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THE IMPACT OF CLIMATE-OPTIMIZED FARMING METHODS ON INCREASING COTTON YIELDS

***Abstract**. Cotton is one of the main raw materials in the textile industry. Cotton yield is directly affected by the climatic conditions of the growing region. In case of favorable climatic conditions, cotton has a high productivity potential. The main factors that play a leading role in this process include temperature stability, humidity level, soil fertility, and the presence of pests. To successfully grow cotton, it is necessary to take all these factors into account and develop adaptive strategies, including the use of modern agronomic methods and technologies that will help optimize the production process in a changing climate. Climate-smart agricultural practices can have a long-term impact on cotton yield. Taken together, this implies the use of more climate-resistant varieties and new irrigation technologies.*

The paper analyzes the impact of climate-smart agricultural practices and identifies and formulates the prerequisites for increasing cotton yield. These methods will facilitate the adaptation of farms to changing climate conditions, which will be reflected in increased productivity and sustainability of agriculture in the long term. The article also examines the economic effect of climate-optimized farming methods. The introduction of such methods allows for an increase in the yield of cotton by 10-30%, which contributes to the growth of profitability of farms. Optimizing the use of resources such as water and fertilizers through precise irrigation and sustainable varieties reduces production costs. Moreover, sustainable production can attract premiums for environmental friendliness, as well as access to markets where products with a low carbon footprint are valued. Together, this leads to an increase in the competitiveness and sustainability of cotton farms, especially in conditions of limited natural resources.

***Keywords**: cotton, textile industry, climatic conditions, management methods, economic effect, agriculture.*

Introduction

Relevance

The imperative of this research is substantiated by contemporary trends related to climate change, which, in turn, exert a profound influence on agriculture, specifically examined in the climatically vulnerable Turkestan region of Kazakhstan. Among crops, cotton holds a pivotal position in the area, playing a substantial role in the regional economy. Nonetheless, ongoing global climate alterations – manifesting as excessive heat, insufficient precipitation, and other phenomena attributable to global warming – pose a substantial threat to the sustainability and productivity of cotton cultivation.

It is essential to place considerable emphasis on the effort to ascertain the extent to which agricultural practices must be adapted to climate variability. Identifying the climate change variables that jeopardize cotton yields, alongside devising strategies to mitigate the adverse effects of climate change on yields, has become of paramount importance for ensuring food security and promoting sustainable agriculture in the region.

The relevance of this study is further accentuated by the need to develop alternative and enhanced agro technical methods for cotton cultivation, aiming to preserve and augment yields with minimal alteration to the area and resource inputs. In light of the escalating influence of climate change, the conclusions presented in this research could provide a foundation for the development of more effective cultivation practices, enabling better adaptation to evolving climate conditions.

Scientific Significance

About non-irrigated conditions, there is a general decline in yield across all scenarios, indicating that efforts should prioritize the implementation of irrigation systems and the adjustment of planting dates to mitigate losses. The availability of these studies suggests that devising solutions to align with the evolving climatic conditions of a region would be advantageous, including optimizing planting times, developing irrigation strategies, and breeding more resilient crop varieties. Such approaches are essential for safeguarding the future of cotton production in the context of global climate change.

The study's findings emphasize the significance of the temperature regime in enhancing cotton production under changing climatic conditions. The regression analysis revealed that temperature positively affects yield growth. Specifically, increasing the average temperature by 1°C leads to a 5 to 7 quintal per hectare increase in cotton productivity. This result supports earlier postulated hypotheses concerning maintaining appropriate temperature levels to ensure optimal yields in cotton cultivation.

However, other climatic shifts experienced by farmers, such as alterations in precipitation patterns alongside rising temperatures, pose serious challenges to the sustainable development of cotton farming. When temperatures exceed 37°C, photosynthetic efficiency decreases, resulting in lower overall yields. These climatic changes further aggravate the yield challenges in regions like the Turkestan area of Kazakhstan, where temperature fluctuations and unpredictable rainfall are becoming increasingly common.

Analyzing the collected data allows the conclusion that climate-adapted farming techniques are not only instrumental in improving yields but are also imperative for the continued expansion of agricultural production.

Research Objective

This research seeks to evaluate the effects of climate conditions, particularly temperature and rainfall, on cotton production in the Turkestan region of Kazakhstan. Given the distinct climatic characteristics of this key cotton-producing region, it is crucial to understand how changes in these factors impact production. The objective of this study is to identify the critical climatic conditions that influence cotton crop growth and to assess whether climate-optimized agricultural practices that boost yield are viable. Through this comparison, the study aims to guide the sustainable cultivation of cotton in response to increasing climate volatility and unpredictability.

Main body

Literature Review

Cotton yield is highly contingent on climatic factors, and numerous studies have focused on enhancing the capacity of agricultural systems to address the challenges posed by climate change. To the best of the researcher's knowledge, Anapalli S. S. et al. [1] conducted a study on the impact of climate change on the cotton planting season in the lower Mississippi Delta region. In their work, the authors integrated long-term climate data with the CSM-CROPGRO-Cotton v4.6 model to determine optimal planting times for cotton under both irrigated and rainfed conditions. The study demonstrated that adjusting planting dates, specifically planting a second crop, significantly improves yields, particularly under irrigation conditions, where it increased cotton yields to 1000 kg/ha compared to non-irrigated scenarios. These findings emphasize the necessity of aligning planting dates with shifting climate parameters to achieve optimal results.

Gérardeaux E. et al. [2] employed the CROPGRO-cotton model to evaluate the possibilities for adaptation in rain-fed tropical agriculture in Sub-Saharan Africa. Their research demonstrated that the development of new cotton varieties with broader adaptability, higher leaf area index, enhanced photosynthetic efficiency, and increased resistance to adverse climate changes could bolster resilience. Furthermore, computer simulations indicated that, by 2050, climate change will not drastically impact cotton yields in northern Cameroon, though it will shift the months associated with rainfall. This research highlights the importance of establishing future priorities for improving climate change resilience in rain-fed agricultural regions of Africa through the cultivation of new cotton varieties.

Anapalli S.S. et al. [3] also examined the vulnerability of cotton farming in the Mississippi Delta to climate change and proposed various adaptation strategies. A series of simulations assessed the potential impact of climate change on projected cotton yields using the CROPGRO-cotton model under wide greenhouse gas emission scenarios (RCP). The results predicted that moderate emissions—RCP 2.6, 4.5, and 6.0—would increase cotton yields by 2050 and 2080, while the highest emission scenario, RCP 8.5, would lead to a decrease in yields by 2080.

