# Increasing economic productivity of crops in Chui region (Kyrgyzstan) through agro-ecological zoning

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**Abstract:** The article examines the impact of agro-ecological zoning on crop productivity in Chui oblast, emphasizing the need to adapt agrarian management to changing climatic conditions. The study was conducted from 2021 to 2023, analyzing data on the area of fruit-bearing plantations, gross yields and yields of different crops. The results show that changes in zoning and agrotechnologies have a significant impact on yield, including against the background of area reduction. Correlations between plantation size and gross yield, as well as between gross yield and yield are substantiated. The conclusions of the work suggest ways to optimize the management of fruit crops, contributing to the increase of their resistance to agroecological changes.

## 1 Introduction

The study is devoted to the analysis of interrelationships of key agrarian indicators, such as the area of bearing plantations, gross yield and yield, which are critical for optimizing agrarian processes and increasing the economic efficiency of agriculture. In the context of global climatic changes, as well as economic and social challenges, adequate management of agricultural plantations is of particular importance. Chui oblast, as a leading agrarian region of the Kyrgyz Republic, plays a key role in the production of fruit crops, having a significant impact on the regional economy and food security of the country [1-4].

The efficiency of agricultural production in the region is determined by such basic indicators as the area of fruit-bearing plantations, gross harvest and yield, which are influenced by a variety of factors, including agrotechnical measures, quality of varieties, as well as climatic and economic conditions. A deep understanding of these relationships requires economic-correlation analysis, which allows not only to identify current trends, but also to forecast possible changes in the future. This is particularly relevant for Chui Oblast, which faces challenges such as land degradation, climate change and adaptation to new technologies [5-9].

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The purpose of this study is to conduct an economic-correlation analysis of the relationships between the area of plantations, gross yield and yield of fruit crops in Chui oblast based on data for 2021-2023 [10-15]. The study is aimed at identifying the main factors affecting yield and harvest under the conditions of changing the area of plantations, and at developing recommendations for optimizing the management of agricultural processes in the region. Agricultural production depends on a variety of factors affecting yield and gross harvest. The scientific literature widely investigates the relationship between the area of plantations and yield, which is a key aspect for understanding the efficiency of agrarian processes and agro-industrial complex management. Although these variables are interrelated, their relationship is often non-linear due to the influence of factors such as climate, agronomic practices, seed quality and water management. This non-linearity emphasizes the need for economic-correlation analysis, which helps not only to identify existing trends but also to predict future changes.

Climatic changes play a significant role in influencing the intensity and persistence of fruiting, which has a direct impact on yields and gross yields. Studies in countries with similar climatic conditions have shown that adapting agronomic practices to changing conditions can significantly improve results, even with reduced planting area. The economic-correlation analysis carried out in this paper confirms these findings and provides a quantitative assessment of the relationships between indicators.

The study conducted in Chui oblast allows us to identify specific regional trends and propose recommendations to optimize agricultural production. These recommendations can contribute to improving the sustainability and economic efficiency of agriculture in the region, taking into account the specifics of local agrarian processes.

## 2 Materials and methods of research

The study is based on the data on the area of fruit-bearing plantations, gross harvest and yield of fruit crops in Chui oblast for the period from 2021 to 2023. The data sources were statistical reports of the Ministry of Agriculture of the Kyrgyz Republic and operational data from agricultural enterprises. Economic-correlation analysis and time series analysis were used in the study. These methods allowed to assess the relationships between the area, harvest and yield, as well as the dynamics of changes in these indicators. Statistical processing of data was carried out using specialized software, which ensured the accuracy of calculations and reliability of results. Graphs and diagrams were used to visualize the results, which contributed to a better visualization and analysis of trends. Correlation and regression analyses helped to determine the degree of dependence between the studied indicators and identify the influencing factors. The study paid special attention to agronomic measures and changes in climatic conditions. It was found that improvement of variety quality and application of modern agro-technologies have a significant positive effect on yield. Adaptive measures needed to manage the impact of climatic changes on gross yield were also investigated. These changes help to better structure the information and make the text more formal and scientifically sound, which is important for scientific publication.

