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EMPIRICAL AND REGRESSION ANALYSIS OF AGRICULTURAL DEVELOPMENT IN KARAKALPAKSTAN

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Abstract: This article analyzes the impact of investments, employment, and irrigation systems on the gross regional product (GRP) in the Republic of Karakalpakstan. The study uses economic and mathematical methods to study the factors affecting agricultural production based on statistical data for the period 2015–2023. The results show the importance of investments and irrigation infrastructure, and reveal the positive impact of the employment level on GRP. Based on the results of the study, practical recommendations for the development of agriculture in Karakalpakstan were developed.
Keywords: gross regional product, investments, irrigation, employment, economic analysis, potential, modernization, Karakalpakstan.

ЭМПИРИЧЕСКИЙ И РЕГРЕССИОННЫЙ АНАЛИЗ РАЗВИТИЯ СЕЛЬСКОГО ХОЗЯЙСТВА В КАРАКАЛПАКСТАНЕ

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Аннотация: В данной статье анализируется влияние инвестиций, занятости и ирригационных систем на валовой региональный продукт (ВРП) в Республике Каракалпакстан. В исследовании используются экономико-математические методы для изучения факторов, влияющих на сельскохозяйственное производство, на основе статистических данных за 2015-2023 годы. Результаты показывают важность инвестиций и ирригационной инфраструктуры, а также положительное влияние уровня занятости на ВРП. По результатам исследования были разработаны практические рекомендации по развитию сельского хозяйства в Каракалпакстане.
Ключевые слова: валовой региональный продукт, инвестиции, ирригация, занятость, экономический анализ, потенциал, модернизация, Каракалпакстан.

I. INTRODUCTION

The Republic of Karakalpakstan represents a strategically significant region within the agrarian sector of the Republic of Uzbekistan. Its abundant natural resources, particularly land and water, serve as fundamental inputs for agricultural development. However, persistent challenges such as water scarcity, underutilization of labor resources, and an inadequately developed investment climate have adversely affected the efficiency and productivity of the agricultural sector in the region [1].

Amidst the broader economic reform agenda being pursued in Uzbekistan, the effective mobilization of Karakalpakstan's agricultural potential, modernization of its irrigation infrastructure, and the stimulation of investment inflows have become pressing priorities. In this context, the present study aims to empirically examine the impact of three core variables — investment, employment, and irrigation — on the gross agricultural output (GAO) of the region. The analysis is grounded in recent statistical data and employs economic-mathematical modeling to assess the influence of these factors.

II. LITERATURE ANALYSIS

The theory and practice of the formation of agriculture in foreign countries have been studied to a certain extent by many scientists and researchers. In particular, Radenovich, Jarko and Krstich, Boyan and Markovich, Milan, Muhammad Ali, Nasrida Man, Farrah Muharam, Jai Z., Martinez J.F., Beltran V. and Martinez N.L., Cheung M.F., To U.M., Milanovich, Slavoljub K., Nehra, Mukesh Jangra, Sumit Jangra and others have researched these issues. It is noteworthy that the issues of the agro-industrial complex are widely covered in the scientific research of CIS scientists Bautin V.M., Kozlov V.V., Fedorenko V.F., Koptelov A., Semilyakova K.V., Ananev M.A., Goryaev G.D., Golovkov V.A., Shafranskaya I.V., Asalkhanov P.G., Bendik N.V., Chibisova I.S., Platonova T.E.3 and others.

Among the economists of our country Gulyamov S.S., Shodiev T.Sh., Abdullaev I.S., Begalov B.A., Doschanov T.D., Ruzmetov B.R., Salaev S.K., Saukhanov Zh.K.4 Kuchkarov T.S., Kenjabaev A.T., Mirzatayev S.M., Utemuratov R.U., Jiyemuratov T.P. and others development of agriculture, using available resources efficient use of production processes in the industry modeling, ensuring optimal solutions in agriculture use of information technologies, forecast indicators theoretical and methodological aspects of forecasting based on econometric models scientific and practical problems have been thoroughly researched.

III. RESEARCH METHODOLOGY

In the context of agricultural development, the key drivers of economic growth are widely recognized to include capital investments, the effective utilization of labor resources (employment), and the efficient management of land and water resources (notably through irrigation). Numerous studies by international organizations such as the World Bank and the Food and Agriculture Organization (FAO) of the United Nations emphasize that enhancing the performance of irrigation systems can increase agricultural productivity by approximately 25–30 percent [2].

