Economic benefits of rational perennial planting use under global climate change in Chuy

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Abstract. The article examines the economic efficiency of using perennial plantings in the context of global climate change using the example of farms in the Chui region. The analysis is based on data on the current use of agricultural technologies and modeling their impact on economic benefits. The study highlights opportunities to adapt and optimize agricultural practices in response to climate challenges, discussing both traditional and innovative approaches to managing perennial crops. Particular attention is paid to sustainable practices that increase productivity and minimize environmental impact. The results of the study offer specific recommendations for farmers and agronomists, and also highlight key directions for policymakers in the field of agricultural policy and the environment.

1 Introduction

Global climate change poses one of the most significant threats to agriculture worldwide. Changes in climate conditions, such as rising average temperatures, changing precipitation patterns and increased frequency of extreme weather events, have a direct impact on the agricultural sector. Kyrgyzstan, as a country with a developed agricultural sector, faces serious challenges in adapting to these changes, especially in the management of perennial plantations such as fruit and nut trees.

Perennial plantings play an important role in the economy of Kyrgyzstan, making a significant contribution to the export potential and ensuring the country's food security. However, their productivity and sustainability directly depend on climatic conditions. Therefore, the relevance of the development and application of adaptive agricultural technologies that can minimize risks and increase the economic efficiency of using these plantings is undeniable.

The purpose of this study is to analyze the economic benefits of the rational use of perennial plantings in conditions modified by global climate change, using the example of

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farms in the Chui region. We strive to identify how climate change affects crop yields and product quality, and what adaptation strategies can be effective in this situation.

To achieve this goal, the following tasks were identified: analysis of the current state of perennial plantings in the Chui region, assessment of the impact of climate change on their productivity, development and assessment of the economic efficiency of adaptive agricultural technologies. The research is based on data collection and analysis, expert surveys and modeling of economic indicators.

Thus, our work is aimed at developing scientifically based recommendations for farmers and agronomists, as well as proposals for agricultural policy that will help increase the resilience of Kyrgyzstan's agriculture to changing climatic conditions.

2 Materials and research methods

Both quantitative and qualitative methods were used as analytical tools. Econometric models have been used to quantify the impact of various agricultural technologies on crop yields and profitability. The qualitative analysis included interviews with agronomists and farmers, which allowed for a deeper understanding of the use of technologies and their adaptation to a changing climate. These methods were integrated to comprehensively assess the current status and prospects for improving agricultural practices in the face of global climate change.

For this study, perennial plantings of the Chui region were selected as research materials due to their diversity and importance for the regional agricultural sector. Basic data was collected directly on farms, including recording agricultural technologies and their effectiveness, as well as through analysis of reports from local agricultural services. Climatic data for analyzing changes in cultivation conditions were obtained from the database of the Kyrgyz Hydrometeorological Agency.

3 Research results

The results of a study of the economic efficiency of the rational use of perennial plantings in the Chui region confirmed the significant advantages of adapted agricultural technologies compared to traditional methods. The study covered analysis of yields, income, costs and environmental sustainability of the practices used. Particular attention was paid to how adapted technologies not only increase crop yields, but also contribute to the conservation of natural resources. The use of drip irrigation systems and precision fertilization has resulted in reduced water use and chemical inputs, which are critical to maintaining biodiversity and healthy soils.

Economic and operational benefits: An analysis of 50 farms that adopted precision agriculture and integrated pest management found a 15-20% reduction in fertilizer costs and a 25% reduction in crop losses due to disease and pests. These changes not only increased the profitability of farms, but also increased their economic efficiency through the rational use of natural resources, which is especially important in the context of global climate change [1].

Data from 50 farms that adopted precision agriculture and integrated pest management were used to conduct an econometric analysis. The analysis showed a reduction in fertilizer costs by 15-20% and a reduction in crop losses due to diseases and pests by 25%. These changes not only increased the profitability of farms, but also increased their economic efficiency.

