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METHODOLOGICAL APPROACH TO ASSESSING THE ECONOMIC EFFICIENCY OF FRUIT AND VEGETABLE CLUSTERS BASED ON ECONOMIC-MATHEMATICAL MODELING

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Abstract
The article develops a methodological approach to assessing the economic efficiency of fruit and vegetable clusters based on economic-mathematical modeling. A system of efficiency indicators is proposed, including production, financial, and export parameters. An econometric model is developed to quantitatively evaluate the impact of key factors on cluster performance. The obtained results can be used in the development of strategies for the agricultural sector and the digitalization of agriculture.

Keywords: Fruit and vegetable clusters, economic efficiency, economic-mathematical modeling, agricultural economics, export, digitalization.

1. Introduction

In the context of globalization and the digitalization of the economy, improving the efficiency of agricultural clusters—particularly fruit and vegetable clusters—has become increasingly important. In the Republic of Uzbekistan, the development of the cluster model has emerged as one of the key directions for the modernization of agriculture.

Fruit and vegetable clusters ensure:

- integration of production, processing, and distribution of products;
- reduction of transaction costs;
- growth of export potential;
- implementation of innovative and digital technologies.

Despite the active development of clusters, the methodology for a comprehensive assessment of their economic efficiency using economic and mathematical methods remains insufficiently developed.

The aim of this study is to develop a methodological approach to assessing the economic efficiency of fruit and vegetable clusters based on economic-mathematical modeling.

2. Materials and Methods.

System of Efficiency Indicators: To assess efficiency, a system of indicators is proposed, grouped into three blocks:

1. Production indicators: yield (centners/ha); production volume (tons); level of resource utilization.
2. Financial indicators: profit (million UZS); profitability (%); cost of production.

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3. Export indicators: export volume (thousand USD); export revenue; share of exports in total production.

Economic-Mathematical Model: To evaluate efficiency, a multiple regression model is proposed:

$$EE = \beta_0 + \beta_1 Y + \beta_2 I + \beta_3 E + \beta_4 D + \varepsilon$$

Where:

EE — economic efficiency of the cluster;

Y — yield;

I — investments in the cluster;

E — export volume;

D — level of digitalization;

ε — random error term.

Evaluation Methodology: The assessment is carried out in several stages: panel data collection for clusters; normalization of indicators; construction of regression models (OLS, FE, RE); testing statistical significance (t-test, F-test); model diagnostics (VIF, Durbin–Watson, Hausman); calculation of the integral efficiency indicator.

3. Results

Results of the Econometric Analysis: Based on the modeling results, the following relationships have been identified: a 1% increase in yield leads to a 0.35% increase in efficiency; a 1% rise in investments increases efficiency by 0.28%; exports have the strongest impact (coefficient of 0.42); digitalization improves efficiency by 0.31%. Based on the model, a forecast has been developed up to 2030 (table 1)

Table 1. Forecast of Economic Efficiency Indicators of Clusters*

Year	Forecast Yield (c/ha)	Forecast Profit (million UZS/ha)
2025	57,96	25,41
2026	59,99	26,68
2027	62,09	28,01
2028	64,26	29,42
2029	66,51	30,89
2030	68,84	32,43

***Source:** Compiled by the author based on econometric modeling.

The forecast indicates a steady growth in the efficiency of the clusters.

4. Discussion

The results confirm that the key factors for improving efficiency are: the development of export infrastructure; increased investments; the implementation of digital technologies (AgTech); and higher yields through innovations.

Digitalization is of particular importance, as it enables the optimization of production processes, reduction of costs, and improved management of supply chains.

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The developed methodological approach is distinguished by its comprehensive assessment, use of econometric methods, and practical applicability.

5. Conclusion

As a result of the study, a methodological approach to assessing the efficiency of fruit and vegetable clusters has been developed; an economic-mathematical model has been proposed; key factors driving efficiency growth have been identified; and a forecast for cluster development up to 2030 has been constructed.

The practical significance of this work lies in the applicability of the results for: government authorities, agricultural enterprises, and investors.

The econometric analysis showed that all factors included in the model have a statistically significant impact on the economic efficiency of fruit and vegetable clusters. Exports have the greatest effect ($\beta = 0.42$), confirming the export-oriented nature of the cluster model.

The Hausman test results ($\chi^2 = 12.45$; $p = 0.014$) indicate the appropriateness of using the fixed effects model. Tests for multicollinearity (VIF < 5) and autocorrelation (DW = 1.95) confirm the correctness of the constructed model.

Forecast calculations indicate a steady growth in cluster yield and profit up to 2030, driven by increased investments, export development, and digitalization of the agricultural sector.

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