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WATER SUPPLY IN THE AGRICULTURAL SECTOR OF THE CENTRAL ASIAN REGION: THE NEED FOR RADICAL TRANSFORMATION

ОРТАЛЫҚ АЗИЯ ӨҢІРІНІҢ АГРАРЛЫҚ СЕКТОРЫНДАҒЫ СУМЕН ЖАБДЫҚТАУ: ТҮБЕГЕЙЛІ ҚАЙТА ҚҰРУ ҚАЖЕТТІЛІГІ

ВОДОСНАБЖЕНИЕ В АГРАРНОМ СЕКТОРЕ ЦЕНТРАЛЬНО-АЗИАТСКОГО РЕГИОНА: НЕОБХОДИМОСТЬ РАДИКАЛЬНЫХ ПРЕОБРАЗОВАНИЙ

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Abstract. Central Asia is rich in water resources, yet it is currently facing one of the largest environmental disasters. The disappearance of the Aral Sea is a consequence of inefficient water management and climate change, which pose new challenges for the region and lead to serious problems in utilizing its water potential. *The goal* is to study the current state of the agricultural water supply system in Central Asia and identify ways to enhance the resilience of hydraulic infrastructure. *Methods* – economic-statistical, factor, and comparative analysis aimed at examining the economic, social, and environmental aspects of water resource regulation and irrigated agriculture. *Results* – the current situation in the water sector was analyzed, including the effectiveness of mechanisms for coordinating and controlling transboundary water bodies and attracting investment. The study showed that the existing level of irrigation of agricultural land has led to a significant decrease in water inflow to the Aral Sea, a reduction in arable land area due to soil salinization, and depletion of water reservoirs. Improving water use efficiency and modernizing infrastructure positively impact the sustainable development of the agro-industrial complex. Moreover, the necessity of introducing public-private partnership (PPP) mechanisms into irrigation

projects is emphasized. *Conclusions* – effective exploitation of water resources requires a comprehensive approach, investment attraction, and improved support measures for farming operations. These efforts will enable rational water distribution, enhance the investment appeal of the agricultural sector, and optimize water usage under conditions of scarcity. The future demand for water in food production is enormous and will require large-scale, modern water infrastructure. Hydrosphere management plays a crucial role in water delivery and ecosystem preservation.

Аңдатпа. Орталық Азия су ресурстарына бай, бірақ қазіргі уақытта ең үлкен экологиялық апаттардың бірі болып табылады. Арал теңізінің жойылуы су көздерін тиімсіз басқарудың, сондай-ақ климаттың өзгеруінің салдары болып табылады, бұл осы аумақ үшін жаңа сын-қатерлер туғызады және су әлеуетін пайдалануда елеулі проблемаларға алып келеді. *Мақсаты* – Орталық Азия өңіріндегі ауыл шаруашылығын сумен жабдықтау жүйесінің жай-күйін зерделеу және гидротехникалық инфрақұрылымның орнықтылығын арттыру жолын айқындау. *Әдістері* - су қорын және суармалы егіншілікті реттеудің экономикалық, әлеуметтік және экологиялық аспектілерін зерттеуге бағытталған экономикалық-статистикалық, факторлық және салыстырмалы талдау. *Нәтижелер* - су шаруашылығындағы қалыптасқан ахуал талданып, трансшекаралық су алаптарын үйлестіру және бақылау және инвестициялар тарту тетіктерінің тиімділігі қаралды. Зерттеу көрсеткендей, ауылшаруашылық жерлерін суарудың қазіргі деңгейі Арал теңізіне түсетін су көлемінің айтарлықтай төмендеуіне, топырақтың тұзденуіне байланысты ауылшаруашылық жерлерінің азаюына, сондай-ақ су объектілерінің сарқылуына әкелді. Су пайдалану тиімділігінің өсуі және құрылыстарды жаңғырту агроөнеркәсіптік кешеннің тұрақты дамуына оң әсер етеді. Бұдан басқа, ирригациялық жобаларға мемлекеттік-жекешелік әріптестік (МЖӘ) тетіктерін енгізу қажеттілігі атап өтіледі. *Қорытындылар* - су қорларын тиімді пайдалану үшін кешенді тәсіл, инвестициялар тарту, фермерлік шаруашылықтарды қолдау шараларын жетілдіру қажет, бұл суды ұтымды бөлуді қамтамасыз етуге, аграрлық сектордың инвестициялық тартымдылығын ынталандыруға, сондай-ақ олардың тапшылығы жағдайында су ресурстарын жұмсауды оңтайландыруға мүмкіндік береді. Азық түлік өндірісі үшін болашақ су қажеттіліктері орасан зор және кең ауқымда заманауи су шаруашылығы нысандарын қажет етеді. Гидросфераны басқару сумен жабдықтау және экожүйені сақтау үшін өте маңызды.

