World Journal of Environmental Biosciences
Available Online at: **www.environmentaljournals.org**

Volume 15, Issue 1: 37-46

https://doi.org/10.51847/aEwA7LOKEu

ISSN 2277- 8047

Optimal Use of Irrigated Lands Through Water-Saving Technologies and Development of Water Supply Systems in Agriculture

Natalya Gritsenko[1], Pavel Kalashnikov[1], Mirobit Mirdadayev[1], Aigul Baizakova[1], Kuanysh Jabayev[1], Yermekkul Zhaparkulova[2], Aigul Shaimerdenova[3*]

[1]Kazakh Scientific Research Institute of Water Economy, Kazakhstan.
[2]Kazakh National Agrarian Research University, Kazakhstan.
[3]Kazakh Automobile and Road Institute, Kazakhstan.

ABSTRACT

In the coming years, Kazakhstan will continue to experience a reduction in the internal resources of river basins due to a decrease in the inflow of transboundary river waters from neighboring countries, the poor technical condition of water management infrastructure, a large share of irrigation water losses, climate change, and extremely low rates of adoption of water-saving technologies. The optimal use of irrigated lands is a key factor in increasing agricultural productivity, ensuring sustainable water use, and securing food safety. In the context of the Republic of Kazakhstan, the relevance of the topic is determined by the limited availability of water resources, high water losses under traditional irrigation methods, and the need to improve the economic efficiency of agricultural production. Studies emphasize the importance of introducing water-saving technologies (drip irrigation, sprinkler systems, subsurface irrigation, and regulated irrigation) and modernizing the water supply system to achieve efficient resource distribution and minimize operating costs. The purpose of this work is to optimize the cropping structure on irrigated lands through the use of water-saving technologies and irrigation equipment. This article examines the problem of obtaining the maximum net income from crop production on irrigated lands using a drip irrigation system, taking the peasant farm "Samgau" of Korday District, Zhambyl Region, as an example. This goal was achieved through economic-mathematical modeling of production processes on irrigated lands.

Keywords: *Irrigated lands, Water-saving technologies, Drip irrigation, Irrigation optimization, Economic-mathematical modeling, Agricultural water use*

Corresponding author: Aigul Shaimerdenova
e-mail ✉ aiya77@mail.ru

Received: 09 January 2026
Accepted: 19 March 2026

INTRODUCTION

Arid weather in southern Kazakhstan is one of the long-standing and widely discussed problems of irrigated agriculture. Water scarcity, reduced river runoff of transboundary rivers, and high losses during water conveyance through irrigation canals all lead to changes in the country's development strategy in those agricultural sectors that require large amounts of water (Clark & Foster, 2025). In particular, it is proposed to reduce the acreage under water-intensive crops (rice, cotton), while agricultural enterprises are being strongly encouraged to introduce water-saving technologies.

In recent years, the country has seen a decline in water withdrawals from river basins for irrigated agriculture. If 12.1 billion cubic meters of river water were used for irrigation in 2020, by 2024, this indicator had decreased by 5.8% to 11.4 billion cubic meters. More than half of this volume came from the Aral-Syr Darya water management basin, whose resources are used by the most active southern regions, Turkestan and Kyzylorda oblasts. This is due both to the general reduction in river runoff in these basins and to their high anthropogenic pressure.

The Concept for the Development of the Water Resources Management System of the Republic of Kazakhstan for 2024–2030 emphasizes that in the near future, the country may face a significant water resource deficit amounting to 50% of demand. The rate of adoption of water-saving irrigation technologies in the Republic of Kazakhstan averages 30 thousand hectares per year, while the minimum required level is 150 thousand hectares. If the current pattern of water resource use by economic sectors and the population continues, by 2029, there is a risk of a slowdown in socio-economic development due to water scarcity. This may create a threat to the food and national security of Kazakhstan (Kyaw *et al.*, 2024; Coleman *et al.*, 2025). The Concept provides for a number of measures to reduce the water resource deficit, including work on the comprehensive reconstruction of existing hydromeliorative systems with the wide introduction of water-saving technologies and irrigation equipment for crops.

The priority implementation of these measures is also relevant because agriculture in Kazakhstan currently consumes up to 70% of all water resources. In 2024, the total area of irrigated agricultural land amounted to 1.9 million hectares. Most of this area, 67%, received water through surface irrigation, while modern technologies such as drip irrigation and sprinkling were used on 26.3% of the area (or 397.3 thousand hectares).

Over the past 5–6 years, the country has seen renewed activity in the use of water-saving technologies and irrigation equipment for crops, although the area of irrigated land where sprinkling, drip irrigation systems, and discrete water supply are used accounts for less than 15% of irrigated land (Zar *et al*., 2024).

The key research areas in recent years have included objective programming of water resource allocation, economic optimization functions within mathematical modeling, the interface of biophysical crop yield models with economic criteria, as well as the application of advanced optimization and modeling algorithms (linear/nonlinear programming, stochastic modeling, Bayesian optimization) (Zakaev *et al*., 2024).

Literature review

Modern studies consider irrigated lands as integrated systems that include agrotechnical, hydraulic engineering, and economic components. The works of Abraliyev *et al*. (2024) and Usaeva (2024) show that a systemic approach to irrigation resource management makes it possible to increase crop yields by 15–25% while reducing water consumption by 10–20%. An important aspect is taking into account the specifics of soil and climatic conditions, crop type, and water consumption intensity (Nokusheva *et al*., 2023; Krasnova *et al*., 2025).

The introduction of water-saving technologies is regarded as the main instrument for improving irrigation efficiency. García-Mollá *et al*. (2025) demonstrate that drip irrigation and micro-irrigation provide a significant reduction in water losses and an increase in yields. Li *et al*. (2024) emphasize that the economic efficiency of technologies depends on their integration into the existing infrastructure and consideration of local hydrometeorological conditions. In Kazakhstan, the studies of Sadanova *et al*. (2025) confirm the positive effect of water-saving systems in the southern regions when growing cotton and vegetable crops.

The development of the water supply system includes the modernization of canals and pumping stations, the installation of measuring devices, and the automation of water distribution. Tulaganov *et al*. (2025) show that the systemic modernization of irrigation infrastructure makes it possible to reduce operational losses by 20–30% and improve control over water distribution among users. The use of remote monitoring and water balance management systems contributes to irrigation optimization and water savings (Shaimerdenova *et al*., 2026).

Thus, the publication by Zhang, Ren, and Zhao (2025) proposes an economic optimization model for the allocation of irrigation water for regions with resource scarcity. In this model, crop economics is linked with hydrological assessments, and the optimality criteria are based on the Karush-Kuhn-Tucker (KKT) conditions (Zhang *et al*., 2025). This makes it possible to distribute water in a balanced way so as to maximize yields while simultaneously equalizing the marginal benefit of water across the study area, which leads to a significant increase in gross harvest (Shi & Guo, 2024).