Methods

This study employed a quantitative research approach and utilized regression analysis to examine the relationship between climatic factors and cotton yields in Kazakhstan. The primary data were collected for 2019-2023, encompassing yield indicators for cotton as well as relevant climatic factors, specifically temperature and precipitation levels in March, which are critical for the growth of this crop. The data collection strategy involved accessing regional meteorological records alongside statistical information on agricultural activities.

Two principal independent variables were selected for analysis: the average annual temperature and total annual rainfall, with a particular emphasis on the month of March. The dependent variable was the yield realized from cotton cultivation. Multiple regression analysis was conducted to ascertain the correlation between climatic factors and yield. This analysis incorporated Ridge regression and Lasso regression models, which account for potential multicollinearity among variables, thereby enhancing the stability of the estimates.

To assess the effectiveness and quality of the model, the R^2 coefficient and forecast errors were analyzed. Using these metrics, we were able to estimate the predicted increases or decreases in yield based on variations in climatic factors.

Consequently, the results detailed the impact of each identified climatic factor on cotton yield, facilitating the identification of those factors of greatest significance for agricultural production. The application of regression analysis enabled the quantification of the influence of climate change on cotton yields and provided recommendations for adjustments to agrotechnical practices that would enhance agricultural resilience in the face of climate change.

Results

Studying climatic conditions in agriculture plays an important role in solving the problem of increasing the yield of agricultural crops. This issue is especially relevant for those countries where cotton is one of the main crops. In modern conditions, the principles of using climatically optimized farming methods have been developed and are being actively implemented in the world, which can significantly increase cotton yields [4].

Currently, cotton is widely cultivated in more than 90 countries around the world. 2.5% of the world's arable land is allocated for cotton. The main types of cotton are as follows:

- Gossypium hirsutum (common cotton) occupies more than 90% of the world's crops.
- Gossypium herbaceum (herbaceous cotton) the area of growth is Pakistan, India, and partly Africa.
- Gossypium barbadense (Barbadian cotton) is grown in Egypt, Sudan, USA, Brazil, and Peru.

- Gossypium arboreum (cotton tree) is cultivated in Pakistan, Sri Lanka and India.

The main condition for growing cotton is a warm climate. The leading cotton producers include China, the USA, Uzbekistan, Brazil, and Turkey [5].

Climatic conditions have a significant impact on the process of growing cotton, as this crop is sensitive to environmental influences. The following factors can be attributed to the optimal climatic conditions for cotton:

- Temperature: a warm climate is needed to grow cotton. The optimal temperature regime for its development is the corridor from 21 to 37 °C. Below the set temperature, cotton does not ripen, and above it, lint does not have time to form before drying. The temperature regime is directly related to the final decision of which kind of cotton is suitable for growing in a particular area. Thus, extreme temperatures negatively affect yields, which leads to the need to consider this climatic parameter when growing cotton.
- Precipitation: sufficient water is needed to grow cotton, even though the crop as a whole is drought-resistant. In particular, cotton needs water during the flowering period and the formation of pods. Lack of water resources will lead to a decrease in cotton yields, while excess will cause the growth of plant diseases. Scientists have identified the following relationship between optimal daily growth depending on water quality and plant height, shown in Figure 1.
- Lighting: cotton is a light-loving plant. An insufficient period of sunlight intake leads to a decrease in photosynthesis processes, which leads to a decrease in yield. With a lack of light, cotton begins to develop slowly, which leads to the dumping of young pods in the reproductive period. According to the observations of scientists in the Tashkent region, on a sunny day, the assimilation in 1 hour of 1m2 of the leaf surface of the medium-ripened variety was 1.46 g, and the one precocious was 1.45 g. On the next cloudy day, the intensity of assimilation decreased sharply: in the medium-ripened variety to 0.0073 g, and in the precocious variety to 0.06 g [6, 7].

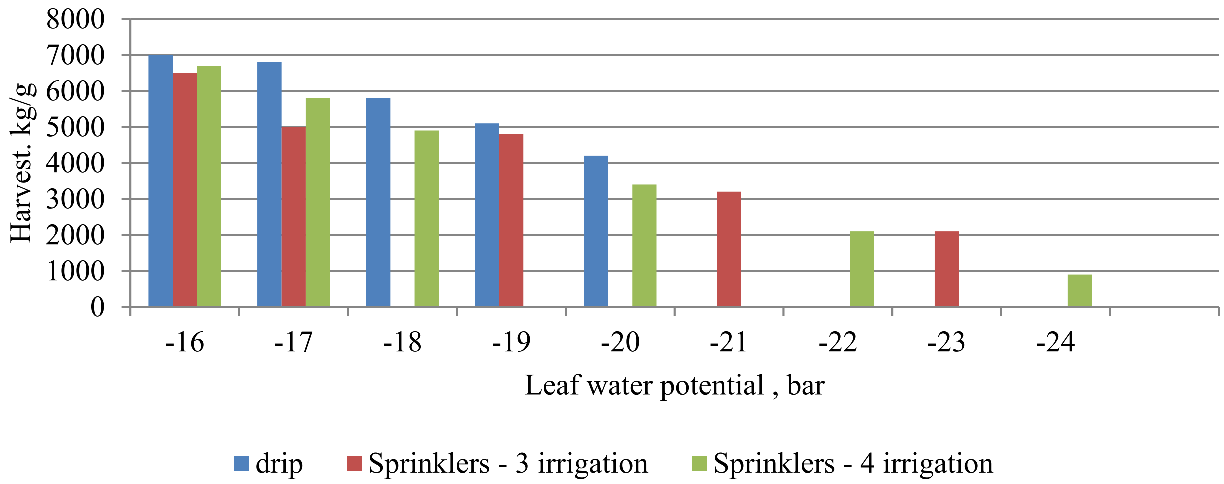

Fig.1. The relationship between optimal daily growth depending on water quality and plant height

- the level of carbon dioxide in the atmosphere: an increase in its concentration has a positive effect on the growth of cotton since carbon dioxide is necessary for photosynthesis. At the same time, there is a danger of new pests and diseases.
- Climate change: Global climate transformations have an impact on regions traditionally engaged in cotton cultivation. Changes in temperature and precipitation levels lead to lower yields in some regions while creating new opportunities for others.

- adaptation and varietal selection: by developing new sustainable cotton varieties capable of adapting to changing climatic conditions, it becomes possible to reduce the negative effects of ongoing climatic transformations.

