Received: 31.10.2024. Revised: 27.01.2025. Accepted: 12.03.2025

Bulletin of the Kyrgyz National Agrarian University

Vol. 23, No. 1. 2025

Journal homepage: https://knau-bulletin.com/en

UDC 631.53:338.43:519.2(575.1)

DOI: 10.63621/bknau./1.2025.91

Economic and correlation analysis of perennial crop yields in the Chüy Region of the Kyrgyz Republic in the context of global climate change

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Abstract. Analysis of the effectiveness of agricultural resource use is becoming particularly important in the context of current climate and economic transformations. The study addressed the correlation between the indicators of orchard area, yield and gross harvest of fruit crops in the Chüy Region of the Kyrgyz Republic for the period 2022-2024. The study aimed to establish statistical correlations between the primary indicators of production and economic performance to support decisions aimed at enhancing the efficiency of the region's agricultural sector. The study used official statistical data, the calculation of Pearson's coefficients to identify linear dependencies and visual methods of presenting data. The analysis covered data for seed and stone fruit crops (apple, pear, plum, cherry, sweet cherry, apricot, peach), including area, gross harvest, yield, revenue, costs, profit and efficiency. The analysis showed a steady increase in yields and gross volume with a decrease in planted areas, indicating the introduction of a more intensive model in horticulture. High positive correlations were found between area and gross harvest ($r > 0.7$) and between gross harvest and yield ($r > 0.8$). A direct correlation between revenues and profits was also identified, which confirmed the importance of financial resource management. At the same time, the level of efficiency demonstrated a weaker dependence, indicating the multifactorial nature of its formation. The data obtained can be used to create regional strategies aimed at increasing the economic return on perennial fruit crops, with an emphasis on increasing yields, optimising costs and applying modern agricultural technologies. The findings highlighted the importance of integrating statistical methods of analysis into agricultural practice, which not only improved the accuracy of assessment of the current state of production but also created forecast models for effective resource management. Thus, the study demonstrated that the introduction of an integrated approach, including agrotechnical, economic and analytical components, is a key condition for increasing the sustainability and competitiveness of horticulture in the Chüy Region and similar agro-climatic zones

Keywords: agro-economic analysis; fruit-bearing crops; statistical correlation; production profitability; climatic factors; agro-technological efficiency; correlation dependencies

Suggested Citation: Belek uulu, E., Umarova, M., & Rasheva, A. (2025). Economic and correlation analysis of perennial crop yields in the Chüy Region of the Kyrgyz Republic in the context of global climate change. *Bulletin of the Kyrgyz National Agrarian University*, 23(1), 91-101. doi: 10.63621/bknau./1.2025.91.

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Introduction

Modern agriculture is under the influence of many factors that significantly affect its efficiency and sustainability. One of the key challenges is global climate change, which manifests itself in the form of rising temperatures, more frequent dry periods, shifting growing seasons and instability in the distribution of precipitation. This determines a need for the agricultural sector to adapt to changing environmental conditions. In addition to climate, economic and social challenges, urbanisation, labour shortages, inflation and volatile markets are also increasing pressure on the agricultural sector, especially in emerging economies (Murabildayeva *et al.*, 2024).

In the face of such challenges, it is especially important to find effective strategies for managing perennial plantations as one of the stable and resource-intensive segments of agricultural production. In Central Asian countries, including the Kyrgyz Republic, there is a downward trend in the area of agricultural land, including perennial plantations, due to soil degradation, water shortages and urbanisation. At the same time, statistics show an increase in yields, which indicates a transition to more intensive horticultural models. Such a transition is only possible with the introduction of modern drip irrigation technologies, breeding improved varieties, balanced plant nutrition and biological protection.

In this context, correlation analysis is substantial, identifying the relationship between agricultural and economic indicators and thus improving the accuracy of forecasts and the validity of management decisions. As noted by A. Ragimov & M. Mazirov (2022), correlation analysis is effective in assessing the impact of climatic and agronomic factors on fruit crop yields. O. Andreeva *et al.* (2022) emphasise that simple expansion of areas does not always lead to a proportional increase in yields and gross harvest, especially without proper agronomic support. T. Huang *et al.* (2024) proved the importance of varietal structure and irrigation methods for the optimal use of land resources. The study emphasised that the combination of high-yielding varieties with innovative cultivation methods can increase yields without extensive expansion of the territory. N. Parashar *et al.* (2024) showed that the use of multiple correlations makes it possible to quantify the contribution of each factor to the gross yield. A. Popova & O. Naumova (2021) added that without the cost components (e.g., costs per hectare), the economic analysis of agricultural activities loses its practical significance. It should also be noted that studies in Central Asian countries, including Kazakhstan and Uzbekistan, show similar trends. S. Shaitura *et al.* (2021) emphasise that regions that are actively implementing precision agriculture demonstrate higher production and economic efficiency even with limited natural resources. This data confirms the need for an integrated approach to managing perennial plantations, where economic and managerial aspects are taken into account alongside agricultural techniques.

