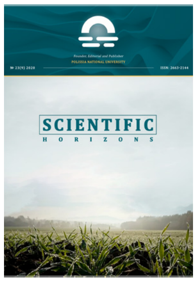
SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 28(2), 104-115



UDC 631.14:551.583
DOI: 10.48077/scihor2.2025.104

Technologies for adaptation of agriculture to climate change in Kyrgyzstan

Victoria Sultanbaeva*
PhD in Agricultural Sciences, Acting Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Srt., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0002-8914-8778

Ainura Batykova
PhD in Technical Sciences, Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Srt., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0001-9173-3151

Taalaibek Osmonkanov
PhD in Technical Sciences, Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Srt., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0002-3486-980X

Nurlan Mamatov
PhD in Agricultural Sciences, Associate Professor
Kyrgyz-Turkish Manas University
720044, 56 Ch. Aitmatov Ave., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0002-9055-3949

Bakytbek Askaraliev
PhD in Technical Sciences, Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Srt., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0002-7180-2671

Article's History:
Received: 14.08.2024
Revised: 20.12.2024
Accepted: 22.01.2025

Abstract. Climate change significantly impacts agricultural productivity, especially in arid regions such as Kyrgyzstan. The cultivation of drought-resistant crops and the introduction of innovative agricultural technologies are key measures to ensure the sustainability of the agricultural sector. The study aimed to assess the efficiency of growing drought-tolerant crops (sorghum, chickpea and millet) in Kyrgyzstan, as well as to analyse the impact of modern technologies, such as drip irrigation, on productivity and efficiency of water use. The study was conducted during two growing seasons (2023-2024) in an experimental field in Kyrgyzstan. Yields were determined

Suggested Citation:
Sultanbaeva, V., Batykova, A., Osmonkanov, T., Mamatov, N., & Askaraliev, B. (2025). Technologies for adaptation of agriculture to climate change in Kyrgyzstan. *Scientific Horizons*, 28(2), 104-115. doi: 10.48077/scihor2.2025.104.

*Corresponding author

by harvesting 1 m^2 plots and then converting to hectare. Water use was measured using Delta-T Devices soil moisture meters (10, 20 and 30 cm depths). Water use efficiency (WUE) was calculated as the ratio of crop yield to water use. Crop conditions were monitored using DJI Agras T30 drones and Sentinel-2 satellite imagery. The results of the study confirmed the high performance of sorghum and pearl millet under drought conditions. Sorghum showed the highest yield of 4.2 tonnes/ha due to its well-developed root system and ability to use moisture efficiently. Millet showed the best WUE – 0.9 kg/m^3 – and the lowest water use (4000 litres/ha), making it an optimal crop for water-stressed regions. Chickpea, despite its lower yield (1.8 t/ha), proved promising due to its nitrogen-fixing properties that improve soil fertility. The use of drip irrigation reduced water consumption by 20-30%, ensuring stable yields even under water deficit conditions. Monitoring using drones and moisture meters helped to optimise irrigation, improving the accuracy of water management. The study confirmed the efficacy of sorghum and pearl millet as key crops for arid regions, and the feasibility of integrating drip irrigation to improve agricultural sustainability. The results of the study provided science-based recommendations for farmers and policymakers on the introduction of drought-resistant crops and modern agricultural technologies in Kyrgyzstan, which will contribute to food security and sustainability of the agricultural sector under climate change conditions

Keywords: drought; drought-tolerant crops; moisture; sorghum; millet; chickpea; irrigation system; water use

INTRODUCTION

In the Kyrgyz Republic, agriculture contributes a significant share of the economy and food security. However, climate change poses serious challenges for the agricultural sector, including droughts, reduced water resources and soil degradation. These factors necessitate the adoption of adaptation technologies to maintain agricultural productivity and ensure food security. Climate change poses serious threats to agriculture in Central Asia, particularly in Kyrgyzstan, due to increased droughts, shrinking water resources and soil degradation (Mukambaeva *et al.*, 2024). According to the Intergovernmental Panel on Climate Change, global warming could lead to a 10-30% reduction in the yield of the region's main crops by 2050. In Kyrgyzstan, wheat yields have already fallen by 15% over the past decade due to reduced rainfall. Water scarcity continues to increase: the availability of water resources in Central Asia has decreased by 20% over the past 20 years. In such circumstances, the introduction of adaptation technologies, such as the cultivation of drought-tolerant crops (sorghum, chickpea and millet), is key to ensuring food security and the sustainability of the agricultural sector.

The Food and Agriculture Organisation of the United Nations is actively implementing measures to support the adaptation of Kyrgyzstan's agriculture to climate change (Kadyraliev *et al.*, 2024). In particular, the Food and Agriculture Organisation is promoting the introduction of drought-tolerant crops such as sorghum, chickpea and millet, which can provide stable yields under climate stress. The organisation is also improving water management practices by introducing modern irrigation systems that minimise water loss. In addition, the Food and Agriculture Organisation implements programmes to train farmers in climate-resilient technologies and provides access to financial instruments to support innovative approaches to agriculture (Shebanina *et al.*, 2024). These measures aim to increase the resilience of the national agricultural sector and ensure its productivity in the face of climate change.

Modern adaptation strategies include the widespread use of digital technologies, such as mobile apps for weather forecasting and crop monitoring. Precision farming can be used to optimise the use of water, fertilisers and plant protection products, which significantly increases yields even in adverse conditions (Pichura *et al.*, 2024). Another important area is the cultivation of drought-tolerant crops that can provide stable productivity with limited resources. M. del Mar Polo *et al.* (2022) discussed the possibilities of introducing climate technologies into the agricultural sector of Kyrgyzstan. The authors analysed the prospects for investment in drought-resistant crops, efficient water management and optimisation of agricultural processes. Barriers to innovation, such as insufficient access to finance for small farmers, and ways to overcome them, were emphasised. The study by P. Khakimov (2019) addressed the general trends of climate change in Central Asia, including Kyrgyzstan, Afghanistan and Tajikistan. The author analysed adaptation policies that promote innovation, emphasising the need to develop local strategies to ensure agricultural sustainability in the region.

