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ECONOMIC DEVELOPMENT OF AGRICULTURE IN KAZAKHSTAN IN THE CONTEXT OF CLIMATE CHANGE

T. Baltabay[1*], L. Bimendiyeva[1], A. Kaliyeva[1]
[1] Al-Farabi Kazakh National University, Almaty, Kazakhstan

ABSTRACT

Purpose – The study explores rising climate fluctuations in Kazakhstan, focusing on agriculture's resilience; it highlights consequences for income security, village communities, or future planning.

Methodology – This research uses descriptive methods alongside comparison techniques, relying on existing data. It examines patterns in rising temperatures, shifts in rainfall, more frequent droughts, declining soil quality, or limited water access. These environmental factors are then connected to how well farming performs over time.

Originality / value – The study adds to existing work on climate risks in Central Asia by linking environmental, financial, and sector-level factors into one analysis approach - while using varied structural choices per sentence. A rare look at how farming and climate interact in Kazakhstan is provided, showing local adaptation efforts already tested in real conditions instead of relying on generic solutions.

Findings – Results indicate rising heat stress, less rain, frequent droughts, and growing dry areas reduce crop output, animal performance, or soil health, thus harming food access plus income in rural regions. The study highlights key adaptive actions - like smart irrigation tools, varied farming setups, or sturdy equipment and methods - which may improve resistance while aiding lasting growth.

Keywords: agriculture; climate change; Kazakhstan; adaptation; sustainability

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INTRODUCTION

From the point of view of economics and general welfare, agriculture occupies an important place in the advanced economies of the world. And Kazakhstan is no exception, as agriculture accounts for 3.9% of Kazakhstan's total GDP in 2024 [1]. Moreover, over the past 10 years, more than 1/20 of the total population has been engaged in agricultural activities, which once again confirms the strategic importance of the country's social component in the development.

Moreover, our country's wheat market remains the most promising and dynamic in Central Asia. In 2025, wheat demand from other Asian countries increased, and volumes reached almost record levels. Despite the fact that Kazakhstan is facing difficulties, it is also entering new markets and signing agreements. Since last year, exports of wheat products, namely cereals, durum wheat and food grains for animals, have shown only positive dynamics. Thus, Kazakhstan is becoming one of the main players in the wheat trade.

At the same time, the country's agricultural sector is facing a number of external impacts related to the political aspect and climate change. Given the country's characteristics (almost half of the country's territory belongs to the semi-desert class) and geographical location, along with the continental climate, additional factors affecting global climate change increase vulnerability. In addition, the growing water crisis in the Central Asian region has jeopardized crop yields in the southern part of Kazakhstan.

The relevance of this issue is only growing every year, as most of the world's leading economies adhere to the principle of sustainable development and the development of agriculture in the face of climate change requires special “green” impact measures. Moreover, ensuring the sustainable development of agriculture contributes to the provision of food to the population based on the principle of food security. Finally, it will allow the country to put into effect a multi-year plan to diversify the National economy and minimize dependence on the global oil market.

The purpose of this article is to present the impact of climate change on agriculture in Kazakhstan, taking into account measures to prevent it. The growing concern at the international level is not only positively influencing the country's transition to the path of "green" agriculture, but is also an urgent need caused by the rapidly changing environment. The crucial position of agriculture in both domestic and foreign markets creates demand for new adaptation policies for this sector and prepares the country for new realities.

The climate is volatile, which has more threat than benefit to agriculture all over the world. Every year, more and more people fall into the risk category, and moreover, millions of people are left without food and earnings at least for bare minimum. The changes are intensifying, the frequency and territoriality of rains (and precipitation in general) is changing, storms occur more often – all this significantly harms the fertility of the harvest of the main crops. Because of this, the quality of the soil suffers and the fertile layer is lost, there are fewer and fewer water resources, pests spread exponentially and harm the fields, and new diseases affect the crops. Corn, wheat, rice, and soybeans grow fewer in units and gradually lowering quality. The case is harsh for small farms due to their reliance on entirely nature provides. In order to combat the consequences, country needs skillful solutions and a willingness to change.

How the weather changes is immediately evident from the harvest. The drought, the rains are changing drastically. It is becoming increasingly difficult for farmers to plan their work. The land is suffering, crops are less productive. As a result, there is less food, and prices are rising along a logical chain.

Global warming and precipitation are where it all starts. By the end of the century, the planet may warm up by 0.3–4.8 degrees, because of this, the precipitation will alternate, and the storms will become more regular. This will damage the crops, and the harvest will decrease. In addition, droughts and floods have become more frequent - the land is eroding, agricultural sector in turn, calls to action. Another problem is that pests and diseases are spreading faster now, spoiling what they have grown. To cope, it is recommended to plant different crops and choose varieties that are flexible to drastic modifications. Thus, the harm from the changing climate might get slightly reduced, if scientists will develop plant varieties that can withstand the new conditions, as well as plant different crops. In addition, it is important to use water wisely, for example, to use an economical irrigation system, because there is less and less water resources to meet current demand. [2,3].

Politics and international cooperation are an important part of working on climate change, which helps to develop sustainable agriculture and the ability to adapt. Although much is known about the harm of changes to farming, it is worth remembering that in some places the effect may even be beneficial [3]. In some places, it may be easier for plants to grow due to the warmer season or more carbon dioxide. However, the overall consequences are usually destructive, so it is important to figure out how to adapt to the changes [4].

In Central Asia, the weather is changing in such a way that it becomes difficult for farmers, therefore the harvest there largely depends on irrigation, and the climate itself is not predictable. Temperature is alternating - it's affecting food and crops, calling policymakers to react quickly. It is estimated that, on average, it will become warmer by almost one and a half degrees, or even more, if the world continues to shift at the same rate[5]. Despite the fact that the temperature accelerates the process of melting glaciers, and logically there are more voluminous resources, in fact, water reruns are rapidly depleted and cause the following risks of drought[6]. The evolving of the warming weather means it will be longer periods without precipitation, which is extremely risky for farmers. In order to cope to such consequences, agriculturalists are thinking about how to spend water more economically. It is important to water the fields properly and protect the land, otherwise nothing will stand.

Moreover, the variety of plants grown, an idea that is often suggested as a universal remedy, is quite suitable here. After all, switching to stronger varieties will help reduce losses from the vagaries of the weather [7]. In addition, it is important to develop agriculture in a way of improvement of the farmer support system and infrastructure in order to successfully combat with the changing climate.

Although there are risks, some believe that the region, due to its small impact on the global climate, has the right to ask for help and investments in sustainable agriculture. So difficulties can become a springboard for growth. It is linked that Kazakhstan is facing complex environmental challenges that can be costly for the country. The droughts in 2010 and 2021 have shown how vulnerable agriculture and the whole of environment are. We are particularly concerned that the lands are turning into a desert, and urgent solutions are vital. For instance, a two-year drought (2010-2011) occurred due to the heat and low rainfall. Harvests have fallen, water has become scarce, and food supplies and the economy of entire regions have been threatened [8]. The problem of the outdated system for assessing agricultural risks caused by the weather has become obvious. Therefore, new methods have been developed – machine learning and deep learning – to more accurately predict drought, reaching up to 99% accuracy in some regions [9].

