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ECONOMETRIC ASSESSMENT OF RESOURCE USE EFFICIENCY IN THE AGRICULTURE OF THE REPUBLIC OF KARAKALPAKSTAN

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Abstract. This article examines the identification of the main resource factors affecting the development of agricultural production in the Republic of Karakalpakstan, the econometric assessment of their impact on the dependent variable, and the forecasting of prospective trends in the sector's development. Gross agricultural output was selected as the dependent variable, while the area of irrigated land, water resources, agricultural machinery, labor resources, and investment were selected as the main explanatory factors. The impact of these factors on agricultural production was assessed using correlation and regression analysis and the Cobb–Douglas production function. Elasticity coefficients reflecting the degree of influence of resource factors on production outcomes were determined. In addition, the ARIMA model was used to forecast future trends in the dynamics of gross agricultural output. The research results provide a basis for developing scientific and practical recommendations aimed at ensuring the sustainable development of agricultural production in the Republic of Karakalpakstan, improving the efficient use of limited land and water resources, directing investment and technical resources toward priority areas, and increasing the economic efficiency of the agricultural sector.

Keywords: agriculture, resource potential, efficient use of resources, econometric modeling, Cobb–Douglas function, correlation and regression analysis, ARIMA model, forecasting, land resources, water resources, investment.

Аннотация. В данной статье исследуются вопросы определения основных ресурсных факторов, влияющих на развитие сельскохозяйственного производства в Республике Каракалпакстан, эконометрической оценки степени их воздействия на результативный показатель, а также прогнозирования перспективных тенденций развития отрасли. В качестве результативного показателя выбран объём валовой сельскохозяйственной продукции, а в качестве основных факторов — площадь орошаемых земель, водные ресурсы, сельскохозяйственная техника, трудовые ресурсы и инвестиции. Влияние данных факторов на сельскохозяйственное производство оценено на основе корреляционно-регрессионного анализа и производственной функции Кобба–Дугласа. Определены коэффициенты эластичности, отражающие степень воздействия ресурсных факторов на результаты производства. Кроме того, для оценки будущих тенденций изменения динамики валовой сельскохозяйственной продукции использован метод прогнозирования на основе модели ARIMA. Результаты исследования служат основой для разработки научно-практических рекомендаций по обеспечению устойчивого развития сельскохозяйственного производства в Республике Каракалпакстан, эффективному использованию ограниченных земельных и водных ресурсов, направлению инвестиций и технических ресурсов в приоритетные сферы, а также повышению экономической эффективности аграрной отрасли.

Ключевые слова: сельское хозяйство, ресурсный потенциал, эффективное использование ресурсов, эконометрическое моделирование, функция Кобба–Дугласа, корреляционно-регрессионный анализ, модель ARIMA, прогнозирование, земельные ресурсы, водные ресурсы, инвестиции.

INTRODUCTION

Today, the growing global population, the need to ensure food security, and the increasing relevance of issues regarding the rational use of natural resources make the sustainable development of agriculture one of the strategic tasks. In particular, the shortage of water resources, the deterioration of land reclamation conditions, climate change, and environmental problems negatively affect the efficiency of agricultural production. Therefore, the efficient use of available land, water, labor, technical, and investment resources in the agricultural sector and the scientific assessment of their impact on production volumes are of great importance.

In Uzbekistan, measures are being implemented to modernize agriculture, introduce innovative and resource-saving technologies, improve the use of land and water resources, and enhance the competitiveness of the agricultural sector. In these processes, taking into account the natural and economic characteristics of the regions, identifying the factors affecting agricultural production and quantitatively assessing their level of impact are of particular scientific and practical importance.

Agriculture in the Republic of Karakalpakstan is characterized by complex natural and climatic conditions, limited water resources, declining soil fertility, and environmental problems, which directly affect the efficiency of agricultural production. From this perspective, identifying opportunities for the efficient use of available resources in the sustainable development of agricultural production in the region, assessing the main influencing factors, and forecasting prospective development indicators are among the important tasks.

The multifactorial nature of agricultural production necessitates a comprehensive analysis of the relationships among the factors influencing its development. The use of econometric modeling methods makes it possible to determine the influence of land, water, technical, labor, and investment resources on the volume of gross agricultural output, assess the elasticity of each factor, and forecast future production dynamics. This approach also forms an important information base for developing scientifically grounded management decisions aimed at increasing the efficiency of resource use.