Аннотация. Центральная Азия богата водными ресурсами, однако в настоящее время испытывает одну из крупнейших экологических катастроф. Исчезновение Аральского моря является следствием неэффективного управления водными источниками, а также изменения климата, что создает новые вызовы для данной территории и приводит к серьезным проблемам в использовании водного потенциала. *Цель* – изучение состояния системы водоснабжения сельского хозяйства в Центрально-Азиатском регионе и определение пути повышения устойчивости гидротехнической инфраструктуры. *Методы* - экономико-статистический, факторного и сравнительного анализа, направленные на изучение экономических, социальных и экологических аспектов регулирования водного фонда и орошаемого земледелия. *Результаты* - проанализирована сложившаяся ситуация в водном хозяйстве, рассмотрена эффективность механизмов координирования и контроля трансграничными водными массивами и привлечения инвестиций. Исследование показало, что существующий уровень орошения сельхозугодий привел к значительному снижению объемов воды, поступающих в Аральское море, сокращению площади сельскохозяйственных земель из-за засоления почв, а также истощению водоемов. Рост эффективности водопользования и модернизация сооружений оказывают положительное влияние на устойчивое развитие агропромышленного комплекса. Кроме того, отмечается необходимость внедрения механизмов государственно-частного партнерства (ГЧП) в ирригационные проекты. *Выводы* - для результативной эксплуатации водных запасов необходим комплексный подход, привлечение инвестиций, совершенствование мер поддержки фермерских хозяйств, что позволит обеспечить рациональное водораспределение, стимулировать инвестиционную привлекательность аграрного сектора, а также оптимизировать расходование водных ресурсов в условиях их дефицита. Будущие потребности воды для производства продуктов питания огромны и потребуются современные водохозяйственные объекты в крупном масштабе. Управление гидросферой имеет важное значение для водоподачи и сохранения экосистемы.

Keywords: agriculture, irrigated farming, water supply, water resources, scarcity, irrigation system, water management, public-private partnership.

Түйінді сөздер: ауыл шаруашылығы, суармалы егіншілік, сумен жабдықтау, су ресурстары, тапшылық, суару жүйесі, суды пайдалануды басқару, мемлекеттік-жекеменшік әріптестік.

Ключевые слова: сельское хозяйство, орошаемое земледелие, водоснабжение, водные ресурсы, дефицит, ирригационная система, управление водопользованием, государственно-частное партнерство.

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Introduction

The irrigated lands of Central Asian countries account for 66% of agricultural production and play a crucial role in ensuring food and security. However, due to the heavy burden on water scarcity, the possibilities for the extensive development of irrigated agriculture have been practically exhausted. Currently, 80% of water resources are used for irrigation, yet water use efficiency remains at a low level. Waterways losses through canals reach up to 40%, and more than half of the irrigated lands are affected by salinization. Water scarcity significantly impacts the sustainability of agriculture, the income of farming households, and the ecological situation. This phenomenon manifests in soil salinization, waterlogging, decreased fertility, desertification, and the withdrawal of several lands from agricultural use.