In this context, we will examine the cotton yield in Kazakhstan over the five years from 2019 to 2023 (Figure 2) alongside the air temperature data for the Turkestan region (Figures 3-4).

Climatically optimized farming methods are aimed at adapting agricultural practices to changing climatic conditions. These methods include the use of sustainable plant varieties, effective management of water resources, the use of organic fertilizers, and the use of technologies for monitoring and forecasting the weather [8, 9].

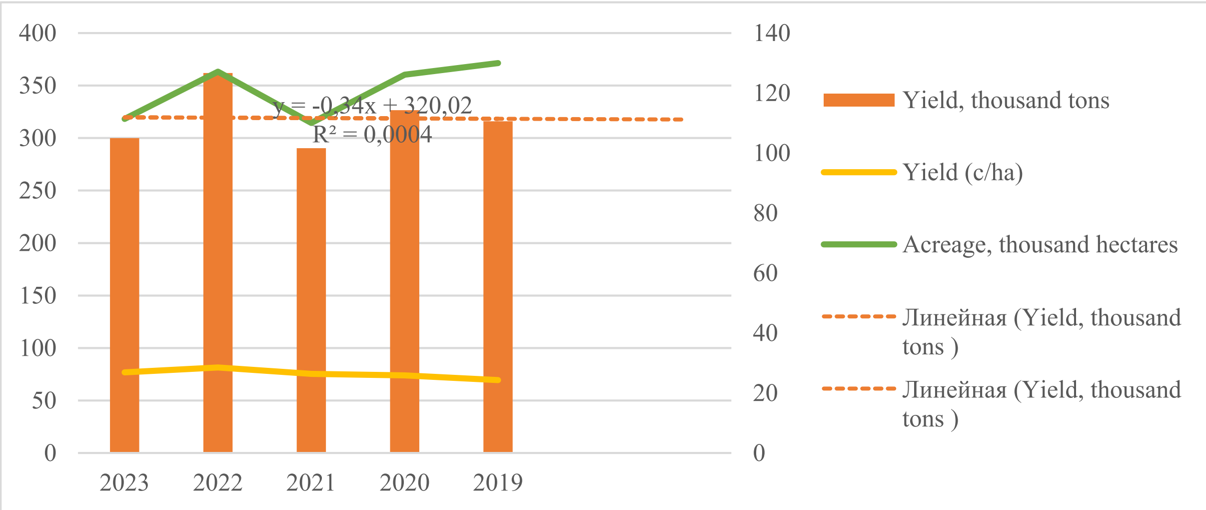

Figure 2. Cotton yield in Kazakhstan during the five-year period from 2019 to 2023

We analyze the temperature in the Turkestan region, as it is the sole area in Kazakhstan where cotton is cultivated and where the majority of greenhouses (over 67%) are concentrated, covering a total area of 844 hectares. The region produces more than 300,000 tons of cotton annually and hosts 22 cotton processing plants, employing approximately 25,000 individuals in production.

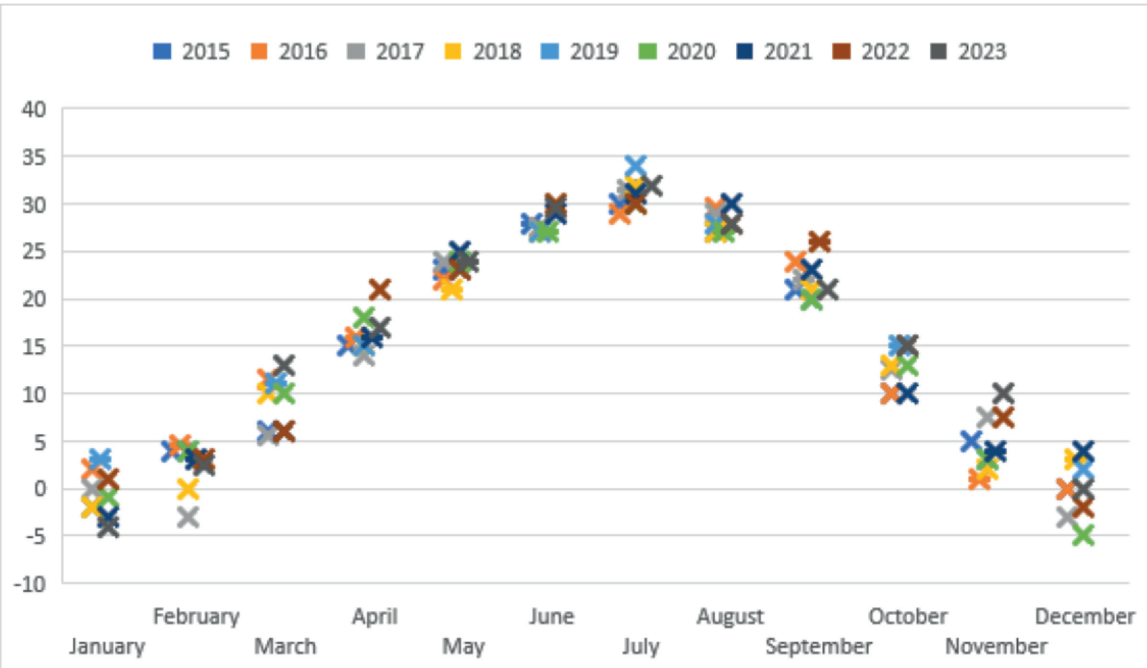

Figure 3. Temperature in the Turkestan region from 2015-2023, °C

A wet day is defined in this study as any day with 0.04 inches or more of liquid or liquid-equivalent precipitation. In the Turkestan region, the frequency of rainy days varies throughout the year, allowing us to identify several periods with a high probability of precipitation occurrence.

