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Analysis of Sustainable Agricultural Development in Kazakhstan: Key Economic and Climatic Indicators

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ABSTRACT

Agriculture is a key sector in Kazakhstan's economy, contributing significantly to employment and GDP. However, geographic, climatic, economic, and policy-related factors contribute to substantial regional differences in agricultural performance. This paper aims to assess the level of agricultural development across Kazakhstan's regions using an integral index based on key variables that influence productivity, such as soil surface temperature, producer price indices, total sown area, employment figures, and domestic R&D expenditure. The paper used the following methods: correlation analysis to determine the relationship, regression analysis after filtering variables, integral index for a generalized assessment of agricultural productivity by region, and cartographic analysis. The findings highlight significant geographical variations, with regions like Almaty and Turkestan showing high productivity, benefiting from favorable climatic conditions and infrastructure. In contrast, regions such as North Kazakhstan and Pavlodar need to catch up, primarily due to harsher environmental conditions and lower investment levels. These differences point to the need for a targeted approach aimed at supporting less developed regions, as well as the dissemination of best practices from successful areas. The cartographic analysis visualizes these imbalances. The southern regions are highlighted as zones of high productivity, while the northern and eastern regions are shown as risk zones that require priority attention and resources. This research underscores the need for adaptive strategies to address regional inequalities, aiming to boost agricultural productivity and foster sustainable growth across Kazakhstan.

KEYWORDS: Agriculture, Agricultural Productivity, Economy, Diversification, Sustainability, Climate Change, Agricultural Policy

SCSTI: 06.77.35

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1. INTRODUCTION

Agriculture is the leading sector in Kazakhstan's economy, as it forms the most important source of employment and contribution to GDP. However, despite being very promising, with its great extents of arable land and a wide variety of climatic zones, agriculture has serious challenges, especially those related to regional disparities in agricultural productivity and development. These inequalities pose challenges in attaining food security and sustainable development; hence, a close analysis is necessary concerning those conditions that affect agricultural performance in different regions.

The geographical diversity of Kazakhstan largely affects the mode of its agricultural practices. With its vast steppes, mountain areas, and very productive river valleys, the country supports an extensive range of crops and livestock. The southern parts, like Almaty and Turkestan, have good climatic conditions with fertile soils, thus enabling them to produce higher agricultural output. On the other hand, northern parts, such as North Kazakhstan and Pavlodar, are generally crippled by harsher climates that give way to meager crop yield and agricultural productivity. Understanding these geographic and climatic influences is critical for making appropriate agricultural policies targeted to the needs of each and every region.

Not considering geographical factors, the economic conditions of the land also play an important role in determining productivity in agriculture. Also, access to markets, investment in technology, and infrastructure development form the basic ingredients that determine performance in the agricultural sector. As can be seen, regions that invest highly in R&D often realize increased productivity through the adoption of new methods and technologies in farming. Besides, favorable market conditions sign of stability in the producer price index of agricultural products and farmers' confidence to enhance their operations, thus contributing to increased agricultural growth.

Government policies are significant and have a direct effect on agricultural development. Good support programs involving subsidies, credit facilities, and infrastructure investment in agriculture raise productivity very substantially in lagging regions. Policymakers must consider regional needs when developing strategies and ensure that support mechanisms address specific challenges and opportunities.

Climate change has become the most pressing topic affecting Kazakhstan's agricultural development. Indeed, shifting rainfall patterns and increasing temperatures may pose an unusually high risk to crop yields and livestock production, especially in areas already vulnerable to climatic variability. According to the literature, climate change exacerbates existing problems, and therefore, adaptive measures need to be implemented to mitigate its negative impacts on agricultural productivity. In fact, there is an urgent need to understand how climate change interacts with local agricultural practices to develop appropriate responses that ensure increased resilience and sustainability.

The paper aims to comprehensively assess agricultural development across different regions of Kazakhstan by using an integral index that represents key variables influencing productivity. These include soil surface temperature, the producer price index of agricultural products, total sown area, number of employed, domestic R&D expenditure, and others that may serve for a multidimensional analysis of agricultural performance. It is possible to find out the relations between these variables and agricultural productivity using appropriate weights to create a robust integral index through correlation and regression analyses.

This study's findings surpass the academic debate, providing beneficial information to policymakers, investors, and other agricultural stakeholders. This research will identify areas of strength and weaknesses in agricultural performance to inform appropriate targeted interventions to enhance equitable growth and sustainability within the sector. The findings will also highlight best practices from high-performing regions that could serve as models for less productive areas, fostering knowledge transfer and innovation.