According to forecasts, by 2028–2029 the Central Asian region may face a prolonged shortage of water resources amounting to 5-12 km³ (Vinokurov E., Akhunbaev A., Usmanov N. et al.) [1]. As a result, crises may arise in agriculture, industry, and the energy sector. A lack of food, drinking water, and electricity could lead to mass migration from rural areas to cities or other regions. Special attention to this issue was given at the Summit of the Heads of State Founders of the International Fund for Saving the Aral Sea, held in Dushanbe, Tajikistan. It was noted during the summit that by 2050 the number of migrants could reach 5 million people (Akorda – Official website of the President…) [2]. Changes in the region's water balance will impact the hydrological regime, climate change, and demographic growth.

One of the central challenges of agricultural water supply in the Central Asian region lies in the outdated and inefficient state of irrigation infrastructure. A significant portion of irrigation canals and distribution systems were constructed during the Soviet era and have not undergone sufficient modernization. As a result, water delivery remains highly uneven, especially in remote and marginal farming zones. Poor maintenance of canals and lack of technological upgrades contribute to massive water losses before it even reaches the fields.

Moreover, the fragmented institutional structure and lack of coordination among water management agencies hinder the formulation of a unified regional strategy. Many water users, particularly smallholder farmers, lack access to reliable water scheduling and efficient allocation mechanisms. This results in both overuse in some areas and acute shortages in others.

The seasonal variability of river flows, coupled with limited storage capacity and increasing upstream water abstraction, further exacerbates the imbalance between water demand and supply. Without immediate attention to modernize the water delivery network, introduce water metering, and improve governance frameworks, the agricultural sector in Central Asia risks falling into long-term decline.

Thus, sustainable agricultural water supply must be prioritized through integrated planning, investment in smart irrigation, and regional cooperation among riparian states.

Literature Review

The issue of transboundary water resource management in Central Asia has beed widely addressed in the scientific literature (Thaler T.; Kreibich H., Blauhut V., Aerts J.C.J. et al.). [3,4]. The region can be divided into two parts based on water usage regimes: in the northern part, where precipitation is abundant, rain-fed agriculture predominates, while in the southern part, due to the arid climate, agriculture largely depends on irrigation systems. Most southern regions, especially Turkmenistan and Kazakhstan, are already experiencing water shortages (Umirbekov A., Akhmetov A,. Gafurov Z.) [5].

The uneven distribution of water resources among the countries, like Kazakhstan, Kyrgyzstan, Tajikistan, Turkimenistan, and Uzbekistan creates contradiction in their usage. Kyrgyzstan and Tajikistan, located in the upper reaches of the rivers, rely on hydroelectric energy, while Uzbekistan, Turkmenistan, and Kazakhstan, located downstream, primarily use water for irrigated agriculture.

Except for Kazakhstan, electricity tariffs in all other countries do not cover the full cost of energy production and transmission, threatening the financial viability of the sector and hindering technical modernization and expansion (Boute A.) [6].

In recent years, the role of irrigation management in ensuring food security has significantly increased (Postel S.) [7]. The benefits of regional cooperation are particularly relevant to food security, as it is determined not only by national self-sufficiency in certain crops but also by the ability to adequately meet food demand. International trade has been proven to be a key factor in ensuring food sein countries where the cultivation of certain crops is

limited by factors such as meteorological conditions (Baer-Nawrocka A., Sadowski A.) [8].

Thus, it would be more efficient for countries to prioritize high value-added agricultural production based on crops for which they have comparative advantage due to climatic and institutional conditions (Lombardozzi L., Djanibekov N.) [9], while compensating for the insufficient production of other crops through international trade.