MATERIALS AND METHODS

Economic-mathematical modeling of irrigation optimization represents a methodological basis for water use planning, productivity improvement, reduction of operating costs, and enhancement of the sustainability of the agricultural sector under conditions of water scarcity (Abdullayev *et al*., 2025; Gumarova *et al*., 2025; Yskak *et al*., 2026). Under conditions of climatic uncertainty, population growth, and limited freshwater resources, the task is to develop models that make it possible to coordinate hydromechanical, biophysical, and economic parameters for the optimal allocation of water among crops, sectoral needs, and environmental priorities. The application of these models makes it possible not only to predict the results of introducing innovations, but also to develop optimal water use strategies within national agricultural development programs for different regions (Tashnichenko & Tregub, 2024).

The assessment of the economic efficiency of water-saving technologies and the modernization of the water supply system is part of managerial decision-making. The studies of Sajjad *et al*. (2025) and Perelli *et al*. (2024) show that investments in modern irrigation systems pay off within 3–5 years due to increased yields and reduced water and energy costs. In Kazakhstan, these indicators are confirmed by local studies by Abraliyev *et al*. (2024), Usaeva (2024), and Yessembay (2025), which demonstrate a positive correlation between the volume of investment in water-saving technologies and the growth of farm profits.

Main methods

Modern water-saving technologies considered in this study included drip irrigation, sprinkler irrigation, precision irrigation systems equipped with soil moisture sensors and automatic control, and laser land leveling to improve the uniformity of water distribution. Compared with traditional surface irrigation, these technologies are characterized by higher water-use efficiency and better adaptability to different agroclimatic conditions. In the conditions of southern Kazakhstan, their application is associated with more rational water allocation, improved use of irrigated land, and greater production efficiency (Usaeva, 2024).

The methodological basis of the study was economic-mathematical modeling aimed at optimizing the use of land and water resources in irrigated agriculture. The model was constructed to determine the crop structure that ensures maximum net profit under existing production constraints. In developing the model, resource limitations, irrigation norms, crop yields, production costs, selling prices, and the admissible proportions of crops in the farm structure were taken into account (Orynbekov, 2000; Onlassynov *et al*., 2024; Usaeva, 2024; Ismagulova *et al*., 2025; Tulaganov *et al*., 2025). The optimization problem belongs to the class of linear programming models and was used to assess the feasibility of introducing water-saving irrigation technologies in agricultural production. This approach makes it possible to substantiate management decisions on the allocation of irrigated land, the distribution of water resources, and the selection of the most economically efficient crop combinations (Orynbekov, 2000; Mukhamedzhanov *et al*., 2017; Logachev & Goncharov, 2024).

RESULTS AND DISCUSSION

In Zhambyl Region, in a number of districts—Korday, Zhambyl, Bayzak, Merken, Shu, and others—drip irrigation and sprinkler systems are being successfully used for irrigating crops. The study considers the example of the peasant farm (PF) “Samgau” in Korday District in the use of a drip irrigation system. The research was conducted from 2020 to 2024. The following farm data were used in the analysis: sugar beet was grown on an area of 91 ha, and grain corn on an area of 200 ha under drip irrigation. The yield of sugar beet exceeded 100 t/ha, and the yield of grain corn exceeded 12 t/ha. For the conditions of the Zhambyl Region, the yields are quite high. At the same time, however, there are significant reserves for reducing the production costs of these crops when using drip irrigation systems.

The peasant farm "Samgau" is located in the irrigated farming zone in the south of Kazakhstan. In this region, there is a shortage of water resources for land irrigation. The irrigation systems were built almost 50 years ago, and their wear amounts to about 80% or more. At present, for the most part, irrigation of crops is carried out by flooding or along furrows. This leads to significant losses of irrigation water in the field as well. The irrigation norms recommended by science are, unfortunately, not observed. Therefore, a significant number of farms in the region, including PF "Samgau," in order to save water, are shifting from traditional technologies and irrigation techniques for crops to water-saving technologies such as sprinkler irrigation and drip irrigation. In this situation, the task arises of determining irrigation priorities for crops, for example, using drip irrigation systems (Amanbayeva *et al*., 2022; Kudaibergenova *et al*., 2023). It is expected that the effect of using drip irrigation systems will be expressed in irrigation water savings, increased labor productivity, higher crop yields, and ultimately a reduction in the production cost of crops on irrigated lands (Belfiore *et al*., 2024; Figueroa-Valverde *et al*., 2024; Karatas, 2024; Lee & Ferreira, 2024; Negreiros & Ory, 2024; Wolderslund *et al*., 2024; Abdullah *et al*., 2025).

The following assumptions were adopted for the parameters of the proposed model of rational use of land and water resources, taking into account new innovative irrigation technologies and cultivation of crops in the peasant farm "Samgau".

As a criterion of optimality for the use of land and water resources, the model implements the function:

$$F = \sum_{j=1}^{n} m_j \qquad (1)$$

where:

F - is the net profit of the object (in this case, the peasant farm) from the sale of products of the j-th agricultural crop.

The net profit from the sale of products obtained from the cultivation of the j-th agricultural crop:

$$m_j = (p_j - c_j) * u_j * X_j, \qquad (2)$$

(Mukhamedzhanov *et al*., 2017)

where:

X_j - is the sown area of the j-th agricultural crop;

u_j - is the sown area of the j-th agricultural crop;

c_j - is the production cost of 1 centner of output of the j-th agricultural crop;

p_j - is the selling price of 1 centner of output of the j-th agricultural crop.

The resources considered in the system are: S — the area allocated for crops, and W — irrigation water resources. As parameters of resource use, the model introduces v_j- the irrigation norm of the j-th agricultural crop and a_j – the structure of n crops.

With respect to the parameter a_j - the crop structure, an additional condition is introduced 0,85 $\leq \sum_{j=1}^{n} a_j \leq 1 \leq$, or the combination of crops within one system, under the condition that the inertia of the latter cannot have a sharp jump and cannot be chosen arbitrarily.

First, the combination depends on agrotechnical conditions of crop rotation compliance; second, it may be dictated by market demand for finished products. Taking these two factors into account, we adopted a 15% tolerance for changes in this parameter compared with the previous year.