Based on this, this study pays special attention to assessing the main resource factors affecting the development of agriculture in the Republic of Karakalpakstan using econometric methods, determining their degree of influence on the volume of gross agricultural output, and forecasting prospective indicators for the sector's development. The research results serve to develop practical proposals and recommendations for the efficient use of resources in the region, the sustainable development of agricultural production, and an increase in the economic efficiency of the agricultural sector.

LITERATURE REVIEW

Issues concerning the development of agricultural production, the efficient use of resources, and the identification of future development trends in the agricultural sector are considered among the crucial areas of modern economic research. In particular, identifying resource factors affecting agricultural production volumes, econometrically assessing their levels of impact, and developing long-term forecast indicators based on existing trends are of great importance for improving regional agrarian policy. Research conducted in this area by foreign and domestic scholars has formed the theoretical and methodological foundations for evaluating the efficiency of agricultural resource use and modeling production.

In the methodology of econometric analysis and forecasting of agricultural production, research devoted to time-series analysis is of particular importance [1]. The developed ARIMA models make it possible to forecast future indicators by taking into account the historical dynamics and random fluctuations of time series. This approach serves as an important methodological basis for determining trends in the volume of gross agricultural output over the years and forecasting future production volumes. From this perspective, it is advisable to use forecasting methods based on time series when assessing the prospective volume of gross agricultural output in the Republic of Karakalpakstan.

Issues concerning the assessment of resource-use efficiency in agriculture have been extensively studied [2]. In works devoted to the analysis of efficiency and productivity, the theoretical and practical aspects of quantitatively assessing the level of production-resource utilization and analyzing changes in technical efficiency and productivity are highlighted. This approach serves as an important theoretical basis for assessing the impact of land, water, labor, technical, and investment resources on production efficiency in agriculture.

In research devoted to the economics of agricultural production, the economic relationships among production factors, resource utilization, and agricultural production efficiency are theoretically substantiated [3]. This approach provides an important scientific basis for systematically studying the resource factors that determine production volumes in agriculture and evaluating the efficiency of their use. These studies can also be used as a theoretical basis for constructing production functions in the agricultural sector.

In agriculture, the assessment of resource efficiency using the Cobb–Douglas production function occupies a special place [4]. In studies of Indian agriculture, the impact of production factors on efficiency across regions was analyzed using the Cobb–Douglas production function. This approach makes it possible to determine the elasticity coefficients of resource factors in agricultural production, assess their relative impact, and identify priority factors for improving production outcomes. In this regard, this study is scientifically and methodologically close to evaluating the impact of irrigated land area, water resources, machinery, labor, and investment on gross agricultural output in the Republic of Karakalpakstan using the Cobb–Douglas function.

Issues concerning the sustainability of agricultural development and the intensive use of resources have been investigated [5]. The authors emphasize the need to ensure environmental sustainability alongside

economic efficiency in the process of intensifying agricultural production. Their approach demonstrates the importance of managing available resources in an environmentally and economically efficient manner rather than merely increasing resource use to raise agricultural production volumes. This conclusion is particularly important in the conditions of the Republic of Karakalpakstan, given its limited land and water resources and existing environmental problems.

Local researchers have also paid special attention to developing econometric and forecasting models for agriculture in the Republic of Karakalpakstan. The study "Integrated Modeling Approaches in Forecasting and Managing Agricultural Production in Karakalpakstan" highlights issues related to the use of integrated modeling approaches in forecasting and managing agricultural production [6]. This study substantiates the need for the integrated use of economic-mathematical and econometric models in agricultural production management.

Additionally, the scientific work "Analysis and Forecast of the Resource Potential of Agriculture in the Republic of Karakalpakstan" analyzes the formation of the resource potential of the region's agriculture, the current state of available resources, and future trends in their development [7]. An important aspect of this study is that, along with assessing the resource potential of agriculture, it focuses on forecasting its future state. This approach serves as an important basis for making strategic decisions regarding the development of the resource base of the region's agricultural sector.

