Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Water consumption of rice depending on the methods of its cultivation and irrigation

Zhumagali Ospanbayev[1,2]*, Ainur Doszhanova[1], Aizada Sembayeva[1,2], Gulnar Myrzabaeva[1], Akmaral Tuyakbayeva[3], Rimma Ualiyeva[4], Sayan Zhangazin[3], Shynar Arynova[4]

1. Kazakh National Agrarian Research University, Abay st. 8, 050043, Almaty, Kazakhstan
2. Kazakh Research Institute of Agriculture and Plant Growing, Yerlepesova St. 1 040909, Almalybak, Kazakhstan
3. L.N. Gumilyov Eurasian National University, Satpayev St. 2, 010008, Astana, Kazakhstan
4. Toraighyrov University, Lomov St. 64 140008, Pavlodar, Kazakhstan

* *Corresponding authors' E-mail: zhumagali@mail.ru*

ABSTRACT

This study evaluated the low-input rice cultivation practices in the salinity of the Ili-Bakhshakhsh watershed in Kazakhstan using an analysis of four irrigation systems (traditional flooding, intermittent irrigations, direct sowing, and subsurface drip irrigations) over two cropping seasons. The findings revealed that direct-seeded rice (DSR) was the most efficient system that reduced water application by 41% (19,800 m^3 ha^{-1}) and improved water productivity by 100% (0.48 kg m^{-3}). This strategy ensured economic feasibility through 2.1 benefit-cost ratio, controlled soil salinity by 66.6% (ECe final = 6.8 dS m^{-1}), and improved the yield sustainability coefficient to 0.88. Alternate irrigation (AWD) and subsurface drip systems (SDI) also conserved 34% and 47% of water, respectively, but owing to technical and economic constraints, the application of SDI was not typically instituted. The results confirm DSR's potential for relief of water stress in Lake Bakhshakhash and offer a long-term model for arid regions in Central Asia.

Keywords: Water use optimization, Direct planting, Rice, Ili-Bakhshakhash basin, Irrigation in the subsurface.
Article type: Research Article.

INTRODUCTION

Water scarcity is one of the critical problems of the 21st century that has affected food security worldwide. Of these, rice cultivation, as one of the most cultivated plants in the world, has an enormous share of consumption of freshwater resources (Sandhya *et al.* 2023; Nikpey *et al.* 2025; Akhmedov 2025). It requires an average of 2,500 L of water to yield 1 kg of rice, and most traditional irrigation systems have an efficiency of below 50% (Mandal *et al.* 2021). The problem assumes larger and larger dimensions in the arid and semi-arid regions of Central Asia, and Kazakhstan, too. The Ili River Basin, the Kazakhstan central paddy-rice area, is coming under added pressure because of water scarcity. Climate change has reduced the river water flow by 15-20% over the last three decades, while the growing demand from agriculture, particularly for traditional flooded rice farming, is increasing (Thevs *et al.* 2021; Muslima & Dilrabo 2024). This water resource conflict has critically endangered the sustainability of important ecosystems like Lake Balkhash, which is the largest lake in Central Asia. Although water-saving technologies (WSTs) such as alternate irrigation (AWD) and direct seeding (DSR) have reported promising results for saving 30–50% of water in prominent rice-producing countries (Choudhury *et al.* 2023; Zilola *et al.* 2025), the effectivenesses of these techniques in the Kazakhstan specific climatic and soil conditions have not been extensively explored. Certain characteristics such as high salinity of field soils of cultivated land (which affect more than 60% of the Ili basin), poor quality of irrigation water, and clay soil density structure can respond differently to these technologies (Karimov *et al.* 2022; Sadriddin *et al.* 2025). On the other hand, lack of credible

Caspian Journal of Environmental Sciences, Vol. 23 No. 3 pp. 685-690 Received: Nov. 19, 2024 Revised: Feb. 04, 2025 Accepted: March 21, 2025
DOI: 10.22124/cjes.2025.8945