L. Liang *et al.* (2021) assessed the vulnerability of Kyrgyzstan's agricultural systems to droughts, focusing on the need to grow drought-resistant crops and adopt efficient irrigation methods. These findings are complemented by S. Park *et al.* (2021) in a study on the impact of climate change on the suitability of land for agriculture. The authors propose scenarios for future land use with a focus on maintaining the productivity of the agricultural sector. B. Emileva *et al.* (2023) investigate the role of digital technologies in improving the accuracy of climate change perceptions among farmers in Kyrgyzstan, Mongolia and Uzbekistan. The results highlight the importance of mobile apps for accessing weather information and supporting decision-making in the face of climate challenges. I. Chumarev (2023) also analysed the technical and economic aspects of establishing a Central Asian drought monitoring system that contributes to climate risk forecasting and rational resource use.

T. Thomas *et al*. (2021) analysed the forecasts of production of major crops in Central Asia, considering climate change, and justified the need to implement adaptation strategies. In turn, K. Keneni (2022) and P. Juyal (2021) addressed the role of drought-tolerant crops and biotechnology in increasing agricultural resilience, which is essential for food security. Despite significant progress in the introduction of climate technologies, the issue of local adaptation strategies, particularly the introduction of drought-tolerant crops, remains insufficiently studied in Kyrgyzstan. The limited amount of empirical data makes it difficult to assess their effectiveness in the face of climate change, which is a key issue for the national agricultural sector. Cultivation of crops such as sorghum, chickpea and millet could be a promising strategy to increase the resilience of agricultural systems to droughts and other climate stresses.

The study aimed to scientifically analyse the efficiency of growing drought-tolerant crops such as sorghum, chickpea and millet in an experimental field in the Kyrgyz Republic. The study analysed agronomic parameters such as yields, water consumption and resilience to adverse climate change conditions, as well as the economic feasibility of their implementation.

MATERIALS AND METHODS

The study was of empirical and experimental nature, aimed to analyse the efficiency of growing drought-tolerant crops in the face of climate change. The field experiments were conducted during two growing seasons, from April 2023 to October 2024, at an experimental field in the Kyrgyz Republic. Data were collected through field experiments on the cultivation of three drought-tolerant crops: sorghum, chickpea and millet. All ethical standards set by the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973) were followed during the study, which ensured compliance with the principles of sustainable plant use. Each crop was sown on separate plots divided by soil type and irrigation conditions. The experiment was conducted on a representative sample of areas, including 15 plots with a total area of 1.5 hectares, which was used to address the variability of soil and climatic conditions in the region. When selecting plots, three types of soil typical for the region were considered: loamy, sandy and sandy loam, which was used to analyse the adaptive properties of crops in different conditions. The size of each plot was 0.1 hectares, which provided sufficient area to obtain reliable data for each variant of conditions. Crops were selected based on their relevance to dry conditions and preliminary studies confirming their adaptive properties. The irrigation conditions varied, with one group of plots using drip irrigation while the other relying on traditional methods such as surface and furrow irrigation, allowing for a comparative analysis of the effectiveness of the irrigation systems. Standard agronomic methods were used to measure key parameters such as yield, water consumption and resilience to climate stress.

Yields were determined by harvesting 1 m_2 control plots and then calculating the weight of the crop per hectare. Soil moisture was measured using soil moisture meters at depths of 10, 20 and 30 cm. Leaf area was calculated using the weight proportion method, in which dried leaves were weighed and their area was determined using the correlation formula between weight and area (1):

$$A = \frac{W \times As}{Ws}, \tag{1}$$

where A – total leaf area (cm^2); W – mass of fleshly harvested leaves (g); As – area of sample part of the leaves (cm^2); Ws – weight of sample part of the leaves (g).

The amount of precipitation was recorded using a weather station installed in the experimental field, which also provided data on air temperature and humidity. Plant heights were measured manually using a tape measure from the early stages of growth to the harvest period. All parameters were recorded weekly for further analysis of crop development dynamics. Quantitative methods were used to analyse agronomic parameters, including statistical calculations of average yields and water consumption for each crop. To assess plant resistance to drought, the WUE calculation method was used to compare the water use efficiency of different crops:

$$\text{WUE} = \frac{x}{y}, \tag{2}$$

where x – water consumption (m^3/ha); y – yield (kg/ha).

The cost-effectiveness of cultivation was analysed using the cost-benefit method [3]:

$$\text{CBA} = \frac{a}{b}, \tag{3}$$

where CBA – coefficient of economic efficiency of cultivation; a – costs; b – income.

This method involved calculating the costs of seed, fertiliser, irrigation and other inputs, as well as the projected profit from the sale of the crop. The obtained data were compared with yield, resistance to unfavourable climatic conditions, cultivation and processing costs, and market value of products to identify the most promising crop in terms of economic feasibility. Comparison of water use statistics of sorghum, chickpea and pearl millet with traditional crops in the region such as wheat, barley and maize were compared

(Pashchenko, 2024) and the economic benefits of the plants were also compared (State Programme for…, 2017). These crops were selected due to their importance for agriculture in the region: wheat, barley and maize are the main food security crops, while sorghum, chickpea and millet are considered promising drought-tolerant alternatives. The comparison made it possible to determine their economic efficiency under the conditions of water scarcity characteristic of the region and to identify the most climate-resilient crops.

The study applied modern agronomic and digital technologies, including drip irrigation for rational water use, mulching to conserve soil moisture and organic fertilisers to improve soil fertility. The use of DJI Agras T30 drones (5 units, manufactured in China), Sentinel-2 satellite imagery (European Space Agency) and Delta-T Devices soil moisture meters (5 units, manufactured in the UK) provided accurate monitoring of crop health and irrigation control, increasing the resilience of agricultural systems to climate change. Possible limitations of the methods used include measurement errors that may arise from technical limitations of the equipment used or human error in data collection. In addition, the results could be affected by external factors, such as weather anomalies, sudden changes in temperature, abnormal precipitation or droughts, which could alter crop growth and productivity. These limitations should be addressed when interpreting the data and appropriate adjustments should be made to improve the accuracy of the conclusions. The interpretation of the results was based on an analysis of a combination of agronomic and economic indicators. The data were compared between crops to determine the most adapted to climate change conditions. The results were also compared with previous studies to verify the validity of the findings.

RESULTS

Agronomic characteristics of the crops under study

Field experiments conducted in the Kyrgyz Republic during two growing seasons showed that sorghum demonstrated the highest yield among the crops studied – 4.2 tonnes/ha. This is due to its ability to adapt to different soil types and effectively utilise available moisture. Millet yielded 3.6 t/ha, which was the second-best result, but due to its lowest water use among all crops, it is a very promising crop. Chickpea showed the lowest yield of 1.8 t/ha, probably due to its sensitivity to high temperatures during flowering. These results emphasise the differences in the adaptation mechanisms of the crops under study, including the ability of sorghum and pearl millet to produce yields even under a limited water supply.