This, therefore, has implications for a study in Kazakhstan, which also has set for itself economic diversification and rural development. Improved agricultural productivity and reduced regional disparities will mean the sector can better contribute to national development goals of poverty reduction and food security. The developed integral index in this paper will be a crucial tool in understanding the complex dynamics of agricultural development across the different regions of Kazakhstan, as it gives substance to informed decision-making and strategic planning.

The challenges and opportunities facing Kazakhstan's agriculture are at the core of the complex interaction between geographical, climatic, economic, and policy factors. Addressing prevailing regional disparities in pursuit of inclusive growth and ensuring the sector's sustainability against changing environmental conditions is essential. This study's integral index and comprehensive analysis will provide valuable insights for stakeholders in the process of developing agricultural productivity and sustainable practices throughout Kazakhstan.

2. LITERATURE REVIEW

Sustainable agricultural development is shaped by economic, climatic, and technological factors, which significantly influence regional productivity and resource management. A review of existing literature highlights the critical role of adaptive strategies, investment in innovation, and regional policy measures in addressing disparities and ensuring long-term growth in the agricultural sector.

Environmental challenges and social sustainability in agriculture play a crucial role in the sector's development. Agriculture is both a victim and a contributor to environmental degradation. Gomiero, Pimentel, and Paoletti (2011) explore the environmental impacts of different agricultural management practices, focusing on the comparison between conventional and organic farming methods. As Johnson and Villumsen (2020) note, the sector suffers from climate change impacts, such as altered precipitation patterns, extreme weather events, and soil degradation. The adoption of sustainable agricultural practices has gained prominence as a solution to mitigate environmental degradation. Practices such as crop rotation, agroforestry, and conservation agriculture enhance soil health, reduce dependency on chemical inputs, and align agriculture with global climate goals (Suchkov et al., 2021). These methods promote ecosystem resilience by maintaining soil fertility, controlling pests, and reducing erosion. The concept of “climate-smart agriculture” (CSA), introduced by the FAO, represents a holistic approach to managing agricultural systems under climate change. CSA integrates three pillars: increasing productivity, enhancing resilience, and reducing emissions. According to Maniatakou et al. (2024), CSA strategies include precision farming, efficient irrigation systems, and integrated crop-livestock systems. These approaches not only reduce environmental footprints but also improve farmers' incomes and contribute to biodiversity conservation.

The social dimension of agriculture emphasizes equitable labor practices, resource distribution, and rural livelihoods. Allen et al. (1991) stress the importance of addressing issues such as land ownership rights, gender inequality, and farm workers' access to education and healthcare. As suggested by Jackson-Smith (2004), empowering women in agriculture leads to substantial productivity and household income gains. Janker and Mann (2020) further emphasize that ensuring food safety and combating malnutrition are integral to the social sustainability of the agricultural sector. Pandey and Pandey (2023) examine the critical role of agriculture and geospatial technology in advancing food security and achieving Sustainable Development Goals (SDGs) in their study published in Sustainable

Development. The paper highlights how geospatial tools, such as remote sensing and GIS, can optimize agricultural practices, monitor resources, and enhance decision-making processes.

The role of agriculture in economic growth is discussed in this section. Agriculture has long been recognized as a cornerstone of economic development, especially in emerging economies. Advanced agricultural techniques, such as those explored by Omorogiuwa et al. (2014), significantly enhance productivity, driving economic output. However, the benefits are region-specific, relying on resource availability, governance structures, and infrastructure investments. Awokuse and Xie (2015) explore the critical role of agriculture in driving economic growth in developing countries, challenging traditional perspectives that often downplay its significance. The article examined whether agriculture serves as a primary catalyst for economic development or if its impact is limited to specific conditions. Using empirical data and econometric analysis, the authors demonstrate that agriculture significantly contributes to economic growth, especially in economies with high reliance on the agricultural sector. The findings highlight that investment in agricultural productivity and infrastructure can yield substantial economic benefits, including poverty reduction and employment generation. This work emphasizes the importance of integrating agriculture into broader economic policies to ensure inclusive and sustainable development in developing regions.

Effective governance and well-structured policy frameworks are critical for guiding agricultural development, ensuring resource efficiency, and addressing regional disparities. Governance plays a crucial role in shaping agricultural development. Lio and Liu (2008) underscore the importance of strong institutions and transparent policies in ensuring efficient resource allocation, adherence to environmental regulations, and equitable benefit distribution. Bayyurt and Arikan (2015) highlight the role of public-private partnerships and international collaborations in promoting sustainability by facilitating access to funding, technology, and expertise. For instance, the EU's Common Agricultural Policy (CAP) is a model for balancing subsidies with environmental and social compliance. The article analyzed governance indicators such as transparency, accountability, and institutional effectiveness to assess their impact on agricultural outcomes. Using a combination of theoretical frameworks and empirical data, the authors argue that good governance enhances resource allocation, reduces inefficiencies, and fosters sustainable agricultural development. Their findings suggest that improving governance practices, such as reducing corruption and increasing institutional support, can significantly boost agricultural efficiency, particularly in developing economies. This research underscores the importance of integrating governance reforms into agricultural policies to achieve long-term growth and sustainability.