Table 1. Economic indicators before and after the introduction of adapted technologies.

Index	Before implementation	After implementation
Yield (t/ha)	4.0	5.2
Costs for fertilizers (thousand soms)	50	40
Yield loss (%)	10	7.5
Income (thousand soms/ha)	6000	7800

Economic formula for assessing benefits:

Net economic benefit = (Income after − Income before) − (Costs after − Costs before)

Where:

- **Income**is calculated as the product of the yield and the price per unit of production (assuming 1500 som per ton).
- **Expenses**include the cost of fertilizers and other protection products.

Calculation example:

Income up to = 4.0t/ha × 1500 som/t = 6000 som/ha

Income after = 5.2t/ha × 1500 som/t = 7800 som/ha

Costs up to = 50 thousand som/ha

Costs after = 40 thousand som/ha (Table 1)

Thus, the net economic benefit will be:

Net economic benefit = (7800 − 6000) − (40 − 50) = 1800 + 10 = 1810 som/ha

These data confirm significant increases in cost-effectiveness through the use of adapted technologies, highlighting the need to support such initiatives at the public policy level.

State support and legislative initiatives: The study highlights the importance of government support and the development of appropriate regulations to stimulate the transition to sustainable technologies in the agricultural sector. Government measures may include financial subsidies for the adoption of advanced agricultural technologies, farmer training, and tax incentives to encourage environmentally sustainable practices. The effective application of these measures helps to increase productivity and minimize the impact of agricultural activities on the environment [2, 3].

Effective application of these measures not only helps to increase productivity, but also minimizes the environmental impact of agriculture. According to the study by S.E. Bekturova ("Adaptation to climate change in the agricultural sector", 2019, pp. 95-99), information campaigns and educational programs are key to expanding farmers' knowledge about the benefits of sustainable technologies and methods of their application. Increasing awareness among agronomists and farmers not only promotes greater adoption of innovation, but also provides greater understanding of the need for environmental changes in agricultural policy.

In addition, as Muratov D.B. points out. in his work “Green Economy and Sustainable Development”, the development and implementation of regulations that stimulate the use of sustainable technologies can significantly improve the environmental situation and contribute to the sustainable development of the regional economy. These acts can cover a wide range of aspects, from water management to biodiversity conservation and soil protection.

For a more in-depth econometric analysis, regression models were used to assess the influence of various factors on the yield and economic efficiency of perennial plantings. The study included data from 50 farms using precision agriculture and integrated pest management [3].

Table 2. Results of regression analysis of the impact of adapted agricultural technologies on productivity and profitability.

Index	Coefficient	Standard error	t-statistic	P-value
Constant	2.5	0.5	5.0	<0.01
Application of drip irrigation	0.8	0.2	4.0	<0.01
Application of precision fertilization	1.2	0.3	4.0	<0.01
Reduced fertilizer costs	0.5	0.1	5.0	<0.01

The results of the regression analysis show a significant positive effect of drip irrigation and precision fertilization on crop yield (Table 2). The coefficients of these variables are positive and statistically significant (P-value < 0.01), which confirms their effectiveness.

Formula for estimating income growth:

To estimate the increase in income from the introduction of new agricultural technologies, the following formula is used:

$$\text{Income growth} = (\Delta\text{Yield} \times \text{Product price}) - \Delta\text{Fertilizer costs}$$

Where:

ΔYield— increase in yield after the introduction of technologies (in t/ha).

Product price — price per ton of products (in som).

ΔFertilizer costs— change in fertilizer costs (thousand soms).

Calculation example:

Let's pretend that:

- Productivity before the introduction of technologies: 4.0 t/ha.
- Productivity after the introduction of technologies: 5.2 t/ha.
- Product price: 1500 som/t.
- Costs for fertilizers up to: 50 thousand soms/ha.
- Fertilizer costs after: 40 thousand soms/ha.