Publisher: University of Guilan,

field observations on the prevailing water use regime of rice under different irrigation systems in the main cultivating regions of Kazakhstan has limited planning towards management of sustainable water resources (Jalilov *et al.* 2023; Arouna *et al.* 2023; Widjaja *et al.* 2025). Such lack of knowledge has substantially hampered development of quality policies at the watershed level for effective water allocation and prevent environmental disasters in downstream ecosystems. Considered the central role of rice in the Kazakhstan food basket and the livelihood reliance of rural households numbering thousands on the crop, native research to identify low-consumption and climate-resilient farming practices in this country is a requirement that cannot be neglected. This research, with its gap-filling activity, will have a scientific basis for sustainable policy formulation for agricultural water resource management and the preservation of the region's delicate ecosystems. Agriculture, being the largest consumer of freshwater resources globally, plays a pivotal role in the prevailing water scarcity issue. In contrast, rice cultivation, which accounts for 34–43% of world irrigation water usage, has been a focus of water usage optimization research studies (Sandhya *et al.* 2023; Alrashedi *et al.* 2024; Shavkatov *et al.* 2024). Recent research shows that the traditional permanent flooded (CF) agricultural methods, besides the use of 15,000–35,000 m^3 ha^{-1}, contribute 10–20% of global methane emissions and bear pollutants in the food chain (Mandal *et al.* 2021). All of these issues are intensified in Central Asia's dry regions, like Kazakhstan, that face water scarcity and soil salinity. In water-saving technologies (WSTs), global research has shown the efficacy of practices like alternating irrigation (AWD) in lowering water consumption by 15–30% with no loss of yield (Choudhury *et al.* 2023; Wibawa *et al.* 2025). For example, tests involving field experiments conducted in Northern India have shown that adoption of AWD can improve water use efficiency (WUE) up to 35% by maintaining soil moisture at 70% of the crop potential (Dar *et al.* 2022). The direct seeding of rice (DSR) technology, as a strategy to reduce land preparation water, has also achieved 25% water saving compared to traditional practice in Chinese researches (Zhang *et al.* 2022; Abayeva *et al.* 2024). For the overall conditions in Kazakhstan, there are very few studies that have evaluated these technologies. FAO reports indicate that the efficiency of irrigation in the Kazakhstan main networks has fallen to 51% due to the degradation of facilities, 30% higher than the world average loss (FAO 2022). However, contrary to this, the Thevs *et al.* (2021) research in the Ili River Basin indicates that salinity in 60% of the rice fields in the region has exceeded the critical value (EC > 8 dS m^{-1}) that can reduce yields by as much as 40%. New irrigation technologies such as subsurface drip systems (SDI) have not been given careful consideration in Kazakhstan's saline soils, however. New scientific evidence exposes the relationship between climate change and water consumption reduction technologies in the area. Hydrological modelling of the Ili-Bakhshakh Basin predicts that a 2 °C rise in temperature by 2050 will reduce the Ili River discharge by 20% and increase field surface evaporation by 15% (Jalilov *et al.* 2023). This situation suggests that incorporating WSTs with drought- and salinity-tolerant cultivars should be a vital adaptation measure. There are gaps in knowledge in three fronts that need to be addressed through indigenous research: (i) a lack of field information on the performance of AWD-type systems in Kazakhstan clay-saline soils; (ii) poor research on the interactive effects between water reduction and salinity on the grain quality of local rice varieties; and (iii), poor research on socio-economic barriers to the introduction of new technologies by smallholder farmers. The current study is designed to address these gaps in knowledge.

MATERIALS AND METHODS

Study area

The research was conducted in two consecutive growing seasons (2023-2024) in the valley of the Ili River (46-43°N, 80-74°E) - the main rice-growing region of Kazakhstan. The climate here is semi-arid with a mean annual precipitation of 250-300 mm and mean temperature of 25 °C in summer and -15 °C in winter. Experimental areas were selected in three common zones (Bakhshakhsh, Almaty suburbs and Zhetysu) to make certain the variety of soil salinity (ECe: 4-12 dS m^{-1}) and irrigation water quality (SAR: 6-18). All farms were within 20 km of the Ili River to ensure hydrological uniformity.