Our republic, among other problems, can quickly lose forest resources and expand in territorial desertification. According to information from the United Nations report for 2025, three quarters of agricultural land has already been damaged – this is the cause of desertification, salinization, leaching of soil or simply its poverty. The reasons are diverse: failure of natural cycles and humanity are the entailers too. Almost half of the country suffers from this. It is especially difficult for the southern regions, where there are lacking water sources and suitable land is used improperly. With the help of satellites like MODIS, scientists monitor the situation in Central Asia, observing how vegetation over periods are changing. There are deficient water resources in Kazakhstan due to the increasing drought, which is influenced by the weather, the land, and finally poor management of resources. Droughts can last for different periods of time, and they are especially long in winter [10]. Research briefly dives into environmental problems, but we need to look more broadly at the entire regional perspective. There are similar difficulties in Central Asia, so if the states work together, the solutions will become more effective. It's important to remember that everything is connected, especially when it comes to climate change and resource use.

In our time, studying the relationship between climate change, agriculture, and government policy as a response is not widespread. It is clear that the necessary comprehensive work is not enough. Although farming is not the main source of income and prosperity for the country, it is important to develop it taking into account climate change as an external factor. Scientists in Central Asia are not sufficiently concerned about the topic of warming; there is still very little research on this issue [11]. Nevertheless, accounting that more than seventy percent of Kazakhstan land is pastures, from which agriculture develops, it becomes clear why it is critical. If these lands deteriorate, food and livestock farming will be at risk [12]. In addition, current rules for farmers do not fit well with plans to combat climate change, which means that it is impossible to accumulate more carbon in the soil [13].

Research is needed to link agriculture to the fight against climate change, which will help make it more reliable and durable [14]. Although there are difficulties, some people believe that smart farming can provide an opportunity to work in a new way, increasing yields and protecting from the weather fluctuations. Unfortunately, there are still few papers that combine all these issues, so it is difficult to develop proper action plans in Kazakhstan.

MAIN BODY

The study focuses on how the changing climate affects agriculture in Kazakhstan. The work is based not only on numbers, but rather on a detailed analysis of existing reports. The reason is simple: the situation is too complicated to describe in numbers alone – you need to take into account the economy, society and politics. Materials from FAO, the World Bank and the UNDP were mainly used, i.e., verified sources. Planning papers, state statistics as well as the works of the scientists in agriculture were used in the work. From these sources, you can learn everything about weather changes and yields, which means you can understand what the difficulties are and what is being done about them.

To understand the situation in Kazakhstan, we internally analyzed general effective adoption measures with the focus on pilot projects. Certainly, this cannot be completely adopted in the same way, but such examples help to understand which methods are suitable and tailored for agriculture in Kazakhstan, so that it is more resistant to weather changes.

The analysis is based on three things that are closely related. First, they find out what dangers there are due to the weather are thread for the country. We examine how the increase in heat, lack of moisture, deterioration of the land and severe storms affect Kazakhstan's agriculture, its productivity and its ability to hold on. Following, we consider ways to adapt, focusing on what is already being done and what else can be done, such as planting crops that are not affected by heat, using precision farming, combining modernity with agriculture, or using digital tools to track the weather and make predictions.

Understanding Kazakhstan's agriculture, we look at its weaknesses from different angles -comparing and analyzing the data as well as enquiring methods of adoption. This gives a complete picture of how susceptible is our agriculture to weather changes and how it can adapt. As a result of this approach, the work shows not just the impact of climate, but helps Kazakhstan to shape its leading role in the discussion of the future of agriculture around the world.

Agriculture for Kazakhstan is not just an industry, it affects people's lives, well–being and nature. Our country is the main supplier of grain in the whole of Central Asia, and almost the only strategic one. About a third of the country's inhabitants live thanks to the earnings from the steppes, where crops grows, livestock feed and etc.

Among other things, animal husbandry is a significant part of the economy. Almost three quarters of the farmland is used for pasture. Although sheep play a major role in cattle farming, the rest cattle types such as cows, pigs, horses, and even camels are kept for food and earnings. Below, we will analyze the specified acreage of the main agricultural crops of Kazakhstan from 1990 to 2024 in thousand ha. Grains and legumes are the basis of agriculture in Kazakhstan.

However, the acreage has decreased: if in 1990 there were 23.3 million hectares, by 2024 there were about 16.7 million, (figure 1) showing a decrease in the important part of grain cultivation.

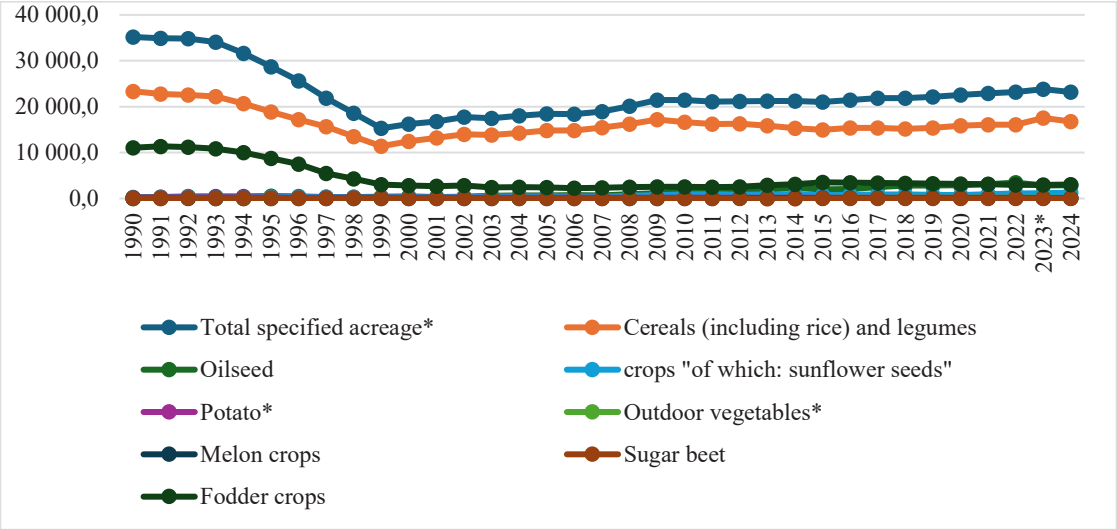

Figure 1 – The specified acreage of the main agricultural crops of Kazakhstan from 1990 to 2024 in thousand ha. Note: Author's compilation based on [15] data

Despite this, most of the land – more than seven tenths of the total arable land – is still occupied by conventional crops. This suggests that agriculture is still focused on the production of raw materials. The planting of oilseeds has grown especially strongly: from two hundred and sixty-six and a half thousand hectares in the nineties to almost three million now – an increase exceeding tenfold. This leap shows how farmers are adapting to what the market needs and what goods can be sold abroad (for example, rapeseed, sunflower or soybeans).