Technological advancements, such as precision agriculture and improved seed varieties, are crucial for enhancing productivity. Connor et al. (2011) also note that technology-driven approaches, such as drip irrigation and precision agriculture, minimize waste while maximizing yields. Zhang et al. (2022) emphasize that investment in R&D fosters innovation, enabling farmers to adopt new practices that improve efficiency and yield. However, a significant challenge lies in ensuring these innovations reach less productive regions, often constrained by limited resources and infrastructure. Also, Getahun and et. al. (2024) examined the application of precision agriculture technologies in promoting sustainable crop production and environmental sustainability in their systematic review. The study explores various precision agriculture tools, including remote sensing, GPS-based systems, and drone technology, and their role in optimizing resource use and minimizing environmental impacts. The Getahun and et. al. highlighted that these technologies enable precise monitoring of soil health, water usage, and crop growth, leading to increased productivity and reduced waste. Furthermore, the review emphasizes the potential of precision agriculture to mitigate the adverse effects of climate change by promoting adaptive farming practices. The study concludes that integrating precision agriculture technologies is crucial for achieving sustainable development goals related to food security and environmental conservation.

Green finance has emerged as a mechanism for promoting resource efficiency, reducing environmental degradation, and fostering sustainable economic growth in the face of global environmental challenges. Xu, She, Gao, and Sun (2023) investigated the role of green finance in promoting resource efficiency and fostering green economic growth. The study highlights how green finance mechanisms, such as green bonds, sustainability-linked loans, and eco-friendly investments, can enhance resource allocation, reduce environmental degradation, and stimulate economic activities that align with sustainability goals. Using empirical analysis, the authors demonstrate that green finance not only drives innovation in sustainable technologies but also incentivizes businesses to adopt environmentally responsible practices.

Agriculture in Kazakhstan is integral to national economic stability, rural development, and food security. However, significant regional disparities in productivity and resource allocation persist. The country’s geographical diversity, including vast steppes, mountains, and varied climatic conditions, creates unique challenges for farmers. Southern regions benefit from warmer temperatures and longer growing seasons, whereas northern regions face shorter seasons and cooler climates, necessitating region-specific agricultural policies. Tolkynova and Shalabayev (2021) highlight significant disparities between the northern and southern regions, with the north favoring cereal crops due to its cooler climate and fertile soils, while the south supports fruit and vegetable cultivation due to its warmer weather and longer growing seasons. The study emphasizes the need for region-specific agricultural policies and practices to optimize productivity and sustainability.

Technology and innovation remain underutilized in many regions, with less productive areas particularly lagging due to limited resources and infrastructure. The paper, which is written by Gollin (2010) discussed the long-term impacts of technological innovation, policy reforms, and market integration on enhancing productivity. By analyzing historical and contemporary data, Gollin underscores agriculture's foundational role in initiating and sustaining economic growth, while also addressing the challenges of resource allocation and environmental sustainability in the agricultural sector. Climate change poses a pressing challenge for Kazakhstan’s agriculture, with extreme weather events, shifting precipitation patterns, and rising temperatures impacting crop yields and livestock health (Tleuberdin & Abdimanapov, 2020).

Socio-economic factors, including rural employment and market dynamics, further influence the sector’s performance. Stable producer prices and targeted government interventions, such as subsidies and credit facilities, are essential for addressing disparities and ensuring sustainable growth (Nurbekov et al., 2021; Toimbek, 2022). Moreover, Tsoy and Nurbatsin (2024) and Abraliyev et al. (20214) highlighted the regional disparities in agricultural development within Kazakhstan in their study. The paper explores the variations in agricultural productivity, infrastructure, and resource allocation across different regions of the country. Through the combination of quantitative and qualitative analyses, the authors identify the important factors contributing to these disparities, such climatic conditions, economic policies, and technological changes.

The reviewed literature highlights the multifaceted nature of agricultural development, influenced by climatic, technological, socio-economic, market-related, and policy-driven factors. Addressing regional disparities through tailored approaches that account for unique geographical and climatic conditions is crucial for Kazakhstan. Technology, infrastructure, and R&D investments, combined with adaptive strategies to combat climate change, can boost agricultural productivity and sustainability. Integrating ESG principles into agricultural policies will further enhance the sector's resilience and contribute to achieving broader economic, social, and environmental goals. By fostering collaboration between the government, research institutions, and farming communities, Kazakhstan can establish a more equitable and sustainable agricultural sector that ensures long-term food security and rural development.