The three types of soil studied in the experiment differed significantly in their physical and chemical characteristics, which assessed the adaptive properties of sorghum, chickpea and millet in different conditions. Due to its high moisture capacity and fertility, loamy soil creates favourable conditions for crop growth even with limited rainfall. Sandy loam soil is characterised by low moisture capacity, but its lightness and good aeration ensure optimal development of the root system. The sandy soil, with minimal moisture retention capacity, modelled the extremely dry conditions typical of some areas of the region. This approach identified how the crops under study adapt to different soil types and to determine their potential for use in conditions of water scarcity (Table 1).

***Table 1**. Influence of soil type on the yield of the studied crops*

Crop	Loamy soil (t/ha)	Sandy loam soil (t/ha)	Sandy soil (t/ha)
Sorghum	4.5	4	3.5
Chickpea	2	1.8	1.5
Millet	3.6	3.8	3.2

***Source:** compiled by the authors*

Sorghum showed the highest yields on loamy soil due to its high-water capacity, which provides the plant with the necessary moisture throughout the growing season. Chickpea also showed the best results on loamy soil, which creates optimal conditions for growth and promotes its ability to fix nitrogen, improving soil fertility. This feature makes chickpeas valuable for integration into crop rotations. Millet, due to its adaptability to limited resources, grew most efficiently on sandy loam soil, where its yields remained consistently high. On sandy soil, all crops showed a decrease in productivity due to their low water-holding capacity, but millet was better adapted to these extreme conditions.

Sorghum, chickpea and millet showed different growth characteristics in the dry climate. Sorghum was distinguished by its powerful root system, which allows the plant to extract moisture from deep soil layers. The observations determined that even during periods of high temperature (up to +38°C), sorghum showed no signs of stress. Millet showed rapid growth rates in the early stages of the growing season, which provides it with an advantage in the short-term availability of moisture. Due to its short growing season (85 days), millet completed its development cycle before the onset of critical dry periods. Chickpea, despite its relatively short growing season (95 days), was more sensitive to high temperatures during flowering, which negatively affected its yield. This highlights the need for further research into its resistance to heat stress.

The results of the study confirmed the high drought tolerance of sorghum and pearl millet. Both crops withstood a reduction in soil moisture levels of up to 40% of their field capacity. Sorghum showed high tolerance to prolonged periods of high temperatures (up to +40°C), making it a suitable crop for growing in regions with extreme climatic conditions. Millet also showed considerable tolerance to climatic stresses due to its low moisture requirements and efficient utilisation of short-term rainfall. Chickpea, despite its medium level of tolerance, requires improved agronomic approaches to increase its tolerance to heat and water stresses (Table 2).

***Table 2**. Agronomic characteristics of the crops under study*

Characteristic	Sorghum	Chickpea	Millet
Average yield (t/ha)	4.2	1.8	3.6
Duration of vegetation (days)	110	95	85
Water consumption (l/ha)	5,200	4,500	4,000
Resistance to drought	High	Average	High
High-temperature tolerance	High	Average	High

***Source:** compiled by the authors*

The analysis of the data shows that sorghum and millet are highly adaptable to dry conditions. Sorghum has the highest yields, which underlines its effectiveness even under significant climatic stress. Millet, due to its short growing season and low water requirements, is a promising crop for regions with a moisture deficit. Chickpea shows potential for crop rotation due to its agronomic characteristics but requires adaptation of agricultural practices to improve yields in drought conditions. The study of the agronomic characteristics of sorghum, chickpea and millet confirmed their importance for the adaptation of agriculture in the Kyrgyz Republic to climate change. Sorghum and millet showed the best results in terms of yield and resistance to climatic stress, while chickpea, despite its lower yield, can be useful for crop rotations. The findings provide a scientific basis for scaling up the cultivation of these crops to improve food security and resilience in the region's agricultural sector.

Efficiency in the use of water resources

Water use efficiency is one of the key parameters for assessing the adaptation potential of crops under drought conditions. As part of the study, water use of sorghum, chickpea and millet was analysed and WUE was calculated. This was used to compare the ability of each crop to form a crop at minimum water use. Sorghum consumed the most water among the studied crops – 5,200 l/ha, which is due to its intensive growth and large biomass. Millet, on the other hand, had the lowest water consumption of 4,000 l/ha, which is a significant advantage in conditions of water scarcity. Chickpea had an average of 4,500 l/ha, but its water consumption was uneven during the growing season, with a peak during flowering and seed formation.

The data obtained show that the high-water consumption of sorghum is justified by its highest yield (4.2 t/ha). Millet, despite having the lowest water consumption, showed a significant yield of 3.6 t/ha, indicating its high level of adaptation to dry conditions. Chickpea, although having an average level of water consumption, demonstrated the lowest yield of 1.8 t/ha, which may be due to its insufficient resistance to heat stress. According to water use efficiency calculations, millet showed the highest WUE of 0.9 kg/m^3, which confirms its efficiency in converting limited water resources into crop yields. Sorghum had a coefficient of 0.81 kg/m^3, which is the second highest considering its high-water use. Chickpea showed the lowest coefficient of 0.4 kg/m^3, indicating the need to optimise its cultivation under water deficit conditions. The water consumption rates of sorghum, chickpea and millet, as well as their WUE, were used to compare the ability of crops to produce crops under conditions of limited water resources (Table 3).

***Table 3**. Indicators of water use and WUE of the studied crops*

Crop	Water consumption (l/ha)	Yield (t/ha)	WUE (kg/m^3)
Sorghum	5,200	4.2	0.81
Chickpea	4,500	1.8	0.4
Millet	4,000	3.6	0.9

***Source:** compiled by the authors*

The table shows that millet is the most water-efficient crop with the highest WUE (0.9 kg/m^3) and the lowest water use (4,000 l/ha), as it provides a stable yield even with minimal water resources. Sorghum, despite its higher water consumption (5,200 l/ha), shows a high yield (4.2 t/ha), making it a productive option for regions with available water resources. Chickpea, with the lowest WUE (0.4 kg/m^3), requires additional agronomic measures to increase its productivity. The behaviour of crops in the process of water consumption also depended on the developmental stage. Sorghum showed stable water use throughout the growing season due to its deep root system. Millet used water mainly at the initial stages of growth, which allowed it to complete the development cycle before the onset of dry conditions. Chickpeas had a significant peak in water consumption during flowering, which created a risk of crop losses in case of insufficient rainfall.