This study employs a combination of statistical analysis and econometric modeling techniques to explore the relationship between gross agricultural output (GAO) and selected explanatory variables. In particular, regression analysis is applied to quantify the relative impact of investment, employment, and irrigation on agricultural productivity.

The data utilized in this research were obtained from official sources, including the State Committee on Statistics and the Ministry of Economy and Agriculture of the Republic of Karakalpakstan, covering the period from 2015 to 2023. The study also underscores the importance of synergistic cooperation between public and private sectors, as well as enhanced engagement with international financial institutions. Such collaborative efforts are viewed as critical for fostering sustainable and resilient agricultural development in the region.

IV. RESULTS AND DISCUSSION

Given its geographical location and arid climatic conditions, the Republic of Karakalpakstan is critically dependent on the efficiency of its irrigation systems for agricultural development. In this region, the foundation of crop production — and, by extension, the fate of every harvest — is closely tied to the effective and rational use of available water resources. Every drop of water drawn from the Amu Darya River and other water basins plays a vital role in sustaining fertile fields and ensuring abundant yields. Therefore, irrigation serves not only as the lifeblood of the

agricultural sector but also as a fundamental pillar for maintaining ecological balance and the overall well-being of the population.

A well-functioning irrigation system ensures stability in crop production. Conversely, water shortages or the deterioration of irrigation infrastructure can lead to insufficient watering, thereby reducing yields or resulting in the complete loss of crops. These risks are particularly acute in the climatic context of Karakalpakstan, where crops become highly vulnerable to drought during the intense heat of summer. Hence, the uninterrupted operation of every canal, sluice, and water gate — and the timely and sufficient delivery of water — is of paramount importance.

Moreover, the expansion of irrigation facilitates the reclamation of new lands and the enlargement of cultivated areas. Historically, agriculture has thrived wherever there was access to water — and this principle remains as relevant today as ever. Extending irrigation networks to new territories can substantially increase the volume of agricultural production, thereby contributing to food security and enhancing export potential.

However, the limitations of water resources — particularly those associated with the environmental disaster of the Aral Sea — necessitate the prudent and efficient use of water. The modernization of aging Soviet-era irrigation systems, along with the introduction of water-saving technologies such as drip and sprinkler irrigation, offers a viable solution for minimizing water loss. These innovations not only conserve water but also reduce delivery costs, mitigate soil erosion, and lessen the risk of land salinization.

In addition, the expansion of irrigation capabilities opens up new opportunities for crop diversification. Beyond traditional crops such as cotton and grain, the cultivation of fruits, vegetables, melons, and forage crops — which, though more water-intensive, are often more economically rewarding — becomes feasible. This diversification enriches the structure of gross agricultural output, increases farmers' incomes, and strengthens the region's economic resilience.

In sum, irrigation is not only a critical instrument for addressing current challenges in the agricultural sector of Karakalpakstan but also represents a strategic priority for ensuring the region's long-term development and sustainability.

The following section presents statistical data from 2015 to 2023 on the gross agricultural output of Karakalpakstan, the level of employment in the sector, the area of irrigated land, and the volume of investments:

1-table

GAO and key factors in the Republic of Karakalpakstan from 2015 to 2023 (bln. UZS or thous. hectares)[1]

Year	GRP (bln UZS)	Investment (bln UZS)	Employment in the sector (thous. people)	Irrigation (thous. ha)
2015	1 900	280	112	210
2016	2 100	310	114	215
2017	2 450	370	116	217
2018	2 900	450	118	219
2019	3 200	500	120	220
2020	3 500	540	122	222
2021	3 950	600	124	225
2022	4 400	670	125	227
2023	4 850	720	126	230

These figures indicate that the gross agricultural output (GAO) increased by a factor of 2.55 over the nine-year period, reflecting a favorable dynamic within the agrarian sector. While this growth can be attributed to a variety of contributing factors, the primary drivers have been the expansion of investment and the improvement of irrigation infrastructure (see Figure 1).

[1] FAO. Water for Sustainable Agriculture. – Rome: FAO Publishing, 2018. – P. 28–36.