Issues concerning the econometric modeling of agricultural development in the Republic of Karakalpakstan are examined in detail in the study "Econometric Modeling of Agricultural Development in the Republic of Karakalpakstan" [8]. This study emphasizes the assessment of factors influencing agricultural development using econometric methods and reveals the possibilities for quantitatively analyzing the development dynamics of the agricultural sector. This work is methodologically close to the present research and serves as a basis for identifying the factors influencing agricultural development in the Republic of Karakalpakstan and assessing their levels of impact through econometric models.

At the same time, the study "Theoretical Foundations and Evaluation Criteria for the Effective Use of Agricultural Resources" develops the theoretical and methodological foundations and evaluation criteria for the efficient use of agricultural resources [9]. This study substantiates the need to evaluate resource efficiency not only in terms of economic outcomes but also from the perspective of rational resource use and sustainable development. This approach serves as an important theoretical basis for comprehensively assessing the impact of land, water, machinery, labor, and investment resources in the present research.

An analysis of the literature reviewed above shows that the research of foreign scholars has primarily focused on assessing agricultural production efficiency, determining resource-utilization levels, estimating factor elasticity using the Cobb–Douglas production function, ensuring sustainable intensification, and forecasting based on time series. In domestic research, significant attention has been paid to the theoretical and methodological foundations of resource potential, production forecasting, econometric modeling, and the efficient use of resources in agriculture in the Republic of Karakalpakstan.

However, in most existing studies, issues concerning the simultaneous assessment of the influence of irrigated land area, water resources, machinery, labor, and investment factors on agricultural development using a unified, integrated econometric approach, the determination of elasticity coefficients for each factor, and the forecasting of future gross agricultural output indicators based on the results obtained have not been studied sufficiently systematically.

In this regard, unlike existing studies, the scientific approach of the present research is aimed at comprehensively assessing the main resource factors influencing agricultural development in the Republic of Karakalpakstan. In this study, the elasticity levels of resource factors are determined using the Cobb–Douglas production function, their relationships with gross agricultural output are assessed through correlation and regression analysis, and the prospective dynamics of the sector's development are determined using the ARIMA model. As a result, it will be possible to identify priority areas for the efficient use of agricultural resources in the Republic of Karakalpakstan and develop scientifically grounded proposals to ensure the sustainable development of the sector.

RESEARCH METHODOLOGY

The methodological basis of this study is an econometric approach aimed at comprehensively assessing the resource factors affecting the development of agricultural production in the Republic of Karakalpakstan, determining their degree of influence on the resulting indicator, and forecasting future trends. During the study, methods of economic and statistical analysis, a systems approach, comparison, correlation and regression analysis, econometric modeling, and time-series forecasting were used comprehensively.

The information base of the study consists of statistical data reflecting the development of the agricultural sector in the Republic of Karakalpakstan from 2010 to 2025.

During the forecasting process based on the ARIMA model, the historical dynamics of gross agricultural output were analyzed, and trends and dynamic changes in the time series were evaluated. The forecast results obtained using the model served as the basis for determining the prospective volume of agricultural production in the Republic of Karakalpakstan and assessing its future development trends.

An important feature of the research methodology is that the processes of assessing and forecasting the factors affecting agricultural development were carried out in an interconnected manner. Initially, the degree of correlation between the main factors and the resulting indicator was determined through correlation analysis. Subsequently, the elasticity coefficients of the resource factors were estimated using the Cobb–Douglas production function. At the final stage, the future volume of gross agricultural output was forecast using the ARIMA model.

To ensure the reliability of the research results, attention was paid to the statistical significance and economic validity of the econometric models. The results obtained served as a methodological basis for determining the impact of resource factors on agricultural production, identifying priority factors, and developing scientifically grounded proposals to increase resource efficiency.

Thus, the selected research methodology allows for a comprehensive assessment of agricultural development in the Republic of Karakalpakstan in terms of the influence of resource factors, production elasticity, and prospective dynamics. The results obtained using this approach can be used in making practical decisions on the efficient use of land and water resources in the region, attracting investment in priority areas, improving technical support, and ensuring the sustainable growth of agricultural production.

The sustainable development of the agricultural sector in the Republic of Karakalpakstan, the efficient use of available resources, and the increase in production volumes are currently considered among the most critical areas of the regional economy. The complex natural and climatic conditions of the region, the shortage of water resources, declining soil fertility, and environmental problems require the application of scientifically grounded management methods in the agricultural sector. From this perspective, an in-depth analysis of the factors influencing agricultural development using econometric models is of particular scientific and practical importance. The study focuses specifically on assessing the efficiency of land, water, technical, and labor resource utilization, as well as forecasting future development trends.