The areas for potatoes and vegetables have not changed much. On average, fields occupy from 150 to 200 thousand hectares – people buy steadily, but it is difficult to sell abroad. But sugar beet crops have sharp-

ly decreased: from 43.6 thousand hectares in the nineties to 25 now.Closed factories and imported sugar are to blame. But the group of watermelon and melon crops, on the contrary, are growing, especially in the south – from 35.8 thousand hectares in the nineties to almost one hundred thousand today. And yet: livestock feed(fodder crops) is being grown less and less – there were eleven million hectares, now there are only three. In the nineties and early 2000s, the number of livestock decreased, and the land for growing fodder also became smaller. During this time, Kazakhstan's fields have become more diverse. Grains are still the most important, but oilseeds are gaining popularity, as are vegetables. Gradually, farming becomes more reliable, focusing on the market. At the same time, the decrease in crops for livestock and industry suggests that the entire industry needs to be seriously upgraded, produce more domestically and process raw materials more deeply.

The harvest in Kazakhstan, which has been monitored since 1990, generally shows better results every year, especially for cereals and legumes. After decreasing to 5-7 quintals per hectare in Soviet times, yields increased to 15.2 c/ha by 2024 thanks to the latest technologies combined with more reasonable farming methods. (figure 2) Since the beginning of the new millennium, yields of oilseeds, especially sunflower, have more than doubled due to improved plant breeding and increased use of machinery. Potato farming has made even greater strides; between 1995 and 2024, yields have almost tripled thanks to improved irrigation systems and high-quality seeds. Vegetable and melon farms also flourished, producing 284 and 253 pieces per hectare, which indicates sound management of water resources and improved cultivation technologies.

The greatest success has been achieved in the cultivation of sugar beet: yields have increased from about 150-200 quintals per hectare in the nineties to more than 500 by 2024, as a result of government assistance in modernizing and improving land management. These changes demonstrate that Kazakhstan's agriculture is becoming more efficient, adopting new technologies, and also developing to some extent, despite the fact that unpredictable weather continues to affect wheat production

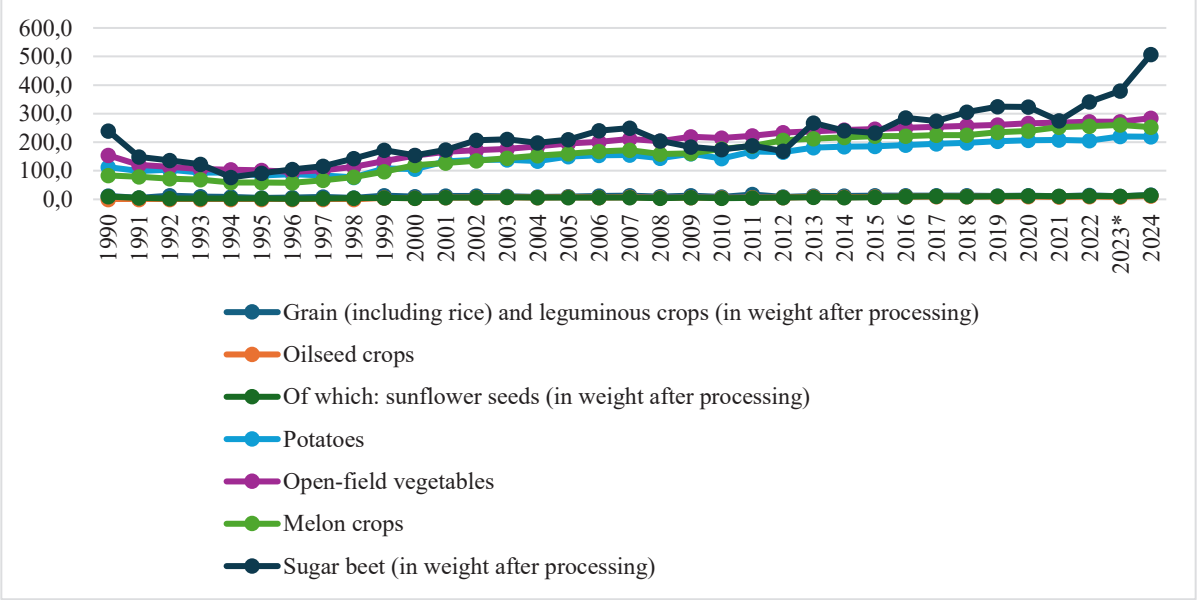

Figure 2 – Productivity of the main agricultural crops of Kazakhstan from 1990 to 2024, in c/ha.
Note: Author's compilation based on [15] data.

Sugar beets thrive because farming gets better alongside their knack for handling shifting weather. They really hold up well even when it heats up - often boosting harvests, particularly where water is scarce. Because they mature quickly – around six or seven months – they're a good option instead of sugarcane if water supplies are tight. How well sugar beets grow depends on how they're farmed alongside weather patterns – key factors for getting the most from each harvest. They thrive when air and ground temperatures stay between 15–25°C. Moreover, their tolerance for salty soil along with little water makes them ideal where finding

enough irrigation is tough. Considering our changing climate, these qualities suggest sugar beets could be a reliable choice, continuing to produce even as temperatures fluctuate and water becomes scarcer.

Kazakhstan's animal husbandry has changed a lot from 1990 to 2024, either because of the economy or because of agricultural policy. In the nineties, production collapsed, but then it began to grow slowly. Now, especially in 2022-2024, growth has slowed down again. Back in 1990, meat output stood at 2.63 million tons. (figure 3) Kazakhstan's livestock industry has changed a lot from 1990 to 2024, either because of the economy or because of agricultural policy. In the nineties, production collapsed, but then it began to grow slowly. Now, especially in 2022-2024, growth has slowed down again. Back in 1990, meat output stood at 2.63 million tons. By 1998, however, that figure nearly halved, hitting around 1.2 million. Big agricultural operations failed; ownership shifted into private hands while animal numbers dwindled.

