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Article

Determining Optimal Parameters for Meat Livestock Sector Development in The Syrdarya Region

Kushakov Fakhriddin Bakhtiyarovich

1. Independent Researcher at Guliston State University
* Correspondence: faxriddinkushakov413@gmail.com

Abstract: This article provides a comprehensive study on determining the optimal scale of beef cattle breeding development in the Syrdarya region. The study analyzes production volumes of livestock farms, resource utilization efficiency, feed base conditions, and regional market infrastructure. In addition, economic and organizational factors influencing the optimal farm size are identified, and scientifically grounded recommendations are developed to improve sector efficiency considering regional characteristics.

Keywords: beef cattle breeding, optimal farm size, economic efficiency, regional development, production concentration, resource utilization efficiency, feed base, livestock infrastructure, Syrdarya region, agricultural economics.

1. Introduction

In recent years, the diversification of agricultural sectors, ensuring food security for the population, and sustainably meeting the growing demand for meat products have become among the priority directions of agrarian policy in our country [1]. In this regard, the development of the meat livestock sector and the improvement of its economic efficiency have gained significant scientific and practical importance at the regional level [2].

The Syrdarya region is considered one of the territories with relatively high agro-economic potential in the republic, where favorable natural-climatic conditions and infrastructure opportunities exist for the development of livestock farming. However, analyses indicate that the current level of development of the meat livestock sector in the region is characterized by the incomplete and inefficient utilization of available resources, the absence of optimally structured farm sizes, and a low level of production concentration [3].

Under market economy conditions, the economic efficiency of livestock farms largely depends on the correct determination of their optimal sizes. In this process, factors such as production scale, the level of resource utilization, the condition of the feed base, the development of infrastructure, and regional market conditions play an important role. Therefore, there is a need to determine and scientifically substantiate the optimal scales for the development of meat livestock farming in the conditions of the Syrdarya region [4].

The purpose of this article is to develop optimal farm size models for meat livestock enterprises in the Syrdarya region, identify the main economic and organizational factors influencing them, and formulate scientifically grounded proposals and recommendations aimed at improving sector efficiency.

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The research findings will contribute to the development of meat livestock farming in the region by taking into account territorial characteristics, ensuring the rational use of resources, and increasing production efficiency [5].

Literature Review. Issues related to the development of meat livestock farming and the assessment of its regional factors are among the actively researched areas in economics and agricultural sciences. Scientific studies conducted in this field demonstrate that the rational use of resources, deepening of regional specialization, and modernization of production play a crucial role in improving the efficiency of the livestock sector [6].

In the studies conducted by M. Yu. Kudryashova and V. N. Emelin, the problems and prospects of introducing innovative technologies into the livestock sector were comprehensively analyzed. The authors identified the implementation of modern technologies, digitalization, and automation of production processes as key factors in increasing production efficiency in livestock farming. At the same time, insufficient financial resources, limited human capital, and underdeveloped technical infrastructure were noted as the main barriers to the practical implementation of innovative technologies. The findings substantiate that the widespread adoption of innovations in the livestock sector can enhance productivity and improve production efficiency (Kudryashova & Emelin, 2014).

Research conducted by N. L. Titov and co-authors examined the development of the material and technical base as a means of improving the efficiency of meat livestock farming. The authors emphasized that the introduction of modern machinery and technologies, mechanization of production processes, and modernization of infrastructure can increase labor productivity and reduce production costs. Furthermore, the development of the material and technical base was substantiated as an important factor in strengthening the competitiveness and sustainable development of the sector (Titov et al., 2020).

In the studies conducted by I. E. Glotova, issues related to optimizing the economic parameters of agricultural enterprises were investigated. The author emphasized the importance of the rational use of production resources, minimization of costs, and maximization of income in improving enterprise efficiency. In addition, the study substantiated that optimizing economic parameters can increase farm profitability and ensure production stability (Glotova, 2019).

Research by V. S. Buyarov, I. V. Komolikova, and A. V. Buyarov analyzed the development of livestock and poultry sectors in Russia within the framework of import substitution policy. The authors demonstrated that expanding domestic production, ensuring efficient resource utilization, and increasing competitiveness could reduce dependence on imports. They also highlighted state support measures and technological modernization as important factors in ensuring sectoral sustainability (Buyarov et al., 2024) [7].

The studies carried out by T. M. Vasilkova, N. A. Sereda, and A. A. Vasilkov focused on substantiating the optimal parameters of farms specializing in raising young cattle. The authors noted that production scale, the level of technological support, feed supply, and labor resource utilization are important factors affecting economic efficiency. The findings indicated that determining optimal farm sizes could reduce production costs and increase profitability (Vasilkova et al., 2016).

Scientific studies conducted by Kazakh specialists extensively covered innovative and technological approaches to the development of meat livestock farming, improvement of production efficiency, and rational resource utilization. In particular, opportunities to increase sector profitability through improving breeding systems, strengthening the feed base, and modernizing production processes in cattle farming were substantiated. Moreover, the necessity of intensifying livestock development, optimizing production concentration, and improving state support mechanisms while considering regional conditions was emphasized (Kenjaboyev et al., 2019).