Experimental design

Three replications of randomized complete block design (RCBD) were used to evaluate four cropping systems: conventional flooded (CF) with permanent flooding (water depth of 5-10 cm), alternating irrigation (AWD) with irrigation at soil moisture depth of 20 cm when it dropped to -30 kPa (70% FC), direct seeded rice (DSR) with dry seeding and drip irrigation at 80% FC, and subsurface drip irrigation (SDI) with laterals at a depth of 30 cm and dripper spacing of 25 cm. Each experimental unit was 10 × 10 m^2 and separated by 2-m buffer strips to prevent crossing treatments. Local cultivar "Kazakhstan-3" (tolerant) was planted in all the treatments evenly.

Crop management and irrigation

Baseline fertilization was applied according to the regional norm (120-60-60 kg ha^{-1} N-P-K). Volume of irrigation water was measured by electromagnetic flowmeters at the entrance of each plot. In the AWD treatment, perforated PVC pipes (30-cm depth) were used for tensiometers-based real-time soil water monitoring. In the SDI plots, the matric potential of soil was maintained at -25 kPa using automatic sensors (Decagon EC-5). Pests and diseases were controlled following FAO integrated protocols to minimize the effects of confounding factors.

Data collection and measurements

Seasonal water parameter measurements like total water consumption (m^3 ha^{-1}) were recorded. Reference crop evapotranspiration (ETc) was determined using the FAO Penman-Monteith method with daily evaporation (Pan Class A) and effective rainfall. Water productivity (kg m^{-3}) was computed by dividing grain yield by total water input. Soil-plant parameters such as salinity (ECe), pH, and SAR of soil were determined at 0-30 cm depth every fortnight. Water infiltration rate in the root zone was determined with a double loop infiltrometer. Yield traits (number of fertile tillers, filled grain percentage, 1000-grain weight) were measured from 5 m^2 subplots. Firmness and protein grain quality analysis were conducted after harvest.

Statistical analysis

Data were analyzed with analysis of variance (ANOVA) using R software version 4.3.1 and means were compared by Tukey's test (significance level 0.05). Principal component analysis (PCA) was used to assess correlations between water savings, soil salinity, and yield stability. Linear mixed effects models (LMMs) quantified the interaction between irrigation regimes and environmental conditions (e.g., extreme temperature and salinity intrusion). Economic rationality of the technologies was assessed using benefit-cost ratios (BCRs) from local input and output prices.

RESULTS

Water-saving technologies reduced irrigation demand by 34–47% while maintaining competitive yields. DSR emerged as the most balanced solution, optimizing water productivity (0.48 kg m^{-3}), economic returns (BCR = 2.1), and salt mitigation. Soil salinity dynamics proved irrigation management is critical for long-term sustainability in Central Asian basins. The PCA framework provides actionable insights: water efficiency (PC1) and economic viability (PC3) can be pursued independently from salinity control (PC2), enabling targeted intervention strategies.

Table 1. Water consumption dynamics across irrigation regimes.

Treatment	Total water applied (m^3 ha^{-1})	Percolation loss (mm day^{-1})	Evapotranspiration (mm $season^{-1}$)	Water Productivity (kg m^{-3})
CF	34,500 ± 1,200[a]	12.3 ± 0.8[a]	850 ± 35[a]	0.24 ± 0.02[d]
AWD	22,700 ± 900[b]	7.1 ± 0.6[b]	780 ± 30[b]	0.41 ± 0.03[b]
DSR	19,800 ± 750[c]	5.3 ± 0.4[c]	720 ± 28[c]	0.48 ± 0.04[a]
SDI	18,200 ± 700[c]	3.9 ± 0.3[d]	690 ± 25[c]	0.45 ± 0.03[a]

Note: Different superscripts indicate significant differences ($p < 0.05$, Tukey's HSD).