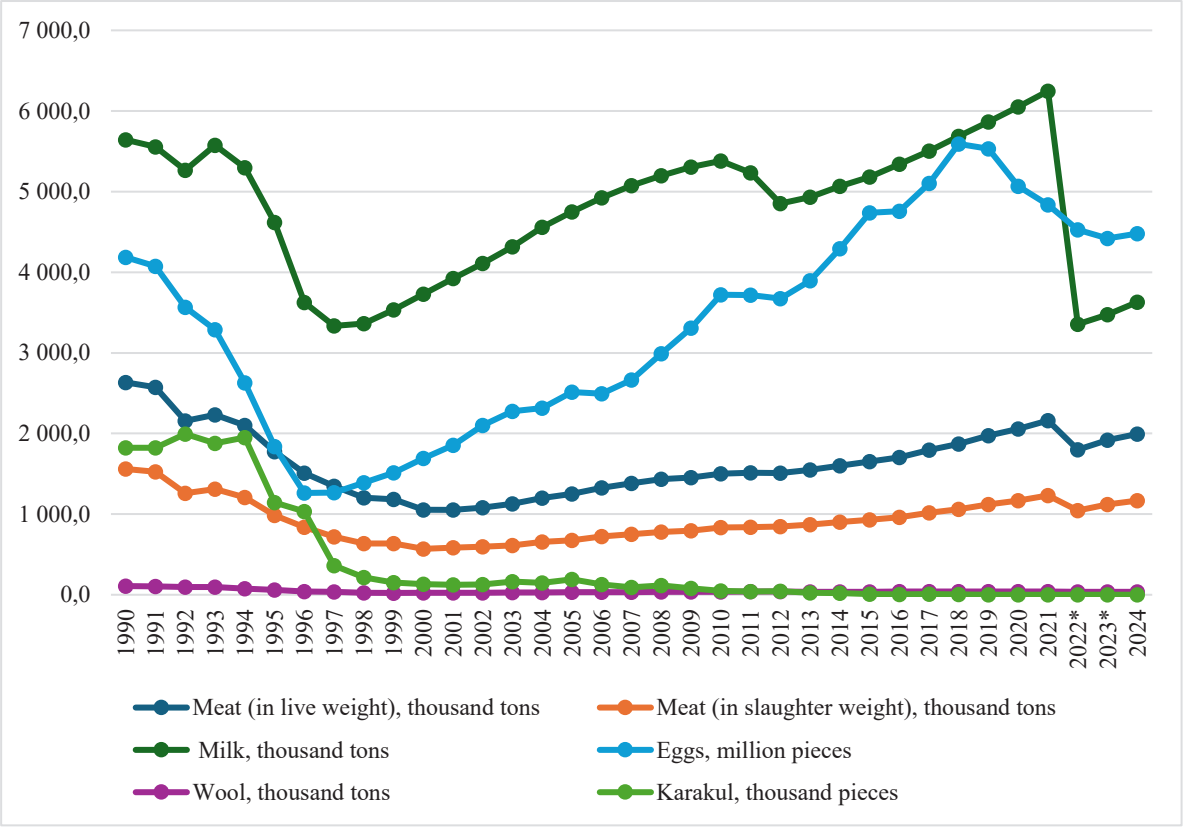

Figure 3 – Production of certain types of livestock products in Kazakhstan from 1990 to 2024
Note: Author's compilation based on [15] data

Afterward, things turned around, so that by 2021, production reached 2.16 million tons - comparable to levels seen decades before. In 2024, production hit 1.99 million tons. A small drop could stem from conditions - or costly animal food. Milk volume shrank considerably, moving from 5.64 million tons during the 1990s down to 3.33 million tons later in the decade. The number climbed steadily, hitting 6.25 million by 2021. However, things have shifted; currently, we see just 3.63 million tons. It looks like farm sizes are shrinking alongside decreasing output. Egg numbers shifted quite a bit. They began at 4.18 billion during the nineties, then surprisingly fell to 1.26 billion - still within the nineties. Afterward, figures climbed once more, reaching 5.5 billion by the nineteenth century. Lately though, there's been a small dip; currently, we see around 4.48 billion. Less now compared to the nineties, though still significant. Wool output - similarly, Karakul skin yields - dropped dramatically, by a factor of ten.

In the nineties, almost one hundred and eight thousand tons of wool were wound, and one and a half million tons of Astrakhan wool type. By now, there are only thirty-six thousand tons of wool and two hundred

hides left. This means that there are noticeably fewer sheep, and at the same time, the opportunity to make more earnings from selling has been lost. In Kazakhstan, the production of meat and dairy products is closely related to how agriculture is changing. The serious recession of the nineties was left behind; the industry revived when personal farms appeared and the state began to help livestock production in the new millennium. If in 1990 meat was produced in the amount of 1.56 million tons (already ready for sale), by 2021 it was only 1.23 million tons, and then it decreased to 1.17 million tons by the current time. In the period from 2010 to 2019, exports of beef and mutton in Kazakhstan increased significantly due to government support, including subsidies to farmers. Dairy production, on the other hand, depended on the time of year and place. It levels grew until 2021, but then began to fall, possibly due to expensive feed, drought and deterioration of animal health in the south of the country.

In just over thirty years, the industry has adapted to the way the market works, and has managed to level production. However, the climate change still strongly affects effectives in performance.

Last year of 2024, became a record holder in terms of heat – plus one and a half degrees compared to the figures of the last century [16]. If nothing is done, it will get even hotter by the end of the century, possibly by 3.28 degrees [17]. The graph shows how the average temperature on the planet has changed from 1850 to the present day – almost until 2025. (figure 4)

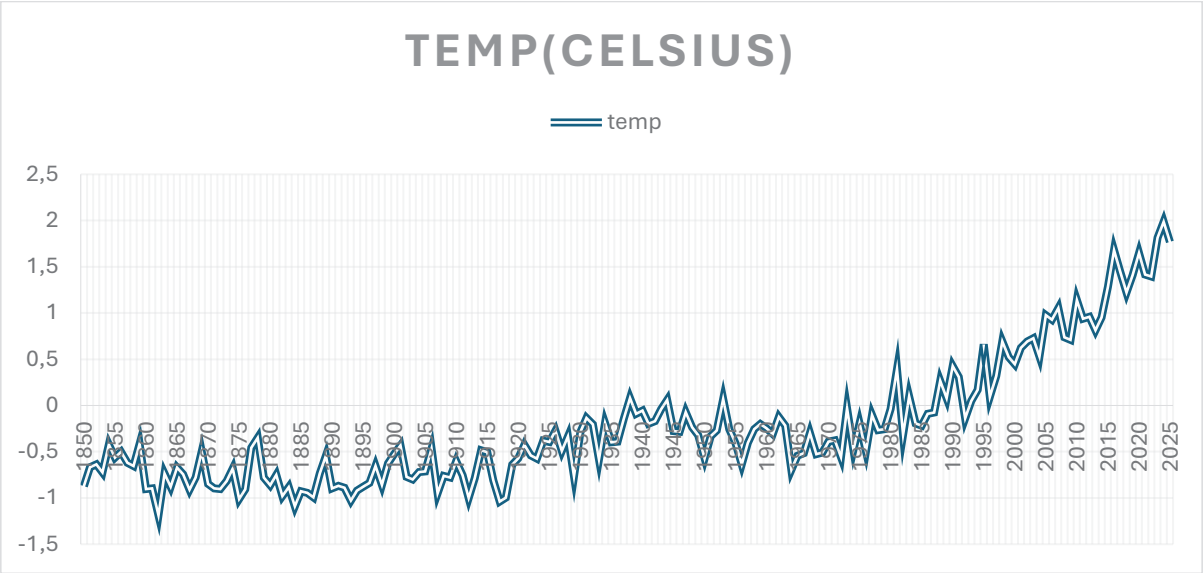

Figure 4 – Global average surface temperature
Note: Author's compilation based on [18] data

It is shown that the trend is going upwards. The old predictions about warming now seem too modest. It is clear that the weather is getting warmer – the question is how this will affect farmers. Will life in the village change, will it affect food security and economics in general? The numerous evidences, suggest that everything is interconnected. Even small fluctuations in the weather – sometimes hot, sometimes cold – affect agriculture. It is more difficult for plants to bloom and grow normally, which is why the harvest is falling. It's like they have less time for everything important to grow.