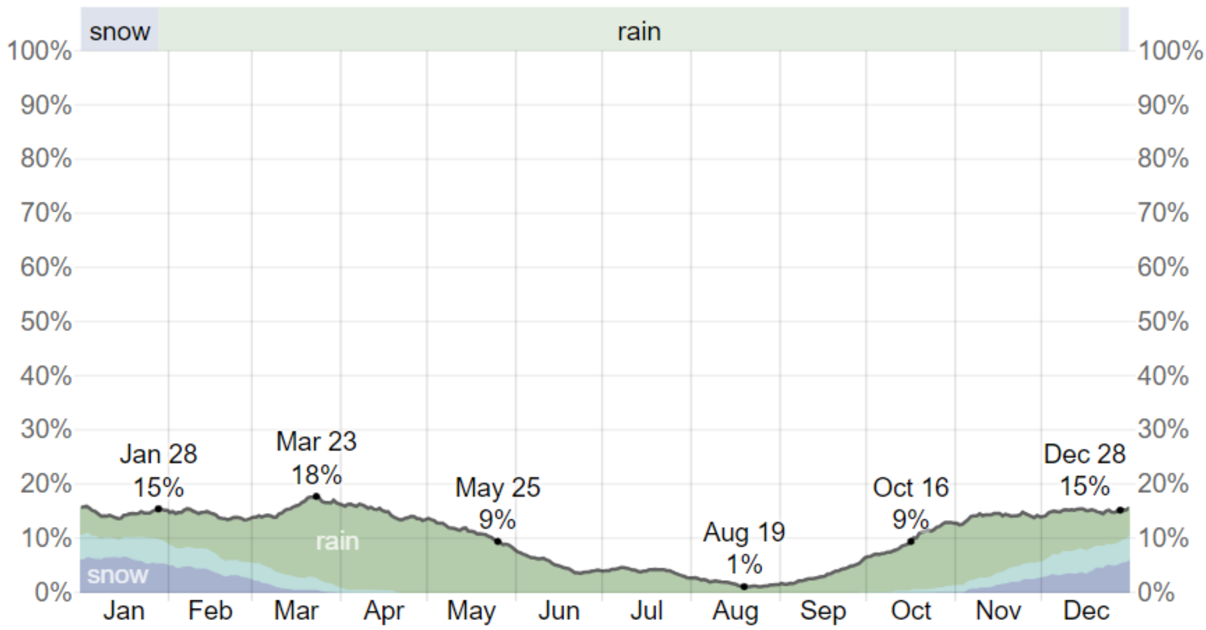

Figure 4. Daily probability of precipitation in the Turkestan region [10]

The likelihood of encountering a rainy day exceeds 9% during the wetter period, which extends from October 16 to May 25. The number of days with at least 0.04 inches of precipitation peaks in March, averaging approximately 4.9 days.

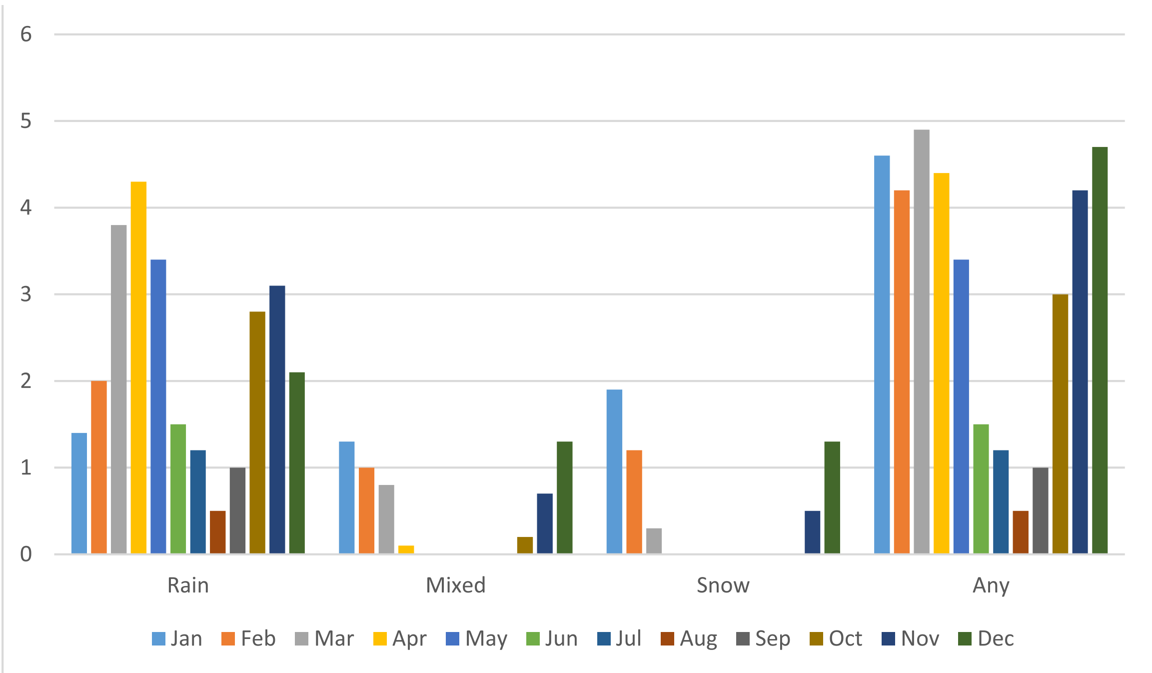

Figure 4. Distribution of Precipitation Types by Month: Rain, Mixed Precipitation, and Snow in the Turkestan Region

The 4.7-month dry season occurs from May 25 to October 16. Based on the aforementioned data, August is recognized as the month with the least frequency of wet days, averaging only 0.5 days per month with at least 0.04 inches of precipitation. We further categorize rainy days into those with only rain, only snow, and those with both.

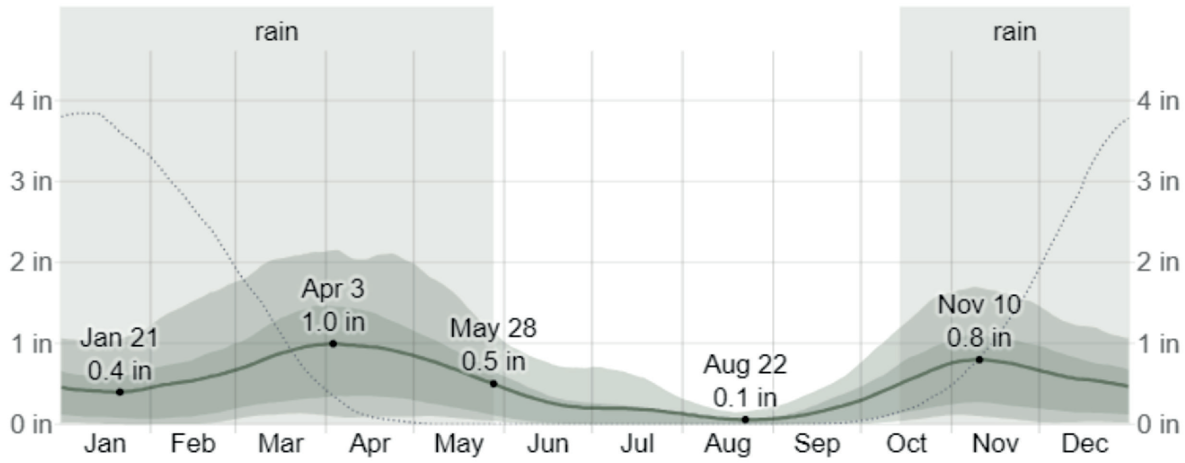

Figure 5. Average monthly precipitation in the Turkestan region [10]

For wet days, we have additional subcategories: days with only rain (Figure 5), only snow, and days with both forms of precipitation. According to this classification, rain predominates in the region throughout the year. For 11 months, from January 28 to December 28, rain is the most common precipitation type. April experiences the highest frequency of rainfall, averaging four days over a 30-day period.