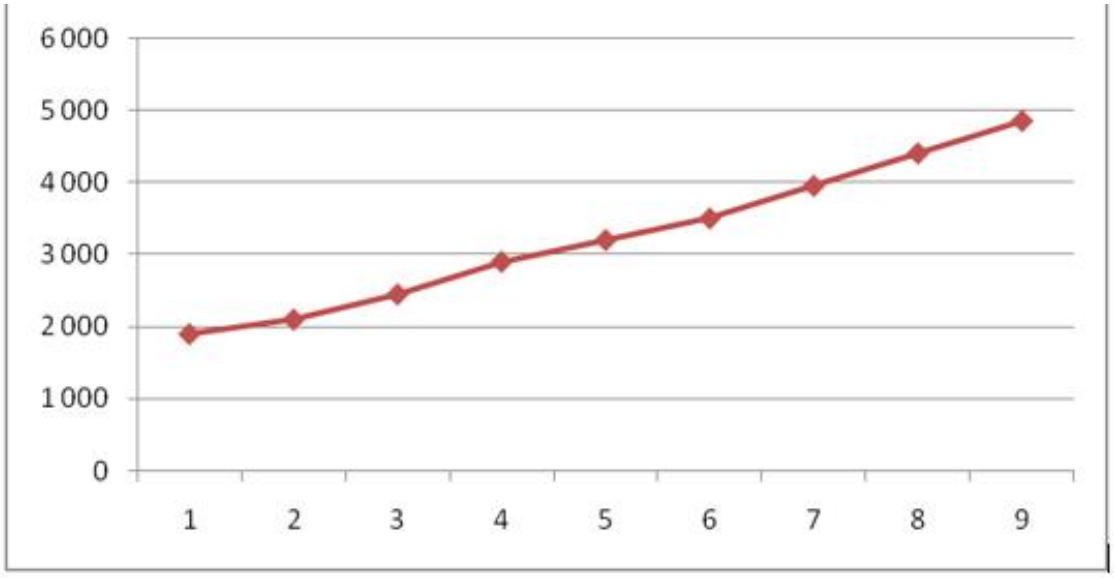

Figure 1. Growth Dynamics of Gross Agricultural Output in Karakalpakstan (2015–2023)[2]

The results of the regression analysis are as follows:

The impact of investment on gross agricultural output (GAO) is strong and statistically significant ($R^2 = 0.91$);

The level of employment is also positively and significantly correlated with GAO ($R^2 = 0.87$);

The expansion of irrigated land shows a moderately positive effect on GAO ($R^2 = 0.76$).

2-table

Regressive analysis of the influence of factors on GRP[3]

Faktor	R^2 coefficient	Impact direction	Interpretation
Investtment	0,91	Positive	The investment variable exhibits a strong and statistically significant positive relationship with GAO. An increase in capital investment is associated with a substantial rise in gross agricultural output, underscoring the critical role of financial inputs in enhancing agricultural productivity.
Employment	0,87	Positive	The employment level demonstrates a strong positive correlation with GAO. A rise in the number of employed individuals in the agricultural sector contributes meaningfully to output growth, indicating the importance of human capital utilization in agricultural production.
Irrigation	0,76	Positive	The area of irrigated land has a moderately strong positive effect on GAO. Although the impact is less pronounced than that of investment or employment, the expansion of irrigated land still plays a notable role in improving crop yields and stabilizing agricultural output.

[2] Compiled by the author based on reports from the Ministry of Economy and Agriculture of the Republic of Karakalpakstan, 2015–2023 – www.agro.uz , www.imv.uz.

[3] O‘zbekiston Respublikasi Davlat statistika qo‘mitasi ma’lumotlari. – www.stat.uz

The highest explanatory power among the analyzed factors is associated with investment, as evidenced by the R^2 coefficient, confirming its role as the principal driving force behind agricultural growth. Employment also demonstrates a substantial and statistically significant impact, reinforcing the importance of the efficient utilization of labor resources in enhancing agricultural output. Irrigation, while exhibiting a comparatively lower coefficient, nonetheless maintains a consistent and positive influence on gross agricultural performance.