At the same time, domestic researchers emphasize the need to develop an effective mechanism for state support in the water management sector, implement new knowledge, and carry out the best innovative projects (Yesbolov T.I., Tireuov K.M., Kerimova U.K.) [10]. Nevertheless, it is a key issue of the modern water management system, where there is the need to strengthen publicprivate partnerships (PPPs), taking into account climate factors, which highlights the importance kf further research in this area. The main goal of PPPs is to attract private capital to the development of irrigated lands, which in turn drives the implementation of irrigation infrastructure projects (Practical guide for investors…) [11].

This partnership forms a complex system built on balanced relations, where each party contributes and shares mutual responsibility. The structure of such cooperation must be clearly defined through contracts, formal documents, and agreements. These agreements should outline the distribution of costs, risk management, and mechanisms for jointly using the outcomes achieved.

At first glance, this system resembles a complex mosaic: each party's interest aligns and various elements work in close coordination. If developed in the right direction, this mechanism can become a shared symphony that not only revitalizes irrigated lands but also leads agriculture as a whole toward a greener and more productive future.

Materials and methods

In the course of the research, a number of practical recommendations were developed for the efficient use of water resources in Central Asia, particularly in the Aral Sea basin. Efficient water resource management is the only viable way to preserve the potential of irrigated lands in the region and to ensure food and water security.The methodology of the research is based on the scientific approach to studying socio-economic phenomena. The theoretical foundation of the study is formed by the scientific works of domestic and foreign scholars, as well as the results of both fundamental and applied research in the field of water resource management and irrigation agriculture.

The research was carried out through a descriptive analysis of the agricultural sector of the region, with a focus on the sectoral and regional aspects of water management.Water use was examined from a sectoral perspective, highlighting the economic significance of irrigated agriculture in ensuring food security. Water resource management is closely linked to the region’s economy. Research has shown that more than 60% of water is used in agriculture; however, a significant portion is lost due to outdated irrigation infrastructure.

Effective water resource management in Central Asia requires a comprehensive approach. This approach should include strengthening transboundary cooperation, adapting to climate change, and modernizing infrastructure. Future research should aim to integrate innovative technologies, promote sustainable develop-ment, and develop mechanisms for resolving political tensions related to water issues.