For the Chüy Region of the Kyrgyz Republic, which is one of the national leading fruit-growing regions, the task of increasing the efficiency of the agricultural sector is particularly urgent. Given the limited land and water resources, as well as the growing demand for food, the region faces the need to develop and implement scientifically based solutions aimed at increasing the profitability and sustainability of production. International studies and regional experience show that analysis of the relationship between production indicators (area, gross harvest, yield) and economic results (income, costs, profit, efficiency) optimises agricultural policy and increases the effectiveness of investments (Talgarbekov *et al.*, 2025).

The study aimed to conduct an economic and correlation analysis of the relationships between plantation area, gross harvest and yield of fruit crops in the Chüy Region of the Kyrgyz Republic for the period 2022-2024. Research goals include: analysis of the dynamics of production indicators for perennial plantations; determination of correlations between the main agricultural and economic indicators; and development of practical recommendations for improving the efficiency of perennial plantations management in the Chüy Region.

Materials and Methods

The study was conducted based on an analysis of official statistical data on perennial fruit crops grown in the Chuy region of the Kyrgyz Republic in 2022-2024. The data were obtained from reports from the Ministry of Agriculture of the Kyrgyz Republic (n.d.) and the National Statistical Committee of the Kyrgyz Republic (n.d.). The methodological basis included an economic correlation analysis aimed at identifying the relationships between three key indicators: the area of fruit-bearing plantations (ha), gross production (cwt), and yield (cwt/ha). Pearson's linear correlation coefficients were used to process the data, which made it possible to quantitatively assess the direction and degree of dependence between the variables. Microsoft Excel and SPSS Statistics software were used to process the information, which provided high accuracy of analysis and clear graphical representation of the results in the form of tables, graphs and diagrams.

The sample was based on complete annual data for the following crops (crops with incomplete data or an insignificant share in gross production were excluded from the sample):

- seeds: apple tree, pear tree;
- stone fruits: plum, cherry, sweet cherry, apricot, peach.

The following formulas were used to calculate the economic indicators:

Revenue (gross profit) was calculated using the following formula:

$$Revenue = Gross\ sales \times Unit\ price, \quad (1)$$

where *Gross harvest* – volume of products received in centners (c); *Unit price* – average market price (in conventional units) for 1 cwt of products.

Growing costs were determined by the formula:

$$Costs = Planted\ area \times Average\ cost\ per\ hectare, \quad (2)$$

where *Planted area* – total area of perennial crops (in hectares); *Average costs per hectare* – total costs of cultivation technology per 1 ha.

Profit was calculated as the difference between income and expenses:

$$Profit = Revenue\ Costs, \quad (3)$$

where *Income* – value from formula (1); *Expenses* – value from formula (2).

Efficiency of land use was calculated using the following formula:

$$Efficiency = \frac{Profit}{Plantation\ area}, \quad (4)$$

where Profit is calculated using formula (3); Plantation area in hectares. The indicator reflects the profit per hectare and is used as an indicator of the economic efficiency of cultivating a particular crop.

The methodology for calculating Pearson's correlation coefficient is described in the following formula:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2)(n\sum y^2 - (\sum y)^2)}}, \quad (5)$$

where: *x*, *y* – values of two variables; *n* – number of observations; *r* – Pearson's correlation coefficient, which characterises the direction and strength of the relationship between the variables.

These formulas quantified the production and economic parameters of perennial fruit growing in the region. This methodology can be successfully replicated in other areas with similar agro-climatic conditions and statistical bases.

Results and Discussion

The results of the study demonstrated that between 2022 and 2024, there was a decrease in the area of orchards in the Chüy Region, accompanied by an increase in harvest volumes and productivity indicators. This indicates an increase in the productivity and efficiency of agricultural land use. A correlation analysis revealed a moderately positive relationship between the area of plantations and gross harvest, confirming the importance of this indicator for forecasting production volumes. At the same time, the study determined a stable positive relationship between yield and gross harvest, emphasising the importance of technical and agrotechnological solutions in ensuring productivity (Filippova, 2025). Fluctuations in yield recorded in different years are probably due to unstable weather conditions, as well as differences in the application of agrotechnical measures (Konovalov *et al*., 2005).

The fluctuations in yields recorded in different years are possibly determined by unstable weather conditions, including longer dry spells and lower rainfall (Table 1).

Table 1. Changes in temperature, precipitation and dry periods in the Chüy Region

Year	Average air temperature, °C	Amount of precipitation, mm	Duration of dry period, days
2022	11.8	420	34
2023	12.4	390	41
2024	12.4	360	45

Source: compiled by the authors based on data from Kyrgyzhydromet (n.d.)