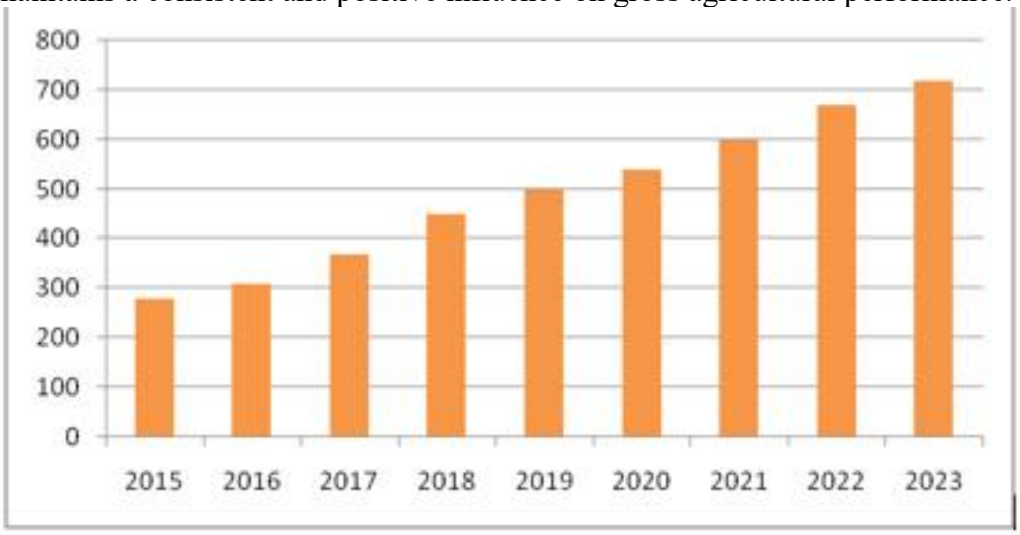

Figure 2. Dynamics of Investment in the Agricultural Sector of Karakalpakstan (2015–2023)[4]

The strong correlation between gross agricultural output and investment volume ($R^2 = 0.91$) underscores the critical dependence of agrarian development on sustained financial support. Without adequate investment, the advancement of the agricultural sector is virtually unattainable.

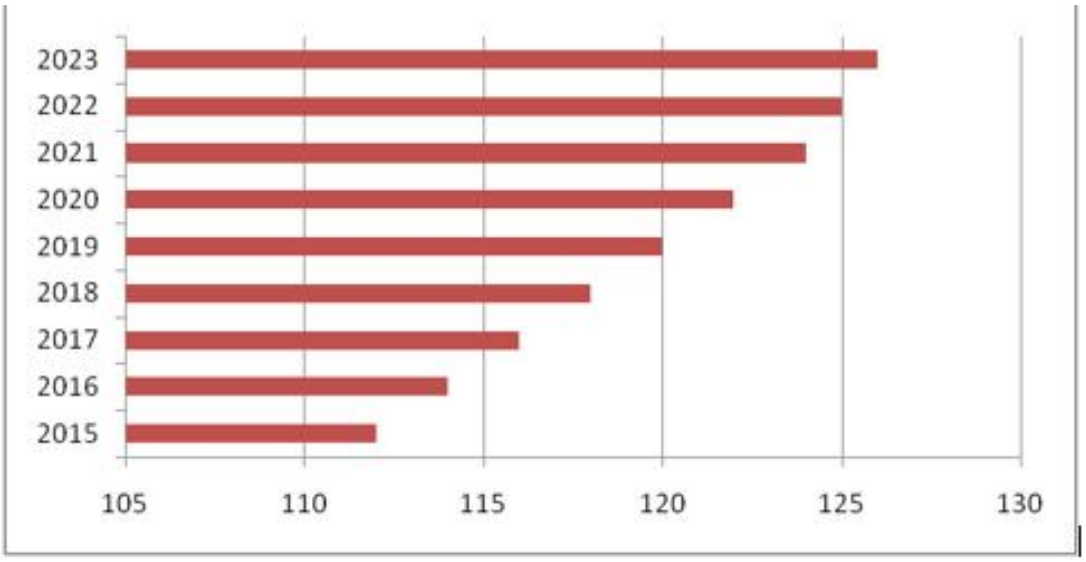

Figure 3. Dynamics of Agricultural Employment in Karakalpakstan (2015–2023)[5]

The available data reflect an upward trend in the quantity of labor resources employed in the agricultural sector. However, beyond quantitative growth, there remains a pressing need for

[4] Compiled by the author based on reports from the Ministry of Economy and Agriculture of the Republic of Karakalpakstan, 2015–2023 – www.agro.uz , www.imv.uz

[5]Compiled by the author based on reports from the Ministry of Economy and Agriculture of the Republic of Karakalpakstan, 2015–2023 – www.agro.uz, www.imv.uz.

improvements in qualitative aspects, including worker skill levels, professional training, and the adoption of innovative competencies.