Among the precipitation types, snow is most prevalent for one month, occurring from December 28 to January 28. The average number of days with only snow in the Turkestan region is 1.9 days, predominantly in January.

To illustrate the variability within calendar months rather than merely presenting monthly totals, we plotted daily rainfall using 31-day moving averages for each day of the year. There is a slight fluctuation in rainfall amounts over the twelve months in the Turkestan region.

The precipitation season spans seven and a half months, from October 14 to May 28, with a sliding 31-day rainfall of at least half an inch. The maximum rainfall recorded in Turkestan occurs in April, averaging 25.4 mm.

The rainy season lasts only 4.5 months, from May 28 to October 14, characterized by limited rainfall. The lowest precipitation levels are observed in August, averaging 0.1 inches or 2.5 mm.

Next, we will examine the statistics on emissions of liquid and gaseous substances into the atmosphere in the Turkestan region.

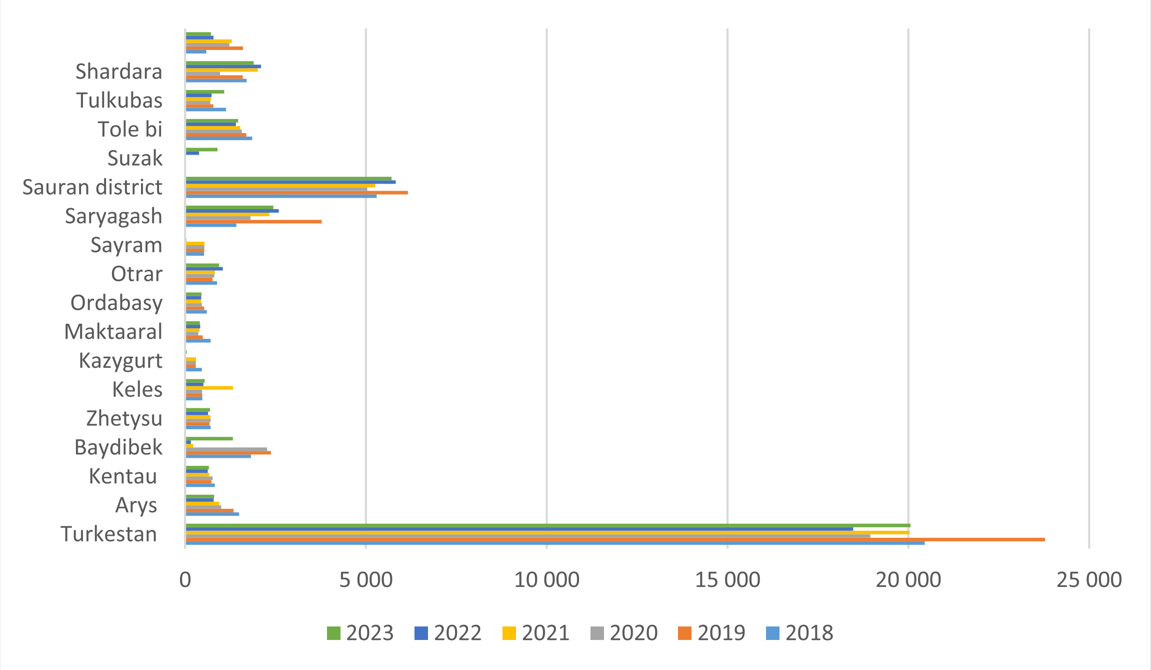

Figure 6. Emissions of liquid and gaseous substances into the atmosphere in the turkestan region (2018 to 2023)

Consequently, it is essential to analyze the relationship between climate change and cotton yields. To avoid overfitting the model and to mitigate the effects of noise in the data, Ridge or Lasso regression methods are preferable. These regularization techniques assist in preventing overfitting, particularly in situations with small sample sizes or multiple parallel tests.

In cases of limited observations, the bootstrap procedure can be employed to obtain more accurate estimates. This method enables us to generate resamples for corresponding calculations, thus enhancing statistical conclusions, even with a small dataset.

When considering coefficient variability, especially given the relatively small sample size, Bayesian regression provides probabilistically more relaxed estimates, accommodating data variability and potential scenarios associated with the coefficients (Figure 7).

```
from sklearn.linear_model import Ridge, Lasso, BayesianRidge
from sklearn.preprocessing import StandardScaler
from sklearn.utils import resample
import numpy as np
```

```
data = {
    'Year': [2019, 2020, 2021, 2022, 2023],
    'Yield': [243, 259, 264, 285, 269],
    'Temperature': [154, 142, 148, 157, 157],
    'Rain_days': [4.6, 3.4, 4.9, 4.2, 4.7],
}
```

```
df = pd.DataFrame(data)
Y = df['Yield']  # Урожайность хлопка
X = df[['Temperature', 'Rain_days']]
```

```
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)
ridge = Ridge(alpha=1.0)
ridge.fit(X_scaled, Y)
```

```
Ridge()
```

```
lasso = Lasso(alpha=0.1)
lasso.fit(X_scaled, Y)
bayesian_ridge = BayesianRidge()
bayesian_ridge.fit(X_scaled, Y)
```

```
BayesianRidge()
```

```
coef_samples = []
for i in range(1000):
    X_resampled, Y_resampled = resample(X_scaled, Y)
    model = sm.OLS(Y_resampled, sm.add_constant(X_resampled)).fit()
    coef_samples.append(model.params)
```

```
bootstrap_means = np.mean(coef_samples, axis=0)
ridge_coef = ridge.coef_
lasso_coef = lasso.coef_
bayesian_ridge_coef = bayesian_ridge.coef_

ridge_coef, lasso_coef, bayesian_ridge_coef, bootstrap_means
```

Figure 7. Ridge regression, Lasso regression, and Bayesian regression

Utilizing the results from the Ridge regression model, we find that an increase in temperature by 1°C, holding other factors constant, correlates with an increase in yield by 5.48 quintals per hectare. Conversely, for each additional rainy day, yield decreases by 3.20 quintals per hectare. Similarly, the Lasso regression model indicates that each 1°C rise in temperature yields an increase of 7.41 quintals per hectare, while an increase in rainy days results in a loss of 4.84 quintals. Bayesian regression produced significantly lower coefficients, suggesting high variability in the model, indicating that the impact of climatic factors on yield, as demonstrated by other models, may not be very strong. Bootstrap analysis indicated that the influence of temperature is significant at 12.61, while the variability of the rainy days is high, making their impact more difficult to estimate accurately.