To assess the adaptive potential of the crops under study, it is important to compare their water requirements with traditional crops in the region, such as wheat, barley and maize. For instance, wheat consumes about 6,000 l/ha, which is higher than even sorghum (5200 l/ha), and has an average WUE of 0.7 kg/m^3. Maize, with water use of up to 7500 l/ha, has a WUE of about 0.8kg/m^3 but is much less suitable for regions with limited water resources compared to millet (Pashchenko, 2024). Comparison and analysis of water use efficiency confirmed the feasibility of replacing or supplementing traditional crops with drought-resistant crops, such as sorghum and millet, in the adaptation strategies of agriculture in the Kyrgyz Republic. In addition to reducing water inputs, this will increase yields in the face of climate change and improve the overall resilience of the region's agricultural systems.

Economic feasibility of growing drought-resistant crops

The cost and profitability analysis of drought tolerant crops was based on data on the costs of seeds, fertilisers, irrigation, crop protection products and labour, as well as expected revenues from crop sales using the cost-benefit analysis method. Millet demonstrated the highest economic efficiency among the crops studied. The cost of its cultivation was about USD 300 per hectare, while the profit reached USD 700 per hectare, which provided a maximum profitability of 133%. Sorghum, although it had higher irrigation and fertiliser costs (USD 350 per hectare), generated profits of USD 800 per hectare due to high yields, resulting in a 129% profitability. Chickpea, due to its low yields and uneven consumption of inputs, showed the least attractive economic performance. Its costs amounted to USD 320 per hectare, while the profit was only USD 400 per hectare, providing a profitability of 25%.

Compared to traditional crops in the region, such as wheat and barley, drought-tolerant crops have proven to be more cost-effective in the face of water scarcity. For example, the cost of growing wheat was around USD 400 per hectare, while the profit was USD 600, with a profit margin of 50%. Barley showed a profitability of 45%. This data highlights the significant advantages of millet and sorghum, which are not only less dependent on water resources but also provide higher economic returns (Fig. 1).

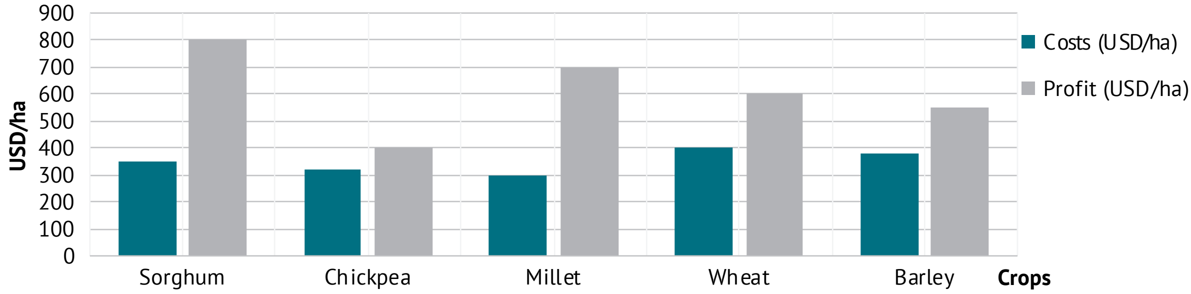


***Figure 1**. Economic performance of drought tolerant and traditional crops*

***Source:** compiled by the authors based on the State Programme for the Development of the Agro-Industrial Complex of the Republic of Kazakhstan for 2017-2021 (2017)*

The diagram clearly demonstrates the comparison of profitability and costs of growing drought-tolerant and conventional crops, confirming the economic viability of growing millet in resource-limited environments, while sorghum can be effective when sufficient water resources are available. Chickpea requires optimisation of agronomic approaches to increase its economic efficiency. A significant advantage of drought-tolerant crops is their stable yields even in extreme drought conditions. While conventional crops significantly lose productivity when there is a lack of irrigation, drought-tolerant crops demonstrate adaptation to climate stress, rendering them more attractive to farmers in arid regions. Based on the analysis, it is recommended that drought-tolerant crops be gradually introduced into the region's agriculture. Millet should be the main target for scaling up, given its high profitability and low water requirements. Sorghum can also be widely used in regions with accessible water resources due to its high productivity.

Modern agronomic approaches, such as improved varieties, drip irrigation and optimised plant nutrition, should be introduced for chickpea. This will increase its productivity and profitability, therefore competitive with other crops. Government support is also critical in encouraging the cultivation of drought-tolerant crops. This could include subsidies for the purchase of seeds and equipment, investments in irrigation systems and training for farmers. Such measures would accelerate the region's transition to adaptive agriculture. Cost-benefit analyses indicate that pearl millet and sorghum are more cost-effective than traditional crops in the region, especially in water-scarce regions. Millet has better profitability, and sorghum shows significant potential in regions with available water resources. Chickpea, although less economically viable, can be optimised through the adoption of new technologies. Scaling up the cultivation of drought-tolerant crops, combined with government support, will contribute to increasing the resilience of the region's agriculture to climate change.

Adaptation technologies and their impact on the sustainability of agricultural systems

Modern technologies of adaptation to climate change are key for ensuring the sustainability of agricultural systems in arid regions. One of the most effective methods of optimising water balance is the use of drip irrigation. This technology allows water to be delivered directly to the root system of plants, reducing evaporation losses and ensuring uniform soil moisturisation. In the study, the use of drip irrigation reduced water use in sorghum, chickpea and pearl millet by 20-30% compared to traditional methods such as surface or furrow irrigation. These traditional methods, which are widespread in the region, are characterised by significant water losses due to evaporation and infiltration into the lower soil layers. A more precise and rational drip irrigation approach promotes more efficient use of limited water resources (Yeraliyeva *et al.*, 2017).

Agricultural practices such as mulching and the use of organic fertilisers play an equally important role. Mulching helps to retain moisture in the soil, reducing evaporation and preventing the growth of weeds that compete with crops for resources. Organic fertilisers help to improve soil structure, increase its fertility and resistance to erosion (Yzakanov *et al.*, 2024). The application of these methods in this experiment increased the yield of millet by 15%, sorghum by 10% and chickpea by 8%, which is a significant result for dry conditions. Digital technologies such as the use of DJI Agras T30 drones, Sentinel-2 satellite imagery and Delta-T Devices soil moisture sensors provide accurate monitoring of crop health and enable rapid response to changes in growing conditions. In this study, analysing sensor data helped optimise irrigation schedules and prevent crop losses due to water deficits during critical phases of plant development. Such tools also help to reduce manual labour costs and improve farm management efficiency.