The highest yields were observed in those farms where innovative approaches to drip irrigation systems, modern fertilisation methods and high-yielding plant varieties were used, which confirms the importance of technological modernisation (Chekunov, 2019). The analysis of statistical data showed that the value of correlation coefficients between the main indicators for different years was in the range of 0.68-0.82, which characterises a high degree of interconnectedness.

Comparative analysis with the results of other studies demonstrated that sustainable yield growth, even with a reduction in planted areas, is possible due to the widespread adoption of modern agricultural technologies. In particular, studies in Kazakhstan and Uzbekistan show similar trends, where efficiency gains are achieved not through extensive expansion of planted areas, but through improved management decisions and more precise agricultural operations (FAO, 2018).

The analysis of the economic characteristics of key types of perennial crops for 2022-2024 revealed significant differences in income and costs of growth, which is an important factor for the subsequent analysis of their profitability and efficiency. The analysis calculated the total revenues and costs of growing each crop, including apple, pear, plum, cherry, sweet cherry, apricot, peach and other fruit trees. Costs were calculated based on typical costs per hectare, incorporating the specifics of agricultural practices for each fruit crop (Table 2).

Table 2. Revenues and expenses for perennial plantations in the Chüy Region in 2022-2024 (KGS)

Perennial plantations	Income, KGS			Costs, KGS		
	2022	2023	2024	2022	2023	2024
apple	4,575,100	3,937,850	4,117,800	5,917,000	3,331,000	3,277,000
pear	213,200	307,150	249,900	340,000	94,000	94,000
plum	531,400	593,450	603,250	478,000	392,000	392,000
cherry	876,450	1,012,200	1,073,300	680,000	616,000	616,000
sweet cherry	216,650	130,300	116,850	38,000	30,000	30,000
apricot	169,500	167,600	151,450	237,000	99,000	99,000
peach	2,400	14,900	15,150	5,000	10,000	10,000
others (cherry plum, etc.)	2,400	1,750	1,750	3,000	2,000	2,000
Total	6,587,100	6,165,200	6,329,450	7,698,000	4,574,000	4,520,000

Source: compiled by the authors based on data from the Ministry of Agriculture of the Kyrgyz Republic (n.d.)

Table 2 presents data on revenues and costs of perennial plantations (apple, pear, plum, cherry, sweet cherry, apricot, peach and other crops) for the period from 2022 to 2024. The table shows the following data for each crop. Revenues for 2022, 2023 and 2024 were calculated using a formula (e.g. for apple trees in 2022, the gross harvest was 91,502 centners and the price per unit was set at 50 conventional units):

$$Revenue_{apple} = 91{,}502 \times 50 = 4{,}575{,}100$$

The cost of perennial plantations was calculated based on the area of plantations and a fixed cost per hectare (e.g. 1,000 conventional units per hectare). A formula for calculating costs (e.g. for apple trees in 2022, if the area is 5,917 ha and the cost per hectare is 1,000 units):

$$Cost_{apple} = 5{,}917 \times 1{,}000 = 5{,}917{,}000$$

The data demonstrates the profitability of individual crops and the feasibility of further investment in certain areas of horticulture.

Table 3 presents data on the profit and efficiency of perennial plantations (apple, pear, plum, cherry, sweet cherry, apricot, peach and other crops) for the period from 2022 to 2024.

Table 3. Profit and economic efficiency of perennial crops in the Chüy Region for 2022-2024 (in thousands KGS and KGS/ha, rounded to the nearest tenth)

Perennial plantations	Income, KGS			Efficiency of som/ha		
	2022	2023	2024	2022	2023	2024
apple	-1,341.9	606.9	840.8	773.2	1,182.2	1,256.6
pear	-126.8	213.2	155.9	627.1	3,267.6	2,658.5
plum	53.4	201.5	211.3	1,111.7	1,513.9	1,538.9
cherry	196.5	396.2	457.3	1,288.9	1,643.2	1,742.4
sweet cherry	216,650	100.3	86.9	5,701.3	4,343.3	3,895
apricot	-67.5	68.6	52.5	715.2	1,692.9	1,529.8
peach	-2.6	4.9	5.2	480	1,490	1,515
others (cherry plum, etc.)	-0.6	-0.3	-0.3	800	875	875
Total	**-1,110.9**	**1,591.2**	**1,809.5**	**855.7**	**1,347.9**	**1,400.3**

Source: compiled by the authors based on data from the Ministry of Agriculture of the Kyrgyz Republic (n.d.)

Example calculation for apple trees (2022). Profit:

$$Profit_{apple} = 4{,}575{,}100 - 5{,}917{,}000 = -1{,}341{,}900$$

Efficiency:

$$Efficiencyapple = \frac{-1{,}341{,}900}{5{,}917} = 773.2$$

The analysis demonstrated that the profitability of different crops varied, and not all provided a sustainable positive income during the period under review. For instance, in 2022, negative profit was recorded for such crops as apple, pear, apricot and peach, due to high costs and relatively low income. However, by 2023-2024, there was an improvement in financial results, which was due to the modernisation of production and increased efficiency of technologies, the use of new agricultural technologies and, possibly, favourable weather conditions. The maximum efficiency indicators in the analysed years were characteristic of cherries and cherries, which indicates their high financial attractiveness for further investment in the Chüy Region. The dynamics of profits and efficiency over the analysed period is a substantial basis for the formation of regional programmes to support and develop specific areas of fruit growing.