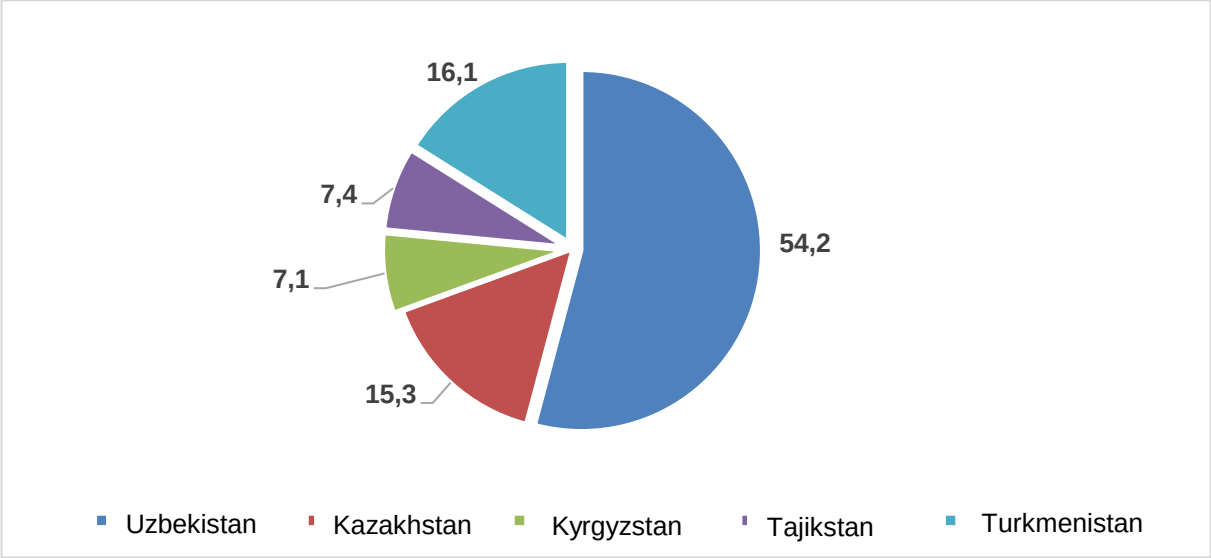
Results

Agriculture in Central Asian countries operates in complex natural and climatic conditions, with geographical remoteness from global markets and lack of access to the sea. The agricultural fields and lands in the region have undergone significant degradation, with outdated techniques and technologies being used, and exacerbated water and environmental issues.

The arable land suitable for irrigation-based agriculture is limited, while the region is also facing challenges such as water shortages and depletion of resources. Water scarcity is one of the main structural constrains to the socio-economic development of Central Asian countries. The per capita water availability in the region has decreased from 3 500 m³ to 1 712 m³ (as of 2023), which is almost halved compared to the Soviet era. According to international classification, the countries of the region fall under the category of "water-scarce" countries (1 000-1 700 m³ per capita annually) and may join the group of "water-deficient" countries by 2050 (Vinokurov E., Zaboev A., Malahov A. et al.) [12].

In these countries, the main consumer of water is agriculture. In 2023, out of the total 127.3 km³ of water used, 100.4 km³, or 79%, was used for irrigation purposes. Irrigated agriculture forms the basis of farming and plays a crucial role in ensuring food security. Irrigated lands account for approximately 66% of the total value of agricultural production: 100% in Turkmenistan, 87% in Uzbekistan, 85% in Kyrgyzstan, 82% in Tajikistan, and 40% in Kazakhstan (Vinokurov E., Ahunbaev A., Chuev S. et al.) [13].

In the structure of water consumption, Uzbekistan (54.2%) and Turkmenistan (16.1%) hold the largest shares. These countries have traditionally specialized in cotton cultivation. Following them are Kazakhstan (15.3%), Tajikistan (7.4%), and Kyrgyzstan (7.1%) (figure 1).

