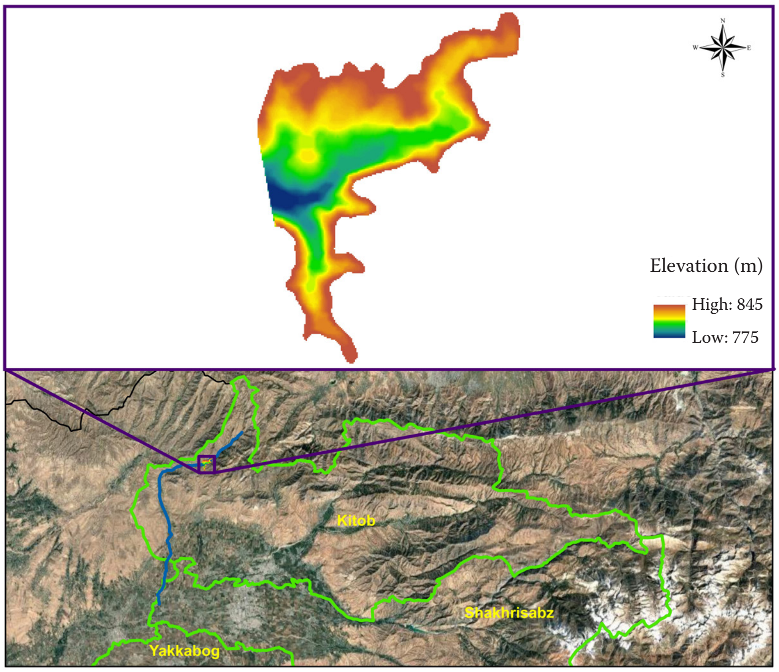

Figure 7. Spatial model of the proposed small reservoir (SR)

The relationship illustrated in Figure 9 shows that as the reservoir volume increases, the surface area also expands. Since the bottom of the reservoir is narrow, the surface area initially increases gradually as water is added. However, as the volume continues to grow and the water level rises, the surrounding terrain becomes broader, leading to the more rapid expansion of the surface area. This means that, at higher elevations, each additional unit of water occupies a significantly larger surface area.

This graph can be used during the operational period of the reservoir to determine the surface area based on the volume of the stored water. This is important for calculating water levels and evaporation losses. By knowing the surface area, it becomes possible to estimate the volume of water lost to evaporation. Moreover, in hydraulic modelling, this curve is useful for assessing water level dynamics, inflow and outflow patterns, and for planning reservoir operation strategies.

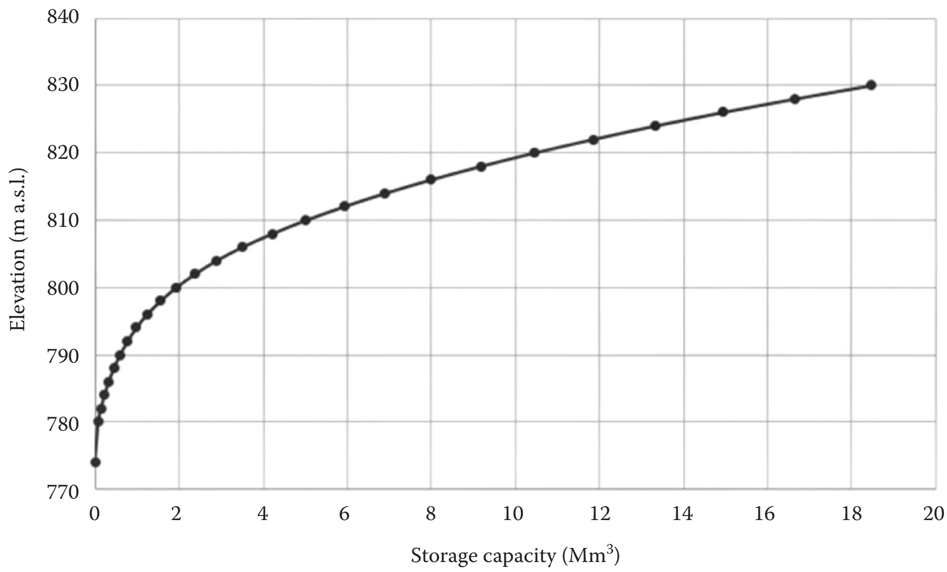

Figure 8. The relationship between capacity volume and elevation curve of the reservoir

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Effectiveness/outcomes of the proposed SR. Construction of a 60-meter dam to collect 18 Mm^3 of water may not seem economically justified at first glance. However, considering the elimination of the need for two pumping stations as a result of the reservoir's construction significantly shifts the economic outlook.