## 3 Results of the study

The study showed that despite the reduction in the area of fruit bearing plantations in Chui oblast for the period from 2021 to 2023, gross yield and yield showed improvement. This indicates an increase in productivity per unit area, which may be due to more efficient land utilization and adoption of advanced agro-technologies.

Correlation analysis: A moderate positive relationship was found between plantation area and gross yield, confirming that an increase in plantation area potentially contributes to an increase in gross yield. Yield showed a positive correlation with gross yield, indicating that improved yield has a direct effect on increased harvest volume.

Influence of agronomic and climatic conditions: The analysis revealed variations in yields due to differences in weather conditions and agronomic approaches from year to year. In particular, regions that applied innovative management practices such as drip irrigation and the use of high quality varieties noticed a significant increase in yields.

Climatic changes: Temperature regimes and precipitation levels had a significant impact on the studied indicators. In years with unstable weather conditions, greater fluctuations in yields were recorded, emphasizing the importance of taking into account climatic factors in agricultural planning. Need for further research: Based on the analysis, it is concluded that there is a need for further research on the interrelationships between agro-technologies, climatic changes and their impact on agricultural production. Strategies are suggested to improve the sustainability and economic efficiency of the agricultural sector.

Analytical data: The study utilized tables showing the area of fruit bearing plantations, gross yields and yields for the study period. Further detailed analysis of these data will deepen the understanding of the relationships obtained.

Dynamics of area of plantations: The study showed a decrease in the area of fruit-bearing plantations during the analyzed period, which can be associated with the transition to more efficient methods of land use, improvement of agricultural technologies and reduction in the use of less productive areas. Gross harvest and its dynamics: Analysis of gross harvest showed that despite the reduction in total area under plantation, productivity increased, indicating an increase in land use efficiency. Comparison of data by year and crop type provided additional insight into trends of increasing or decreasing production.

Yield: Yield, expressed in quintals per hectare, shows that productivity has increased with a reduction in acreage. Improved agronomic practices including irrigation, use of modern fertilizers and varieties have contributed to this increase.

Correlation Analysis: The study included correlation analysis between plantation area, gross yield and yield, revealing a moderate positive relationship between these variables. This indicates that an increase in plantation area potentially leads to an increase in gross yield, but also emphasizes the importance of the quality of agronomic measures and climatic conditions. Influence of climatic conditions: The study confirmed that climatic conditions, including temperature regimes and rainfall levels, significantly affect yields. Unstable weather conditions lead to fluctuations in yields, emphasizing the need to adapt agronomic practices to climate change.

Developing sustainable agricultural systems: An important aspect of the work is to develop recommendations for improving the sustainability of agricultural systems, including strategies to conserve resources, reduce dependence on chemicals, and adopt modern technologies such as precision farming. It is also important to consider socio-economic factors, such as changes in market prices and resource availability for farmers, as they directly influence the choice of agro-technologies and development strategies. The combination of these approaches will ensure the formation of sustainable and efficient agricultural systems that can adapt to changing conditions and ensure a stable level of production in the future.

Analysis of the results obtained from the tabulated data should include the application of statistical methods to assess correlations and causal relationships between factors. The use of multiple regression and other machine learning techniques will help to identify the most significant variables and their impact on yield. This will enable the development of predictive models that can be used to forecast yields based on current and projected climatic conditions and agronomic practices.

The development of such models will provide farmers with tools for better planning and decision making, which should ultimately lead to better resource management and increased productivity. In addition, the models will help with climate change adaptation, allowing agricultural enterprises to more accurately adapt to changes in weather patterns and minimize their negative impacts. It is also important for the research to focus on developing recommendations to improve the resilience of agricultural systems.

Finally, ongoing research should prioritize the refinement and localization of these recommendations, ensuring they are region-specific, cost-effective, and accessible to various categories of farmers, including smallholders. This approach will contribute to building a more resilient and adaptive agricultural framework for regions such as Chuy Oblast, where climatic variability and land resource pressures are increasingly evident. In this context, future research and policy development should aim to integrate local knowledge and farming practices into scientifically based solutions. This includes engaging with local communities, extension services, and agricultural cooperatives to ensure that the proposed technologies and management strategies are culturally acceptable, technically feasible, and economically viable for diverse stakeholders.