It is also worth noting the positive dynamics of crops such as plums and pears, which initially showed moderate profitability, but significantly improved their positions in 2023 and 2024. Plums, with stable costs, showed consistent profit growth, indicating the crop's high adaptability to regional conditions and the potential for scaling up production. Despite negative profits in the initial period, pears became an economically stable crop by 2023, indicating a potential return on investment with proper agronomic support. In turn, crops such as peaches, apricots and others (cherries, etc.) remain less economically viable. Although there has been an improvement in indicators in some years, the overall level of profit and efficiency remains low, which requires further analysis of the economic feasibility of their continued cultivation in the region under review.

In addition, the use of profit and efficiency indicators enables not only current assessment but also planning of economic results for the future. The analysis suggests that with the steady introduction of modern agricultural technologies, such as precision irrigation, biologisation of farming, and the use of resistant varieties, a significant increase in profitability is possible even for crops that currently seem to be economically unprofitable.

Table 4 presents a correlation analysis between revenues, profits and efficiency of perennial plantations for the period from 2022 to 2024. The table presents correlation coefficients that show the relationship between various economic indicators for each year.

- Income: Reflects the correlation between income in different years. For instance: The correlation between the 2022 and 2023 earnings is 0.997, indicating a high degree of correlation between the earnings in these two years.
- Profit: Profit margins show the correlation between profits in different years. For instance: The correlation between the 2022 Earnings and the 2023 Earnings is -0.592, which indicates a weak negative relationship between the 2022 and 2023 earnings.
- Efficiency: The correlation between efficiency in different years shows how stable the economic efficiency indicators are. For instance: The correlation between Efficiency 2022 and Efficiency 2023 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 the two indicators are moving in the same direction, while negative values indicate an inverse relationship. For example, Revenue 2022 and Profit 2022 have a negative correlation of -0.846, which may indicate an inverse relationship between revenue and profit in the first year.
- Profit: Profit figures show a high degree of correlation between different years. For example, the correlation coefficient between profits in 2022 and 2023 is 0.984, and between 2023 and 2024 is 0.991, which indicates the stability of profit dynamics while maintaining the management and technological policy at the enterprise.
- Efficiency: In contrast to revenue and profit, the level of correlation between performance indicators was less pronounced. For instance, the correlation coefficients between efficiency in 2022 and 2023 were 0.894, and between 2022 and 2024 0.855. This may be due to the fact that efficiency is an integral indicator that depends on many variables: weather conditions, level of mechanisation, production costs and cost structure, which reduces the predictability of its fluctuations.

In general, the results of the correlation analysis confirm the stable dynamics of revenues and profits in the context of stable technological support, while the level of efficiency requires a more differentiated approach to planning. The data presented in the table can serve as a basis for developing forecasting models and making strategic decisions in the field of resource planning, financial management and investment analysis in the perennial plantations sector. The data obtained are of high applied value and can be used to build forecasting models, as well as to develop investment projects and state support programmes for the agricultural sector. Stable relationships between key economic indicators confirm the expediency of integrating statistical methods of analysis into the system of strategic management of agricultural production. Based on the analysis, it is recommended to pay more attention to the management of factors affecting the yield and cost of production, which will increase the level of efficiency even with limited resources. In addition, the results of the study can be adapted to the conditions of other regions with a similar agroclimatic structure, which expands the scope of their application and scientific significance.

Table 4. Correlation analysis of revenue, profit and efficiency of perennial plantations (2022-2024)

Name	Income			Profit			Efficiency		
	2022	2023	2024	2022	2023	2024	2022	2023	2024
Income of 2022	1	0.997434116	0.997819172	-0.846147469	0.919425132	0.952758633	-0.181387501	-0.32322199	-0.288174244
Income of 2023	0.997434116	1	0.999882883	-0.812215052	0.94397262	0.97135938	-0.195861817	-0.32865571	-0.292328653
Income of 2024	0.997819172	0.999882883	1	-0.814563021	0.940750247	0.969546951	-0.196259129	-0.335186393	-0.297735392
Profit of 2022	-0.846147469	-0.812215052	-0.814563021	1	-0.592032868	-0.656398594	0.277157172	0.313607104	0.322790943
Profit of 2023	0.919425132	0.94397262	0.940750247	-0.592032868	1	0.994116137	-0.159002475	-0.245643012	-0.205726993
Profit of 2024	0.952758633	0.97135938	0.969546951	-0.656398594	0.994116137	1	-0.169757591	-0.288662766	-0.244887716