First, if the proposed reservoir with a capacity of 18 Mm^3 is constructed, it will provide water to a total area of 26.5 thousand ha, distributed as follows: 8.5 thousand ha in Yakkabog district, 7.0 thousand ha in Chirokchi district, 4.5 thousand ha in Kamashi district, and 1.5 thousand ha in Shahrisabz district. Currently, the water supply to the study area relies heavily on the Eskiankhor and Ankhor (Dam) canals. However, if the proposed reservoir is built, the pressure on these canals will be significantly reduced (Figures 4–6). This reduction in demand on the canals will enable a more reliable and consistent water supply to the districts above, enhancing the water management efficiency and addressing the regional water scarcity challenges. This expansion of irrigated land will create the opportunity to increase the total production of key agricultural crops in the region to 21 500 t, including 10 000 t of grain, 2 500 t of raw cotton, 3 500 t of potatoes, and 5 500 t of vegetables.

Second, the proposed SRs will eliminate the need for the water currently sourced from the Zarafshan and Pakhtakor pumping stations, as well as from 15 vertical irrigation wells. Currently, the energy and maintenance costs for operating these facilities are approximately 6–7 billion soums annually.

Third, by enhancing the water supply for agricultural activities, the overall quality of life for the region's rural population – comprising more than 200 000 people – will be significantly improved. Additionally, approximately 30 000 individuals will gain employment opportunities within the agricultural production sector.

Fourth, the construction of SRs will not only enhance water availability for agricultural purposes, but also provide critical protection for settlements along the river by mitigating the risk of mudflows. These reservoirs serve as buffers, capturing and regulating water flow during heavy rainfall, which helps prevent the accumulation of debris and sediment that contribute to destructive mudflows. As a result, communities situated along the riverbanks will benefit from increased safety and reduced exposure to natural disasters.

Discussion. Small reservoirs (SRs) have emerged as a vital component of sustainable water resource management strategies, particularly in arid and semi-arid regions where water scarcity and climatic variability pose serious threats to agricultural productivity. This study on the construction of a new small reservoir on the Ayakchisoy River in Kashkadarya Province complements and contrasts with recent research conducted across various geographic and socio-economic contexts.