In general, it can be stated that temperature positively influences cotton yield, corroborated by all models, though the extent of this impact varies. In contrast, rainy days negatively affect yield, with the Bayesian regression indicating the smallest effect.

Thus, climatic conditions significantly influence the cotton growing process. Climate change can yield both positive and negative effects on this crop in various regions worldwide. Cotton is particularly sensitive to fluctuations in climatic conditions such as temperature, humidity, and precipitation. Currently, researchers are developing and actively implementing climate-optimized agricultural practices.

The use of climate-optimized farming methods can lead to an increase in cotton yields. For example, resistant plant varieties can help plants better tolerate high temperatures and drought. Effective water management allows water to be used more efficiently, which can also increase yields. However, it is worth noting that the impact of climate-optimized farming methods on increasing cotton yields may depend on many factors, including specific climatic conditions, cotton grade, and other factors [11].

Based on the generalization of available data, it is possible to identify and structure approaches and technologies that are the basis for the application of climate-optimized farming methods:

1. *Promoting crop sustainability* Selection of plant varieties resistant to climatic stresses such as drought, salinization, and diseases. The use of genetically modified organisms (GMOs) and traditional breeding methods to create varieties more resistant to climate change.

2. *Agroecological practices*: The application of methods that take into account ecosystem principles, such as crop rotation, mixed crops, and the use of cover crops to improve soil health and moisture storage.

Climate change has a significant impact on agriculture. In this case, the introduction of climate-optimized farming methods is taking an increasingly leading position. From the point of view of cotton production, these methods can significantly increase such indicators as yield and quality of final products [12, 13].

3. *Intensive use of resources*: Optimization of water use through drip irrigation, sprinkling, and other modern irrigation systems that allow efficient use of water and reduce losses.

It is important to note that water is one of the most important natural resources in cotton cultivation. Nevertheless, in the Turkestan region, inefficient use of this type of resource is observed due to outdated irrigation infrastructure, significant water losses during transportation, and low implementation of modern water-saving technologies. These methods of irrigation include furrow and surface irrigation and characterized by high rates of evaporation and filtration of water. For this reason, a large portion of the water supply for irrigation is lost even before it reaches the agricultural land reducing yields and increasing the cost of using water.

Therefore, to solve this problem, the adoption of new ideas like drip irrigation and specialized sensors for determining soil moisture as key aspects of sustainable technologies is required. These technologies can reduce water consumption to the greatest extent due to their targeted delivery to the roots of plants while avoiding losses and maximizing yields. It is only possible to achieve further sustainable and cost-effective production of cotton where natural resources are scarce by better management of water. The levels of influence of climate-optimized methods the presented in the following Figure 8.