As the planet warms, agriculture is facing serious challenges. Due to the heat, the duration of plant growth is shortened, which leads to stress for plants and animals. This is putting our food supplies at risk, so we need new ways to deal with it. Chaudhary and other experts predict that warmer weather may speed up harvesting, which will actually shorten the growing season. Hot and dry weather threatens corn and soybean crops - yields may fall by 8-21%. Better quality seeds, along with irrigation systems, appear to be the key to minimizing damage [20]. Intense heat also affects how plants digest food and maintain healthy color, affecting growth)

[19]. Dairy cattle are also under risk: high temperatures not only reduce fodder yields for cattle consumption, but also affect their ability to reproduce. Prolonged exposure to temperatures above 84°F (around 28 Celsius) dramatically reduces productivity [21,22]. Because of this, the dairy business carries a huge financial burden - more than half of all costs are spent on combating heat stress.

Figure 5 – Consequences of temperature rise to agriculture
Note: Authors compilation based on [19]

To protect local businesses and the country's finances, manufacturers can install cooling systems or equip shaded areas, but this multiplies cost and final product price. Even though the weather is getting hotter, others believe that better farming practices - combined with new technologies - could help us overcome barriers, possibly reducing damage to both farms and livestock.

In addition, is following issue in Central Asia, that strategic region is facing increasing water shortages as glaciers are shrinking as a result of climate change. This reduction affects the volume of river basins in the Southern territories, endangering farms located near natural habitats, as glaciers usually provide the population with the necessary water. Since 1970, glaciers throughout Central Asia - have shrunk significantly, losing almost thirty percent of their size. For instance, experts predict that summer runoff in the Syrdarya river will decrease by sixteen to thirty percent by 2100. Similarly, the melting of glaciers feeding the Ili River is endangering Lake Balkhash, a situation similar to the disaster in the Aral Sea. With glaciers disappearing, countries with access to these waters will have to negotiate more harshly and political conflicts are possible. Lack of water poses challenges to agriculture, energy, and economic well-being throughout the region. Despite the difficulties, more precipitation may fall in some regions, which will temporarily reduce the impact of melting glaciers, demonstrating how geographically the climate is changing. In spring, especially in the north and west, rivers are increasingly overflowing their banks. So far, this is just a disaster for the surrounding area, but also an opportunity to address the issue of preserving the country's water resources.Since in the north of Kazakhstan, every year in the spring, rivers leave the riverbed due to filling, in the south of the country, on the contrary, there is a process of shallowing of river basins and reservoirs. For example, the Syrdarya River in southern Kazakhstan is getting shallower – this is already noticeable. The climate is changing, it's getting warmer, and the problem is only getting worse. Based on this, the following problems arise: the lands dry up, become saline, and erosion occurs. All this affects crops and generally harms nature, and in response, the earth and climate become even worse. Lands are being degraded due to unreasonable use, weather conditions and natural disasters – crop levels are falling, products are becoming more expensive and inaccessible to ordinary citizens. The weather is changing, it is getting hotter, although the earth's surface reflects less light [23]. Fewer plants bear fruit on saline soils, which threatens starvation [24]. Erosion is increasing due to rain and wind, as well as storms becoming more frequent [25]. Badapalli and his colleagues (2023) confirm this sad picture [26]. The loss of topsoil reduces yields, while disrupting natural processes and reducing the diversity of life. It is common to talk about how climate change harms the soil, but there is an opinion that reasonable land use can reduce this damage. Methods such as soil conservation, proper fertilization, and land restoration can improve soil health and its ability to withstand climate change [23,24].

In 2021, Kazakhstan faced a drought that demonstrated the effects of climate change on farmers. Crops and livestock were severely affected, and everyone was devastated due to incorrect climate change forecasts. Climate change has led to more frequent periods without water. A natural disaster has occurred in Kazakhstan:

due to drought, many animals have died due to a decrease in feed yields. Nevertheless, there is a chance of salvation – modern developments such as machine learning are able to predict drought almost accurately, often with an accuracy of 99%, despite the rapid change of circumstances [9]. Due to the drought, harvesting was unstable for those who expected rain, so they should quickly notice the problems [27]. There is little water, so plants and livestock suffer, as well as wallets [28,29]. In addition, the weather is changing, which is why there is less wheat in some regions of Kazakhstan: from 2000 to 2019, it was harvested by 6-8% less [30]. Droughts happen more often, so it means that the one more stable negatively affecting factor for agriculture is to consider. Although it's not simple now, it's become clear that we need more accurate weather forecasts and a willingness to immediate actions.

The first IPCC reports indicate that adaptation is needed to reduce the challenges and costs of a changing climate. This means trying to harm nature less. Farmers are threatened by weather changes, but there are ways to adapt by preserving crops and providing food for people. To adapt to the changes, we need solutions – technical and simply competent approaches that take into account the specifics of the area, as well as support from the state and reliable organizations. Earlier, we talked about problems like droughts, lack of moisture and temperature fluctuations. Kazakhstan has signed the Paris Agreement in 2015 and is already using various adaptation methods to deal with these challenges. In particular, economical irrigation is being introduced – drip or sprinkling, crops are being planted that tolerate heat, precise farming methods are being used, the land is being protected and the management system is being changed. We can already see that water is being saved by a quarter or half, crops are growing by a tenth or a third, and there are successful experiments in the regions. Water is a serious issue for Kazakhstan, as almost half of its reserves come from other countries. In the southern regions, new ways of using resources wisely are already being tried, which not only helps the economy, but also gives people jobs and reduces the problems caused by the changing climate.

To tell the truth, the state has its own difficulties – how to adapt farming to a changing climate. The climate here is like this: the heat is unbearable, then there is almost no rain, so the harvest suffers greatly from the weather. Let's talk about how agriculture in Kazakhstan is coping with the changes. For example, let's look at the experience of using drip irrigation – it has already been tested in many regions of the country, and the results are good [31]. It turned out that thanks to it, water is consumed more economically – almost half less than with conventional flooding of fields. In addition, the soil is improving, it is becoming less salty. The projects were launched both in the north and in the south of the republic. It turns out that there is less water loss during delivery to the field, the land bears fruit better, and in general, this technology helps out especially where there is not enough water, for example, in the south.Tests of sprinkling in northern Kazakhstan showed a noticeable increase in yield, as Turbekova and colleagues found out in 2023 [32]. The results of this test on three types of crops as spring wheat, barley and triticale are reflected in table 1 below. As the result of sprinkling test, it is seen that this method shows positive impact in productivity of this certain plant cultures. Proving that in large-scale it can be a game changing method and strategy.

Furthermore, smart sensors for measuring soil moisture have been tested in the southern regions of the country [33]. Thanks to them, water consumption has decreased by a quarter or half, sometimes even more, although the result is usually comparable to other methods. At the same time, the harvest increased by a fifteenth to a thirtieth part.A new system is being tested in South Kazakhstan: They put sensors in the fields, look at the weather forecast – this is how they teach farmers to save water and manage farms better. Together with accurate watering, this gives a good result, the harvest grows, and less water is consumed.