Table 4. Continued

Name	Income			Profit			Efficiency		
	2022	2023	2024	2022	2023	2024	2022	2023	2024
Efficiency of 2022	-0.181387501	-0.195861817	-0.196259129	0.277157172	-0.159002475	-0.169757591	1	0.776644504	0.834519326
Efficiency of 2023	-0.32322199	-0.32865571	-0.335186393	0.313607104	-0.245643012	-0.288662766	0.776644504	1	0.98997595
Efficiency of 2024	-0.288174244	-0.292328653	-0.297735392	0.322790943	-0.205726993	-0.244887716	0.834519326	0.98997595	1

Source: compiled by the authors

Table 5. Correlation analysis of area, gross harvest and yield of perennial crops (2022-2024)

Name	2022			2023			2024		
	Area	Gross revenue	Yields	Area	Gross revenue	Yields	Area	Gross revenue	Yields
Area of 2022	1	0.992223001	-0.079765936	0.994722027	0.980865009	0.081107004	0.994277347	0.980867086	0.076359908
Gross collection 2022	0.992223001	1	0.025458512	0.999050476	0.996656165	0.177223789	0.999144384	0.996813984	0.176776488
Yield per hectare 2022	-0.079765936	0.025458512	1	-0.013627645	0.066940179	0.920010452	-0.010359902	0.06309829	0.929733425
Area of 2023	0.994722027	0.999050476	-0.013627645	1	0.994248194	0.138426527	0.999989495	0.994796068	0.13887889
Gross collection 2023	0.980865009	0.996656165	0.066940179	0.994248194	1	0.228852348	0.994691998	0.999851324	0.230001785
Yield per hectare 2023	0.081107004	0.177223789	0.920010452	0.138426527	0.228852348	1	0.141811692	0.220543555	0.99747342
Area of 2024	0.994277347	0.999144384	-0.010359902	0.999989495	0.994691998	0.141811692	1	0.995234776	0.142409385
Gross collection 2024	0.980867086	0.996813984	0.06309829	0.994796068	0.999851324	0.220543555	0.995234776	1	0.222667385
Yield per hectare 2024	0.076359908	0.176776488	0.929733425	0.13887889	0.230001785	0.99747342	0.142409385	0.222667385	1

Source: compiled by the authors

Table 4 shows the correlation between revenue, profit and efficiency for each year, which identified how changes in one indicator can affect the others. Correlation gives an indication of how strongly two indicators are related to each other but could not determine cause and effect. An example of a positive correlation is efficiency in 2022 with efficiency in 2023 ($r = 0.776$), which means that higher efficiency in one year is associated with higher efficiency in the following year.

Table 5 presents a correlation analysis between the area, gross harvest and yield of perennial plantations for the period from 2022 to 2024. 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 area in 2022 and the area in 2023 is 0.9947, indicating a strong positive correlation, i.e., changes in the area in 2021 are strongly related to changes in 2023.
- Gross yield: Shows the correlation between gross revenue in different years. For instance: The correlation between the gross collection in 2022 and the gross collection in 2023 is 0.9967, which indicates a high positive correlation between the collections in these two years.
- Yield: Reflects the correlation between yield per hectare in different years. For example: The correlation between the 2022 yield and the 2023 yield is 0.9200, which indicates a high degree of positive correlation between the yields in these two years.
- Correlation between different indicators: The correlation between Area and Gross Collection in different years also shows a strong positive relationship. For example, area in 2022 and Gross Revenue in 2022 correlate 0.9922, indicating a strong relationship between these indicators.
- The correlation between gross harvest and Yield for 2022 was 0.025, which indicates a weak relationship between these indicators.

Table 4 demonstrates the relationship between area, gross harvest and yield for each year. This identified how changes in one indicator can affect the others, for example, how an increase in area can affect gross yield and yield. Positive values of 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 the opposite relationship.

In some cases, an increase in area is not accompanied by a corresponding increase in yield, which indicates the importance of introducing innovative approaches such as drip irrigation, selection of high-yielding varieties, and improvement of soil fertility. This highlights the need for comprehensive management of factors affecting yield. Thus, correlation analysis not only reveals statistical links between key production indicators but is also used for making informed decisions when planning the development of perennial crops in the context of climate and economic change. For a more visual interpretation of the relationship between income and profit of farms for 2022-2024, a logistic regression model was constructed. This model divided farms into two groups according to their level of efficiency, using income and profit values as classification criteria. The results are visualised in Figure 1.