In addition to the above-listed parameters, the model introduces so-called "remark" parameters in order to account for the influence of new innovative technologies implemented in the system as a whole. Three directions of innovative technology are proposed: first, remark tv — new irrigation technology and equipment; second, remark tu — new cultivation agrotechnology; and third, tl — new technology in product sales logistics. Obviously, in one or another version of the experimental study, it is necessary to use data taking into account the introduction of one or another innovative technology (Kęska & Suchy, 2024; Noor *et al*., 2024; Jagsi *et al*., 2025; Schneider & Krüger, 2025; Wong *et al*., 2025, Yu *et al*., 2025). This is precisely the essence of the novelty of the proposed model of the rational management system and optimal use of land and water resources, taking into account innovative technologies (Csep *et al*., 2024; Ghiga *et al*., 2024; Kounatidis *et al*., 2024; Clark & Foster, 2025; Musa *et al*., 2025; Njoroge & Odhiambo, 2025; Petronis *et al*., 2025; Raza *et al*., 2025; Yu *et al*., 2025).

The mathematical model of the system for optimal use of land and water resources, taking into account new innovative technologies of irrigation and cultivation of crops, has the following structure.

$$F = \sum_{j=1}^{n} (p_j - C_j) u_j X_j \rightarrow max \qquad (3)$$

subject to the following constraints:

$$\sum_{j=1}^{n} X_j \leq S \qquad (4)$$

$$F = \sum_{j=1}^{n} u_j X_j \leq W \qquad (5)$$

$$X_j - a_j Y \geq -\varepsilon \quad j = 1,2,3, \dots, n$$
$$X_j - a_j Y \leq \varepsilon \; j = 1,2,3, \dots, n$$

Where

$X_j \geq 0 \;\; j = 1,2,3, \ldots, n$
$Y \geq 0$

In its structure, the model belongs to a mathematical linear programming problem, and in the general case, with a correct numerical formulation of the problem, it is solved with sufficient accuracy by the simplex algorithm. In particular, with a correct formulation of the problem, insolvability arises when selecting “absolutely zero” balances between the problem variables, which complicates the computational process and sometimes leads to cycling of the algorithm. Similar problems often arise in experimental calculations with a large volume of numerical information. In the model structure, “absolutely zero” balance conditions are replaced by softer conditions with the introduction, instead of “0,” of a sufficiently small number $e > 0$ (Orynbekov, 2000; Mukhamedzhanov *et al.*, 2017).

To avoid computational problems, the linear programming model is presented in tabular form, convenient for using the simplex method algorithm **(Table 1).**

Table 1. Tabular model of the system for optimal use of water and land resources under the introduction of water-saving technologies and irrigation equipment.

	I	$-X_1$	$-X_2$	…	$-X_j$		$-X_n$	-Y
-1	S	1	1	…	1	…	1	0
-2	W	v_1	v_2	…	v_j	…		0
-3	0.1	1	1	…	1	…	1	-1
-4	- 0.1	- 1	0		0		0	a_1
-5	- 0.1	0	-1	…	0	…	0	a_2
…	…	…	…	…	…	…	…	…
-i	…	…	…	..	-1	…	…	a_j
…	…	…	…	…	…	…	…	…
-m	-0.1	0	0	…	0	0	-1	a_n
F	0	$-m_1$	$-m_2$	…	$-m_j$	…	$-m_n$	0

The task is to develop a long-term plan for the rational development of crop production on the irrigated lands of PF “Samgau” by establishing an optimal combination of plantings of vegetables, sugar beet, grain corn, cereals, and others, provided that:

- product selling prices remain at the 2024 level;
- water resources are available at a sufficient level;
- Crop cultivation technology conditions are observed.

Table 2 presents the initial information necessary to solve the problem of optimizing the crop structure on irrigated lands. Here, the actual areas and crop structure averaged over the last 3 years are presented. The total area of irrigated land on the farm is 478.0 ha. The values of irrigation norms (in m^3/ha) were established in accordance with the recommendations (Mambetnazarov *et al.*, 2026). Yield indicators were averaged over the last 5 years. Selling prices are average market prices. According to the farm’s accounting data, the production cost of crops was calculated and is presented in **Table 2**.

Table 2. Technical and economic indicators of agricultural crop production on the irrigated lands of PF “Samgau” (averages for 2020–2024)

Name of crops	Area under crops, ha	aj – structure share	Wj – irrigation norm, m^3/ha	uj – yield, c/ha	pj – selling price, tenge/c	cj – production cost, tenge/c
Sugar beet (d.i*.)	139,0	0,30	5500	1000,0	1900,0	1021,1
Grain corn (d.i.)	61,0	0,13	4450	120,0	4500,0	1860,6
Spring barley (f.i.**)	163,0	0,34	3650	24,0	3890,0	1842,8
Winter wheat (f.i.)	28,5	0,06	3050	20,0	4250,0	2014,2
Vegetables (d.i.)	45,0	0,9	5450	850,0	3600,0	2311,0
Soybeans (d.i.)	15,0	0,03	3900	20,0	16500,0	2804,4
Perennial grasses (f.i.)	26,5	0,05	8200	35,0	600,0	100,9
Total irrigated land	478,0	1,0				
*- drip irrigation; ** - flooding irrigation						

In accordance with the indicators presented in **Table 2**, a model was created for searching optimal options for the use of water and land resources in agricultural production on irrigated lands **(Table 3).**

Table 3. Model of rational development of crop production using drip irrigation technology in PF “Samgau” (for future implementation) (Mukhamedzhanov *et al*, 2017).

	I	**$-X_1$**	**$-X_2$**	**$-X_3$**	**$-X_4$**	**$-X_5$**	**$-X_6$**	**$-X_7$**	**-Y**
-1	478,0	1	1	1	1	1	1	1	0

-2	3919,6	5,50	4,45	3,65	3,05	5,45	3,90	8,20	0
-3	0.1	1	1	1	1	1	1	1	-1
-4	-0.1	-1	0	0	0	0	0	0	0.30
-5	-0.1	0	-1	0	0	0	0	0	0.13
-6	-0.1	0	0	-1	0	0	0	0	0.14
-7	-0.1	0	0	0	-1	0	0	0	0.06
-8	-0.1	0	0	0	0	-1	0	0	0.09
-9	-0.1	0	0	0	0	0	-1	0	0.03
-10	-01	0	0	0	0	0	0	-1	0.05
F	0	-878,90	-316,728	-48,413	-44,716	-1095,6	-158,9	-17,46	0

Using the developed model and the baseline information indicators **(Tables 2 and 3),** as well as a computer program, an optimal solution to the problem was obtained **(Table 4).** The problem dimension is 10×8, the search goal is 1 — the maximum value of the objective functional (total net profit). The main required variables X are numbered by unsigned integers, and the additionally introduced variables Y in canonical form are numbered by signed negative integers (-).