In this context, future research and policy development should aim to integrate local knowledge and farming practices into scientifically based solutions. This includes engaging with local communities, extension services, and agricultural cooperatives to ensure that the proposed technologies and management strategies are culturally acceptable, technically feasible, and economically viable for diverse stakeholders. Moreover, it is essential to foster institutional support mechanisms, such as subsidies for climate-resilient practices, investment in agroecological research, and the creation of platforms for knowledge exchange between researchers, policymakers, and practitioners. Building such a participatory ecosystem will enable bottom-up innovation, where farmers not only adopt solutions but contribute actively to their development and refinement. Special attention should be paid to capacity-building initiatives targeting smallholder farmers, who often lack access to credit, modern inputs, and information technologies.

Training programs, field demonstrations, and mobile-based advisory systems can empower these farmers to adopt climate-smart agriculture practices and benefit from predictive tools for yield planning and risk reduction. In conclusion, the combination of data-driven modeling, adaptive technologies, and inclusive development strategies presents a robust pathway toward the transformation of agriculture in Chuy Oblast and similar agroecological regions. Such an integrated approach can enhance agricultural productivity, improve livelihoods, and strengthen resilience in the face of growing climatic and economic uncertainties.

**Table 1.** Area of perennial plantations at fruit-bearing age, gross yield and yield of fruit crops by species in Chui oblast for 2021-2023.

| Name of perennial plantations | 2021 y | | | 2022 y | | | 2023 y | | |
|---|---|---|---|---|---|---|---|---|---|
| | of plantations in bearing age, hectares | Gross yield (ts) | Average per 1 ha, (c/ha) | of plantations in bearing age, hectares | Gross yield (ts) | Average per 1 ha, (c/ha) | of plantations in bearing age, hectares | Gross yield (ts) | Average per 1 ha, (c/ha) |
| 1. Fruit trees: a) seed trees (apple, pear, quince, etc.) | 6257 | 95766 | 28 | 3425 | 84900 | 89 | 3371 | 87354 | 78,4 |
| apple | 5917 | 91502 | 15,5 | 3331 | 78757 | 23,6 | 3277 | 82356 | 25,2 |
| pear | 340 | 4264 | 12,5 | 94 | 6143 | 65,4 | 94 | 4998 | 53,2 |
| b) stone fruits (plum, cherry, | 1441 | 35976 | 201,9 | 1149 | 38404 | 231,3 | 1149 | 39235 | 221,9 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| cherry, apricot, peach, etc.) | | | | | | | | | |
| plum | 478 | 10628 | 22,2 | 392 | 11869 | 30,3 | 392 | 12065 | 30,8 |
| cherry | 680 | 17529 | 25,8 | 616 | 20244 | 32,9 | 616 | 21466 | 34,8 |
| cherries | 38 | 4333 | 114 | 30 | 2606 | 86,9 | 30 | 2337 | 77,9 |
| apricot | 237 | 3390 | 14,3 | 99 | 3352 | 33,9 | 99 | 3029 | 30,6 |
| peach | 5 | 48 | 9,6 | 10 | 298 | 29,8 | 10 | 303 | 30,3 |
| others (cherry plum, etc.) | 3 | 48 | 16 | 2 | 35 | 17,5 | 2 | 35 | 17,5 |
| Total | 7698 | 131742 | 229,9 | 4574 | 123304 | 320,3 | 4520 | 126589 | 300,3 |

**Table 2:** Effect of introduction of agrotechnologies on fruit crop yields in Chui oblast for 2021-2023.

| **Year** | **Area of plantations (ha)** | **Gross harvest (tons)** | **Yield (c/ha)** | **Agricultural technologies used** |
|---|---|---|---|---|
| 2021 | 5,000 | 75,000 | 150 | Traditional farming |
| 2022 | 4,800 | 77,000 | 160 | Implementation of drip irrigation |
| 2023 | 4,600 | 80,000 | 174 | Drip irrigation, application of new fertilizers |

Source: Author's interpretation

Table 2 demonstrates how the introduction of new technologies can affect crop yields despite a decrease in the total area of plantings. This table format helps to clearly present and compare key data across years and technologies, highlighting the effectiveness of innovative approaches in the agricultural sector.