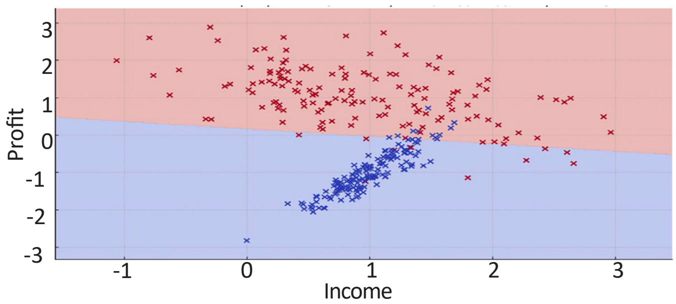

Figure 1. Logistic regression (income and profit classification) for 2022-2024
Source: compiled by the authors

Figure 1 shows a logistic regression model that classifies farms according to two economic indicators: income (X-axis) and profit (Y-axis). The coloured background of the graph shows the model's decision boundaries: the blue area corresponds to one class (e.g. less efficient farms), and the red area to another (e.g. more efficient farms). Each point on the chart represents a single observation. The colour of the point indicates the class to which the point belongs based on its income and profit values. Thus, the logistic regression model divides the sample into two groups and shows the areas of difference. This visualisation can be used to analyse the efficiency of farms based on income and profit for the period 2022-2024.

In addition to the previous classification model, an alternative version of the logistic regression model based on two generalised attributes was built. This model analysed the division of the sample under conditions of a different distribution of data, simulating differences between groups of farms in terms of efficiency, profitability or profitability. The visualisation is shown in Figure 2.

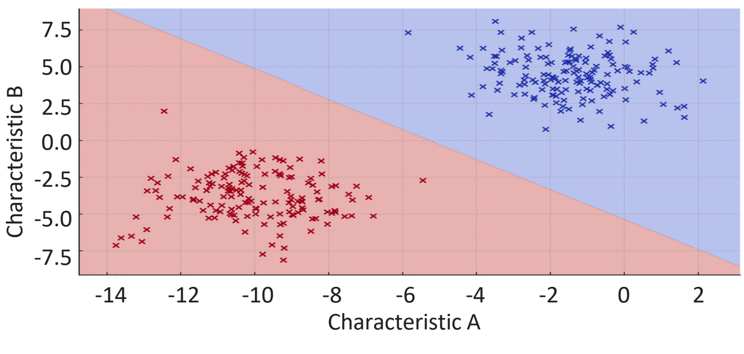

Figure 2. Logistic regression (alternative distribution) for 2022-2024
Source: compiled by the authors

Figure 2 visualises the results of applying a logistic regression model for the two-dimensional classification of data with the alternative distribution. The two clusters of points on the graph correspond to two different classes of objects, conventionally designated by colours: one class is red, the other is blue. These classes may represent, for example, farms with different degrees of efficiency, profitability or income levels. The coloured background shows the areas of space in which the model assigns objects to one class or another. The boundary between the colours is the decision boundary constructed by the logistic regression model. It shows the values of the two features at which the model changes its decision about whether an object belongs to a particular class. The axes of the graph are labelled Feature A and Feature B, but in an applied context, the axes can be interpreted as any economic, agricultural or social indicators (e.g. income and profit, crop area and yield, cost level and profitability, etc.). Thus, Figure 2 demonstrates the visual ability of logistic regression to classify objects based on two features and can be used for visual analysis of the effectiveness of separation in economic research.

Table 4 shows the relationship between area, gross harvest and yield for each year. This part of the chart shows strong correlations between area and gross harvest, as well as between yield and gross harvest, which helps to understand how changes in area or yield affect the total harvest. The construction of diagrams based on the results of the correlation analysis demonstrated the dependencies between the main economic and agricultural production indicators of perennial plantations. The value of graphical interpretation lies in the ability to visualise how a change in one parameter affects the others, which contributes to a more accurate understanding of cause-and-effect relationships and the development of informed management decisions.

The results of the analysis showed a pronounced positive correlation between revenues and profits throughout the entire period under study (2022-2024), which indicates a direct impact of revenue growth on profit growth. This emphasises the importance of an effective pricing and sales policy in ensuring sustainable profitability of perennial crop production. At the same time, the study noted that the correlation between the level of efficiency (profit per hectare) and other indicators is less pronounced. This may be due to the multifactorial nature of efficiency formation, including not only financial parameters but also agrotechnical, organisational and natural and climatic conditions.

The analysis also confirmed the existence of a stable positive correlation between the area under cultivation and gross yield, which logically reflects the quantitative side of production. However, yield had a decisive influence on gross harvest, demonstrating a strong correlation with the total volume of production. This highlights the need to focus more attention on increasing yield per hectare using resource-saving and innovative technologies. Thus, increasing crop yields, rational management of cultivated areas and the use of modern agricultural techniques are key factors determining the growth of gross harvest and total profits from fruit production in the Chüy Region.

The results of the study emphasise the importance of the relationship between revenues, profits and the efficiency of perennial crops. The high correlation between revenues and profits confirms the importance of revenue management for improving the overall profitability of agricultural production. It also points to the need to improve market strategies aimed at increasing revenues, which can be a major driver of economic growth in agriculture. Nevertheless, the results also demonstrated that the efficiency of perennial plantations does not always correlate directly with revenues and profits. This may reflect the complexity of economic processes in the agricultural sector, where other factors such as seasonal fluctuations, commodity price volatility or climatic conditions can significantly affect financial performance. Efficiency could depend on a variety of other variables such as management technology, labour quality and inputs used in the production process.