During the study, regression and correlation analysis, the ARIMA model, and multifactor production functions were used to determine the interrelationships among the main factors affecting gross agricultural output. The model is based on official data from the Department of Statistics of the Republic of Karakalpakstan, the Ministry of Agriculture, and the Ministry of Water Resources for the period from 2010 to 2025. The main objective of the study was to evaluate the efficiency of resource utilization, determine the degree of elasticity of the resources, and develop practical recommendations aimed at increasing production efficiency.

Under the conditions of the Republic of Karakalpakstan, the gradual introduction of laser land-leveling technologies, taking into account the regional characteristics of the terrain, and the optimal use of machinery are of great importance for the sustainable development of the agricultural sector. This will not only conserve water resources but also contribute to increasing soil fertility, improving crop yields, and steadily increasing farm incomes.

During the study, the main factors influencing the volume of agricultural production in the Republic of Karakalpakstan were selected. Specifically, the volume of gross agricultural output was taken as the resulting indicator, while the main resource factors influencing it were the area of irrigated land, the volume of water used in agriculture, the number of agricultural machines, labor resources, and the volume of investment in the agricultural sector.

The model defines:

Y — the volume of gross agricultural output, billion soums;

x_1 — the area of irrigated land, thousand hectares;

x_2 — the volume of water used in agriculture, million m^3 ;

x_3 — the number of agricultural machines, units;

x_4 — the number of labor resources, thousand people;

x_5 — the volume of investment in agriculture, billion soums.

To determine the resource dependence of agricultural production, the multifactor Cobb–Douglas production function was used:

$$Y = A \cdot x_1^{\alpha_1} \cdot x_2^{\alpha_2} \cdot x_3^{\alpha_3} \cdot x_4^{\alpha_4} \cdot x_5^{\alpha_5}$$

ANALYSIS AND RESULTS

As a result of econometric calculations, the following values of the model parameters were determined:

$$Y = 1,28 \cdot x_1^{0,31} \cdot x_2^{0,22} \cdot x_3^{0,18} \cdot x_4^{0,14} \cdot x_5^{0,27}$$

The results obtained showed that the area of irrigated land and the volume of investment have the greatest impact on the volume of agricultural production.

Table 1

Elasticity coefficients of factors influencing the development of agriculture in the Republic of Karakalpakstan¹

Indicators	Elasticity coefficient	Level of impact
Irrigated land area (x_1)	0,31	High
Volume of water resources (x_2)	0,22	Moderate
Technical resources (x_3)	0,18	Moderate
Labor resources (x_4)	0,14	Low
Investment volume (x_5)	0,27	High

The ARIMA model was also used to forecast changes in agricultural production over time. After comparing various options, the following model was selected as the optimal model:

$$ARIMA (1,1,1)$$

The forecast results based on this model showed that, by 2030, the gross agricultural output of the Republic of Karakalpakstan will grow by an average of 5.2–5.8 percent per year. These results indicate the potential for the sustainable development of agricultural production through more efficient resource use, technological modernization, and increased investment.

The results of the study may provide an evidence base for agricultural modernization, the introduction of resource-saving technologies, and the sustainable growth of agricultural production.

Table 2

Forecast indicators of gross agricultural output in the Republic of Karakalpakstan²

Years	Gross agricultural output, trillion soums	Growth index, %
2025	28,4	104,8
2026	30,1	105,2
2027	31,9	105,6
2028	33,8	105,8
2029	35,7	105,6
2030	37,8	105,9

The forecast results showed that there is an opportunity to further increase production volumes through the efficient use of available resources in the agricultural sector of the Republic of Karakalpakstan. In particular, the optimization of water and technical resources, the widespread introduction of modern agricultural technologies, and the digitalization of production processes can significantly improve the efficiency of the agricultural sector.

Additionally, increasing investment in the agricultural sector will expand opportunities for purchasing modern agricultural machinery and technologies, digitalizing production processes, and optimizing resource utilization. This is also confirmed by the high elasticity coefficient of investment.

¹ Source: Calculated by the author based on the econometric model.

² Source: Forecast calculations by the author based on official statistical data.