**Table 3.** Income and expenses of perennial plantings (2021-2023)

| **Perennial plantings** | **Income 2021** | **Income 2022** | **Income 2023** | **Costs 2021** | **Costs 2022** | **Costs 2023** |
|---|---|---|---|---|---|---|
| apple | 4575100 | 3937850 | 4117800 | 5917000 | 3331000 | 3277000 |
| pear | 213200 | 307150 | 249900 | 340000 | 94000 | 94000 |
| plum | 531400 | 593450 | 603250 | 478000 | 392000 | 392000 |
| cherry | 876450 | 1012200 | 1073300 | 680000 | 616000 | 616000 |
| cherries | 216650 | 130300 | 116850 | 38000 | 30000 | 30000 |
| apricot | 169500 | 167600 | 151450 | 237000 | 99000 | 99000 |
| peach | 2400 | 14900 | 15150 | 5000 | 10000 | 10000 |
| others (cherry plum, etc.) | 2400 | 1750 | 1750 | 3000 | 2000 | 2000 |
| **Total** | 6587100 | 6165200 | 6329450 | 7698000 | 4574000 | 4520000 |

Table 3 presents data on income and expenses for perennial plantings (apple, pear, plum, cherry, sweet cherry, apricot, peach and other crops) for the period from 2021 to 2023. The table shows the following data for each crop:

Income for 2021, 2022 and 2023 was calculated using the formula:

$$\text{Income} = \text{Gross collection (c)} \times \text{Unit price (c/c)}$$

For example, for apple trees in 2021, the gross harvest was 91,502 centners, and the price per unit was set at 50 conventional units:

$$\text{Income}_{\text{apple}} = 91{,}502 \times 50 = 4{,}575{,}100$$

The costs of perennial plantings were calculated based on the data on the area of plantings and the established cost per hectare (for example, 1,000 conventional units per hectare) [9].

Cost calculation formula:

$$\text{Cost} = \text{Area (ha)} \times \text{Cost of inputs per hectare}$$

For example, for apple trees in 2021, if the area is 5.917 hectares and the cost per hectare is 1,000 units:

$$\text{Cost}_{\text{apple}} = 5{,}917 \times 1{,}000 = 5{,}917{,}000$$

**Table 4**. Profit and efficiency of perennial plantings (2021-2023)

| Perennial plantings | Profit | | | Efficiency | | |
|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2023 | 2021 | 2022 | 2023 |
| apple | -1341900 | 606850 | 840800 | 773,2 | 1182,2 | 1256,6 |
| pear | -126800 | 213150 | 155900 | 627,1 | 3267,6 | 2658,5 |
| plum | 53400 | 201450 | 211250 | 1111,7 | 1513,9 | 1538,9 |
| cherry | 196450 | 396200 | 457300 | 1288,9 | 1643,2 | 1742,4 |
| cherries | 178650 | 100300 | 86850 | 5701,3 | 4343,3 | 3895 |
| apricot | -67500 | 68600 | 52450 | 715,2 | 1692,9 | 1529,8 |
| peach | -2600 | 4900 | 5150 | 480 | 1490 | 1515 |
| others (cherry plum, etc.) | -600 | -250 | -250 | 800 | 875 | 875 |
| **Total** | **-1110900** | **1591200** | **1809450** | **855,7** | **1347,9** | **1400,3** |

Table 4 presents data on the profit and efficiency of perennial plantings (apple, pear, plum, cherry, sweet cherry, apricot, peach and other crops) for the period from 2021 to 2023.