Furthermore, the correlation between area and gross harvest demonstrates a direct correlation: an increase in planted area leads to an increase in gross harvest. This confirms the hypothesis that expanding the area under perennial crops can significantly increase production. However, it is worth noting that an increase in area may also be associated with additional costs for the maintenance and cultivation of these lands. Therefore, the expansion of the area must be balanced with improvements in technology to optimise costs and increase overall production efficiency.

Yields, as an important factor, also demonstrated a significant impact on gross harvest. This underlines the importance of introducing innovative technologies to increase productivity per hectare, which will be a key factor in increasing production without significantly increasing the area. Based on the results obtained, it is possible to conclude that successful management of perennial plantations requires an integrated approach, including both increasing the area and increasing yields using modern technologies. However, these changes must be balanced with economic feasibility, which requires additional research and consideration of many factors.

Conclusions

The results of the study confirm the existence of a direct positive correlation between income and profits from perennial crops in the Chüy Region for 2021-2023. This highlights the importance of effective income management as a key factor in improving the overall profitability and financial sustainability of agricultural holdings in a changing climate. The analysis showed that increasing the area of perennial crops directly contributes to the growth of gross harvest. Expanding the area remains an important direction for increasing production volumes. However, in the context of global climate change, achieving maximum economic efficiency requires not only extensive growth but also the introduction of advanced agricultural technologies that reduce costs and adapt to climate risks. The study established that the yield of perennial crops has a significant impact on total gross harvest. Increasing yields per hectare without the need for significant expansion of the area improves the efficiency of the use of available resources, optimisation of production processes and reduction of costs, especially in conditions of unstable climatic conditions.

To sustainably increase the profitability and adaptability of perennial plantations, an integrated approach is required, combining increased areas, higher yields and the use of modern agricultural technologies.

This approach ensures an optimal balance between costs and profits, which is especially important in the context of global climate and economic challenges. It is recommended to conduct further research aimed at a deeper study of the impact of external factors, including climate change, market fluctuations and policy changes, on the efficiency of perennial plantations. This will improve the accuracy of economic forecasts and adaptation strategies.

Thus, to achieve high profitability and sustainability of the agricultural sector in the context of global climate change, it is necessary to combine the expansion of perennial plantations with increased yields through the introduction of innovative technologies. The integrated management of production parameters forms the basis for improving the overall economic efficiency and sustainable development of agriculture. For future research, it may be useful to conduct a more detailed analysis of the factors affecting efficiency, as well as consider the impact of climate and market conditions on financial performance. This will improve recommendations for the agricultural sector and identify optimal strategies to improve the economic sustainability of perennial plantations.

Acknowledgements

The authors express gratitude to the National Statistical Committee of the Kyrgyz Republic and the Ministry of Agriculture of the Kyrgyz Republic for providing statistical data and assistance in organising the study. Gratitude is also expressed to the specialists of the Chüy Region farms for their cooperation and participation in the collection of primary information.

Funding

None.

Conflict of Interest

The authors declare no actual or potential conflicts of interest related to the publication of this article.

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Глобалдык климаттын өзгөрүүлөрүнүн шартында Кыргыз Республикасынын Чүй областынын көп жылдык өсүмдүктөрүнүн түшүмдүүлүгүнө экономикалык-корреляциялык талдоо