3. RESEARCH METHODS

A multidimensional approach was used to assess the level of development of the agricultural sector in the regions of Kazakhstan. This approach includes an assessment of agricultural production volume and indicators of its profitability and sustainability. The primary research tool is an integral index that considers key indicators affecting productivity. The paper used the following methods: correlation analysis to determine the relationship, regression analysis after filtering variables, integral index for a generalized assessment of agricultural productivity by region, and cartographic analysis.

Thus, the analysis in this work was carried out in four stages:

Step 1. Correlation Analysis. The first step was a correlation analysis to determine the direction and strength of the relationship between independent variables (such as soil temperature, producer price index, acreage, etc.) and the dependent variable - the volume of agricultural products. This analysis allowed us to identify significant factors affecting productivity and eliminate insignificant ones.

Step 2. Regression Analysis. In the next stage, regression analysis was used to assess the magnitude and significance of the influence of independent variables on the dependent variable. This method allowed us to determine the weight of each factor in the formation of the overall result and assess its statistical significance. Based on the regression analysis results, weights were calculated for each factor, which were then used in constructing the integral index.

Step 3. Building an integral index. The integral index is a composite indicator combining many agricultural development factors into one measure. The weights applied to each factor were derived from regression analysis and reflect the relative importance of each indicator in determining the level of agricultural production. Thus, this index allows to identify regional differences and areas for increasing agrarian productivity and sustainability in various regions of Kazakhstan.

Step 4. Cartographic method and recommendations. The proposed approach allows not only to identify the weaknesses and strengths of agricultural development in each region, but also to formulate recommendations for improving the situation in those regions that need support. The cartographic method was also used to visualize the data obtained and their spatial analysis, which made it possible to identify regional differences and identify areas with the greatest potential for development.

The methodology integrates statistical and spatial tools to provide a comprehensive framework for analyzing regional agricultural productivity and sustainability. Several steps were undertaken to evaluate the regions of Kazakhstan, as illustrated in Figure 1.

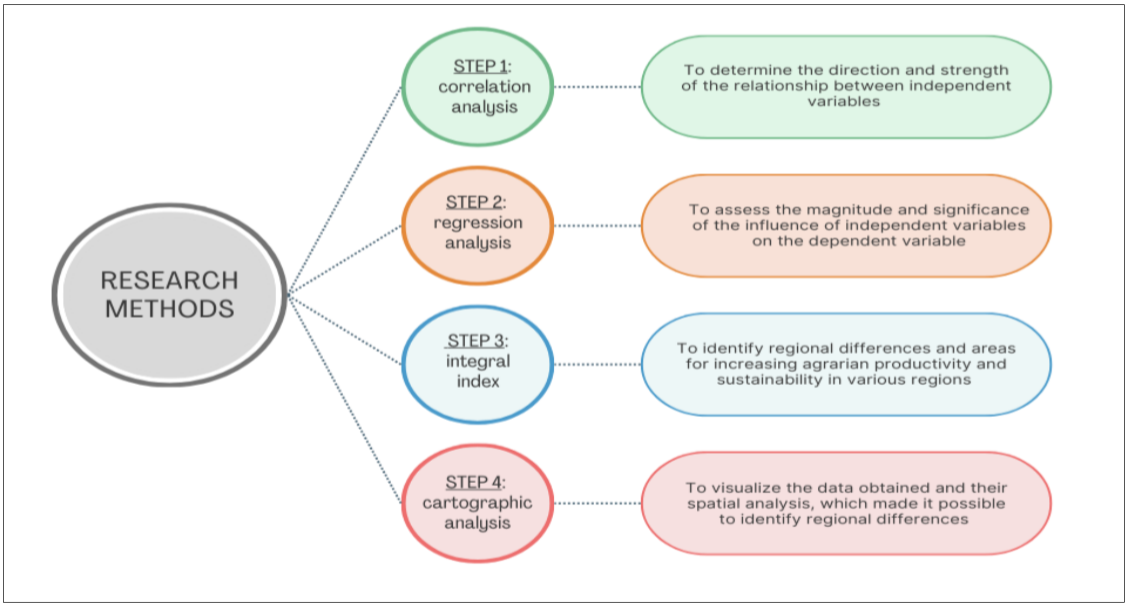

FIGURE 1. The steps of analysis

Note: compiled by authors

Figure 1 shows that the first step was to conduct a correlation analysis. This determines the direction and strength of the relationship that exists between independent variables - for example, soil temperature, producer price indices, sown area, etc., and the dependent variable. On the other hand, variables which are poorly correlated or show a negative relationship might have less impact or be harmful to growth. Correlation sifts those variables that have the most significant impact on agricultural output, otherwise the importance of less relevant variables or underestimate important factors.