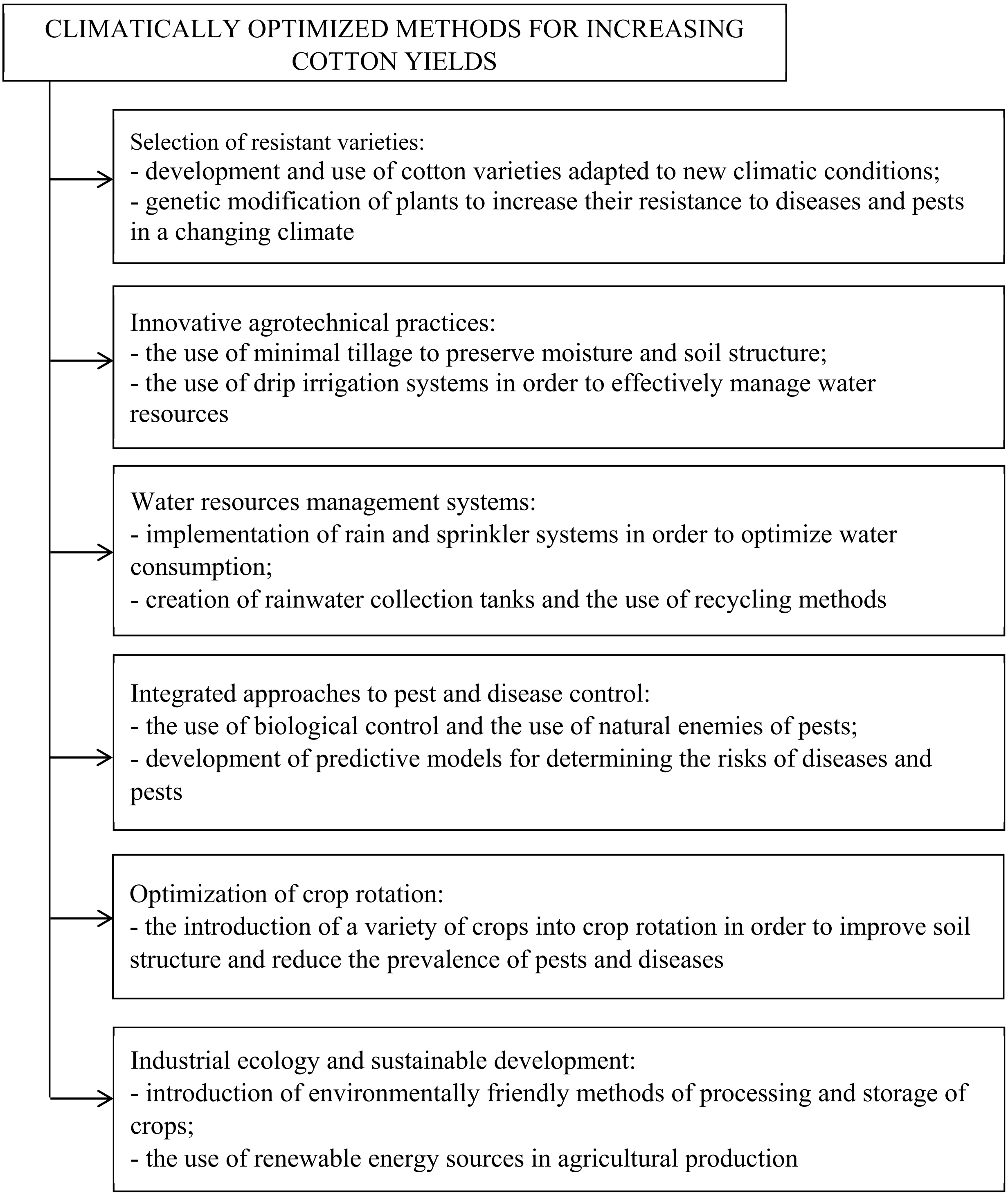

Fig. 8. Climatically optimized methods for increasing cotton yields

Reducing greenhouse gas emissions: The application of methods aimed at reducing the carbon footprint of agricultural operations, such as minimal tillage, agroforestry and the use of organic fertilizers.

Water resources management: The introduction of technologies for collecting and storing rainwater, as well as the creation of systems for recycling and efficient use of water.

Monitoring and prediction systems: The use of technologies such as satellite systems and sensors to monitor the condition of crops and soil, as well as to predict weather conditions, which allows for more informed decisions.

Education and dissemination of information: Training farmers in new farming methods and sharing experiences between agricultural producers to optimize practices.

Mixed agriculture: Integration of crop and livestock production, which allows for more efficient use of available resources and increase the sustainability of agroecosystems.

To conduct an accurate analysis of the efficiency of water use in cotton cultivation in the Turkestan region, it is necessary to rely on statistics on water consumption by cotton, cotton yield and water efficiency.

The economic efficiency of water use in cotton cultivation can be estimated using a formula that relates yield to the volume of water consumed:

$$E = \frac{Cotton\ yield\ (kg/ha)}{Water\ Consumption\ (m^3/ha)}$$

Below is a table with the results of the efficiency analysis before and after the introduction of water-saving technologies (Table 1).

Table 1. The results of the efficiency analysis before and after the implementation of water-saving technologies

Before the implementation of the methods			
Year	Water Consumption (m3/ha)	Cotton yield (kg/ha)	Water use efficiency
2019	10,735	1,980	$E = \frac{1980}{10735} \approx 0.18$
2020	10,564	2,050	$E = \frac{2050}{10564} \approx 0.19$
2021	9,872	2,300	$E = \frac{2300}{9872} \approx 0.23$
2022	9,452	2,850	$E = \frac{2850}{9452} \approx 0{,}30$
2023	8,415	3,122	$E = \frac{3122}{8415} \approx 0{,}37$
After the implementation of the methods			
2024	5823	3523	$E = \frac{3523}{5823} \approx 0{,}61$
2025	5478	3825	$E = \frac{3825}{5478} \approx 0{,}7$
2026	5284	4029	$E = \frac{4029}{5284} \approx 0{,}76$
2027	5113	4261	$E = \frac{4261}{5113} \approx 0{,}83$
2028	4987	4418	$E = \frac{4418}{4987} \approx 0{,}89$

The forecast for 2024-2028 shows that the introduction of water-saving technologies will continue to improve the efficiency of water use. By 2028, the efficiency will reach 0.89 kg/m3, while reducing water consumption to 4987 m3/ha and increasing cotton yield to 4418 kg/ha. This trend indicates a significant potential for sustainable growth in the agricultural sector.

The following results will result from the introduction of climate-optimized methods to increase cotton yields:

- yields will increase due to the introduction of climate-resistant varieties, as well as the development of effective agrotechnical practices [14];
- improving the quality of cotton through the use of optimized methods will lead to an increase in their cost and competitiveness;
- cost reduction by saving water and other resources through the use of effective irrigation and tillage methods [15, 16];

- ecosystem conservation based on the introduction of environmentally friendly approaches to improve soil conditions and biological diversity.

To assess the economic impact of climate-optimized farming methods on increasing cotton yields, several key factors that have a direct impact on the production economy are considered:

1. Increase in productivity. Optimizing farming methods to adapt to the climate can improve plant resistance to droughts, extreme temperatures and other adverse conditions. The introduction of agricultural technologies such as drip irrigation, mulching, minimal tillage and the use of more resistant varieties can increase yields by 10-30%, depending on the region and initial conditions. An increase in cotton yields means a direct increase in the profitability of farms, as this leads to an increase in harvest volumes at the same cost of acreage.

2. Reducing resource costs. Climate-optimized methods such as precision farming help reduce water, fertilizer, and pesticide consumption. In the case of cotton farming, which requires a large amount of water, such measures can lead to significant cost reductions. For example, precision irrigation systems that optimize water consumption can reduce water costs by 20-50%, which is especially important for regions with water scarcity.

3. Reducing the risk of losses due to climatic conditions. The use of sustainable methods reduces the likelihood of crop losses from climatic extremes. Resistant varieties adapted to drought or elevated temperatures allow you to maintain stable yields and profitability. Lower crop losses due to the prevention of climate risks ensure income stability and may reduce the need for insurance against climate risks.

4. Awards for eco-friendly production. There is a growing demand on the global market for products manufactured taking into account climatic requirements. For example, certification programs like the Better Cotton Initiative (BCI) offer awards to farmers who follow sustainable practices. Cotton produced with a minimum carbon footprint and in compliance with environmental standards can be sold at higher prices, which further increases profitability.

5. Reducing greenhouse gas emissions and improving soil health. Methods such as minimal tillage and the use of siderites help to increase the carbon content in the soil and reduce carbon dioxide emissions, which can open access to "carbon credits". This allows farmers to earn additional income by selling such loans on international markets.

With the standard approach, the average yield is 1.5 tons of cotton per hectare, and thanks to climate-optimized methods, it increases to 1.8 tons, which will give an increase of 20%. With an average price of 1 ton of cotton on the world market of about $1,500, the yield will increase by $450 per hectare. If cost reductions and additional bonuses are included, the overall economic effect can be even greater. Climate-responsive agricultural optimization is not only a way to increase yields, but also a strategic step for long-term economic growth and agricultural sustainability.

Discussion

Climate change in the world is an inevitable fact that dictates the need for agriculture to implement climate-optimized methods. Issues of increasing the sustainability of cotton production in the face of climate change deserve special attention, since this particular crop is the main raw material in the textile industry. The introduction of climate-optimized farming methods will increase cotton yields, as well as create prerequisites for further expansion of the cotton cultivation area, taking into account the changing climate.