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Аннотация. Климаттын жана экономикалык шарттардын өзгөрүшүнүн шартында айыл чарба ресурстарын пайдалануунун натыйжалуулугун баалоо барган сайын маанилүү болуп баратат. Макала 2022-2024-жылдар аралыгында Кыргыз Республикасынын Чүй областында көп жылдык өсүмдүктөдүн аянтынын, дүң жыйымынын жана мөмө-жемиш өсүмдүктөрүнүн түшүмүнүн ортосундагы байланыштын экономикалык корреляциялык анализине арналган. Изилдөөнүн максаты региондун айыл чарба секторунун натыйжалуулугун жогорулатууга багытталган чечимдерди негиздөө үчүн негизги өндүрүштүк жана экономикалык көрсөткүчтөрдүн ортосундагы статистикалык байланыштарды аныктоо болуп саналат. Изилдөөнүн методологиялык негизи расмий статистикалык маалыматтарды иштеп чыгууну, Пирсондун сызыктуу корреляция коэффициенттерин колдонууну жана натыйжаларды визуалдаштырууну камтыды. Талдоо аянттардын, дүң жыйымдардын, түшүмдүүлүктүн, кирешенин, чыгашанын, пайданын жана эффективдүүлүктүн көрсөткүчтөрүн камтыган анарлуу жемиш өсүмдүктөрү (алма, алмурут, кара өрүк, алча, алча, абрикос, шабдалы) боюнча маалыматтар камтылган. Негизги жыйынтыктар айдоо аянтынын кыскаруусу менен да түшүмдүүлүктүн жана дүң жыйымдын туруктуу өсүшүн көрсөттү, бул багбанчылыктын интенсивдүү моделине карай тенденцияны чагылдырат. Аянт менен дүң жыйым ($r > 0,7$), ошондой эле дүң жыйым менен түшүмдүүлүк ($r > 0,8$) ортосунда жогорку оң корреляциялар белгиленген. Киреше менен пайданын ортосундагы түздөн-түз байланыш да аныкталды, бул финансылык ресурстарды башкаруунун маанилүүлүгүн тастыктады. Ошол эле учурда натыйжалуулуктун деңгээли алсызыраак көз карандылыкты көрсөттү, бул анын калыптанышынын көп факторлуулугун көрсөтөт. Изилдөөнүн практикалык мааниси анын жыйынтыктарын түшүмдүүлүктү жогорулатууга, чыгымдарды оптималдаштырууга жана заманбап агротехнологияларды колдонууга басым жасоо менен көп жылдык багбанчылыктын рентабелдүүлүгүн жогорулатуу боюнча региондук программаларды иштеп чыгуу үчүн пайдалануу мүмкүнчүлүгүндө турат. Алынган натыйжалар айыл чарба практикасына талдоо жүргүзүүнүн статистикалык ыкмаларын интеграциялоонун маанилүүлүгүн баса белгилейт, бул өндүрүштүн учурдагы абалын дагы так баалоого гана эмес, ресурстарды натыйжалуу башкаруунун болжолдуу моделдерин калыптандырууга мүмкүндүк берет. Ошентип, изилдөө агротехникалык, экономикалык жана аналитикалык компоненттерди камтыган комплекстүү мамилени ишке ашыруу Чүй областында жана ушул сыяктуу агроклиматтык зоналарда багбанчылыктын туруктуулугун жана атаандаштыкка жөндөмдүүлүгүн жогорулатуунун негизги шарты экенин көрсөтүп турат

Негизги сөздөр: агроэкономикалык талдоо; жемиш өсүмдүктөрү; статистикалык байланыштар; өндүрүштүн рентабелдүүлүгү; климаттык факторлор; агротехнологиялык эффективдүүлүк; корреляциялык көз карандылык

Экономико-корреляционный анализ урожайности многолетних насаждений в Чуйской области Кыргызской Республики в условиях глобальных изменений климата

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Аннотация. Анализ результативности применения аграрных ресурсов становится особенно важным на фоне текущих климатических и экономических трансформаций. В работе рассмотрена корреляционная взаимосвязь между показателями площади садов, уровнем урожайности и объемом валового сбора плодовых культур в Чуйской области Кыргызской Республики за период 2022-2024 гг. Исследование было направлено на установление статистических корреляций между основными показателями производства и экономической результативности для обоснования решений, направленных на повышение эффективности аграрного сектора региона. В исследовании использовались официальные статистические сведения, расчет коэффициентов Пирсона для выявления линейных зависимостей, а также визуальные методы представления данных. Анализ охватывал данные по семечковым и косточковым культурам (яблоня, груша, слива, вишня, черешня, абрикос, персик), включая показатели площади, валового сбора, урожайности, доходов, затрат, прибыли и эффективности. Анализ продемонстрировал стабильное увеличение показателей урожайности и валового объема при уменьшении посевных площадей, что указывает на внедрение более интенсивной модели в садоводстве. Были установлены высокие положительные корреляции между площадью и валовым сбором ($r > 0,7$), а также между валовым сбором и урожайностью ($r > 0,8$). Также была выявлена прямая зависимость между доходами и прибылью, что подтверждало значимость управления финансовыми ресурсами. В то же время уровень эффективности демонстрировал более слабую зависимость, свидетельствующую о многофакторном характере его формирования. Полученные данные могут быть применены при создании региональных стратегий, направленных на повышение экономической отдачи многолетних плодовых культур, с акцентом на повышение урожайности, оптимизацию затрат и применение современных агротехнологий. Полученные результаты подчеркнули важность интеграции статистических методов анализа в аграрную практику, что позволяет не только точнее оценивать текущее состояние производства, но и формировать прогнозные модели для эффективного управления ресурсами. Таким образом, исследование продемонстрировало, что внедрение комплексного подхода, включающего агротехнические, экономические и аналитические компоненты, является ключевым условием повышения устойчивости и конкурентоспособности садоводства в условиях Чуйской области и аналогичных агроклиматических зон

Ключевые слова: агроэкономический анализ; плодоносные культуры; статистическая взаимосвязь; рентабельность производства; климатические факторы; агротехнологическая эффективность; корреляционные зависимости