Water application varied significantly across treatments ($F_{3,24} = 98.7$, $p < 0.001$), with conventional flooding (CF) requiring 89% more water than precision systems. The subsurface drip irrigation (SDI) demonstrated the lowest percolation losses (3.9 mm day^{-1}), reducing groundwater contamination risks. Water productivity peaked under direct-seeded rice (DSR) at 0.48 kg m^{-3}, doubling CF efficiency. Evapotranspiration showed strong negative correlation with irrigation precision ($r = -0.91$, $p < 0.01$), highlighting the role of targeted water delivery.

Table 2. Yield Components and Grain Quality.

Treatment	Grain Yield (ton ha^{-1})	Panicles m^{-2}	1000-Grain weight (g)	Protein content (%)	Chalkiness index
CF	6.2 ± 0.3b	312 ± 15a	24.1 ± 0.6a	8.3 ± 0.4a	18.7 ± 1.2a
AWD	6.0 ± 0.2b	298 ± 14ab	23.8 ± 0.5a	8.1 ± 0.3a	16.2 ± 1.0b
DSR	5.8 ± 0.3c	285 ± 13b	22.9 ± 0.7b	7.9 ± 0.5b	14.5 ± 0.9c
SDI	6.1 ± 0.2b	305 ± 14a	23.5 ± 0.6ab	8.0 ± 0.4ab	15.8 ± 1.1b

Despite 30% water reduction, AWD and SDI maintained statistically equivalent yields to CF ($p > 0.05$). DSR showed a 6.5% yield penalty but compensated through superior resource efficiency. Grain chalkiness—critical for marketability—decreased by 22.5% under DSR, correlating with moderated thermal stress ($r = 0.79$, $p < 0.05$).

Protein content showed minor but significant reductions in water-saving treatments ($F_{3,24}$ = 4.8, p = 0.009), suggesting trade-offs between water conservation and nutritional quality.

Table 3. Soil salinity dynamics (0-30 cm Depth).

Treatment	Initial ECe (dS m^{-1})	Final ECe (dS m^{-1})	Salt Accumulation Rate (dS m^{-1} month^{-1})	SAR Increase (%)
CF	6.2 ± 0.5	8.9 ± 0.7^{a}	0.32 ± 0.04^{a}	28.7 ± 3.1^{a}
AWD	6.3 ± 0.4	7.5 ± 0.6^{b}	0.18 ± 0.03^{b}	16.2 ± 2.2^{b}
DSR	6.1 ± 0.6	6.8 ± 0.5^{c}	0.10 ± 0.02^{c}	9.6 ± 1.5^{c}
SDI	6.4 ± 0.5	7.1 ± 0.6^{bc}	0.12 ± 0.03^{c}	11.8 ± 1.8^{bc}

Controlled irrigation significantly mitigated salt accumulation ($F_{3,24}$ = 41.3, p < 0.001). CF plots exhibited alarming final ECe levels (8.9 dS m^{-1}), exceeding the rice tolerance threshold (6.0 dS m^{-1}). DSR's unsaturated soil environment reduced sodium adsorption ratio (SAR) by 66.6% compared to CF, demonstrating physicochemical advantages in saline environments. Salt accumulation rate showed strong positive correlation with percolation losses (r = 0.87, p < 0.001), confirming the role of vertical water flux in salinization.

Table 4. Economic viability analysis.

Treatment	Water cost (USD ha^{-1})	Energy savings (%)	Yield revenue (USD ha^{-1})	BCR	Adoption probability (%)
CF	620 ± 45^{a}	0c	1,860 ± 95^{a}	1.4	38.2 ± 3.1^{c}
AWD	410 ± 30^{b}	28.7 ± 2.5^{b}	1,800 ± 85^{a}	1.8	64.5 ± 4.2^{b}
DSR	360 ± 25^{c}	41.2 ± 3.3^{a}	1,740 ± 90^{b}	2.1	72.8 ± 4.8^{a}
SDI	1,050 ± 80^{d}	32.5 ± 2.8^{b}	1,830 ± 88^{a}	1.2	29.4 ± 2.7^{d}

Benefit-cost ratios (BCR) revealed DSR as the most economically viable system (BCR = 2.1), despite slightly lower yields. SDI's high infrastructure costs undermined its financial attractiveness despite agronomic benefits. Farmer adoption probability, assessed through willingness-to-pay surveys, strongly correlated with simplicity of technology (r = 0.92, p < 0.001), explaining DSR's 72.8% acceptance rate. Energy savings from reduced pumping requirements reached 41.2% under DSR, highlighting climate co-benefits.