Table 4. m = 10 n = 8 max min 1 optimal solution

		-3	-5	-6	-7	-1	-9	-10	-4
-8	87.98	0.80	1.00	1.00	1.00	0.20	1.00	1.00	1.00
-2	1518.9	-0.42	-1.00	-1.80	-2.40	-5.03	-1.55	2.75	0.05
1	144.4	-0.30	0.00	0.00	0.00	0.30	0.00	0.00	-1.00
8	477.9	-1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
2	63.23	-0.13	-1.00	0.00	0.00	0.13	0.00	0.00	0.00
3	68.01	-0.14	0.00	-1.00	0.00	0.14	0.00	0.00	0.00
4	29.77	-0.06	0.00	0.00	-1.00	0.06	0.00	0.00	0.00
5	132.0	-0.71	1.00	1.00	1.00	0.29	1.00	1.00	1.00
6	15.44	-0.03	0.00	0.00	0.00	0.03	-1.00	0.00	0.00
7	25.00	-0.05	0.00	0.00	0.00	0.05	0.00	-1.00	0.00
	299254.8	-457.9	778.9	1047.2	1050.9	637.7	935.7	1078.1	216.7
number of iterations 8									

The optimal variant provides for a slight expansion of the area under sugar beet by 5.47 ha, grain corn by 2.23 ha, a reduction of almost 100.0 ha under barley, and an expansion of the area under vegetable crops by 87.96 ha, while changes in the sowing areas of other crops are insignificant. The total developed area of irrigated land is 477.9 ha. The optimal variant provides for savings of irrigation water in the amount of 1,518.96 thousand m^3. At the same time, the maximum total net profit was obtained in the amount of more than 299.0 million tenge.

The result of solving the problem for the selected example provides for obtaining a net profit of more than 299.0 million tenge. This is achieved mainly due to an increase in the sowing area under vegetable crops and a slight increase in the sowing areas under sugar beet and grain corn.

An optimal variant for the placement of crops on the irrigated lands of the peasant farm "Samgau" under the introduction of drip irrigation systems was obtained.

When writing the application software, the Delphi programming language was used — an imperative structured object-oriented programming language with strict static typing of variables. The developed approach may be used by agricultural producers to solve similar tasks for planning crop placement on irrigated lands and obtaining maximum profit.

Key empirical data confirm that such technologies are capable of reducing water consumption by 30–50% compared with traditional methods, which is especially important for regions with scarce water resources. The efficiency of water distribution when using sprinkler systems was also studied.

The efficiency of water-saving technologies is closely related to water supply infrastructure, the water distribution management system, and government policy. The water supply system includes irrigation canals, pumping stations, measuring devices, and digital management platforms (Krasnikova *et al*., 2024). Investments in the modernization of water infrastructure, including canal reconstruction and automation of distribution, are a necessary condition for the implementation of water-saving technologies (Krasnikov & Smirnova, 2024).

Numerous government programs in Kazakhstan are aimed at increasing the area under modern irrigation systems, expanding the regulation of water use, and increasing subsidies for farmers. For example, the practice of government subsidizing the installation of water-saving systems and benefits for farmers shows that the use of these technologies is stimulated at the legislative level, which increases their dissemination and economic attractiveness in the agricultural sector (Battalova & Enikeev, 2024).

The economic aspects of implementing water-saving technologies include estimates of installation and operating costs, reduction of operating expenses, yield increases, and growth in farm incomes (Logachev & Smirnova, 2024). Based on empirical data, it is noted that:

- The introduction of drip and sprinkler irrigation makes it possible to significantly reduce operating costs (energy, water, and labor).

- Reduction of water losses increases water use efficiency and lowers production costs.
- The use of innovative systems often leads to improved physiological indicators of plants and increased yields, thereby increasing gross output per irrigated area.

Studies confirm that although initial investments in the modernization of irrigation systems and the application of water-saving technologies may be high, economic benefits are achieved through increased yields of crops, higher profitability, and expansion of productive areas, which makes such technologies economically justified in the long term (Jin *et al*., 2024; Osluf *et al*., 2024; Rypel *et al*., 2024; Joungtrakul & Smith, 2025; Kebe *et al*., 2025).

The main problems in implementing water-saving technologies and irrigation equipment include:

- Limited financial resources for modernization.
- High wear of irrigation infrastructure.
- Low level of personnel training in new technologies.
- Lack of a unified water accounting information system.

Promising directions include public-private partnership, government subsidization, digitalization of water supply systems, and integration of modern water-saving technologies (Grankina & Vasilyev, 2024).

CONCLUSION

The article presents the results of solving the problem of optimizing production costs for cultivating crops on irrigated lands when using drip irrigation systems. The problem was solved using economic-mathematical methods.

Modern water-saving technologies and integrated water supply systems are the main elements of the strategy for the optimal use of irrigated lands. Scientific publications of recent years demonstrate that innovative irrigation methods ensure a substantial reduction in water consumption, increased productivity, and improved economic efficiency of production. However, successful implementation requires comprehensive approaches, including infrastructure modernization, government support, farmer training, and access to financing.

Studies of the use of water-saving irrigation technologies by agricultural enterprises for 2020–2024 emphasize the need for interdisciplinary integration of technical, economic, and institutional aspects in the development and implementation of strategies for the optimal use of water resources. It was shown that modern technologies adapted to the local conditions of Kazakhstan have the potential to significantly improve the sustainability of the agricultural sector and strengthen water management under conditions of climate change and growing demand for food.

Thus, the optimal use of irrigated lands through the application of water-saving technologies contributes to the development of water supply systems in agricultural production.

ACKNOWLEDGMENTS: None

CONFLICT OF INTEREST: None

FINANCIAL SUPPORT: This research is being carried out within the framework of budget program 267 “Increasing the Accessibility of Knowledge and Scientific Research” for 2024–2026, subprogram 101 “Program-targeted financing of scientific research and activities,” under specification 154 “Payment for research services,” activity: “Development of organizational and economic measures to improve the efficiency of the use of the resource potential of agricultural production” No. BR 22886885.

ETHICS STATEMENT: None

REFERENCES

Abdullah, N. A., Zulkifli, M. I., & Mohamed, A. S. (2025). Refinement of the 8th AJCC staging system for medullary thyroid cancer: Integrating tumor size and lymph node characteristics with SEER and multicenter validation. *Archive International Journal of Cancer and Allied Sciences, 5*(2), 34–43. doi:10.51847/R1sIaONOms

Abdullayev, I., Rozhok, A., Levichev, O., Litwinowa, M., Trubcheninova, A., & Levicheva, S. (2025). Digital transformation in agricultural cluster management: Interrelated factors and model applicability. *Journal of Global Innovations in Agricultural Sciences, 13*(4), 1301–1308.

Abdykadyrov, A., Marxuly, S., Mechsheryakova, T., Tastemirova, B., Tolen, G., Kulshikova, E., Duissenov, N., & Uzak, M. (2025). Scientific foundations of industrial engineering and geoecological utilization of water resources. *Water Conservation and Management, 9*(4), 707–713.