Then, after filtering the variables, regression analysis was used to estimate the magnitude and significance of the relationships between independent variables and the dependent variable. In this case, the dependent variable is regional agricultural productivity, while the integral index is an aggregated measure of multiple factors influencing agricultural development. The weights assigned to each factor were obtained through regression analysis and reflect the relative importance of each variable in determining agricultural output. To further deepen the analysis, a cartographic approach is employed. This method adds a spatial dimension to the research, allowing the visualization of data collected and calculated in previous stages. By mapping out regional differences, it becomes easier to highlight spatial discrepancies in agricultural productivity and pinpoint underperforming areas. Identifying regions with the greatest potential for growth helps to better understand the spatial variation and effectively communicate findings with policymakers and stakeholders.

The approach outlined integrates statistical and spatial analyses to provide a comprehensive understanding of regional agricultural dynamics. The presented methodology effectively addresses complex regional agricultural issues.

4. FINDINGS AND DISCUSSIONS

The analysis of agricultural productivity in Kazakhstan requires a comprehensive understanding of the factors that influence regional performance. Key indicators such as soil surface temperature, economic variables like producer price indices and R&D expenditure, and agricultural activity metrics like sown area and harvested area provide a holistic framework for evaluation. By employing correlation and regression analyses, this study identifies the main drivers and barriers to agricultural output, highlighting the interconnectedness of environmental, economic, and production-related variables. These findings offer insights into regional disparities and potential strategies for enhancing agricultural sustainability and efficiency across Kazakhstan.

The selection of the variables listed for the study of agricultural development in Kazakhstan, particularly for the assessment of regional development in crop production, is based on their direct and indirect influence on agricultural productivity and economic sustainability in Table 1.

TABLE 1. Indicators for analysis

No.	Type	Indicator / unit of measurement
1	Weather and climate conditions	Soil surface temperature, degrees.
2	Agricultural price indices	Producer price index for agricultural products.
		Producer price index for crop products.
		Producer price index for livestock products.
3	Tarif index	Index of tariffs for freight transportation by all types of transport.
4	Economic indicators	Domestic R&D expenditure (research and development), million tenge.
		Employment in the economy (total and in agriculture), thousand people
5	Agricultural activity indicators	Total adjusted sown area, hectares.
		Harvested area of main agricultural crops, hectares.
		Indices of physical volume of gross agricultural output (services).

Note: compiled by authors

These variables offer a comprehensive framework to analyze the agricultural performance and regional development in Kazakhstan. They balance both natural factors (such as soil temperature) and economic indicators (price indices, R&D expenditure, employment), along with production metrics (sown area, harvested area, output index).

In figure 2, we observe the relationships between nine variables related to agricultural and economic factors in Kazakhstan.

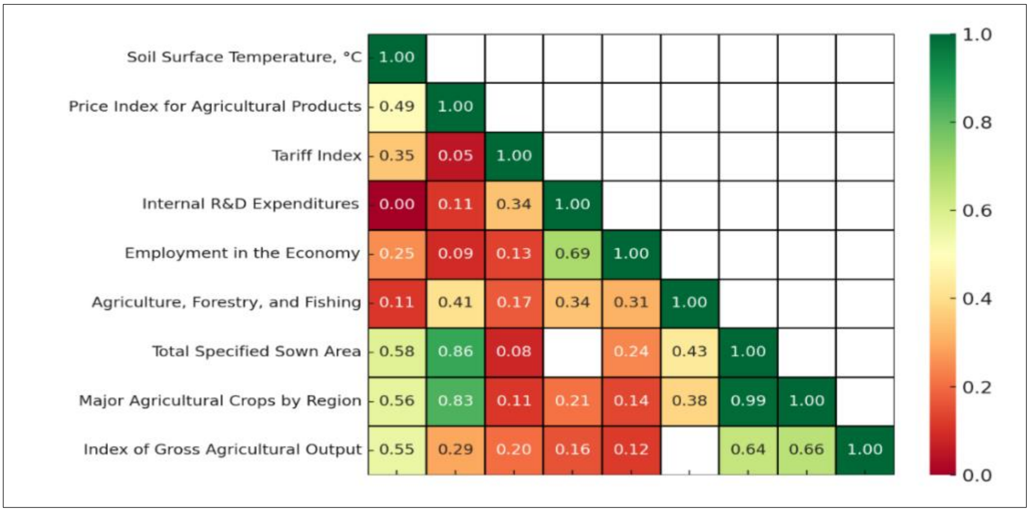

FIGURE 2. Results of correlation analysis

Note: compiled by authors

In the presented diagram, a correlation matrix between various variables is visualized as a heat map in the format of heat maps. The color scheme shows the degree of relationship between variables, with green indicating a high positive correlation and red indicating a low correlation. For variable soil surface temperature, both positive and negative correlations were identified. The correlation with the producer price index for agricultural products was 0.49, indicating a moderate positive relationship. This suggests that higher soil temperatures are associated with higher prices for agricultural products. However, for variables such as total specified sown area and harvested area of major agricultural crops, the correlation was negative. A high negative correlation could indicate that, with increasing soil temperature, areas sown and areas harvested are lower. This is probably due to poor growing conditions in hotter climates for crops.