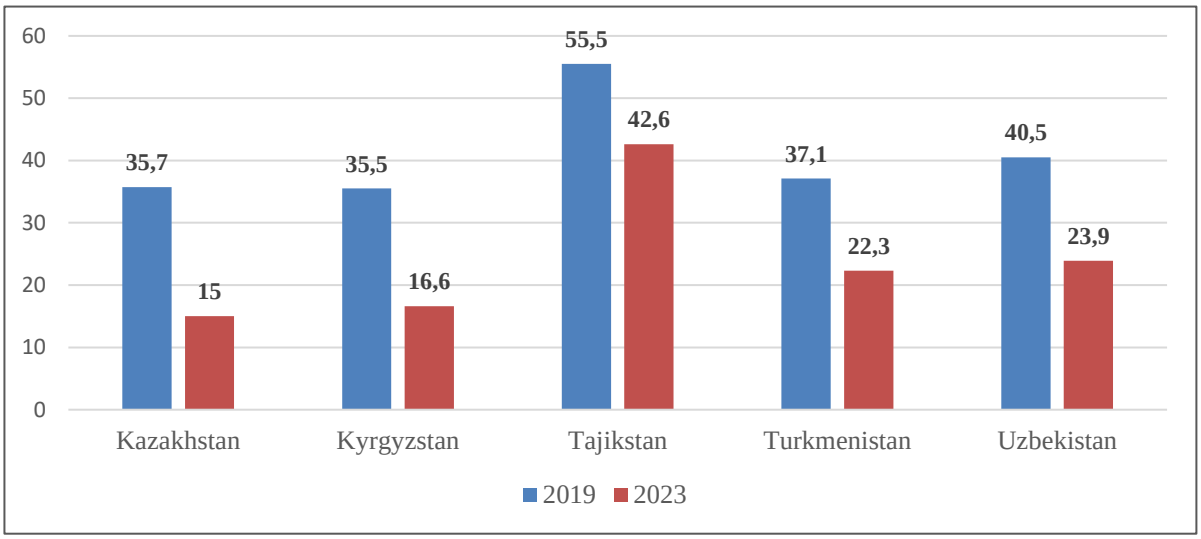


Note: compiled by the authors

Figure 1 - Structure of water consumption in agricultural by country, %

The degradation and salinization of irrigated lands is a critical issue for the countries in the region, with nearly 50% of the irrigated areas affected by salinization. This problem is causing significant difficulties due to the lack of financial resources in small farming households to maintain irrigation infrastructure at the required level and implement land reclamation measures.

Although the proportion of the rural population in the region has decreased by half compared to the Soviet era, it is still high, with approximately 60% of the population relying on agriculture as their main source of income (figure 2).



Note: compiled by the authors

Figure 2 - Proportion of the population employed in agriculture, %

One of the main factors influencing the development of agriculture in these countries is the high level of government regulation and the direct involvement of the state in managing this sector. However, the priorities of agriculture often change, with support measures being reviewed, subsidy regulations, and policies to support the export of local products being continuously adjusted. Many agricultural issues are addressed by the government through individual decisions, but these decisions often fail to consider the social aspects of increasing production efficiency. The lack of a systematic and comprehensive approach to solving issues in the sector

reduces the efficiency of agricultural production and weakens its competitiveness.

Additionally, agricultural production faces challenges such as high costs and low investment returns from existing technologies. Scientific and practical research shows that the most optimal way out of this situation is the introduction of innovate technologies into agricultural production.

Modern technologies in crop production are aimed at saving resources and energy, ensuring ecological safety, enhancing profitability, and maximizing the efficient use of irrigated land. Investments in such innovative methods pay off only due to a 50% or greater increase in productivity (Shadskikh V., Peshkova V., Rasskazova O.) [14].

Another feature of Central Asian countries is the very low efficiency of water use, with one of the main reasons being the high level of water losses. Research conducted by Royal Haskoning has shown that significant amounts of water are lost during transportation from the intake point to the fields, as well as during the irrigation process. The study, based on especially developed modal and analysis of multi-year data, calculated the average water loss in the irrigation system and the fields themselves. The results showed that the level of water loss in the system is very high, with only a small portion of the water being used directly for its intended purpose (Royal Haskoning…) [15].

Discussions

When calculating the payment for water supply services in regional water resource management and irrigated agriculture,only the actual volume of water delivered to the specific consumer is taken into account,while also considering the efficiency factor of the main and distribution canals.

The water separation points are all equipped with specially tested water metering devices or water flow measurement sensors.

In irrigated agriculture,two tariff systems are mainly used:

- one-component tariff-based only on the volume of water used(in cubic meters);

- two-component tariff-based on the area of land (hectares) and the amount of water actually consumed (cubic meters) (Manzhina S., Medvedeva L.) [16].

However the difference in tariffs for water supply to agricultural producers by country is visible. As a result, the cost of irrigation is also different: in Kyrgyzstan - 0.043 cents/m3, in Tajikistan - 0.21 cents/m3, and in Kazakhstan - 4.15 cents/m3 Organisation for Economic Co-operation and Development (OECD) (Financing a Water Secure Future…) [17]. The actual costs of water management organizations for the supply of water to water users exceed the fee for the services provided several times.

Therefore, based on the experience of developed countries, it is proposed to widely use two-rate and multi-rate tariffs in the system of payment for water used for irrigation (Safarova N., Vasilyev S., Akopjan A. et al.) [18]. In settlements between water users and water supply organisations,the use of often mixed or two-rate tariffs takes into account many factors.