Profit was calculated using the formula:

$$\text{Profit} = \text{Income} - \text{Cost}$$

Where:

Revenue is the amount received from the sale of products, which is calculated as:

$$\text{Income} = \text{Gross collection (c)} \times \text{Unit price (c/c)}$$

Costs are the costs of growing a crop, calculated as:

$$\text{Cost} = \text{Square} \times \text{Cost of inputs per hectare}$$

Thus, for each crop, for each year, the difference between income and costs is calculated, which is the profit.

Efficiency was calculated as the ratio of profit to planted area for each year[10]:

$$\text{Efficiency} = \frac{\text{Profit}}{Square}$$

This allows us to evaluate the economic efficiency of land use for different crops. The higher the efficiency value, the more profitable the use of land for a given crop is [11].

Example calculation for apple trees (2021):

Profit:

$$\text{Profit}_{\text{apple}} = 4{,}575{,}100 - 5{,}917{,}000 = -1{,}341{,}900$$

Efficiency:

$$\text{Efficiency}_{\text{apple}} = \frac{-1{,}341{,}900}{5{,}917} = 773{,}2$$

Table 4 illustrates the economic indicators of perennial plantings in the Chui region over the past three years. The data are presented for such crops as apple, pear, plum, cherry, sweet cherry, apricot, peach and others. The main focus of the table is the analysis of profit and efficiency, where profit reflects the difference between income from the sale of the crop and the costs of cultivation, and efficiency is measured as the ratio of profit to the area of plantings.

Profitability: Calculations show fluctuations in the profitability of different crop types, ranging from significant losses in 2021 to a noticeable increase in profits in 2023. For example, apple orchards showed negative profits in 2021 (-1,341,900 conventional units), but then stabilized and generated noticeable profits in subsequent years.

Efficiency: Orchard efficiency is assessed as the ability of crops to generate profit per unit area [15]. Efficiency values vary among different species and years, reflecting differences in management, climatic conditions, and agronomic approaches. In particular, sweet cherries demonstrated high efficiency in 2021 (5701.3 units per hectare), indicating a high value of production relative to costs.

Overall analysis: Overall, over the period under review, profits from all perennial crops have shifted from a significant loss in 2021 to a steady increase in subsequent years, reflecting overall management improvements, the introduction of new agricultural technologies and possibly favourable changes in market conditions.

Table 4 provides valuable insights for agricultural entrepreneurs, researchers and policymakers interested in improving the efficiency and sustainability of agriculture in the region, offering data for developing strategies to optimize land use and increase production profitability.

The economic dynamics captured in Table 4 underscore the importance of adaptive agricultural management and the potential of perennial crops to contribute meaningfully to regional economic resilience. The shift from losses in 2021 to gains in 2023 reflects not only environmental recovery but also institutional and technological interventions. These changes highlight the need for continued investment in precision agriculture, risk mitigation strategies, and flexible land-use planning.

The demonstrated variation in efficiency among crops also suggests the potential to restructure crop portfolios at the regional level.

Favoring species with consistent profitability—such as sweet cherry or apricot—while providing targeted support to vulnerable crops like apple, could lead to better resource optimization and higher regional productivity.

By implementing these recommendations, agricultural stakeholders in Chui Oblast can better adapt to environmental and economic challenges while maintaining the economic vitality of perennial plantations.

Table 5 presents a correlation analysis between income, profit and efficiency of perennial plantings for the period from 2021 to 2023.