The study revealed that temperature plays a vital role in enhancing cotton yield rates. The Ridge regression estimates indicate that a 1°C increase in temperature corresponds to an increase in yield of approximately 5 to 7 quintals per hectare, as supported by Lasso regression findings. This highlights the importance of temperature as a factor in cotton growth, as favorable temperature conditions positively influence crop development. However, once a certain temperature threshold is reached, the effects can become detrimental, outweighing the benefits.

Conversely, shifts in climate—such as rising temperatures and prolonged seasonal heat—may lead to decreased cotton productivity. Specifically, fluctuations in temperature and the increasing frequency of extreme meteorological events, resulting from climate change, undermine optimal conditions for cotton cultivation in the Turkestan region. This underscores the urgent need for implementing adaptive strategies in agricultural practices to mitigate the adverse impacts of climate change.

Thus, while temperature is a key determinant of cotton yields, climate change poses a real threat to the sustainable production of cotton in the region, necessitating the development of effective coping mechanisms to address these challenges.

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ВЛИЯНИЕ КЛИМАТИЧЕСКИ ОПТИМИЗИРОВАННЫХ МЕТОДОВ ВЕДЕНИЯ СЕЛЬСКОГО ХОЗЯЙСТВА НА ПОВЫШЕНИЕ УРОЖАЙНОСТИ ХЛОПКА

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Аннотация. *Хлопок является одним из основных видов сырья в текстильной промышленности. Урожайность хлопка напрямую зависит от климатических условий региона выращивания. При благоприятных климатических условиях хлопок обладает высоким потенциалом урожайности. Основными факторами, которые играют ведущую роль в этом процессе, являются стабильность температуры, уровень влажности, плодородие почвы и наличие вредителей. Чтобы успешно выращивать хлопок, необходимо учитывать все эти факторы и разрабатывать адаптивные стратегии, включая использование современных агрономических методов и технологий, которые помогут оптимизировать производственный процесс в условиях меняющегося климата. Внедрение агротехнических приемов, учитывающих климатические условия, может оказать долгосрочное влияние на урожайность хлопка. В совокупности это предполагает использование более устойчивых к климатическим условиям сортов и новых технологий орошения.*

В статье анализируется влияние климатически рациональных методов ведения сельского хозяйства, а также выявляются и формулируются предпосылки для увеличения урожайности хлопка. Внедрение этих методов будет способствовать адаптации фермерских хозяйств к изменяющимся климатическим условиям, что отразится на повышении производительности и устойчивости сельского хозяйства в долгосрочной перспективе. Также приведен экономический эффект от внедрения климатически оптимизированных методов ведения сельского хозяйства. Внедрение таких *методов позволяет увеличить урожайность хлопка на 10-30%, что способствует росту доходности хозяйств. Оптимизация использования ресурсов, таких как вода и удобрения, за счёт точного орошения и устойчивых сортов, снижает затраты на производство. Более того, устойчивое производство может привлечь премии за экологичность, а также доступ к рынкам сбыта, где ценятся продукты с низким углеродным следом. В совокупности, это ведёт к повышению конкурентоспособности и устойчивости хлопководческих хозяйств, особенно в условиях ограниченности природных ресурсов.*

Ключевые слова: *хлопок, текстильная промышленность, климатические условия, методы ведения хозяйства, экономический эффект, сельское хозяйство.*

АУЫЛ ШАРУАШЫЛЫҒЫНЫҢ КЛИМАТТЫҢ ӨЗГЕРУІНЕ ОҢТАЙЛАНДЫРЫЛҒАН ТӘЖІРИБЕСІНІҢ МАҚТА ӨНІМДІЛІГІН АРТТЫРУҒА ӘСЕРІ

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Аңдатпа. *Мақта – тоқыма өнеркәсібіндегі негізгі шикізат түрлерінің бірі. Мақтаның өнімділігі өсіп келе жатқан аймақтың климаттық жағдайына тікелей байланысты. Қолайлы климаттық жағдайларда мақта өнімділіктің жоғары әлеуетіне ие. Бұл процесте жетекші рөл атқаратын негізгі факторлар температураның тұрақтылығы, ылғалдылық деңгейі, топырақтың құнарлылығы және зиянкестердің болуы болып табылады. Мақтаны сәтті өсіру үшін осы факторлардың барлығын ескеріп, бейімделу стратегияларын, соның ішінде өзгермелі климат жағдайында өндіріс процесін оңтайландыруға көмектесетін заманауи агрономиялық әдістер мен технологияларды қолдану қажет. Климаттық жағдайларды ескеретін агротехникалық әдістерді енгізу мақта өнімділігіне ұзақ мерзімді әсер етуі мүмкін. Жалпы алғанда, бұл климатқа төзімді сорттар мен суарудың жаңа технологияларын қолдануды қамтиды.*

Мақалада климаттық рационалды ауылшаруашылық әдістерінің әсері талданады және мақта өнімділігін арттырудың алғышарттары анықталып тұжырымдалады. Бұл әдістерді енгізу фермерлік шаруашылықтардың өзгеретін климаттық жағдайларға бейімделуіне ықпал етеді, бұл ұзақ мерзімді перспективада ауыл шаруашылығының өнімділігі мен тұрақтылығының артуына әсер етеді. Сондай-ақ, климаттық оңтайландырылған ауыл шаруашылығы әдістерін енгізудің экономикалық әсері келтірілген. Мұндай әдістерді енгізу мақта өнімділігін 10-30%-ға арттыруға мүмкіндік береді, бұл шаруашылықтардың кірістілігінің өсуіне ықпал етеді. Дәл суару және төзімді сорттар арқылы су мен тыңайтқыш сияқты ресурстарды пайдалануды оңтайландыру өндіріс шығындарын азайтады. Сонымен қатар, тұрақты өндіріс экологиялық таза сыйлықақыларды, сондай-ақ көміртегі аз өнімдер бағаланатын нарықтарға қол жетімділікті тарта алады. Жалпы алғанда, бұл мақта шаруашылықтарының бәсекеге қабілеттілігі мен тұрақтылығының артуына әкеледі, әсіресе табиғи ресурстардың шектеулілігі жағдайында.

Түйін сөздер: *мақта, тоқыма өнеркәсібі, климаттық жағдайлар, егіншілік әдістері, экономикалық әсер, ауыл шаруашылығы*