For example,the payment for water is calculated not only depending on the volume of water supplied or the area irrigated land,but also on the type of technology used for irrigation, the efficiency of irrigation and the profitability of crops grown in the irrigated lands. This approach is the result of a policy of stimulating and sometimes indirectly subsidizing the production of certain agricultural products. In addition, this is one of the measures aimed at supporting the introduction of the most economical irrigation technologies.

Financing of Main and Inter-farm irrigation networks in the countries of Central Asia depends mainly on funds allocated from the state budget. The development of irrigation systems is one of the most expensive industries in agriculture. In this regard, the introduction of a system of paid water use in Water Resources Management is considered as one of the most important reforms, especially in Kazakhstan and Uzbekistan.

However, international experience has shown that despite the successful implementation of paid water use mechanisms, irrigated agriculture still requires significant government subsidies. This is because the volume of necessary investments is far beyong the financial capabilities of farmers in many regions. The main beneficiaries of investments in irrigation systems are government agencies in the water and agriculture sectors, as well as farming, peasant, and agricultural enterprises. Therefore, it is essential to properly organize the institutional and economic measures of this process. In our opinion, in order to use irrigated land and water resources efficiently and increase their productivity, it is necessary to develop public-private partnerships (PPP).

Attracting private capital for the implementation of irrigated infrastructure projects is a key direction of public-private partnerships. In this process, mutual obligations and responsibilities between the parties should be on an equal footing, and this must be clearly outlined in contracts and official documents. These documents should also clearly define the procedure for cost and risk sharing, as well as the share of each party in utilizing the outcomes of the investment (figure 3).