Table 1 – Differences between different crop types before and after using sprinkling irrigation method

Plant type	Before the observation and implementation	After the observation and implementation	% change
Spring wheat	24.9 c/ha (unirrigated)	29.3 c/ha (irrigated)	18%
Barley	34.4 c/ha (unirrigated)	46.9 c/ha (irrigated)	36%
Triticale	28.0 c/ha (unirrigated)	41.6 c/ha (irrigated)	49%
Note: Author’s compilation based on [32] data			

In Kazakhstan, the solution to the problem of drought is inextricably linked to which crops to grow. The main thing is to create varieties that can survive the heat. Scientists advise choosing plants that are suitable for a particular area, taking into account the composition of the soil and climate. It is also important to position crops correctly, focusing on their endurance to drought and alkaline soil [34]. Wheat and barley are especially good where it's dry – they get used to it quickly. Thanks to this, agriculture becomes more reliable, even if the weather deteriorates.In agriculture of Kazakhstan, it is important to properly water the crops and monitor the watering time. A study on soybean cultivation in the south-east of the country using the AquaCrop program revealed that if you carefully approach watering during flowering and bean formation, you can significantly improve water use and get a bigger harvest. According to the results of the experiments, it turned out that the water consumption for producing a kilogram of products decreased by almost one unit – to 0.93 kg/ m2. The harvest grew by about fifteen percent relative to the usual methods. It turned out that it is better to water moderately more often than rarely, but abundantly – especially if there is not enough moisture for normal plant growth.

In arid zone of republic, maintaining soil moisture is the key to reliable farming. Experiments with Aquasorb have shown that this hydrogel, added directly to the soil around the roots of orchards and fruit trees, significantly helps it retain water. This idea will help plants get water even when it is dry, so that they can better tolerate the heat in the gardens. Thanks to this, we will be able to use water more wisely in those regions of Kazakhstan where rains are rare.

In Kazakhstan, weather tracking makes it possible to better plan agriculture. Thanks to nationwide drought and grain harvest control systems, farmers, as well as the authorities, have information for decision-making. Thanks to these systems, it is possible to sow crops on time, taking into account the weather, as well as properly water the plants and save crops – for example, potatoes or wheat – from sudden cold weather. Knowing the climate features of each corner of Kazakhstan, this method helps farmers to benefit more from the land and make agriculture more reliable.

The diversity of crops is like taking care of the land, which means it is an important part of sound farming in Kazakhstan. A recent study of corn fields near the border with China showed that if you alternate crops and fertilize the land with humus, the land holds up and bears fruit better [35]. The soil has improved, and the fields have become stronger in the face of the vagaries of the weather. This helps farmers to work for many years, protecting the land from depletion, especially where it is weak.

In Kazakhstan, crops, especially wheat and barley, are growing worse due to changes in the acidity of the earth [34]. The solution is to feed the land with organic matter, carry out work to improve it, and monitor the level of acidity. This way the soil will be better and the plants will be stronger even where the ground is very alkaline.

In order for agriculture to become stronger, it is necessary to take into account the peculiarities of the land and climate. It is proposed to divide territories into zones and choose crops that will grow well there: for example, it is better to plant wheat in the north, and a mixture of barley and wheat in the south. This way, you can get more crops even if the weather changes, while using the land and other resources wisely.

Observations of corn crops near the border with China have shown that if you alternate crops and even feed the land with humus, the land does not deplete – on the contrary, it resists the vagaries of the weather better [35]. The earth becomes loose, plants receive nutrition, and the harvest pleases for many years. This is an important step towards rational land use.

In the steppes and wastelands of Kazakhstan, a well–thought-out fight against drought is needed - new technologies together with the mind of agriculture. Scientists choose wheat and barley, which are least afraid of thirst, choosing the best options for each area. It turned out that if soybeans are watered on time, especially when they bloom and form fruits, the harvest grows by 14.7%, and each cubic meter of water yields almost a kilogram of soybeans [36].

To make the earth hold water better, they began to use a special gel (Aquasorb) in gardens and fruit plantings – this way plants can tolerate heat more easily even where there is little rain **.** Kazakhstan has introduced a system for monitoring drought and the condition of wheat crops, which helps farmers plan their work taking into account the weather. Now farmers and officials can change the planting time, water crops on time and protect them from frost - this is especially important for wheat and potatoes. Thanks to the timely weather information, agriculture in the region has become more reliable and productive.

Notwithstanding, it is difficult to introduce new irrigation methods – many farms cannot afford expensive equipment. This is especially true for small farming areas where funding and government subsidies are tight. To solve the problem, we need joint government and business projects, direct government assistance, and low-interest loans. This will help to develop agriculture and attract finance to this segment of agriculture.

In order for Kazakhstan's agriculture to withstand climate change, major changes in governance and laws are required. Individual experiments will not help much – policymakers should be obligated to rebuild the entire system. There are technologies, but in order for them to really work, it is necessary to update the management system, put the laws in order and find reliable sources. It is important to strengthen farmers' associations, introduce mandatory accounting of water during irrigation, establish cooperation between departments and attract private funds to upgrade infrastructure.

Currently, the department is scattered across ministries, which creates red tape and hinders both new technologies and government policy. In addition, when water management services, agriculture, and land authorities act uncoordinated, plans to adapt to the changes crumble.

Coordination decisions are crucial such as, organizing a service that would monitor how water is used in agriculture – and not only somewhere there, but everywhere, through local groups. It will be like a water management and farming center. Combining information is the game changer, inconsequence of Kazakhstan government should be initiative to build unified databases for collecting weather and purchasing data.

Due to bureaucratic problems – as a poor communication between departments and lack of experience among those who bring people together to use water - it is difficult to properly plan how to adapt to the changes. In order for new ways of working and technologies to work well, it is important to train farmers together with local officials, as well as help them get the information they lack.

Research shows that in order for technologies to take root in republic's agriculture, comprehensive assistance is needed – not only technology, but also new rules of the game and money. It is important to share experience with farmers, to help them sell what grows well in our climate, and it is also worth thinking about those who find it most difficult.

Recent work [33] shows that in order to increase agricultural efficiency, farmers need to be trained to save water, combine their efforts to use resources wisely, and provide small financial supports – for example, grants or preferential loans – for the purchase of smart irrigation systems with sensors. Together, this will help change agriculture for the better and for a long time.

In Central Asia, water, fields, and electricity are closely linked. In order for everything to work properly, it is necessary to reach an agreement between those who deal with water, farmers and energy companies – especially now, when the weather is changing. It is important to take into account how much water there will be at different times of the year, establish contacts between departments, and pay attention to the northern regions, where vegetable gardens are watered, and the southern regions, where water from the mountains is waiting. Then development will go smoother, and it will become easier for people to adapt to new conditions, because they live at the expense of nature.

In Arnasai village near Astana, the project helped people adapt to the changing weather themselves. How was it done? First, in the pilot project they carefully studied the local problems and strengths, then developed an action plan. Thanks to this approach, life in this agricultural region has become more stable, despite frequent temperature fluctuations.