The introduction of the technologies described has the potential to significantly reduce the dependence of the agricultural sector on water resources, which is especially important in the arid regions of Central Asia. The use of drip irrigation, agronomic techniques and digital tools increases yields, ensuring stable production even with limited rainfall. This helps improve food security and reduce the risks of crop failure, which can have catastrophic consequences for local communities.

The prospects for applying the results go beyond Kyrgyzstan. Given similar climatic conditions, these technologies can be adapted for other Central Asian countries, such as Kazakhstan, Tajikistan and Uzbekistan. In addition, the developed adaptation strategies can form the basis for international agricultural development programmes in regions affected by climate change. The findings demonstrate the need to integrate adaptation technologies into national agricultural support programmes. The sustainability of agriculture in arid conditions depends on a combination of innovative methods of water management, rational use of fertilisers and the development of digital infrastructure. This will not only help to preserve crops but also ensure the long-term development of the agricultural sector in difficult climatic conditions.

The results of the study confirmed the high efficiency of modern adaptation technologies to increase the sustainability of agricultural systems in the arid conditions of Kyrgyzstan. The analysis of water use efficiency revealed the advantages of millet as the most economical crop in terms of WUE, while sorghum demonstrates high productivity with the availability of water resources. Chickpea requires optimisation of agronomic approaches to increase its yield and economic efficiency. The use of drip irrigation, mulching, organic fertilisers and digital technologies has significantly improved yields and minimised dependence on water resources. The prospects for implementing the results in other regions make them an important contribution to combating the global impact of climate change.

DISCUSSION

Adaptation of agriculture to climate change is a key topic of many contemporary studies. The results of this study should be compared with the findings of other authors to identify similarities, differences and generalise effective approaches to increasing the resilience of agricultural systems. G. Jalilova *et al.* (2024) note that farmers in South Issyk-Kul are adapting to climate change using drought-tolerant crops such as sorghum and millet. This is in line with the findings of this study where pearl millet showed the highest WUE (0.9 kg/m^3), demonstrating significant potential under drought conditions. C. Reyer *et al.* (2017) confirmed the importance of drought-tolerant crops in reducing the negative impacts of climate change on food security in Central Asia. Similarly, in this study, sorghum and pearl millet showed high drought tolerance, providing stable yields (4.2 t/ha and 3.6 t/ha, respectively), even under water deficit and elevated temperatures, highlighting their potential for regional agricultural adaptation.

A. Mirzabaev (2018) emphasised the importance of water management technologies for increasing crop yields in Central Asia. The results of the present study confirm the author's conclusions: the introduction of drip irrigation reduced crop water consumption by 20-30% without losses in yield. Similar conclusions were reached by S. Xenarios *et al.* (2019), which emphasises the importance of innovative irrigation methods for water conservation in mountainous areas of Central Asia. N. Michurina *et al.* (2024) emphasised the need to adapt agricultural technologies to reduce environmental impacts and improve resource efficiency. In this study, as in the author's conclusions, drip irrigation was identified as one of the key methods for optimising water use. Similar conclusions were drawn by I. Ologeh *et al.* (2021), who noted that traditional technologies adapted to modern conditions can increase crop yields, especially in water-scarce areas.

Authors D. Saleh and S. Bejaoui (2024) emphasised the importance of government policies, including subsidies for drought-tolerant crops, to reduce financial risks and stimulate innovation in agriculture. Their study confirms the effectiveness of sorghum and millet, which demonstrate high drought tolerance and stable yields, therefore beneficial for Kyrgyzstan. Government support, particularly through subsidies, could accelerate the scaling up of these crops. L. Kuhn *et al.* (2023) emphasise the importance of climate insurance to protect farmers from economic losses due to climate-related risks such as droughts. Combining climate insurance with the introduction of drought-tolerant crops creates an effective tool to increase the resilience of the Kyrgyz agricultural sector. This will ensure production stability and protect farmers' incomes. C. Parra-López *et al.* (2024) and L. Kuhl (2020) highlighted the importance of digital technologies, such as crop monitoring systems, for agricultural adaptation to climate change. Although this study focuses on agronomic aspects, such technologies can be useful for monitoring water consumption and optimising resources. A. Usta and M. Gök (2024) and G. Adamides *et al.* (2020) highlight the benefits of precision farming technologies for reducing water losses and increasing yields. The introduction of drip irrigation in this study confirms the effectiveness of such approaches for drought-tolerant crops.

R. Henry (2020) emphasised the importance of innovations in plant genetics to increase crop resilience to stress. The results of the present study confirm the potential of drought-tolerant crops such as sorghum, which demonstrated high yields (4.2 t/ha) even under water scarcity conditions. F. Nadeem *et al.* (2024) emphasise the selection of species and varieties for semi-arid regions, which is confirmed by the performance of millet in this study due to its highest WUE (0.9 kg/m^3). S. Njinju *et al.* (2022) noted the importance of growing climate-tolerant sorghum varieties for food security in dryland areas. In this study, sorghum also proved to be effective by combining high yield with developed tolerance to heat stress. Similar conclusions were reached by J. Matías *et al.* (2024) in an analysis of the prospects for new crops for food security. This correlates with the results of this study, where sorghum and pearl millet proved their adaptability to climate change, providing stable yields even under harsh conditions. A. Hossain *et al.* (2022) emphasised the importance of integrating climate resilient technologies into traditional agriculture, which confirms the feasibility of using technologies such as drip irrigation to increase productivity.

T. Zenda *et al.* (2020) investigated the adaptation of cereal crops to drought, emphasising the importance of a well-developed root system for crop survival under water deficit conditions. The study observed that a deep root system allows crops to access moisture from lower soil layers even during prolonged droughts. These findings are in good agreement with the results of this study where sorghum showed the ability to utilise water efficiently from deep soil layers, yielding high yields (4.2 t/ha). Similar observations were cited by K. Georgis and B.T. Makonnen (2024) who emphasises the importance of adopting policies and technologies to support dryland farming, including the integration of drought-tolerant crops. The results of this study confirm that sorghum and pearl millet cultivation can be a key element of such strategies, ensuring stable productivity even in water-stressed areas such as Kyrgyzstan. The use of innovative agronomic solutions such as drip irrigation can significantly improve the efficiency of these crops, reducing water use without sacrificing yields.