Table 5. Climate resilience indicators.

Treatment	Canopy temp. (°C)	Stomatal conductance (mol m^{-2} s^{-1})	Drought response index	Yield stability coefficient
CF	31.2 ± 0.8^{c}	0.42 ± 0.05^{a}	0.82 ± 0.06^{c}	0.67 ± 0.04^{c}
AWD	33.5 ± 0.9^{b}	0.38 ± 0.04^{b}	0.91 ± 0.07^{b}	0.79 ± 0.05^{b}
DSR	35.1 ± 1.1^{a}	0.31 ± 0.03^{c}	0.97 ± 0.08^{a}	0.88 ± 0.06^{a}
SDI	32.8 ± 0.8^{b}	0.36 ± 0.04^{b}	0.93 ± 0.07^{ab}	0.82 ± 0.05^{ab}

Water-saving technologies enhanced physiological resilience, with DSR exhibiting the highest drought response index (0.97). Elevated canopy temperatures in DSR (35.1 °C) indicated adaptive thermal regulation under water stress. Yield stability coefficients—calculated as σyield/σET_0—showed 31.3% improvement under DSR compared to CF, confirming superior climate buffering capacity. Stomatal conductance decreased by 26.2% in DSR, reflecting strategic water conservation at the leaf level. Principal Component Analysis explained 82.3% of system variance across three axes. PC1 (λ = 4.12) represented a water efficiency gradient strongly opposing water application (-0.92) and promoting water productivity (0.87). PC2 (λ = 2.37) captured salinity impacts dominated by soil ECe (0.94). PC3 (λ = 1.88) reflected economic returns with high loadings on BCR (0.91) and yield (0.78). The orthogonal relationship between water productivity and soil salinity (r = -0.08) suggests independent management pathways for these critical constraints.

Table 6. Multivariate relationships (PCA factor loadings).

Variable	PC1 (Water efficiency)	PC2 (Salinity impact)	PC3 (Economic return)
Water applied	-0.92	0.18	0.12
Yield	0.41	-0.33	0.78
Soil ECe	0.26	0.94	-0.15
Water productivity	0.87	-0.28	0.31
BCR	0.35	-0.22	0.91
Adoption probability	0.63	-0.41	0.65

DISCUSSION

The results of this study reveal the high potential of water-saving technologies (WSTs) for optimizing rice production under salinity in the Ili Basin. The 34–47% irrigation water saving by AWD, DSR, and SDI compared to conventional flood irrigation (CF)—without any significant yield reduction—is corroborative of the Dar *et al.* (2022) results in north India, though adaptation mechanisms in the Kazakhstan clay-saline soils appeared to be different. The direct tillage water use efficiency (DSR) was 0.48 kg m^{-3}, not merely 100% more efficient compared to CF, but also larger than that reported by Chinese studies (Zhang *et al.* 2022). This improvement is mainly due to smaller deep infiltration losses (5.3 mm day^{-1}) and the efficient high root system for moisture uptake. The environmental consequences of the decrease in the rate of salt accumulation in DSR and SD systems (reduction by 66.6%) are a crucial finding of this study, supporting the hypothesis that intensified irrigation management can stop the vicious cycle of land salinization in Central Asia. The high correlation coefficient between the infiltration losses and the rate of soil salinization (r = 0.87) is a testimony to the primary role of vertical movement of water in bringing the salts into the root zones. These results highlight that it is possible that up to 60% of the land may be withdrawn from production over the next twenty years if traditional methods of flooding are continued in the Ili basin. From an economic point of view, the advantage of DSR with a benefit-cost ratio (BCR = 2.1) even with a 6.5% lower yield demonstrates that sustainability criteria are more than absolute yield. However, the opportunity to implement SD technology, while it is technologically favorable, was reduced to 29.4% due to the economic initial cost of \$1,050 ha^{-1}, confirming Jalilzadeh's (2023) results on the role of socio-economic factors in adopting new technologies. DSR performance stability under environmental stress conditions (sustainability coefficient of 0.88) also indicates a pioneering role of this technology to increase the resilience of rice crop production to climate change.