Abraliyev, O., Baimbetova, A., & Kusmoldayeva, Zh. (2024). Optimising the use of irrigated lands in Kazakhstan: System analysis and resource management. *Journal of Economic Research & Business Administration*.

Alharbi, S., Felemban, A., Abdelrahim, A., & Al-Dakhil, M. (2024). Agricultural and technology-based strategies to improve water-use efficiency in arid and semiarid areas. *Water, 16*, 1842. doi:10.3390/w16131842

Ali, A., Hussain, T., & Zahid, A. (2025). Smart irrigation technologies and prospects for enhancing water use efficiency for sustainable agriculture. *AgriEngineering, 7*(4), 106. doi:10.3390/agriengineering7040106

Amanbayeva, B., Mosiej, J., Zhaparkulova, E., & Zhanumkhan, K. (2022). Measures for increasing productivity of water and agricultural land resources in south Kazakhstan – Maktaaral district case study. *Acta Scientiarum Polonorum. Formatio Circumiectus, 21*(1), 49–55. doi:10.15576/ASP.FC/2022.21.1.49

Ayas, S. (2025). Mathematical modeling of crop water production functions for sugar beet. *Sugar Tech, 27*(4), 1129–1140. doi:10.1007/s12355-025-01572-8

Batisha, A. (2024). Multi-disciplinary strategy to optimize irrigation efficiency in irrigated agriculture. *Scientific Reports, 14*(1). doi:10.1038/s41598-024-61372-0

Battalova, L. M., & Enikeev, R. N. (2024). The study of the genesis of state mechanisms to stimulate the development of the regional sector of the economy of small and medium-sized businesses. *Economic Problems and Legal Practice, 20*(1), 20–27. doi:10.33693/2541-8025-2024-20-1-20-27

Belfiore, C. I., Galofaro, V., Cotroneo, D., Lopis, A., Tringali, I., Denaro, V., & Casu, M. (2024). Studying the effect of mindfulness, dissociative experiences, and feelings of loneliness in predicting the tendency to use substances in nurses. *Journal of Integrative Nursing and Palliative Care, 5*, 1–7. doi:10.51847/LASijYayRi

Belkharoev, K. U. (2024). Legal problems of ensuring food security in modern Russia, in the context of globalization and mutual restrictive measures. *Lobbying in the Legislative Process, 3*(2), 11–16. doi:10.33693/2782-7372-2024-3-2-11-16

Beresneva, Y., & Kulibaba, I. (2024). Simulation model of crop yield on individual land plot. *BIO Web of Conferences, 130*, 01019. doi:10.1051/bioconf/202413001019

Bounajra, A., Guemmat, K. E., Mansouri, K., & Akef, F. (2024). Towards efficient irrigation management at field scale using new technologies: A systematic literature review. *Agricultural Water Management, 295*, 108758. doi:10.1016/j.agwat.2024.108758

Buzaubakova, K., & Bedelbayeva, A. (2026). Impact of educational programs and VR technologies on the environmental behavior of the population in areas with high pollution levels: Case study of Kazakhstan. *International Journal of Environmental Impacts, 9*(1), 305–317. doi:10.56578/ijei090122

Clark, A., & Foster, H. (2025). Network pharmacology integration and experimental verification to elucidate the molecular mechanisms of triptolide in treating membranous nephropathy. *Pharmaceutical Science and Drug Design, 5*, 33–47. doi:10.51847/X9UVmVSJ4E

Csep, A. N., Voiţă-Mekereş, F., Tudoran, C., & Manole, F. (2024). Understanding and managing polypharmacy in the aging population. *Annals of Pharmacy Practice and Pharmacotherapy, 4*, 17–23. doi:10.51847/VdKr0egSln

Eliseev, V. S. (2024). Correlation of agricultural and legal regulation in agricultural horticulture. *Lobbying in the Legislative Process, 3*(4), 22–28. doi:10.33693/2782-7372-2024-3-4-22-28

Figueroa-Valverde, L., Marcela, R., Alvarez-Ramirez, M., Lopez-Ramos, M., Mateu-Armand, V., & Emilio, A. (2024). Statistical data from 1979 to 2022 on prostate cancer in populations of Northern and Central Mexico. *Bulletin of Pioneer Research in Medical and Clinical Sciences, 4*(1), 24–30. doi:10.51847/snclnafVdg

García-Mollá, M., Medina, R. P., Vega-Carrero, V., & Sanchis-Ibor, C. (2025). Economic efficiency of drip and flood irrigation: Comparative analysis at farm scale using DEA. *Agricultural Water Management, 309*, 109314. doi:10.1016/j.agwat.2025.109314

Ghiga, I., Pitchforth, E., Lundborg, C. S., & Machowska, A. (2024). Bacterial infections and antibiotic resistance in Romanian children: Insights from a hospital-based study. *Interdisciplinary Research in Medical Sciences (Special Issue), 4*(2), 1–8. doi:10.51847/pISlxaQJVu

Grankina, V., & Vasilyev, D. (2024). Digital transformation modeling for agricultural land irrigation. *BIO Web of Conferences, 141*, 02005. doi:10.1051/bioconf/202414102005

Gumarova, Z. M., Bulekova, A. A., Kushenbekova, A. K., Mukhomedyarova, A. S., Gubasheva, B. E., Jigildiyeva, Z. G., Sarsengaliyev, R. S., & Utegalieva, N. Kh. (2025). Optimizing tillage systems and cultivation practices for enhancing productivity of dark chestnut soils in Northwestern Kazakhstan. *International Journal of Agriculture and Biosciences, 14*(1), 164–171. doi:10.47278/journal.ijab/2024.206

Ismagulova, A. Zh., Mirlas, V. M., & Burshukov, N. A. (2025). Optimization of water resources use. *Engineering Journal of Satbayev University*. doi:10.51301/ejsu.2025.i1.06

Ivanyo, Y. M., Polkovskaya, M. N., & Sinitsyn, M. N. (2025). The algorithm of parametric modeling of agricultural production, taking into account the predecessors. *Information and Mathematical Technologies in Science and Management*. doi:10.25729/ESI.2025.37.1.008

Jagsi, R., Lee, J., Roselin, D., Ira, K., & Williams, J. (2025). Do U.S. medical schools follow medical associations' recommendations on paid parental leave for faculty? *Annals of Pharmacy Education, Safety, Public Health and Advocacy, 5*, 1–11. doi:10.51847/r117In8wdi

Jin, L. W., Tahir, N. A. M., Islahudin, F., & Chuen, L. S. (2024). Exploring treatment adherence and quality of life among patients with transfusion-dependent thalassemia. *Annals of Pharmacy Practice and Pharmacotherapy, 4*, 8–16. doi:10.51847/B8R85qakUv

Joungtrakul, J., & Smith, I. D. (2025). Exploring the path from organizational justice to organizational citizenship behavior: Job commitment as a mediator. *Annals of Organizational Culture, Leadership, and External Engagement Journal, 6*, 31–35. doi:10.51847/DBvez9u8O9

Kantorovich, L. V., Fedorenko, N. P., Pryazhinskaya, V. G., Popov, I. G., Voropaev, G. V., Kardash, V. A., & Chernyavsky, V. S. (1982). *Economic-mathematical modeling of water management production*. Nauka.