A. Ghaffar *et al.* (2022) analysed the adaptation of crop rotation systems and crop selection to ensure sustainable agricultural production in the face of climate change. The authors emphasise that the integration of drought-tolerant crops into crop rotations allows for optimised use of water and land resources while reducing the risk of crop losses due to climate stress. The results of this study confirm similar conclusions: sorghum and millet demonstrated high productivity even under conditions of limited water supply, which underlines their suitability for rotation. In addition, chickpeas, although with lower yields, can be used as a nitrogen-fixing crop, improving soil fertility and reducing the need for chemical fertilisers. The consistency between these results points to the versatility of approaches to agricultural adaptation in regions with similar climate challenges. Comparison of the results with those of other authors confirms the effectiveness of sorghum and millet cultivation as a strategy for agricultural adaptation to climate change. The combination of drought-tolerant crops with modern technologies such as drip irrigation and monitoring systems is a versatile approach that can be scaled up to other regions with similar climate challenges.

CONCLUSIONS

The research significantly contributed to the study of the adaptive capacity of agriculture to climate change, addressing the cultivation of drought-tolerant crops such as sorghum, chickpea and millet in Kyrgyzstan. The agronomic characteristics of the crops under study confirmed their effectiveness in the face of climate change. Sorghum showed the highest yield (4.2 t/ha) and demonstrated excellent resistance to drought and high temperatures due to its developed root system. Millet was distinguished by its short growing season (85 days) and lowest water consumption (4,000 litres/ha), therefore a promising crop for regions with limited water resources. Chickpea, despite having the lowest yield (1.8 t/ha), showed potential for use in crop rotations due to its nitrogen fixation properties in the soil.

Analysis of water use efficiency showed that millet was the most efficient crop in terms of water balance, with a WUE of 0.9 kg/m^3. Sorghum, despite its higher water use, also showed high productivity (WUE 0.81 kg/m^3). Chickpea, with a WUE of 0.4 kg/m^3, requires improved agronomic approaches to improve water use efficiency. The introduction of modern technologies, in particular drip irrigation, has significantly increased the efficiency of water use in this study. The use of this technology has optimised water consumption, reducing it by 20-30% compared to traditional methods such as surface or rainwater irrigation. The results of the study confirmed that the use of drip irrigation can ensure a stable harvest even in conditions of water shortage, increasing the resilience of agriculture to climate challenges.

The study highlighted the significant adaptive potential of drought-tolerant crops in ensuring food security. Sorghum and millet have proven their ability to maintain stable yields even in harsh climatic conditions, which opens prospects for their scaling up in regions with similar climate challenges. To increase the efficiency of using drought-tolerant crops, it is recommended to scale up experiments in different soil and climatic zones of Kyrgyzstan. Attention should also be paid to breeding new varieties of sorghum, chickpea and millet adapted to local conditions. Further research should address the impact of the introduction of these crops on socio-economic indicators, including farm profitability and water use efficiency. The integration of digital technologies for monitoring and managing water use could be a promising way to ensure the sustainability of the agricultural sector in the face of climate change. One of the main limitations of this study is that the experiments were conducted in only one local field, which may reduce the generality of the conclusions for other regions. In addition, the study focused mainly on agronomic parameters and did not cover socio-economic aspects of drought-tolerant crop adoption at the country level.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

REFERENCES

[1] Adamides, G., Kalatzis, N., Stylianou, A., Marianos, N., Chatzipapadopoulos, F., Giannakopoulou, M., Papadavid, G., Vassiliou, V., & Neocleous, D. (2020). Smart farming techniques for climate change adaptation in Cyprus. *Atmosphere*, 11(6), article number 557. doi: 10.3390/atmos11060557.

[2] Chumarev, I. (2023). *Building the Central Asia drought information system in Kyrgyzstan: Progress and the way forward: Feasibility study.* Retrieved from https://hdl.handle.net/20.500.12870/5684.

[3] Convention on Biological Diversity. (1992, June). Retrieved from https://treaties.un.org/doc/treaties/1992/06/19920605%2008-44%20pm/ch_xxvii_08p.pdf.

[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1973, March). Retrieved from https://www.fisheries.noaa.gov/national/international-affairs/convention-international-trade-endangered-species-wild-fauna-and.

[5] del Mar Polo, M., Santos, N., & Berdikeev, S. (2022). *Adoption of climate technologies in the agrifood system: Investment opportunities in the Kyrgyz Republic*. Rome: Food and Agriculture Organization.

[6] Emileva, B., Kuhn, L., Bobojonov, I., & Glauben, T. (2023). The role of smartphone-based weather information acquisition on climate change perception accuracy: Cross-country evidence from Kyrgyzstan, Mongolia and Uzbekistan. *Climate Risk Management*, 41, article number 100537. doi: 10.1016/j.crm.2023.100537.

[7] Georgis, K., & Makonnen, B.T. (2024). *Dryland agriculture and climate change adaptation in Sub-Saharan Africa: A case of policies, technologies, and strategies in Ethiopia*. Addis Ababa: AICCRA Working Paper.

[8] Ghaffar, A., Rahman, M.H., Ahmed, S., Haider, G., Ahmad, I., Khan, M.A., Afzaal, M., Ahmed, S., Fahad, S., Hussain, J., & Ahmed, A. (2022). Adaptations in cropping system and pattern for sustainable crops production under climate change scenarios. In S. Fahad, M. Adnan & S. Saud (Eds.), *Improvement of plant production in the era of climate change* (pp. 1-34). Boca Raton: CRC Press. doi: 10.1201/9781003286417-1.