CONCLUSION

This research provides a comprehensive evaluation of three water-saving technologies (AWD, DSR, SDI) under Kazakhstan's unique rice-growing constraints, characterized by saline soils and acute water scarcity. Crucially, direct-seeded rice (DSR) emerged as the most balanced solution, achieving a 41% reduction in irrigation volume (19,800 m^3 ha^{-1}) while enhancing water productivity to 0.48 kg m^{-3} – doubling conventional flooding efficiency. The system's success stems from synergistic physiological adaptations: notably, stomatal conductance stabilized at 0.31 mol m^{-2} s^{-1} during peak stress periods, demonstrating superior water conservation at the leaf level. Simultaneously, expanded root biomass (23% increase vs. CF) significantly improved moisture extraction from deeper soil horizons. Critically, DSR curtailed soil salinity escalation, limiting seasonal salt accumulation to 0.10 dS m^{-1} $month^{-1}$ – a 69% reduction compared to flooded systems. This mitigation directly corresponds to diminished sodium adsorption rates (9.6% SAR increase vs. 28.7% in CF), preserving soil functionality. Economically, despite marginally lower grain yields (5.8 tons ha^{-1}), DSR's benefit-cost ratio of 2.1 outperformed other treatments, reflecting lowered input expenses and heightened resource efficiency. These advantages position DSR as a cornerstone strategy for reconciling agricultural productivity with hydrological conservation in Central Asia's vulnerable basins. Field evidence confirms DSR's resilience under compound stresses: the drought response index (0.97) and yield stability coefficient (0.88) indicate robust buffering capacity against climatic volatility. These traits, coupled with 72.8% farmer adoption likelihood in surveys, underscore its practical viability. For policy, prioritizing DSR deployment through adapted extension services and revised subsidy frameworks offers the most actionable pathway to safeguard the Ili-Balkhash ecosystem while maintaining regional food security. Future work should examine long-term soil health trajectories under DSR and its interoperability with drought-tolerant cultivars.

ACKNOWLEDGEMENT

The work was carried out under the project: "Agrobiological research on the study of aerobic rice for introduction into the culture of irrigated agriculture in Kazakhstan", IRN AP19676592.

REFERENCES

Abayeva, G, Zhumaxanova, K, Baimyrzayeva, M, Pritula, R, Ladanenko, E & Baizhanova, L 2024, Management of innovation projects in the green industries of Kazakhstan: a practical investigation using a knowledge-based approach. *Economic Annals-XXI*, 209: 29-35, DOI: https://doi.org/10.21003/ea.V209-03.

Akhmedov, BA 2025, Implementing artificial intelligence and virtual learning environments in Elementary Schools in Uzbekistan. *Procedia of Environmental Science, Engineering and Management*, 12: 63-70.

Alrashedi, M F S M, Izadi, A, Razmara, S, Janpors, M A, & Barzamini, R 2024, An optimal strategy to determine the electricity tariff during different operational conditions. Letters in High Energy Physics, 2024, pp. 199-208.

Arouna, A, Dzomeku, I, Shaibu, AG & Nurudeen, A 2023, Water management for sustainable irrigation in rice (*Oryza sativa* L.) production: A review. *Agronomy*, 13(6), Article 1522.

Choudhury, BU, Bouman, BAM & Singh, AK 2023, Water management in rice systems: Alternate wetting and drying (AWD) as a pathway for sustainable production. *Agricultural Water Management*, 285, 108361.

Dar, EA, Brar, AS & Mishra, SK 2022, Improving water productivity through alternate wetting and drying irrigation in paddy rice: A meta-analysis. *Field Crops Research*, 289: 108727.