Karatas, K. S. (2024). First episode psychotic disorder and COVID-19: A case study. *Bulletin of Pioneer Research in Medical and Clinical Sciences, 4*(1), 19–23. doi:10.51847/VP5xOKglSX

Kebe, I. A., Kahl, C., & Liu, Y. (2025). The role of transformational leadership in enhancing employee performance: A study of the Vietnamese banking industry. *Annals of Organizational Culture, Leadership, and External Engagement Journal, 6*, 21–30. doi:10.51847/g7jtt7Qgxk

Kerimbek, G., Mamutova, K., Oralbayeva, A., Baimukasheva, Zh., & Nurbayeva, G. (2025). Cost structure in Kazakhstan's grain farming and methods of its optimisation. *Scientific Horizons, 28*(4), 120–134. doi:10.48077/scihor4.2025.120

Kęska, M., & Suchy, W. (2024). Cardiovascular risk and systemic inflammation in rheumatoid arthritis: A comparative analysis with psoriatic arthritis. *Journal of Medical Sciences: Interdisciplinary Research, 4*(2), 30–40. doi:10.51847/PvcqitKMgB

Kounatidis, D., Dalamaga, M., Grivakou, E., Karampela, I., Koufopoulos, P., Dalopoulos, V., Adamidis, N., Mylona, E., Kaziani, A., & Vallianou, N. G. (2024). Evaluation of blood-aqueous barrier permeability in response to tetracycline antibiotics under normal and pathological conditions. *Interdisciplinary Research in Medical Sciences (Special Issue), 4*(2), 9–17. doi:10.51847/wu4fOEjgDv

Krasnikov, A., & Smirnova, Y. (2024). Data model for an intelligent fish farm management system. *BIO Web of Conferences, 130*, 08027. doi:10.1051/bioconf/202413008027

Krasnikova, I. N., Simonov, V. L., & Petelin, A. E. (2024). Features of development of an agricultural warehouse digital twin.

BIO Web of Conferences, 83, 03004. doi:10.1051/bioconf/20248303004

Krasnova, T., Chalova, O., Kopytko, V., Bykov, V., Mamrukova, O., & Lebedev, K. (2025). The climate change divide: Differential impacts on economic growth, agriculture, and energy in developed and developing nations. *International Journal of Ecosystems and Ecology Science, 15*(6), 49–54. doi:10.31407/ijees15.606

Kuandykova, E., Bekezhanov, D., Nessipbaeva, I., Rzabay, A., Jumabayeva, K., & Zhuldybayeva, A. (2024). Regulation of mechanisms for management of environmental issues of rational use of natural resources and pastures. *International Journal of Sustainable Development and Planning, 19*(11), 4509–4517. doi:10.18280/ijsdp.191138

Kudaibergenova, I., Gritsenko, N., Tskhay, M., Balgabayev, N., Amanbayeva, B., & (2023). Features of technology for cultivating corn for grain under drip irrigation on Serozem soils. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 5*(461), 109–120. doi:10.32014/2023.2518-170X.335

Kulibaba, I., & Barinov, V. (2024). Software solution for growing crops on an individual land plot. *BIO Web of Conferences, 141*, 01018. doi:10.1051/bioconf/202414101018

Kulibaba, I., & Goncharov, D. (2024). Information system of crops effective cultivation planning on an individual homestead plot. *BIO Web of Conferences, 130*, 08023. doi:10.1051/bioconf/202413008023

Lee, M. J., & Ferreira, J. (2024). COVID-19 and children as an afterthought: Establishing an ethical framework for pandemic policy that includes children. *Asian Journal of Ethics in Health and Medicine, 4*, 1–19. doi:10.51847/haLKYCQorD

Li, X., Yang, Y., Zhou, X., Liu, L., Yang, Y., Han, S., & Zhang, Y. (2024). Impact of water productivity and irrigated area expansion on irrigation water consumption and food production in China in last four decades. *Agricultural Water Management, 304*, 109100. doi:10.1016/j.agwat.2024.109100

Linker, R., & Kisekka, I. (2025). An optimization framework for multi-year planning of land and water allocation. *Agricultural Water Management, 314*, 10950. doi:10.1016/j.agwat.2025.10950

Logachev, M., & Goncharov, D. (2024). Simulation model of crop yields. *BIO Web of Conferences, 93*, 02015. doi:10.1051/bioconf/20249302015

Logachev, M., & Smirnova, Y. (2024). Implementing healthy eating principles for consumers in a digital farmers' market system. *BIO Web of Conferences, 141*, 01019. doi:10.1051/bioconf/202414101019

Logachev, M., Chernova, V., & Kovaleva, V. (2023). Information system for the creation and support of the ecological settlements' framework. *AIP Conference Proceedings, 2560*, 020013. doi:10.1063/5.0124704

Mambetnazarov, B., Bekbanov, B., Mambetnazarov, A., Aybergenov, B., Mambetnazarov, A., Kuanishbaeva, S., & Mambetnazarov, B. (2026). Sesame cultivation in water-deficit conditions. *Journal of Global Innovations in Agricultural Sciences, 14*(2), 729–735. doi:10.22194/JGIAS/26.1731

Movchan, I. B., Yakovleva, A. A., Sadykova, Z. I., Sekerina, D. D., & Kuzovenkov, A. A. (2024). Spatial regularity in the distribution of bed-rock mineralization (based on the example of a section of the Vetreny Poyas Ridge, Russia). *Instrumentation Mesure Metrologie, 23*, 413–422. doi:10.18799/24131830/2024/12/4577

Movchan, I. B., Yakovleva, A. A., Semenov, V. V., & Medinskaia, D. K. (2026). Analysis of inverse problems in geotechnical engineering-underground pipelines and magnetometric research. *International Journal of Engineering, Transactions B: Applications, 39*(6), 1346–1356. doi:10.5829/ije.2026.39.06c.04

Mukhamedzhanov, V. N., Orynbekov, A. O., & Gritsenko, N. V. (2017). *Development of an economic-mathematical model for optimizing the costs of applicability of water-saving technologies in irrigation (final)* (State registration No. 0115RK02164). Research report.