[9] Henry, R.J. (2020). Innovations in plant genetics adapting agriculture to climate change. *Current Opinion in Plant Biology*, 56, 168-173. doi: 10.1016/j.pbi.2019.11.004.
[10] Hossain, A., Maitra, S., Garai, S., Mondal, M., Ahmed, A., Islam, M.T., & Nayak, J. (2022). Next-generation climate-resilient agricultural technology in traditional farming for food and nutritional safety in the modern era of climate change. In K.R. Hakeem & T. Aftab (Eds.), *Plant abiotic stress physiology* (pp. 225-291). New York: Apple Academic Press. doi: 10.1201/9781003180562.
[11] Jalilova, G., Orozakunova, R., Baibagyshev, E., Karabaev, N., & Shergaziev, U. (2024). Farmers' adaptation to climate change in Southern Issyk-Kul. *Ekonomika APK*, 31(4), 23-32. doi: 10.32317/ekon.apk/4.2024.23.
[12] Juyal, P. (2021). *Economic botany, genetics and plant breeding*. Retrieved from http://dspace.kottakkalfarookcollege.edu.in:8001/jspui/bitstream/123456789/6883/1/PLANT%20BREEDING.pdf.
[13] Kadyraliev, A., Oruntayeva, A., Kamchybekov, T., Abyshov, I., & Bigali, A. (2024). The impact of digital technologies on the effectiveness of management in the agricultural sector of the Kyrgyz Republic. *Ekonomika APK*, 31(5), 35-44. doi: 10.32317/ekon.apk/5.2024.35.
[14] Keneni, K.H. (2022). *Smallholder farmers' adaptation practices to climate change: A case study of chiro woreda of West Hararghe zone, Oromia regional state, Ethiopia*. Haramaya: Haramaya University.
[15] Khakimov, P. (2019). *Climate change in Afghanistan, Kyrgyzstan, and Tajikistan: Trends and adaptation policies conducive to innovation*. Khorog: University of Central Asia.
[16] Kuhl, L. (2020). Technology transfer and adoption for smallholder climate change adaptation: Opportunities and challenges. *Climate and Development*, 12(4), 353-368. doi: 10.1080/17565529.2019.1630349.
[17] Kuhn, L., Bobojonov, I., Eltazarov, S., Emileva, B., Filler, G., Goedecke, T., Khodjaev, S., Moritz, L., & Glauben, T. (2023). *Final report joint project climate adaptation: Increasing climate resilience in Central Asia-sustainable rural development through the introduction of innovative agricultural insurance products (KlimALEZ)*. Leibniz: Leibniz Institute of Agricultural Development in Transition Economies.
[18] Liang, L., Zhang, F., & Qin, K. (2021). Assessing the vulnerability of agricultural systems to drought in Kyrgyzstan. *Water*, 13(21), article number 3117. doi: 10.3390/w13213117.
[19] Matías, J., *et al.* (2024). From 'farm to fork': Exploring the potential of nutrient-rich and stress-resilient emergent crops for sustainable and healthy food in the Mediterranean region in the face of climate change challenges. *Plants*, 13(14), article number 1914. doi: 10.3390/plants13141914.
[20] Michurina, N., Amosova, A., Kosnikov, S., Vasilieva, D., & Kholopov, Y. (2024). Adaptation of agricultural technologies to climate change: Ways to reduce environmental impact. *E3S Web of Conferences,* 510, article number 03017. doi: 10.1051/e3sconf/202451003017.
[21] Mirzabaev, A. (2018). Improving the resilience of Central Asian agriculture to weather variability and climate change. In L. Lipper, N. McCarthy, D. Zilberman, S. Asfaw & G. Branca (Eds.), *Climate smart agriculture: Building resilience to climate change* (pp. 477-495). Cham: Springer. doi: 10.1007/978-3-319-61194-5_20.
[22] Mukambaeva, I.B., Akylbekova, N.I., Mukambaev, N.J., Lailieva, E.J., & Nam, I.E. (2024). Comparing the agricultural sectors of the EAEU countries through the sustainability index. In *Ecological footprint of the modern economy and the ways to reduce it. Advances in science, technology & innovation* (pp. 431-435). Cham: Springer. doi: 10.1007/978-3-031-49711-7_71.
[23] Nadeem, F., Rehman, A., Ullah, A., Farooq, M., & Siddique, K.H. (2024). 7 managing drought in semi-arid regions through improved varieties and choice of species. In R. Lal (Ed.), *Managing soil drought* (pp. 212-234). Boca Raton: CRC Press. doi: 10.1201/b23132.
[24] Njinju, S.M., Gweyi, J.O., & Mayoli, R.N. (2022). Drought-resilient climate Smart sorghum varieties for food and industrial use in marginal frontier areas of Kenya. In A. Kumar, P. Kumar, S.S. Singh, B.H. Trisasongko & M. Rani (Eds.), *Agriculture, livestock production and aquaculture: Advances for smallholder farming systems* (pp. 33-44). Cham: Springer. doi: 10.1007/978-3-030-93262-6_3.
[25] Ologeh, I., Adesina, F., & Sobanke, V. (2021). Assessment of farmers' indigenous technology adoptions for climate change adaptation in Nigeria. In W. Leal Filho, N. Oguge, D. Ayal, L. Adeleke & I. da Silva (Eds.), *African handbook of climate change adaptation* (pp. 117-129). Cham: Springer. doi: 10.1007/978-3-030-45106-6_28.
[26] Park, S., Lim, C.H., Kim, S.J., Isaev, E., Choi, S.E., Lee, S.D., & Lee, W.K. (2021). Assessing climate change impact on cropland suitability in Kyrgyzstan: Where are potential high-quality cropland and the way to the future. *Agronomy*, 11(8), article number 1490. doi: 10.3390/agronomy11081490.
[27] Parra-López, C., Abdallah, S.B., Garcia-Garcia, G., Hassoun, A., Sánchez-Zamora, P., Trollman, H., Jagtap, S., & Carmona-Torres, C. (2024). Integrating digital technologies in agriculture for climate change adaptation and mitigation: State of the art and future perspectives. *Computers and Electronics in Agriculture*, 226, article number 109412. doi: 10.1016/j.compag.2024.109412.
[28] Pashchenko, Y.M. (2024). *How to prevent negative phenomena of drought in maize cultivation*. Retrieved from https://mais-seeds.com/kak-predotvratit-negativnye-yavleniya-zasuhi-pri-vyrashhivanii-kukuruzy/.

[29] Pichura, V., Potravka, L., Domaratskiy, Y., & Drobitko, A. (2024). Water balance of winter wheat following different precursors on the Ukrainian steppe. *International Journal of Environmental Studies*, 81(1), 324-341. doi: 10.1080/00207233.2024.2314891.

[30] Reyer, C.P., *et al.* (2017). Climate change impacts in Central Asia and their implications for development. *Regional Environmental Change*, 17, 1639-1650. doi: 10.1007/s10113-015-0893-z.

[31] Saleh, D., & Bejaoui, S. (2024). *Kyrgyz Republic Country strategic opportunities programme*. Retrieved from https://webapps.ifad.org/members/eb-seminars/2024-09-11-12-EB-consultation/docs/EB-2024-OR-10.pdf.