Based on the results of the analysis, for the sustainable development of agricultural production in the Republic of Karakalpakstan, it is advisable to prioritize the efficient use of irrigated land, the introduction of water-saving technologies, and the expansion of investment in the agricultural sector. At the same time, the efficiency of integrated resource use can be increased by improving technical support, enhancing the qualifications of labor resources, and digitalizing production processes.

Overall, the results of the econometric analysis and forecasting showed that resource factors are of great importance in the development of agriculture in the Republic of Karakalpakstan. The results obtained can be used to improve agricultural policy, allocate resources efficiently, direct investment toward priority areas, and develop a strategy for the sustainable development of agricultural production until 2030.

CONCLUSIONS AND SUGGESTIONS

The results of the conducted research showed that the sustainable development of agricultural production in the Republic of Karakalpakstan directly depends on the efficient and rational use of available resources, the accurate assessment of their impact on the production process, and the implementation of comprehensive measures aimed at increasing resource efficiency. The results of the econometric analysis showed that the effects of land, water, machinery, labor, and investment resources on agricultural production outcomes are not uniform; among them, irrigated land and investment have the greatest impact.

According to the results obtained using the Cobb–Douglas production function, the elasticity coefficient of the irrigated land area was 0.31, while the elasticity coefficient of investment volume was 0.27. For the volume of water resources, this indicator was 0.22; for technical resources, 0.18; and for labor resources, 0.14. These results show that, under the conditions of the Republic of Karakalpakstan, in addition to the efficient use of land and investment resources, the optimization of water and technical resources is of great importance in increasing agricultural production.

The forecast results based on the ARIMA model showed that the gross agricultural output of the Republic of Karakalpakstan could increase from 28.4 trillion soums in 2025 to 37.8 trillion soums by 2030. During the forecast period, the annual growth rate of gross agricultural output is expected to range from 104.8 to 105.9 percent. These forecasts indicate the possibility of sustainable growth in agricultural production under conditions of efficient use of available resources, the introduction of innovative technologies, and increased investment in the agricultural sector.

Based on the research results, the following scientific and practical proposals were developed:

First, given the high elasticity coefficient of irrigated land, it is advisable to strengthen measures aimed at the efficient use of existing agricultural land, improving land reclamation, and preventing salinization and degradation processes.

Second, to increase the efficiency of water resource use, it is necessary to widely introduce water-saving technologies, use modern drip and sprinkler irrigation systems, reduce water losses in irrigation networks, and develop a digital monitoring system for water resources.

Third, it is necessary to increase the volume of investment in the agricultural sector and direct it primarily toward areas that yield high economic efficiency. In particular, it is advisable to prioritize investment in modern agricultural machinery, resource-saving technologies, water management infrastructure, and digital agricultural technologies.

Fourth, along with increasing the level of provision with agricultural machinery, it is necessary to improve the efficiency of existing machinery use, gradually replace outdated equipment, and introduce high-performance modern technical means.

Fifth, it is necessary to prioritize qualitative indicators over the quantity of labor resources in agriculture, improve the system for training qualified specialists with knowledge of modern agricultural technologies and digital management methods, and regularly enhance the professional qualifications of farmers and smallholder producers.

Sixth, it is advisable to widely use the results of econometric modeling and forecasting when developing regional programs for agricultural development in the Republic of Karakalpakstan. This will enable the efficient distribution of resources across regions and the direction of investment toward priority areas.

Seventh, through the widespread implementation of laser land leveling, water-saving irrigation, digital monitoring, and precision farming technologies in agricultural production, it is possible to reduce water consumption, increase soil fertility, and stabilize yields.

Eighth, based on the forecast indicators obtained using the ARIMA model, it is necessary to develop medium- and long-term strategic plans to increase the volume of gross agricultural output until 2030, taking into account resource-efficiency and environmental-sustainability indicators.

Overall, the research results showed that the primary condition for increasing agricultural production in

the Republic of Karakalpakstan is the efficient, economical, and innovative use of available resources rather than an increase in their quantity. Therefore, in the future, when formulating agrarian policy, the efficient use of irrigated land, the conservation of water resources, the expansion of investment, and the harmonization of technical modernization and digitalization processes will serve as important factors in ensuring the sustainable development of agriculture in the Republic of Karakalpakstan.

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