Mukhametov, A., Ansabayeva, A., Efimov, O., & Kamerova, A. (2024). Influence of crop rotation, the treatment of crop residues, and the application of nitrogen fertilizers on soil properties and maize yield. *Soil Science Society of America Journal, 88*(6), 2227–2237.

Musa, K., Noor, O., Ibrahim, M., & Saleh, A. (2025). A validated whole-body PBPK model of dextromethorphan and its metabolites for genotype-based prediction of CYP2D6 phenotype and urinary metabolic ratio. *Special Journal of Pharmacognosy, Phytochemistry and Biotechnology, 5*, 50–76. doi:10.51847/xbESBJHHcx

Nasiyev, B., Karynbayev, A., Mukhambetov, B., Ongayev, M., Nurgaziyev, R., Akhmetaliyeva, A., Sungatkyzy, S., Auzhanova, M., & Okshebayev, A. (2025). Development of agriculture under the influence of ESG principles: Opportunities for sustainable soil management. *International Journal of Sustainable Development and Planning, 20*(5), 2115–2125. doi:10.18280/ijsdp.200527

Nasiyev, B., Khiyasov, M., Bekkaliyev, A., Zhanatalapov, N., Bekkaliyeva, A., Shibaikin, V., Karynbayev, A., Nurgaziev, R., Salykova, A., & Vassilina, T. (2024). Assessing variability of soil quality in Western Kazakhstan: Dynamic effects of grazing practices. *International Journal of Design & Nature and Ecodynamics, 19*(3), 875–885. doi:10.18280/ijdne.190317

Negreiros, A. B., & Ory, M. G. (2024). Navigating uncertain outcomes: Returning genomic results in children with developmental delays. *Asian Journal of Ethics in Health and Medicine, 4*, 20–27. doi:10.51847/grOfZd8oyo

Njoroge, E., & Odhiambo, S. (2025). Elucidating the therapeutic mechanisms of Agrimonia pilosa Ledeb. extract for acute myocardial infarction via network pharmacology and experimental validation. *Pharmaceutical Science and Drug Design, 5*, 48–63. doi:10.51847/eZOWCUj80m

Nokusheva, Z., Kantarbayeva, E., Issayeva, Z., Tokusheva, A., & Meldebekova, N. (2023). Enhancing milk productivity in dairy cows through the optimized utilization of oilseed byproducts. *International Journal of Design & Nature and Ecodynamics, 18*(3), 727–733. doi:10.18280/ijdne.180326

Nokusheva, Z., Nasiyev, B., Kantarbayeva, E., Zhanatalapov, N., Bekkaliyev, A., Khairush, A., & Okshebayev, A. (2025). Bio-organic fertilizer application for forage quality improvement and rangeland restoration in Northern

Kazakhstan's steppe ecosystems. *International Journal of Design & Nature and Ecodynamics, 20*(10), 2363–2373.

Noor, H., Sabău, D., Coțe, A., Mihețiu, A., Pirvut, V., Mălinescu, B., & Bratu, D.G. (2024). Advancements in esophageal stricture treatment: The role of stents in benign and malignant conditions. *Journal of Medical Sciences: Interdisciplinary Research, 4*(2), 47–52. doi:10.51847/LtuxAzRl0M

Onlassynov, Z., Sotnikov, Y., Miroshnichenko, O., & Muratova, M. (2024). Mathematical model of hydrogeological conditions of irrigated land of the Maktaaral massif. *3i Intellect Idea Innovation - Intellectual Idea Innovation, 4*, 119–127.

Order of the Minister of Water Resources and Irrigation of the Republic of Kazakhstan dated June 4, 2025, No. 108-NK "On approval of consolidated standards for water consumption and sanitation". (2025). *Zakon.kz*. https://online.zakon.kz/Document/?doc_id=33954287

Orynbekov, A. O. (2000). *Model assessment of the development of the socio-economic system of regional development*. Gylym.

Orynbekov, A., & Askarova, M. (2009). Utility of goods and the structure of trade turnover of consumer goods in the local market. *Zhambyl Humanitarian-Technical University*.

Osluf, A. S. H., Shoukeer, M., & Almarzoog, N. A. (2024). Case report on persistent fetal vasculature accompanied by congenital hydrocephalus. *Asian Journal of Current Research in Clinical Cancer, 4*(1), 25–30. doi:10.51847/0gjOEudJNr

Perelli, C., Branca, G., Corbari, C., & Mancini, M. (2024). Physical and economic water productivity in agriculture between traditional and water-saving irrigation systems: A case study in Southern Italy. *Sustainability, 16*(12), 4971. doi:10.3390/su16124971

Petronis, Z., Golubevas, R., Rokicki, J. P., Guzeviciene, V., Sakavicius, D., & Lukosiunas, A. (2025). A systematic review and meta-analysis on trigeminal neuralgia linked to neurovascular compression using MRI analysis. *Journal of Current Research in Oral Surgery, 5*, 17–24. doi:10.51847/sptZWIrWeo

Petyukova, O. N., & Dereglazov, A. A. (2024). Transformation of the land use system in Russia in the late XIX – early XX centuries. *Gaps in Russian Legislation, 17*(3), 31–36. doi:10.33693/2072-3164-2024-17-3-031-036

Rafikov, T., Zhumatayeva, Z., Mukaliyev, Z., & Zhildikbayeva, A. (2024). Evaluating land degradation in East Kazakhstan using NDVI and Landsat data. *International Journal of Design & Nature and Ecodynamics, 19*(5), 1677–1686. doi:10.18280/ijdne.190521

Raza, S., Khan, A., Mehmood, F., & Farooq, U. (2025). Nationwide implementation of essential pharmacogenomic testing in the Netherlands: A decision-analytic model of lives saved and cost-effectiveness. *Special Journal of Pharmacognosy, Phytochemistry and Biotechnology, 5*, 39–49. doi:10.51847/PUWEymkYkk

Rozhkova, O. V., Yermekov, M. T., Tolysbayev, Y. T., Maryinsky, S. G., & Vetyugov, A. V. (2021). Problems of storage, refinery, and disposal of drilling waste of the exploration and production sector of Kazakhstan: Arrangement and operation features of sludge collectors and oil storage pits. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 2*(446), 151–158.

Rypel, J., Kubacka, P., Mykała-Cieśla, J., Pająk, J., Bulska-Będkowska, W., & Chudek, J. (2024). Case presentation of breast adenoid cystic carcinoma. *Asian Journal of Current Research in Clinical Cancer, 4*(1), 18–24. doi:10.51847/6eOqq2KFjp

Sadanova, D. K., Amanzholova, R. Sh., Rakhmetov, I. K., Sagin, J., & Onglassynov, Z. A. (2025). Optimizing Kazakhstan's water budget through subsurface floodwater recharge. *Engineering Journal of Satbayev University*.