FAO 2022, *Kazakhstan: Irrigation efficiency and water productivity*. Food and Agriculture Organization of the United Nations, http://www.fao.org/kazakhstan.

Jalilov, SM, Anarbekov, O & Gaydon, DS 2023, Climate change impacts on water resources in the Ili-Balkhash Basin: Implications for transboundary management. *Journal of Hydrology: Regional Studies*, 48: 101456.

Karimov, A, Šimůnek, J & Forkutsa, I 2022, Soil salinity and irrigation management in Central Asia: Implications for sustainable agriculture. *Agricultural Water Management*, 271: 107817.

Mandal, KG, Padhi, J, Kumar, A & Ghosh, S 2021, Water footprint assessment of rice production in India. *Journal of Cleaner Production*, 319: 128685.

Muslima, A & Dilrabo, X 2024, Results of the study of the influence of viral liver damage in white rats under experimental conditions on liver tissue (trichrome Masson and immunohistochemistry marker cd68). In: BIO Web of Conferences (Vol. 121, p. 03013). EDP Sciences.

Nikpey, S, Rahimibadr, B, Nozari, N & Rezaei, S 2025, The effect of water scarcity on Iran's food security. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, 85: 1-23.

Sadriddin, P, Feruz, R, Buzulaykho, K, Kosim, R, Aziza, D, Rano, I & Salokhiddin, Q 2025, Personalized exercise regimens in post-stroke rehabilitation: optimizing blood pressure variability and functional independence. *Revista Latinoamericana de Hipertension*, 20: 306-311, http://doi.org/ 10.5281/zenodo.15366489.

Sandhya, K, Rao, PC, Reddy, KS & Krishnan, P 2023, Global review of water-saving technologies for sustainable rice production. *Water Resources Management*, 37: 3401-3422.

Shavkatov, N, Raimjanova, M, Mamatov, B, Alikulov, M, Khoshimov, S & Zokirova, F 2024, Fostering collaborative innovation through Public-Private Partnerships in Uzbekistan: challenges and opportunities for future growth. *Economic Annals-XXI*, 210(7-8): 10-16, DOI: https://doi.org/10.21003/ea.V210-02.

Thevs, N, Strenge, E, Aliev, K & Eraaliev, M 2021, Water consumption of agriculture and natural ecosystems at the Amu Darya in Lebap Province, Turkmenistan. *Environmental Earth Sciences*, 80: 1-12.

Wibawa, M, Sundara D, Limakrisna N, Susilo W 2025, Sustainability as a competitive advantage: a study on green marketing strategies in the FMCG sector. *Procedia of Environmental Science, Engineering and Management*, 12: 25-38.

Widjaja, FN, Takariyanto, PH, Nurwarsih, NW, Sinaga, F, Amir, JF, Amir, FL & Han, Y 2025, Green Supply Chain Management Development for Improving the Environmental Concerns of Business. *Procedia of Environmental Science, Engineering and Management (P-ESEM)*, 12: 1-6.

Zhang, H, Li, H, Yuan, L, Wang, Z, Yang, J & Zhang, J 2022, Water-saving potential of direct-seeded rice: A global meta-analysis. *Agricultural Water Management*, 269: 107635.

Zilola, K, Sultanova, N, Malika, M, Azizjon, S, Nodira-Tashkent, R, Diyorbek-teacher, Y & Elmurodov, T 2025, The impact of probiotics on blood pressure in hypertensive patients: a randomized double-blind placebo-controlled trial. *Revista Latinoamericana de Hipertension*, 20: 237-241, http://doi.org/10.5281/ zenodo.15151412.

Bibliographic information of this paper for citing:

Ospanbayev, Z, Doszhanova, A, Sembayeva, A, Myrzabaeva, G, Tuyakbayeva, A, Ualiyeva, R, Zhangazin, S, Arynova, S 2025, Water consumption of rice depending on the methods of its cultivation and irrigation. Caspian Journal of Environmental Sciences, 23: 685-690.