Overall, the soil surface temperature seems to play a significant role in agricultural productivity, as evidenced by a strong positive correlation with the physical volume index of agricultural output. On the other hand, there is a strong negative correlation between producer prices and areas sown and harvested, indicating that higher prices may be driven by low supplies, resulting in smaller areas of cultivation. While internal R&D expenditure is positively correlated with employment, underscoring the vital role of innovation in creating jobs, agricultural output has almost no relationship with it. Agricultural areas both sown and harvested are inversely related to output, indicating inefficiencies in production, where mere increase in area under cultivation does not lead to increased productivity.

Those variables which may be considered for regression analysis based on their significant relationship in this correlation analysis. These two variables will help model the main drivers and barriers to agricultural productivity in Kazakhstan. Soil surface temperature was chosen since this factor impacts directly agricultural productivity by setting the growth conditions for crops. Including this helps capture the environmental influence on agricultural performance. The producer price index for agriculture products reflects the changes in prices for agricultural products. This becomes important when considering how market conditions affect profitability and sustainability; hence, it is one of the key variables for determining regional economic health. The total area sown broken down indicates the size of the area under agricultural use. It depicts the agricultural potentiality of a region, which is great and needed when assessing the production potentialities and resource allocation. Employment in the economy provides an accounting for the availability of the labor force and its potential impact on regional agricultural productivity and economic conditions.

The Table 2 shows the regression output provides insight into how several factors affect the dependent variable, which is presumably the Index of physical volume of gross agricultural output.

TABLE 2. The result of regression analysis

Indicator	**Coeff.**	**Stnd.Err**	***t***	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	301,99	52,43	5,76	0,00	190,24	413,75
Soil surface temperature	0,84	0,42	1,99	0,07	- 0,06	1,73
Producer price index for agricultural products	-1,95	0,48	- 4,06	0,00	- 2,98	- 0,93
Total specified sown area	-0,01	0,00	- 5,05	0,00	- 0,01	- 0,00
Employment in the economy, total	-0,01	0,01	- 1,47	0,16	- 0,03	0,00

Note: compiled by authors

The intercept, as shown in table 2, means that when all independent variables (soil surface temperature, producer price index, sown area, and employment) are zero, then the expected value of the dependent variable would be 301.99. This is the baseline level of agricultural productivity not explained by the other factors in the model. A 1-degree increase in the soil surface temperature is associated with an increase of 0.84 units in agricultural productivity, holding other variables constant. However, since the p-value is only 0.07, being slightly above 0.05, this relationship cannot be said to be statistically significant at the 5% level, although it is at the 10% level. The wide confidence interval is from -0.06 to 1.73, which might indicate some uncertainty regarding exactly how productivity is affected by temperature. Each 1-point rise in the agricultural product producer price index decreases agricultural productivity by 1.95 units, assuming all other variables are held constant. The negative coefficient would suggest that higher prices of the agricultural product could reduce productivity because either the higher price increases input costs or reduces market demand. This relation is highly significant because of the p-value of 0.00, meaning it is very unlikely to have occurred by chance. Holding all other variables constant, agricultural productivity decreases by 0.01 units with every additional unit area sown. This result is somewhat counterintuitive because one might expect a positive relationship between the sown area and agricultural output. The increase in agricultural productivity is very slight, 0.01 units, for every additional 1,000 persons in total employment, assuming other conditions remain constant. The results seem to indicate that the variables of producer prices and sown area are stronger predictors of agricultural productivity, and at the same time, the employment and temperature variables may not strongly determine agricultural productivity in this specific context. It may be further explored for what reasons larger sown areas and higher producer prices act to depress productivity.

Based on this analysis, weights for the Integral Index Weights is made. The absolute value of coefficients of regression is taken and applied to the data below (Table 3).