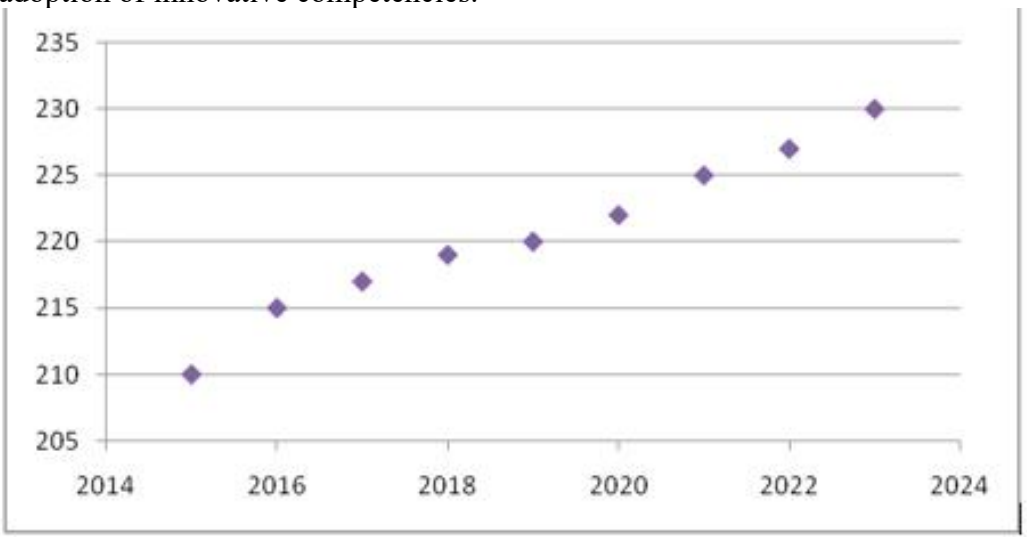

Figure 4. Expansion of Irrigated Land Area Allocated to Agriculture in Karakalpakstan (2015–2023)[6]

Although the increase in irrigated land has contributed positively to productivity, the overall effectiveness of this factor remains limited in the absence of the adoption of modern technologies such as drip and sprinkler irrigation. The implementation of these systems is essential for achieving sustainable improvements in irrigation efficiency.

V. CONCLUSION

The findings of this study indicate that the growth in gross agricultural output (GAO) in the Republic of Karakalpakstan has been significantly influenced by three primary factors: increased investment, rising employment levels, and the development of irrigation systems. Among these, the strategic allocation of investments toward modern technologies presents the greatest potential for enhancing agricultural productivity on a sustainable basis.

In light of the above, the following policy recommendations are proposed for fostering agricultural development in Karakalpakstan:

1. Strengthening Investment Flows

- Encourage both public and private investment initiatives aimed at the modernization of agricultural machinery and infrastructure;
- Provide tax incentives and direct subsidies to both domestic and foreign investors engaged in the agrarian sector;
- Design and implement region-specific annual investment programs at the district level to ensure tailored development priorities.

2. Enhancing Employment Policies

- Establish vocational training centers in rural areas focused on agribusiness and agricultural technologies;
- Promote youth employment by providing microcredit facilities to smallholder farms and entrepreneurial rural initiatives;
- Create seasonal employment opportunities tailored to the needs of the rural population to reduce underemployment and stimulate local economic activity.

3. Modernization of Irrigation Systems

[6] Compiled by the author based on reports from the Ministry of Economy and Agriculture of the Republic of Karakalpakstan, 2015–2023 – www.agro.uz, www.imv.uz.

- Scale up the introduction of modern irrigation techniques, including drip and sprinkler irrigation, to improve water use efficiency;
- Develop a phased program to gradually replace obsolete Soviet-era irrigation infrastructure with modern, sustainable alternatives;
- Allocate targeted subsidies to farms that adopt water-saving technologies and promote sustainable water management practices.

4. Fostering Cooperation and Coordination Mechanisms

- Strengthen public-private partnership frameworks for the implementation of agricultural development projects;
- Establish technical and financial cooperation programs with international financial institutions such as the World Bank, FAO, and others, to mobilize external expertise and funding.

These integrated measures, if effectively implemented, can serve as a foundation for sustainable and inclusive agricultural development in Karakalpakstan, ultimately contributing to regional food security, economic resilience, and long-term prosperity.

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