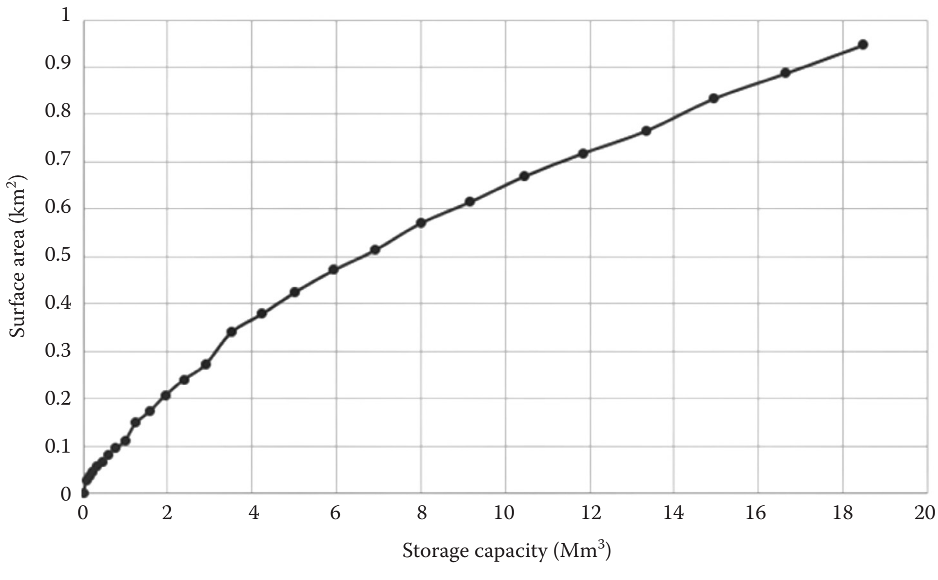

Figure 9. Cumulative analyses of the surface area and the storage capacity

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The study by Aminzadeh et al. (2025) in the MENA (Middle East and North Africa) region shares a similar thematic focus on water scarcity and the role of SRs in agricultural support. However, while their research employs satellite imagery to analyse the effects of climate variability and land use on the existing reservoirs, our work centres on the planning and expected outcomes of a newly proposed reservoir. The MENA study provides valuable insights into how precipitation and temperature trends influence reservoir dynamics, underlining the vulnerability of the existing infrastructure to climatic fluctuations. In contrast, our research adopts a forward-looking approach, proposing a reservoir to enhance the agricultural resilience, boost productivity, reduce operational costs, and mitigate flood risks in a region where such infrastructure is currently lacking.

Similarly, the review by Owusu et al. (2022) on SRs in West Africa underscores their importance in improving food security and livelihoods in drylands. It highlights both the advantages and persistent challenges of SRs, such as sedimentation, irrigation inefficiencies, and poor water quality monitoring. Unlike this regional review, which assesses over 2 000 reservoirs and recommends better long-term management strategies, our study presents a more localised solution by focusing on the site-specific design, planning, and benefits of a new SR in Uzbekistan. While both studies affirm the value of SRs for sustainable rural development, our research emphasises the targeted intervention over regional system-wide reforms.

The study by Casadei et al. (2019) in Italy also supports the development of SRs, though their context deals primarily with rehabilitating underutilised or abandoned reservoirs. Using GIS and remote sensing technologies, they assess the distribution and storage potential of existing SRs. Our work parallels their methodological approach, leveraging similar technologies to identify optimal sites, yet diverges in its focus on new construction rather than revitalisation. This distinction is particularly significant, as our research addresses a region where the SR infrastructure is not only underdeveloped but also urgently needed to ensure agricultural sustainability and socio-economic stability.

In summary, the collective findings of these studies align with and reinforce the conclusions of our research – small reservoirs are critical tools for managing water resources sustainably in water-scarce regions. However, while the reviewed literature often focuses on analysing the existing infrastructure and identifying management challenges, our research offers a proactive model by proposing the construction of a new SR. This proposed reservoir addresses both the present needs and future uncertainties related to water scarcity, while also contributing to agricultural productivity, local employment, and disaster mitigation.

CONCLUSION

This study emphasises the vital role of SRs in mitigating water scarcity and promoting sustainable agriculture in Kashkadarya Province. Utilising advanced GIS and RS technologies, the Ayakchisoy River was identified as the most suitable site for constructing a proposed reservoir with a capacity of 18 Mm^3.

The implementation of this reservoir is projected to significantly improve the water availability for irrigation, serving approximately 26 500 ha of farmland across the Yakkabog, Chirokchi, Kamashi, and Shahrisabz districts. This improvement is expected to boost the agricultural yields, including an estimated 10 000 t of grain, 2 500 t of raw cotton, and 9 000 t of vegetables and other crops.

Furthermore, the reservoir will eliminate the need for two energy-intensive pumping stations and reduce the dependence on 15 vertical irrigation wells, thereby decreasing the operational costs. It will also enable the expansion of irrigated land, contributing to a stable agricultural output, improved food security, and enhanced economic resilience.

In addition to its agricultural and economic benefits, the project is anticipated to create employment opportunities for around 30 000 individuals, thereby improving the local livelihoods. The reservoir will also serve a protective function, mitigating mudflow hazards by regulating water discharge during periods of intense rainfall and reducing the risk of flooding in the surrounding communities.

While the development of small reservoirs presents a viable solution to regional water challenges, their long-term success depends on careful management, including the regular monitoring of downstream water availability and ecosystem health. Future research should explore complementary strategies, such as rainwater harvesting, wastewater reuse, and integrated watershed man-

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agement, to ensure both agricultural productivity and ecological sustainability.

In conclusion, the proposed reservoir on the Ayakchisoy River offers a strategic and forward-thinking response to water scarcity in Kashkadarya. It combines technological innovation, environmental protection, and socio-economic development to enhance the regional resilience in the face of climate change.

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