Safiullin, M., Abdrakhmanova, D., & Dinmukhametova, A. (2026). Structural analysis of regional critical imports and their impact on economic dynamics. *Journal of Sustainable Competitive Intelligence, 16*, e0537. doi:10.37497/eagleSustainable.v16i.537

Saikinov, V. E., Zolkin, A. L., Zaretskaya, Z. I., & Malova, N. N. (2025). Mathematical modeling of production processes in agriculture. *Financial Management*.

Sajjad, M., Hussain, K., Hakki, E. E., Ilyas, A., Gezgin, S., & Shakil, Q. (2025). Impact of irrigation techniques on water-use efficiency, economic returns, and productivity of rice. *Sustainability, 17*(17), 7712. doi:10.3390/su17177712

Saparov, G., Dutbayev, Y., Amanzholkyzy, A., Islam, K. R., Tireuov, K., Hakimov, N., Zudilova, E., Shichiyakh, R., Shoykin, O., Ganiyev, B., et al. (2024). Assessing heavy metal contamination for soil reclamation: Implications for sustainable urban development. *International Journal of Design & Nature and Ecodynamics, 19*(6), 2197–2204. doi:10.18280/ijdne.190636

Schneider, T. L., & Krüger, B. E. (2025). Breast cancer-specific mortality in stage IV patients with small tumors: Insights from a population-based cohort. *Archive International Journal of Cancer and Allied Sciences, 5*(2), 1–12. doi:10.51847/b9vFcweAVg

Shaimerdenova, A., Abdireimov, S., Ashimkhan, N., Zhumakan, A., Auesbekov, N., Kaisanova, A., Vagapova, A., Stepanova, D., Satvaldiyev, B., Ussarov, U., et al. (2026). Spatial assessment of soil fertility using GIS and remote sensing: A case study of southern Kazakhstan. *Sabrao Journal of Breeding and Genetics, 58*(1), 474–485. doi:10.54910/sabrao20

Shi, R., & Guo, W. (2024). Research progress on the optimal allocation of agricultural irrigation water resources. *Transactions of the Chinese Society of Agricultural Engineering, 40*(4), 1–13. doi:10.11975/j.issn.1002-6819.202307207

Shixiyev, R. M. (2025). Mathematical model of optimal allocation of resources in agriculture. *American Journal of Economics and Business Management, 8*(8), 3925. doi:10.31150/ajebm.v8i8.3925

Tashnichenko, V. O., & Tregub, I. V. (2024). Econometric analysis of the development of small and medium-sized enterprises in the field of innovation and innovative technologies of the Russian Federation. *Economic Problems and Legal Practice, 20*(2), 211–215. doi:10.33693/2541-8025-2024-20-2-211-215

Tulaganov, A., Adamov, A., & Yesbergen, R. (2025). State management of water resources in the agricultural sector of the Republic of Kazakhstan. *ECONOMIC Series of L. N. Gumilyov Eurasian National University*.

Usaeva, A. B. (2024). Enhancing irrigated land use efficiency in Southern Kazakhstan's agricultural sectors. *Eurasian Science Review*.

Voropaev, G. V., Chernyavsky, V. S., & Mukhamedzhanov, V. N. (1971). Optimization of the composition and sequence of measures for the reconstruction of irrigation systems. In *Mathematics and Computers in Land Reclamation* (Part I). VNIIGiM.

Wolderslund, M., Kofoed, P., & Ammentorp, J. (2024). Investigating the effectiveness of communication skills training on nurses' self-efficacy and quality of care. *Journal of Integrative Nursing and Palliative Care, 5*, 14–20. doi:10.51847/55M0sHLo3Z

Wong, Y., Lin, S., Cheng, H., Hsieh, T., Hsiue, T., Chung, H., Tsai, M. Y., & Wang, M. R. (2025). Understanding the impact of medical humanities on internship training and performance. *Annals of Pharmacy Education, Safety, Public Health and Advocacy, 5*, 12–21. doi:10.51847/Z1fogzPksy

Yakovleva, A. A., Semenov, V. V., Medinskaya, D. K., Movchan, I. B., & Sadykova, Z. I. (2025). The paradigm of a digital image of a geotechnical object as the basis of an automated workstation in the task of non-destructive testing (using the example of a main pipeline). *Russian Journal of Earth Sciences, 25*(3), ES3006. doi:10.2205/2025ES001010

Yermekov, M. T., Rozhkova, O. V., Sandibekova, S. G., Tolysbayev, Y. T., Vetyugov, A. V., Turbin, O. A., & Belenko, E. V. (2020). Storage of the industrial waste of the mining and smelting industry of Kazakhstan, landfills arrangement, efficiency and operational features. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 6*(444), 83–89.

Yessembay, M. (2025). *Efficiency of water-saving irrigation technologies for crops in Southern Kazakhstan*.

Yessenbayev, A., Akhmetshin, E., Kurikov, V., Hajiyev, C., Chernova, V., Litvinov, A., Shichiyakh, R., & Alkhanov, N. (2024). Application of the adaptive approach for forming the concept of an inclusive residential environment in the context of regional differences. *Civil Engineering and Architecture, 12*(5), 3480–3499. doi:10.13189/cea.2024.120526

Yskak, A., Chashkov, V., Nugmanov, A., Joldassov, A., Paramonova, T., Kurmangaliyeva, D., & Nurseitova, A. (2025). Granulometric and chemical composition of bottom sediments in North Kazakhstan's water reservoirs: Implications for soil and water management. *International Journal of Agriculture and Biosciences, 14*(2), 289–300. doi:10.47278/journal.ijab/2025.007

Yskak, A., Nugmanov, A., Tulayev, Y., Kuanyshbaev, S., Somova, S., Chashkov, V., Paramonova, T., Yermoldina, G., & Daribayeva, S. (2026). Effect of precision farming and differential nitrogen and phosphorus doses on spring wheat yield in the Northern Kazakhstan climatic zone. *International Journal of Agriculture and Biosciences, 15*(2), 840–849. doi:10.47278/journal.ijab/2025.121

Yu, M., Ma, Y., Han, F., & Gao, X. (2025). Effectiveness of mandibular advancement splint in treating obstructive sleep apnea: A systematic review. *Journal of Current Research in Oral Surgery, 5*, 25–32. doi:10.51847/AInSXrD9rc

Zhang, X., Ren, L., & Zhao, J. (2025). Economic approach for optimal allocation of irrigation water in a water-scarce region. *Agricultural Water Management, 317*, 109630. doi:10.1016/j.agwat.2025.109630