The different economic projection models demonstrates that by investing seriously in protection against climate change, Kazakhstan will receive tangible profits. This will result in stimulation of new jobs across the country, fewer losses to farmers due to the weather, as well as good results from irrigation systems and modern farming methods. It turns out that it is worth expanding such measures. Below we present the 4 key factors to succeed in adaption for agriculture in our country, this initiatives are tailored according to the models that succeed in world practices.(figure 6)

Experience shows that in order for everything to work out in Kazakhstan, government and institutions need a constant, thoughtful approach. First, they will try new solutions on small projects, so they can check whether they are suitable for local conditions, refine them, and only then launch them everywhere. If the technologies are tailored to local conditions – the soil, climate, and people's lives – farmers are more willing to use them.

It is also important that they have access to money for a long time. We also need ways to keep track of what's going on, to understand where it's good and where it needs to be improved. Therefore, according to the according to the examination of the existing measures to improve and secure the important sector of out economy the different timeline goals are suggested in table 2.

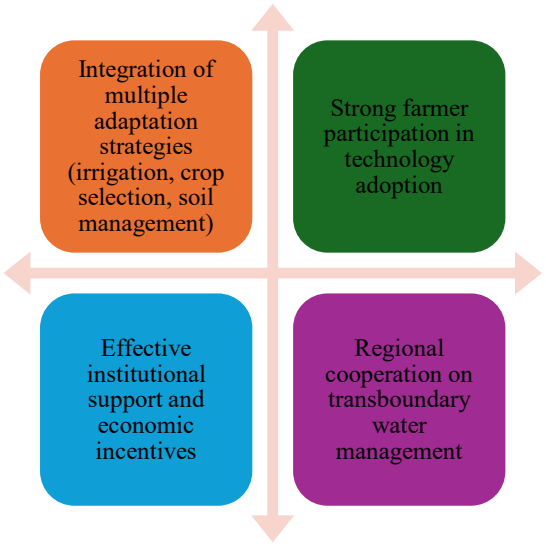

Figure 6 – Key success factors for integration of adaption strategies in Kazakhstan
Note: Authors compilation

Table 2 - Kazakhstan's future directions and policy roadmap for

Immediate Actions implementation	Medium-Term Goals	Long-Term Vision
Scale up pilot projects in drip and precision irrigation	Implement systematic irrigation infrastructure modernization	Achieve widespread adoption of climate-smart agricultural practices
Strengthen extension and advisory services	Support crop breeding programs for drought-tolerant varieties	Establish sustainable water management systems ensuring water security
Develop accessible credit mechanisms for smallholder adaptation	Strengthen value chains for climate-adapted agricultural products	Position Kazakhstan as a regional leader in dryland agriculture adaptation
Note: Author's compilation		

To assist Kazakhstan's agriculture integrate with the changing climate, new technologies, changes in industry management, and collaboration between different regions are needed. It is already clear that saving water during irrigation, plant varieties that are not afraid of heat, as well as smart methods of cultivating the land – all this really works. For everything to work out, government with respective authorities need to keep improving the basics, developing opportunities, and helping with business. The projections of exiting studies proves that step-to-step integration to the new conditions may boost economic well-being and sustainable growth.

RESEARCH RESULTS (CONCLUSIONS)

The climate is changing, and this is noticeable in Kazakhstan's agriculture – water is becoming scarce, land is being depleted, and crops are falling. Everything points to the fact that droughts are becoming more frequent, temperatures are rising, water is becoming less accessible, and the entire economy of the country is tied to the land. Considering that almost half of the water comes from other countries, and the irrigation system is outdated, the situation is ravaging. In addition, there are no clear rules for farming, and farmers have few opportunities to adapt. Agriculture sector of republic requires actions since the soil is acidifying, which is why fewer crops are harvested, and the weather is capricious, which worries farmers and should concern

population. If nothing is changed, the situation will only collapse, because then hunger can become a reality, and with it the welfare of the country's economy get destructed. However, getting used to the new conditions is not only realistic, but also beneficial. To become secured in future, it is worth using modern developments, seeking government support and establishing beneficial contacts with neighboring countries. For example, irrigation systems – drip, sprinkler, or with precise calculation of water supply – can reduce water consumption by a quarter or half, while increasing yields by a fifteenth to a thirtieth. To make farms better able to manage with the weather conditions, country can grow crops that are more productive at the higher temperature. It is also important to choose the right time for sowing. Modern farming methods – for example, when IT tools monitor fields – help save water and resources. The soil becomes healthier if it is cared for and various plants are grown. All this has already been tested in Kazakhstan in the example of pilot projects implemented. The main thing now is to spread and perform these useful methods throughout the country, not to invent new ones.

Now and in nearly future, our republic will find itself in a difficult situation: weather changes hit the country hard, although there is every chance of becoming a major player in the development of agriculture, even in the crisis conditions. If authorities invest wisely in modern technologies that might turn heat and drought in positive factor of growth for some yields. Calculations show that these are not empty words: such investments can provide jobs for about around 80 thousand people and even save national budget annually from losses due to unfavorable conditions. Kazakhstan is also able to share its best practices in adapting to new conditions in order to improve cooperation in the region, make grain exports more profitable taking into account weather changes and livestock farming, as well as interest foreign investors in new solutions in agriculture. However, the existing problems – the need for external water, old irrigation methods and lack of support – need to be urgently addressed, otherwise climate change will occur faster than we can adapt.

For everything to go according to best-case scenario, country needs to focus on four things at once. First of all, industry requires more defined finance for agriculture, which is weakened by the shifts to adaptation. The government, together with businesses, should upgrade the irrigation system and create funds to help farmers using money from international organizations. It is important to invest in smart farming, automatic watering and plant varieties that are not afraid of heat, because this way we can save water. To begin with, it's worth thinking about helping farmers with funds and training – for a reason, but depending on how well they work. It is important to give them the opportunity to take out loans and, in general, to have people working all over the country who would tell them how to properly water the fields, protect the land and grow different crops. Then we need to make sure that the organizations dealing with water resources builds up effective management system, considering water allocation in Central Asia. And yet, it would be game-changing to direct farmers to use natural fertilizers and choose those crops that suit the local climate, because this will help avoid problems with soil salinity.

Kazakhstan is at an important stage now. Climate change is a real problem that can be assessed, but there are solutions. To become a leader in the fight against negative climate change consequences, instead of suffering from it, the country needs to work quickly and harmoniously in all areas: technology, laws, organizations. If to invest wisely, change management and establish ties with strategic partners and succeeded countries in agriculture, Kazakhstan will be able to provide its population with the sustainable growth. It's time to act – otherwise it will only get costly for the economy and nature to stand. To sum up, Kazakhstan has every chance to lead the whole of Central Asia become stronger in the face of external factors in the name of climate change. The main task is not to delay the necessary actions.