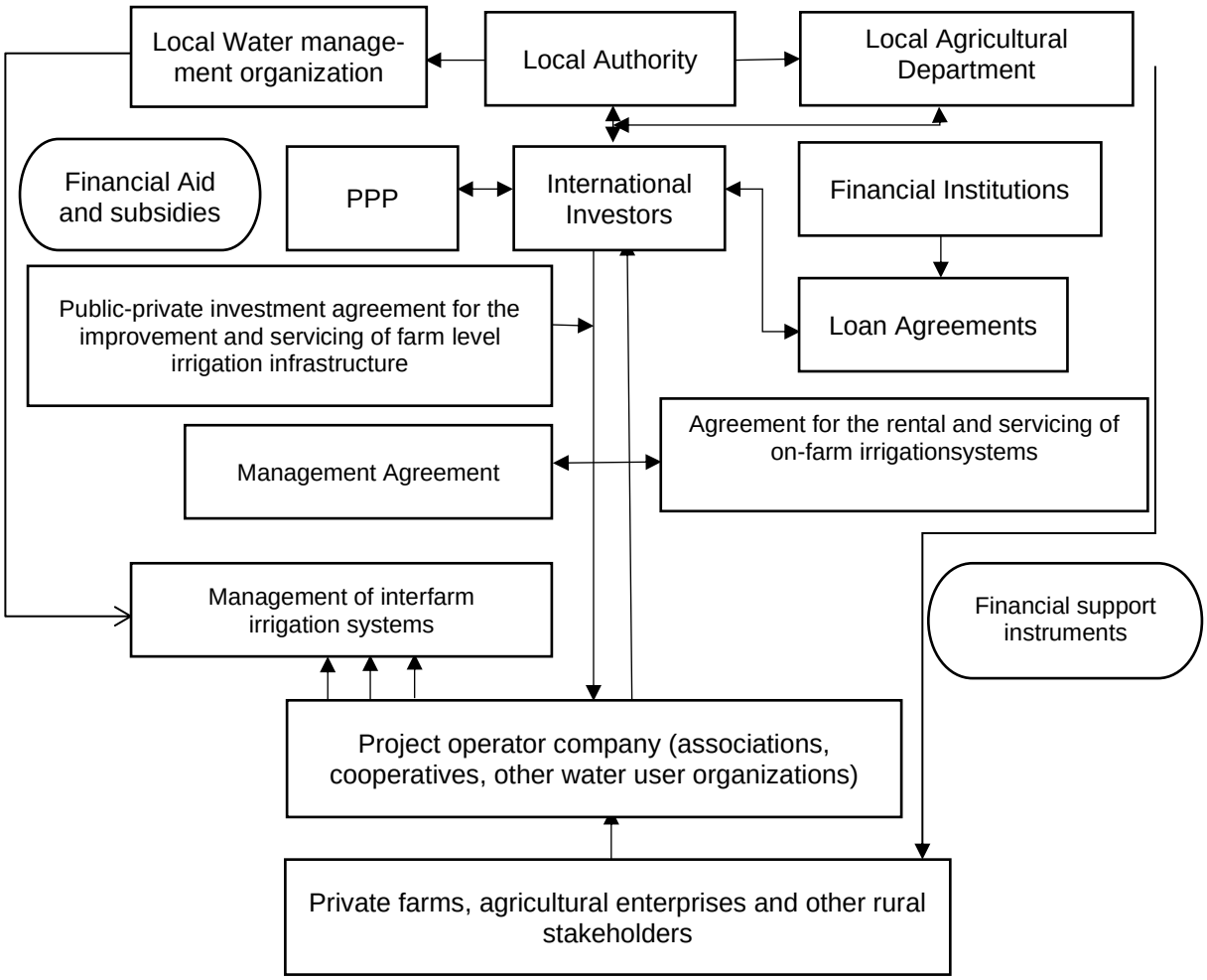


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Figure 3 - Organizational and economic measures aimed at increasing the efficiency of irrigated agricultural lands

Ensuring the effectiveness of water supply management largely depends on considering climatic factors, the rational use of financial resources through public-private partnerships, and the material and technical support of the water resource system. In this case, the social aspect is reflected through the PPP mechanism. Accordingly, the process of modernizing water supply in the context of the Central Asian countries requires a compre-hensive study of this issue.

Conclusion

1.Integrated Wate Resources Management – Strengthening interstate cooperation and developing joint strategies for the use of transboundary rivers are crucial for sustainable water management in the region.

2. Infrastructure Modernization – Improving water transport systems and implementing modern technologies to reduce water loss are necessary steps for increasing water use efficiency.

3.Economic Incentives – Revising tariff and subsidy system to encourage efficient water use and ensure sustainable water resources management.

4. Development of public-private partnerships – Attracting private investments into irrigation infrastructure and enhancing the involvement of farmers and water users. PPP mechanisms ensure a balanced distribution of responsibilities among farmers,investors,and government bodies to promote sustainable infrastructure development. Under PPP, the private sector can contribute to the financing, modernization, and management of irrigation systems, while the government ensures fair water distribution through legal and regulatory frameworks.

5. Cost Assessment and Investment Stimulation - taking into account the cost of modernising and reconstructing irrigation infrastructure, PPP mechanisms offer a high potential for attracting investment to improve the technical condition of irrigation the

technical condition if irrigation facilities within a specified timeframe. Based on global experience, this financing method the water market is seen as both effective and viable. Concessionaires may include budgetary organisations, water users such as agricultural cooperatives, various organisations, and other legal entities interested in improving water supply.

6. Promotion of Regional Cooperation in Agriculture Equipment Production - one of the priority areas for regional cooperation is the development of agricultural machinery manufacturing, agrochemicals, and irrigation equipment. The region currently lacks of the production of agricultural machinery and specific meliorative equipment, including tools for canal maintenance, water accounting devices, and other essential technologies.

Therefore, it is proposed to consider the establishment of a regional cluster for the production of modern irrigation equipment and technologies, taking into account the specific needs of each Central Asian country. Such a cluster could be created based on PPP principles, with the involvement of intergovernmental agreements between stakeholders.

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