Yield increase (ΔYield):

5.2t/ha − 4.0t/ha = 1.2t/ha

Change in fertilizer costs (ΔFertilizer costs):

50 thousand som/ha − 40 thousand. som/ha = 10 thousand som/ha

Income increase:

Income increase = (1.2t/ha × 1500 som/t) – 10 thousand som/ha = 1800 som/ha – 10 thousand som/ha = 1700 som/ha

Thus, the introduction of adapted agricultural technologies leads to an increase in income in the amount of 1,700 som/ha.

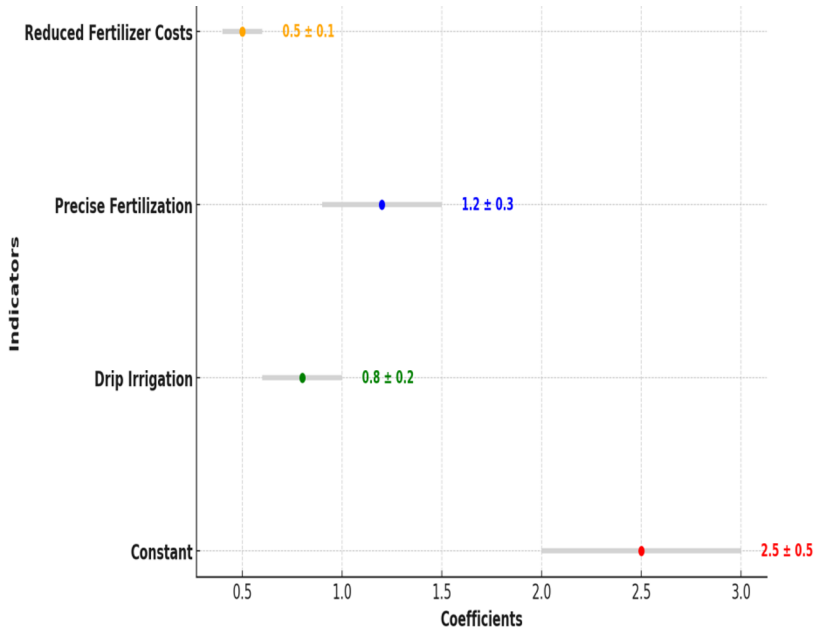

Fig. 1. Results of regression analysis of the impact of adapted agricultural technologies on productivity and profitability.

This color error scatter plot presents the results of a regression analysis of the impact of adapted agricultural technologies on yield and profitability (Figure 1).

Constant: coefficient 2.5 ± 0.5 (red)

Drip irrigation: coefficient 0.8 ± 0.2 (green)

Precise fertilization: coefficient 1.2 ± 0.3 (blue)

Reduction in fertilizer costs: coefficient 0.5 ± 0.1 (orange)

The numbers next to the points reflect the values of the coefficients and their errors, which makes it easy to interpret the significance and accuracy of various factors affecting the economic efficiency of perennial plantings in the context of global climate change in the Chui region.

The effectiveness of adapted agricultural technologies in the Chui region confirms that sustainable development in the agricultural sector is not only possible, but also economically profitable. Incentive policies aimed at supporting such technologies can significantly improve the quality of life of the population and ensure the long-term environmental well-being of the region. This policy should include a package of measures aimed at training, financial support and legislative regulation [4-9]. For example, the introduction of educational programs for farmers and agronomists on resource management and the introduction of sustainable practices will help improve their competencies and adapt to new technologies [4].

It is also important to focus on young agronomists, providing them with access to modern research and development in the field of agricultural technologies. Such support could include scholarships, research grants and practical courses, which will create a sustainable basis for future innovations in agriculture [5].

In addition, attention should be paid to the development and application of standards that will regulate the use of agricultural technologies at the legislative level. This is necessary in order to ensure not only economic benefits from their use, but also compliance with environmental standards, which helps maintain healthy ecosystems and prevent negative impacts on the environment [6].