TABLE 3. Key Indicators of Agricultural Development Across Regions of Kazakhstan

Region	Soil surface temperature	Producer price index for agricultural products	Employed in the economy	Total adjusted sown area
Abay	7,26	103,30	292,5	767,18
Akmola	6,17	93,30	407,1	5 360,03
Aktobe	8,40	104,60	434,9	743,56
Almaty	13,59	105,40	704,8	442,72
Atyrau	14,82	110,50	335,1	7,78
East Kazakhstan	7,41	100,50	368,8	631,98
Zhambyl	14,86	105,30	543,7	745,18
Zhetysu	10,84	106,60	309,3	509,65
West Kazakhstan	9,95	103,90	333,3	620,78
Karaganda	7,54	99,10	535,8	1 225,52
Kostanay	6,56	90,00	449,5	5 576,76
Kyzylorda	16,27	106,80	331,5	190,58
Mangistau	16,07	105,00	336,7	0,97
Pavlodar	7,12	101,70	385,2	1 631,30
North Kazakhstan	5,34	94,40	274,5	4 458,02
Turkestan	17,15	103,00	800,6	863,39
Ulytau	9,46	116,50	100,9	32,77
Almaty city	11,85	105,40	1 045,5	0,49
Astana city	7,63	106,60	658,7	1,41
Shymkent city	15,88	103,30	433,5	27,00

Note: compiled by authors

Positive Areas in Figure 4 appear as green, reflecting stronger agricultural development and productivity. Neutral Areas would be in lighter shades to show moderate agricultural performance. Negative Areas would appear in red to reflect serious problems in agricultural development.

Figure 4 shows a geographic map of the integral index weights of agricultural development within different regions of Kazakhstan, which allows for a visual understanding of the disparities in agricultural performance.

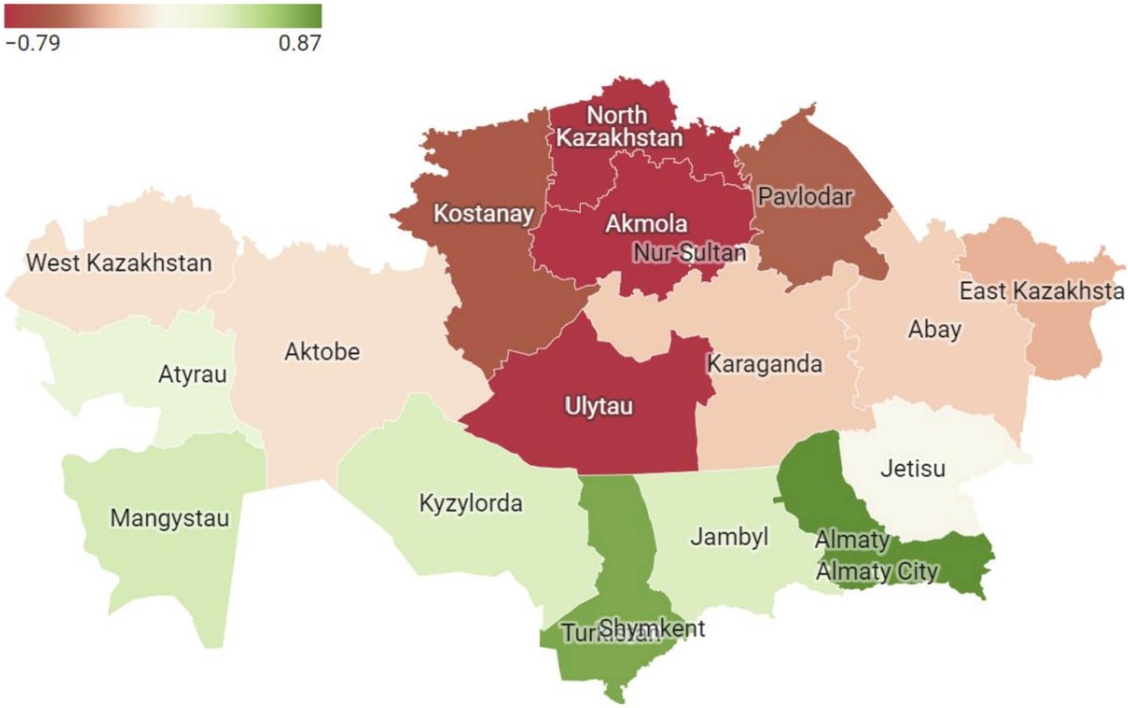

FIGURE 4. Regional Agricultural Development Index Map of Kazakhstan

Note: compiled by authors

Results above of the Integral Index Weights from the geographic table allow for presenting agricultural development for regions of Kazakhstan explicitly: The highest positive weights fall to the Almaty region with 0.87 and the Turkestan region with 0.77, which already shows very strong development of agriculture in these regions.