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КЛИМАТТЫҢ ӨЗГЕРУІ ЖАҒДАЙЫНДА ҚАЗАҚСТАН АУЫЛ ШАРУАШЫЛЫҒЫНЫҢ ЭКОНОМИКАЛЫҚ ДАМУЫ

Т. Балтабай[1*], Л. Бимендиева[1], Ә. Калиева[1]
[1] Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан

АҢДАТПА

Зерттеу мақсаты – бұл мақала климаттық өзгерістердің Қазақстандағы ауыл шаруашылығының тұрақтылығына қалай әсер ететінін қарастырады, себебі экологиялық өзгерістер экономикалық әл-ауқат пен ұзақ мерзімді даму үшін маңызды.

Әдіснамасы – зерттеуде сипаттамалық талдау әдісі қолданылып, температураның өсу тенденциялары, жауын-шашынның өзгеруі, құрғақшылықтың күшеюі және олардың егін өнімділігі, мал шаруашылығы, топырақ деградациясы және тұщы су ресурстарына әсері бағаланады.

Зерттеудің бірегейлігі / құндылығы – бұл жұмыс Орталық Азиядағы климаттық тәуекелдер туралы білімді кеңейтіп, экологиялық өзгерістерді Қазақстанның макроэкономикалық тұрақтылығымен байланыстырады және елде пилоттық жобалар ретінде енгізілген жергілікті бейімделу шараларын ескереді.

Зерттеу нәтижелері – нәтижелер көрсеткендей, жоғары температура, азаюшы жауын-шашын, ұзақ құрғақшылық және шөлейт аумақтардың ұлғаюы ауылдық жерлердегі тұрақты азық-түлікке қолжетімділік пен кіріс көздеріне қауіп төндіреді. Практикалық ұсыныстарға тиімді суару жүйелері, әртараптандырылған егін егудің модельдері және экстремалды жағдайларға бейімделген технологиялар кіреді, бұл зиянды азайтып, әлеуметтік бейімделу мен экономикалық тұрақтылықты арттыруға мүмкіндік береді.

Түйін сөздер: ауыл шаруашылығы; климаттық өзгерістер; Қазақстан; бейімделу; тұрақтылық

Алғыс. Бұл зерттеу Қазақстан Республикасының Ғылым және жоғары білім министрлігінің Ғылым комитеті тарапынан қаржыландырылды (Грант № AP26103913 «Климаттың өзгеруінің ұзақ мерзімді макроэкономикалық салдарын талдау: Қазақстанның агроөнеркәсіптік кешені – орнықты дамудың өсуінің жаңа нүктесі»).

ЭКОНОМИЧЕСКОЕ РАЗВИТИЕ СЕЛЬСКОГО ХОЗЯЙСТВА КАЗАХСТАНА В УСЛОВИЯХ ИЗМЕНЕНИЯ КЛИМАТА

Т. Балтабай[1]*, Л. Бимендиева[2], А. Калиева[3]
[1] Казахский национальный университет имени Аль-Фараби, Алматы, Казахстан

АННОТАЦИЯ

Цель исследования – данная статья исследует, как климатические изменения влияют на устойчивость сельского хозяйства в Казахстане, подчеркивая, что экологические изменения напрямую воздействуют на экономическое благополучие и долгосрочный рост.

Методология – используется метод описательного анализа для оценки тенденций потепления, неравномерного распределения осадков, усиливающейся засухи и их влияния на урожайность, продуктивность животноводства, деградацию почв и наличие пресной воды.

Оригинальность / ценность исследования – исследование расширяет существующие знания о климатических рисках в Центральной Азии, связывая экологические изменения с макроэкономической устойчивостью Казахстана и учитывая местные адаптационные меры, уже опробованные в стране.

Результаты исследования – результаты показывают возрастание стрессовых факторов вследствие повышения температуры, снижения осадков, продолжительных засух и расширения аридных зон, что угрожает стабильному доступу к продуктам питания и доходам сельских жителей. Практические рекомендации включают улучшенные системы орошения, диверсифицированные модели посевов и технологии, устойчивые к экстремальным условиям, что позволяет снизить ущерб и повысить социальную адаптивность и экономическую стабильность.

Ключевые слова: сельское хозяйство; климатические изменения; Казахстан; адаптация; устойчивость

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ABOUT THE AUTHORS

Baltabay Tomiris– PhD Student, HSEB, Al-Farabi Kazakh National University, Almaty, Kazakhstan, e-mail: tomiris.baltabay@gmail.com, ORCID: 0009-0006-5058-7729

Bimendiyeva Laila – Candidate of Economic Sciences, Associate Professor, HSEB, Al-Farabi Kazakh National University, Almaty, Kazakhstan, e-mail: leila.bimendiyeva@kaznu.edu.kz, ORCID: 0000-0003-4965-5908

Kaliyeva Assem – PhD, Senior Lecturer, HSEB, Al-Farabi Kazakh National University, Almaty, Kazakh-stan, e-mail: assem.kaliyeva@gmail.com, ORCID: 0000-0002-1154-4287

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СТРАТЕГИЧЕСКИЕ ОРИЕНТИРЫ РАЗВИТИЯ КАЗАХСТАНА В ГЛОБАЛЬНЫХ ЦЕПОЧКАХ СОЗДАНИЯ СТОИМОСТИ КРИТИЧЕСКИХ МИНЕРАЛОВ

Г. М. Аубакирова[1], П. К. Салибекова[2]*, Г. Б. Исатаева[3]
[1] Карагандинский технический университет имени Абылкаса Сагинова, Караганда, Казахстан
[2] Алматы Менеджмент университет, Алматы, Казахстан
[3] Южно-Казахстанский Педагогический Университет имени Узбекали Жанибекова, Шымкент, Казахстан

АННОТАЦИЯ

Цель исследования – анализ роли критически важных ресурсов в диверсификации экономики Казахстана и оценка стратегии перехода страны на более высокие уровни глобальных цепочек создания стоимости.

Методология – для комплексной оценки факторов, влияющих на позиционирование Казахстана в цепочках поставок критических минералов, использованы систематический обзор литературы, PESTEL-анализ внешней среды, SWOT-анализ внутренних факторов и матрица стратегий TOWS.

Оригинальность / ценность исследования – авторы интегрируют геополитический анализ с экономической оценкой потенциала развития перерабатывающих отраслей Казахстана в контексте глобального энергетического перехода. Рассмотрены возможности страны по продвижению в глобальных цепочках создания стоимости критических минералов с применением матрицы TOWS для формирования конкретных стратегических инициатив.

Результаты исследования – установлено, что при наличии 124 месторождений РЗМ и значительных запасов критических минералов, доля высокотехнологичного экспорта составляет лишь 26,9%. Обосновано, что для продвижения в глобальных цепочках стоимости Казахстану необходимо преодолеть технологические ограничения и развивать международное сотрудничество. Разработана матрица стратегических инициатив (TOWS), включающая создание совместных предприятий с технологическими лидерами, диверсификацию экспортных рынков, привлечение международных партнеров для трансфера технологий и переходу «зеленой» экономике.

Ключевые слова – критические важные ресурсы, Казахстан, диверсификация, энергетический переход, устойчивость, государственное регулирование.

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