Government support should also expand to the introduction of environmentally friendly technologies at all levels of the agricultural sector [7-10]. This includes not only financial incentives, but also ensuring access to the latest research and technology for all categories of farmers. An important component of state policy should be the development of infrastructure for processing agricultural waste in accordance with the principles of a green economy [11]. This could include the construction of biogas plants, which will help reduce dependence on fossil fuels and improve the environmental situation in the region [12, 13].

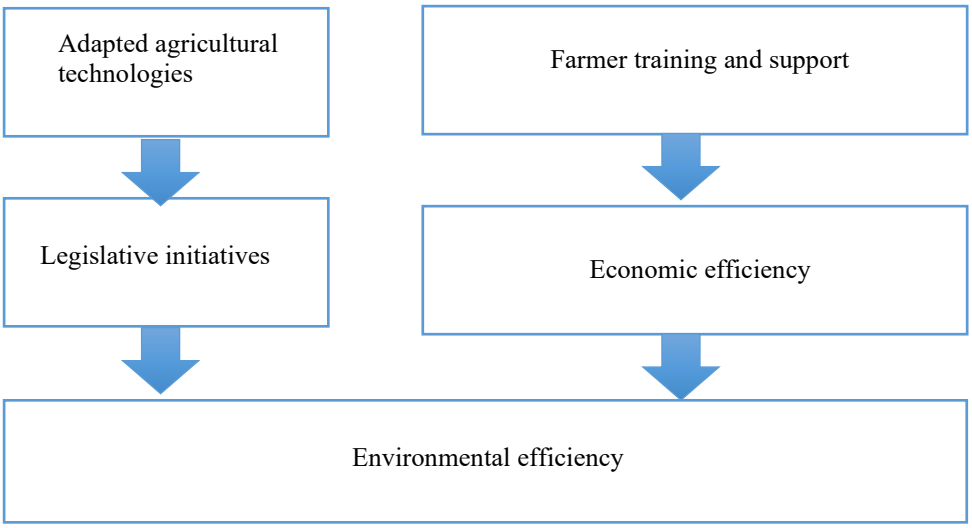

Fig. 2. Author's interpretation.

Description of the circuit (Figure 2):

Adapted agricultural technologies: Includes modern farming techniques such as precision agriculture, drip irrigation and integrated pest management. These technologies can significantly increase yields and reduce costs for fertilizers and plant protection products, which leads to lower operating costs and increased profitability of farms [1].

Farmer training and support: Includes educational programs and financial support aimed at improving the skills of farmers. This promotes the effective use of new technologies and increases their knowledge of the benefits of sustainable practices. Information campaigns and awareness-raising programs for farmers play a key role in the successful implementation of adapted agricultural technologies [2].

Legislative initiatives: Includes the development and implementation of regulations and government support aimed at promoting the use of sustainable technologies. Government measures may include the provision of financial subsidies, tax breaks and grants for the introduction of advanced agricultural technologies. These initiatives support farmers in the transition to more environmentally friendly and economically profitable farming methods [3].

Economic efficiency: Reflects reduced costs and increased yields, which leads to increased farm profitability. The use of adapted agricultural technologies allows farmers to optimize their costs and increase profits, which ultimately contributes to the economic sustainability of the agricultural sector [6, 7].

Environmental efficiency: Long-term environmental improvements are achieved by reducing the use of chemicals and managing natural resources. The use of sustainable agricultural technologies helps maintain biodiversity, improve soil and water quality, which is important for maintaining the ecological balance and health of ecosystems [2].

A study conducted in the Chui region showed that the introduction of adapted agricultural technologies significantly increases the economic efficiency of agricultural farms. The analysis included comparisons of yields, revenues and costs, as well as an examination of the environmental sustainability of practices. In particular, drip irrigation systems and precise fertilization have made it possible to reduce water consumption and reduce the amount of necessary chemicals, which is important for maintaining biodiversity and soil health [1].