This may indicate not only a proper exploitation of resources but also good agricultural practice and, probably, favorable climatic conditions that could raise the agricultural output. This is followed by Almaty City with 0.58: the urban area has considerable agricultural activity. This perhaps indicates the concentration of agricultural services or innovation, or regional support systems that might enhance agricultural output. Further, Mangystau shows 0.41, Jambyl 0.38, and Kyzylorda 0.38-each of these also has positive integral index values, meaning fairly good agricultural development levels in these regions. Neutral to Low Positive Weights Regions like Shymkent at 0.29, Atyrau at 0.29, and Nur-Sultan at 0.27 have lower positive weights, suggesting fair to moderate agricultural development. This might mean that there is still scope for growth but also points toward the issues that need development concerning agricultural infrastructure and investment. The negative weights of regions, such as Aktobe with a weight of -0.07, West Kazakhstan -0.07, Abay -0.15, and Karaganda -0.16, determine their potentially problematic agricultural productivity due to unfavorable environmental conditions, low investment in agricultural practices, or an undeveloped agricultural infrastructure. The most unfavorable regions are East Kazakhstan (-0.27), Pavlodar (-0.50), Kostanay (-0.54), North Kazakhstan (-0.77), Ulytau (-0.77), and Akmola (-0.79); they all show noticeably negative values, which may indicate serious problems in agricultural development. These regions probably need urgent attention to improve agricultural practices, increase funding, or implement policies that help enhance agricultural productivity.

There is much variation in the level of agricultural development across and within regions. However, the central part and southern part seem better off than those in northern and eastern parts. Therefore, the policymakers are suggested giving attention to those regions of negative or low positive weights by investing in their infrastructure, training, and technology so that agricultural productivity may be enhanced. Regions with high positive weights can thus be examples for the leading regions in agricultural practices, sharing resources and best practices to uplift lagging regions. This integrated index provides a useful framework for understanding the disparate magnitudes of agricultural development across various regions in Kazakhstan. By exploiting the strengths of more productive regions and tackling the challenges in less-developed areas, a balanced approach can be used to enhance the overall agricultural output and sustainability in Kazakhstan.

5. CONCLUSIONS

Agricultural development assessment in regions of Kazakhstan represents a very complicated picture with serious differences in the productivity level and resource use. An integral index included in the present study is a tool that helps to explain these variations and enables politicians to define the regions that need immediate attention and support.

The analysis identified both leading regions and problem areas.Thus, the study made a significant contribution to understanding the factors influencing agricultural productivity and provided practical recommendations for economically sound decision-making at both the national policy and regional management levels.

The study highlights pronounced regional disparities in the agricultural development of Kazakhstan, shaped by both natural-climatic and economic factors. Regions such as Almaty and Turkestan exhibit the highest integral index values, a reflection of their favorable climatic conditions, effective resource management, substantial infrastructure investment, and active adoption of innovative practices. These regions represent exemplary management models that could be adapted to improve agricultural performance across other territories.

Conversely, North Kazakhstan, Pavlodar, Kostanay, and Ulytau regions demonstrated negative integral index values, indicative of their lower agricultural productivity. The challenges in these regions stem from limited investment access, low levels of innovation, and adverse climatic conditions, which collectively hinder their economic potential.

Regions like Zhambyl and Kyzylorda, which reported moderate index values, underscore a complex mix of positive trends and persistent structural constraints, such as insufficient technological modernization and low employment levels. These regions present significant growth potential, contingent upon targeted funding and the integration of advanced agricultural technologies.

The economic analysis further emphasizes the critical role of increasing agricultural employment, enhancing infrastructure, and stabilizing market prices for agricultural products. Achieving this will require strategic interventions, including heightened investment in research and development and expanded state support programs tailored to the needs of underperforming regions.

Addressing regional disparities in agricultural productivity is pivotal for advancing overall economic stability and food security in Kazakhstan. By adopting a region-specific approach that accounts for unique local characteristics and systematically monitoring the impact of implemented measures, policymakers can foster a balanced and sustainable agricultural sector that contributes to the nation's broader development goals. Regions such as North Kazakhstan, Pavlodar, Kostanay, and Ulytau demonstrate the weakest agricultural performance, as evidenced by their negative integral index values. These results highlight profound structural and environmental challenges that inhibit productivity. Among the key factors are limited access to investment capital, insufficient integration of innovative practices, and adverse climatic conditions that further exacerbate the constraints on agricultural development.

The persistence of these issues underscores the need for urgent and targeted intervention. Addressing these disparities will require a multifaceted approach, combining enhanced investment mechanisms, support for research and development to drive innovation, and adaptive measures to counteract unfavorable environmental conditions. These regions, characterized by their lagging agricultural output, reflect the broader necessity of crafting strategies that not only address immediate productivity concerns but also pave the way for sustainable, long-term growth. Without such efforts, the economic and social potential of these territories risks remaining unfulfilled, perpetuating regional inequalities in Kazakhstan's agricultural sector.

AUTHOR CONTRIBUTION

Writing – original draft: Assel Jumasseitova.
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