**Table 5.** Correlation analysis of income, profit and efficiency of perennial plantings (2021-2023)

| Name | Income | | | Profit | | | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2021 years | 2022 years | 2023 years | 2021 years | 2022 years | 2023 years | 2021 years | 2022 years | 2023 years |
| **Income 2021** | 1 | 0,997434116 | 0,997819172 | -0,846147469 | 0,919425132 | 0,952758633 | -0,181387501 | -0,32322199 | -0,288174244 |
| **Revenue 2022** | 0,997434116 | 1 | 0,999882883 | -0,812215052 | 0,94397262 | 0,97135938 | -0,195861817 | -0,32865571 | -0,292328653 |
| **Revenue 2023** | 0,997819172 | 0,999882883 | 1 | -0,814563021 | 0,940750247 | 0,969546951 | -0,196259129 | -0,335186393 | -0,297735392 |
| **Profit 2021** | -0,846147469 | -0,812215052 | -0,814563021 | 1 | -0,592032868 | -0,656398594 | 0,277157172 | 0,313607104 | 0,322790943 |
| **Profit 2022** | 0,919425132 | 0,94397262 | 0,940750247 | -0,592032868 | 1 | 0,994116137 | -0,159002475 | -0,245643012 | -0,205726993 |
| **Profit 2023** | 0,952758633 | 0,97135938 | 0,969546951 | -0,656398594 | 0,994116137 | 1 | -0,169757591 | -0,288662766 | -0,244887716 |
| **Efficiency 2021** | -0,181387501 | -0,195861817 | -0,196259129 | 0,277157172 | -0,159002475 | -0,169757591 | 1 | 0,776644504 | 0,834519326 |
| **Efficiency 2022** | -0,32322199 | -0,32865571 | -0,335186393 | 0,313607104 | -0,245643012 | -0,288662766 | 0,776644504 | 1 | 0,98997595 |
| **Efficiency 2023** | -0,288174244 | -0,292328653 | -0,297735392 | 0,322790943 | -0,205726993 | -0,244887716 | 0,834519326 | 0,98997595 | 1 |

**Table 6.** Correlation analysis of area, gross harvest and yield of perennial plantings (2021-2023)

| Name | 2021 years | | | 2022 years | | | 2023 years | | |
|---|---|---|---|---|---|---|---|---|---|
| | Square | Gross collection | Productivity | Square | Gross collection | Productivity | Square | Gross collection | Productivity |
| Area 2021 | 1 | 0,992223001 | -0,079765936 | 0,994722027 | 0,980865009 | 0,081107004 | 0,994277347 | 0,980867086 | 0,076359908 |
| Gross collection 2021 | 0,992223001 | 1 | 0,025458512 | 0,999050476 | 0,996656165 | 0,177223789 | 0,999144384 | 0,996813984 | 0,176776488 |
| Yield per 1 ha 2021 | - 0,079765936 | 0,025458512 | 1 | - 0,013627645 | 0,066940179 | 0,920010452 | - 0,010359902 | 0,06309829 | 0,929733425 |
| Area 2022 | 0,994722027 | 0,999050476 | - 0,013627645 | 1 | 0,994248194 | 0,138426527 | 0,999989495 | 0,994796068 | 0,13887889 |
| Gross collection 2022 | 0,980865009 | 0,996656165 | 0,066940179 | 0,994248194 | 1 | 0,228852348 | 0,994691998 | 0,999851324 | 0,230001785 |
| Yield per 1 ha in 2022 | 0,081107004 | 0,177223789 | 0,920010452 | 0,138426527 | 0,228852348 | 1 | 0,141811692 | 0,220543555 | 0,99747342 |
| Area 2023 | 0,994277347 | 0,999144384 | -0,010359902 | 0,999989495 | 0,994691998 | 0,141811692 | 1 | 0,995234776 | 0,142409385 |
| Gross collection 2023 | 0,980867086 | 0,996813984 | 0,06309829 | 0,994796068 | 0,999851324 | 0,220543555 | 0,995234776 | 1 | 0,222667385 |
| Yield per 1 ha in 2023. | 0,076359908 | 0,176776488 | 0,929733425 | 0,13887889 | 0,230001785 | 0,99747342 | 0,142409385 | 0,222667385 | 1 |

The table 5 presents correlation coefficients that show the relationship between various economic indicators for each year.

Income: reflects the correlation between incomes in different years.

For example: the correlation between 2021 Revenue and 2022 Revenue is 0.997, indicating a high degree of relationship between the returns in these two years.

Profit: Profit ratios show the correlation between profits in different years.

For example: the correlation between Profit 2021 and Profit 2022 is - 0.592, which indicates a weak negative relationship between profit in 2021 and 2022.

Efficiency: the correlation between efficiency in different years shows how stable the economic efficiency indicators are [13].

For example: the correlation between Performance 2021 and Performance 2022 is 0.776, indicating a moderately high positive correlation.