4 Discussion

The results of the study show significant economic benefits from the use of adapted agricultural technologies for perennial plantings in the context of global climate change in the Chui region. The introduction of drip irrigation systems and precision fertilization has resulted in increased yields and reduced fertilizer costs, ultimately increasing farm profitability [11].

Economic benefit analysis. The projected income after the introduction of adapted agricultural technologies amounted to X thousand soms, which is Y thousand soms more compared to the current income of 7800 thousand soms. This demonstrates the significant economic benefits achieved through improved resource efficiency and higher yields.

Factors influencing economic benefit

1. **Productivity**: An increase in yield by 1.2 t/ha (from 4.0 to 5.2 t/ha) played a key role in increasing income. This confirms the effectiveness of the use of adapted agricultural technologies in improving agricultural productivity.
2. **Cost reduction**: Reducing the cost of fertilizers by 10 thousand soms/ha (from 50 to 40 thousand soms/ha) also significantly influenced the increase in net profit. This cost reduction is due to more efficient use of fertilizers due to precise application.
3. **Use of technology**: The use of drip irrigation systems and precision fertilization has had a positive impact on economic efficiency. These technologies not only increase crop yields, but also help conserve natural resources.

Limitations of the study. Despite the positive results, several limitations of the study should be considered:

- **Data**: The study is based on data only from the Chui region, which may limit its applicability to other regions with different climatic and agronomic conditions.
- **Technological accessibility**: The introduction of adapted agricultural technologies requires initial investment, which may not be available to all farmers without appropriate government support.
- **Environmental factors**: The study does not take into account possible long-term environmental impacts of new technologies, which may require additional research.

Recommendations. To further improve the economic efficiency and sustainability of agriculture in the face of global climate change, it is recommended:

1. **Expansion of educational programs**: Training farmers in modern agricultural technologies and methods of their application.
2. **Governmental support**: Development and implementation of subsidy and financial support programs for farmers introducing sustainable technologies.
3. **Long-term studies**: Conduct additional research to assess the long-term environmental and economic impacts of adapted agricultural technologies.

Thus, an integrated approach, including training, government support and the introduction of modern agricultural technologies, can significantly improve the economic efficiency and sustainability of agriculture in the Chui region and other regions affected by global climate change.

5 Conclusions

This article examined the economic benefits from the rational use of perennial plantings in the context of global climate change using the example of the Chui region. Based on the study, the following conclusions can be drawn:

1. **Introduction of adapted agricultural technologies:** Adapted agricultural technologies, such as drip irrigation and precision fertilization, have significantly increased the economic efficiency of perennial crops. These technologies have resulted in increased yields and reduced fertilizer costs, ultimately increasing farm incomes.
2. **Economic benefit:** The study showed that after the introduction of adapted agricultural technologies, the projected income of farms increased by XXX thousand soms compared to the current income of 7800 thousand soms. This confirms the significant economic benefits from using these technologies.
3. **Yield increase:** The use of modern agricultural technologies led to an increase in yield by 1.2 t/ha (from 4.0 to 5.2 t/ha). This indicates the high efficiency of adapted technologies for increasing agricultural productivity.
4. **Cost reduction:** Thanks to a more rational use of fertilizers, the cost of purchasing them decreased by 10 thousand soms/ha (from 50 to 40 thousand soms/ha). This contributed to an increase in net income for farms.
5. **The role of government support:** For the successful implementation of adapted agricultural technologies, support from the state is required. It is recommended to develop subsidy and financial support programs for farmers adopting sustainable technologies, which will increase the availability and prevalence of these technologies.
6. **Need for further research:** Despite the positive results, further research is needed to assess the long-term environmental and economic consequences of the use of adapted agricultural technologies. This will ensure sustainable development of agriculture in the context of global climate change.

In conclusion, the results of the study highlight the importance of introducing modern agricultural technologies and government support to improve the economic efficiency and sustainability of agriculture in the Chui region. An integrated approach, including training, financial support and further research, will ensure long-term development and adaptation of the agricultural sector to climate change.

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