[32] Shebanina, O., Poltorak, A., & Chorniy, D. (2024). Global food security: Challenges in achieving the Sustainable Development Goals. *Ukrainian Black Sea Region Agrarian Science*, 28(4), 9-20. doi: 10.56407/bs.agrarian/4.2024.09.

[33] State Programme for the Development of the Agro-Industrial Complex of the Republic of Kazakhstan for 2017-2021. (2017). Retrieved from https://faolex.fao.org/docs/pdf/kaz179522.pdf.

[34] Thomas, T.S., Akramov, K.T., Robertson, R.D., Nazareth, V., & Ilyasov, J. (2021). *Climate change, agriculture, and potential crop yields in Central Asia.* Washington: International Food Policy Research Institute.

[35] Usta, A.T., & Gök, M.Ş. (2024). Adaptation to climate change: State of art technologies. *Kybernetes*. doi: 10.1108/K-11-2023-2517.

[36] Xenarios, S., Gafurov, A., Schmidt-Vogt, D., Sehring, J., Manandhar, S., Hergarten, C., Shigaeva, J., & Foggin, M. (2019). Climate change and adaptation of mountain societies in Central Asia: Uncertainties, knowledge gaps, and data constraints. *Regional Environmental Change*, 19, 1339-1352. doi: 10.1007/s10113-018-1384-9.

[37] Yeraliyeva, Z.M., Kurmanbayeva, M.S., Makhmudova, K.K., Kolev, T.P., & Kenesbayev, S.M. (2017). Comparative characteristic of two cultivars of winter common wheat (*Triticum aestivum* L.) cultivated in the southeast of Kazakhstan using the drip irrigation technology. *OnLine Journal of Biological Sciences*, 17(2), 41-49. doi: 10.3844/ojbsci.2017.40.49.

[38] Yzakanov, T., Mamytkanov, S., Ibraimova, Zh., Steinberg, E., & Alibakieva, Ch. (2024). Study of agroforestry methods and techniques for soil erosion prevention on agricultural land. *Ukrainian Journal of Forest and Wood Science*, 15(4), 72-89. doi: 10.31548/forest/4.2024.72.

[39] Zenda, T., Liu, S., & Duan, H. (2020). Adapting cereal grain crops to drought stress: 2020 and beyond. In S. Fahad, S. Saud, Y. Chen, C. Wu & D. Wang (Eds.), *Abiotic stress in plants*. London: Intech. doi: 10.5772/intechopen.93845.

Технології адаптації сільського господарства до змін клімату в Киргизстані

Вікторія Султанбаєва
Кандидат сільськогосподарських наук, в.о. доцента
Киргизький національний аграрний університет імені К.І. Скрябіна
720005, вул. Медерова, 68, м. Бішкек, Киргизька Республіка
https://orcid.org/0000-0002-8914-8778

Айнура Батикова
Кандидат технічних наук, доцент
Киргизький національний аграрний університет імені К.І. Скрябіна
720005, вул. Медерова, 68, м. Бішкек, Киргизька Республіка
https://orcid.org/0000-0001-9173-3151

Таалайбек Осмонканов
Кандидат технічних наук, доцент
Киргизький національний аграрний університет імені К.І. Скрябіна
720005, вул. Медерова, 68, м. Бішкек, Киргизька Республіка
https://orcid.org/0000-0002-3486-980X

Нурлан Маматов
Кандидат сільськогосподарських наук, доцент
Киргизько-турецький університет «Манас»
720044, просп. Ч. Айтматова, 56, м. Бішкек, Киргизька Республіка
https://orcid.org/0000-0002-9055-3949

Бакитбек Аскаралієв
Кандидат технічних наук, доцент
Киргизький національний аграрний університет імені К.І. Скрябіна
720005, вул. Медерова, 68, м. Бішкек, Киргизька Республіка
https://orcid.org/0000-0002-7180-2671

Анотація. Зміни клімату суттєво впливають на продуктивність сільського господарства, особливо в регіонах із посушливими умовами, таких як Киргизстан. Вирощування посухостійких культур та впровадження інноваційних агротехнологій є ключовими заходами для забезпечення стійкості аграрного сектору. Метою дослідження була оцінка ефективності вирощування посухостійких культур (сорго, нуту та проса) в умовах Киргизстану, а також аналіз впливу сучасних технологій, таких як краплинне зрошення, на продуктивність та ефективність використання водних ресурсів. Дослідження проводилося протягом двох вегетаційних сезонів (2023-2024 роки) на експериментальному полі в Киргизстані. Урожайність визначали шляхом збирання врожаю з ділянок площею 1 м^2 і подальшого перерахунку на гектар. Водоспоживання вимірювали з використанням ґрунтових вологомірів Delta-T Devices (глибини 10, 20 і 30 см). Коефіцієнт ефективності використання води (WUE) розраховувався як співвідношення врожайності до обсягу водоспоживання. Моніторинг стану посівів здійснювався за допомогою дронів DJI Agras T30 та супутникових знімків Sentinel-2. Результати дослідження підтвердили високу ефективність сорго та проса в умовах посухи. Сорго продемонструвало найвищу врожайність – 4,2 т/га – завдяки розвиненій кореневій системі та здатності ефективно використовувати вологу. Просо показало найкращий WUE – 0,9 кг/м^3 – і найнижче водоспоживання (4000 л/га), що робить його оптимальною культурою для регіонів із дефіцитом водних ресурсів. Нут, незважаючи на нижчу врожайність (1,8 т/га), виявився перспективним завдяки своїм азотфіксувальним властивостям, які покращують родючість ґрунту. Застосування крапельного зрошення дало змогу знизити водоспоживання на 20-30%, забезпечуючи стабільний рівень врожайності навіть в умовах дефіциту води. Моніторинг з використанням дронів і вологомірів сприяв оптимізації зрошення, підвищуючи точність управління водними ресурсами. Дослідження підтвердило ефективність вирощування сорго та проса як ключових культур для посушливих регіонів, а також доцільність інтеграції краплинного зрошення для підвищення стійкості сільського господарства. Результати роботи надають науково обґрунтовані рекомендації для фермерів і політиків щодо впровадження посухостійких культур і сучасних агротехнологій у Киргизстані, що сприятиме продовольчій безпеці та стійкості аграрного сектору в умовах зміни клімату

Ключові слова: посуха; посухостійкі культури; волога; сорго; просо; нут; система зрошення; водокористування