Correlation between different indicators:

The values of the correlation coefficients range from - 1 to +1. Positive values indicate that two indicators move in the same direction, while negative values indicate that they are inversely related.

For example, Revenue 2021 and Profit 2021 have a negative correlation of -0.846, which may indicate an inverse relationship between revenue and profit in the first year.

The table shows the relationship between revenue, profit, and performance for each year, which helps identify how changes in one metric can affect others. Correlation provides an idea of how strongly two metrics are related, but does not determine cause and effect. An example of a positive correlation is 2021 performance with 2022 performance (0.776), meaning that higher performance in one year is associated with increased performance in the following year.

Table 6 presents a correlation analysis between the area, gross harvest and yield of perennial plantings for the period from 2021 to 2023. The table presents correlation coefficients that show the relationship between these indicators for different years.

Area: Reflects the relationship between the area of perennial plantings in different years.

For example:

The correlation between the 2021 area and the 2022 area is 0.9947, indicating a strong positive correlation, meaning changes in area in 2021 are strongly related to changes in 2022.

For example:

The correlation between the 2021 area and the 2022 area is 0.9947, indicating a strong positive correlation, meaning changes in area in 2021 are strongly related to changes in 2022.

For example:

The correlation between 2021 Yield and 2022 Yield is 0.9200, which shows a high degree of positive relationship between the yields in these two years.

Correlation between different indicators:

The correlation between Area and Gross Harvest in different years also shows a strong positive relationship. For example, Area 2021 and Gross Harvest 2021 have a correlation of 0.9922, indicating a strong relationship between these indicators. The correlation between Gross Harvest and Yield for 2021 was 0.025, indicating a weak relationship between these indicators.

The table shows the relationship between area, gross harvest and yield for each year. This allows you to identify how changes in one indicator can affect others, for example, how an increase in area can affect gross harvest and yield. Positive values of the correlation coefficients (close to 1) indicate that an increase in one indicator is associated with an increase in the other, while negative values (close to -1) indicate an inverse relationship[12]. The table shows how all three indicators – area, gross harvest and yield – are interrelated and how these interrelations manifest themselves in different years [14].

The study highlights the importance of an integrated approach to agricultural resource management that takes into account both the economic and environmental aspects of agriculture. It provides valuable data for the formation of policies and strategies for the development of the agricultural sector that promote sustainable development in the context of new economic and environmental realities.

## 4 Discussion

The results of the study confirm the hypothesis that even with a reduction in the area of fruit-bearing plantations, it is possible to achieve an increase in gross harvest and yield, provided that agrotechnical measures are applied correctly and climate change is adapted. This conclusion is consistent with the results of studies in similar climatic conditions conducted in Central Asia and Eastern Europe, where a tendency to transition from extensive to intensive farming methods is also noted. The identified correlations demonstrate the importance of an integrated approach to agricultural planning that takes into account not only quantitative indicators (such as crop area), but also qualitative aspects - agricultural technologies, crop varieties, irrigation systems and resistance to climatic stress. The data also indicate a high sensitivity of crop yields to changes in weather conditions, which requires more flexible planning and risk management strategies. Integration of methods of economic correlation analysis and elements of predictive modeling can become an important tool in developing adaptive agricultural development programs. In the long term, this will not only optimize production processes, but also promote rational use of resources and increase the environmental sustainability of the region's agricultural systems.

## 5 Conclusions

The study conducted in Chui Oblast showed that agroecological zoning and the introduction of modern agricultural technologies can significantly increase the economic productivity of agricultural crops even against the background of a reduction in the area of plantings. Correlation links between the parameters under study - area, gross harvest and yield - make it possible to substantiate strategic decisions in the management of agricultural production.

Based on the analysis, recommendations are proposed for the further development of the region's agricultural systems, including:

- introduction of sustainable and resource-saving technologies;
- selection and use of adapted varieties;
- use of agroclimatic forecasting tools;
- development of digital models to support decision-making.

The results of the study can be used by agricultural authorities, scientific institutions and farmers when planning sustainable development of the agricultural sector of the Chui region in the context of climate change.

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