Belarusian scholars E. E. Epimakhova and N. I. Kudryavets deeply analyzed current issues in the intensive development of the livestock sector. The authors highlighted the introduction of intensive technologies, improvement of breeding and selection practices,

strengthening of the feed base, and rational use of resources as essential factors for increasing production efficiency. They also substantiated the need for broader implementation of scientifically grounded management approaches to ensure intensive development in livestock farming (Epimakhova & Kudryavets, 2020).

Research conducted by T. Alemneh and M. Getabalew examined the main factors influencing the growth and development of meat-oriented livestock. The authors emphasized that genetics, feed quality, adequacy of feed resources, management conditions, and environmental factors directly affect livestock productivity indicators. Their findings substantiated the necessity of a comprehensive approach for achieving efficient growth and high-quality meat production in livestock farming (Alemneh & Getabalew, 2019).

Studies by E. C. Webb and N. H. Casey analyzed physiological limitations in animal growth and their relationship with meat quality. The authors argued that growth processes in meat livestock farming are constrained by the biological capacities of animals, which play an important role in balancing productivity and meat quality. Furthermore, they substantiated that increasing growth rates under intensive production conditions may sometimes negatively affect the organoleptic and technological quality characteristics of meat (Webb & Casey, 2010).

Research by L. Zhao and co-authors investigated stage-specific nutritional management aimed at optimizing meat production. The authors emphasized that appropriate feeding strategies during embryonic, growth, and maturation stages help fully realize animals' biological potential, increase productivity, and improve meat quality. In addition, they substantiated that the developmental programming approach can enhance long-term economic efficiency (Zhao et al., 2023).

In the scientific literature, studies by P. L. Greenwood and A. W. Bell examined the influence of developmental programming and tissue growth processes on meat production efficiency. The authors noted that nutrition and management conditions during embryonic and early postnatal periods play a decisive role in determining later growth rates, muscle tissue formation, and meat quality indicators. They also substantiated that creating optimal developmental conditions can improve production efficiency and ensure the production of high-quality meat (Greenwood & Bell, 2019).

Studies conducted by M. Du, S. P. Ford, and M. J. Zhu focused on maternal nutrition management and fetal developmental programming as means of increasing livestock production efficiency. The authors emphasized that proper nutritional strategies during pregnancy directly influence the growth rate, health, and productivity potential of offspring. Moreover, this approach was shown to contribute to improved meat production efficiency and rational resource utilization (Du, Ford & Zhu, 2017).

Research conducted by H. J. Andersen and co-authors analyzed the relationship between livestock feeding systems and meat quality, as well as future development trends. The authors substantiated that feed composition, feeding regimes, and nutrient balance directly affect muscle tissue formation, organoleptic characteristics, and technological quality of meat. Furthermore, the application of individualized feeding approaches and scientifically grounded rations was identified as an important future direction for improving meat quality (Andersen et al., 2005).

Among local researchers, S. Adilov analyzed the role of livestock farms in the formation of cattle product markets. The author emphasized that production capacity and market access opportunities of livestock farms play a significant role in ensuring the stable supply of meat products. At the same time, underdeveloped market infrastructure and deficiencies in logistics and processing chains were shown to negatively affect product delivery efficiency. The findings highlighted the necessity of integrating livestock farms with market systems and improving production chains (Adilov, 2024).

Another local researcher, G. Yu. Eshmuratova, analyzed the importance of specialization in the efficient organization of meat production under the conditions of the Republic of Karakalpakstan. The author emphasized that specialization of livestock farms according to specific production directions is an important factor in increasing production efficiency, ensuring rational use of resources, and reducing production costs.

Furthermore, the study substantiated that developing specialized production systems considering regional natural and economic conditions contributes to increasing meat production volumes and ensuring sectoral sustainability (Eshmuratova, 2026).

Among Karakalpak scholars, J. K. Saukhanov analyzed issues related to identifying перспективные directions for livestock development in the region and developing forecast indicators. The author emphasized the importance of efficiently utilizing natural and economic potential, forecasting production volumes, and optimally allocating resources in livestock sector development. At the same time, the study substantiated that the use of scientifically grounded forecasting models can ensure sustainable sectoral development and increase productivity (Saukhanov, 2022).

Although numerous scientific studies have been conducted within the framework of this research topic, the issue of developing meat livestock farming based on regional characteristics, particularly substantiating the optimal sizes of farms through economic-mathematical approaches, has not been sufficiently explored. Existing studies mainly focus on general sectoral development trends, productivity improvement, and efficiency of resource utilization, whereas comprehensive approaches to optimizing production concentration and farm scale at the regional level remain limited. Therefore, identifying the optimal sizes of meat livestock farms in the conditions of the Syrdarya region, analyzing them based on economic-mathematical models, and developing practical recommendations constitute an important and relevant scientific problem [8].

2. Materials and Methods

This study applied a comprehensive scientific approach aimed at determining the optimal scales for the development of meat livestock farming in the Syrdarya Region and evaluating the efficiency of the sector. The methodological framework of the research is based on economic analysis, statistical grouping, comparative analysis, econometric modeling, and optimization methods.

During the analysis process, indicators such as the production volume of livestock farms, the level of resource utilization, the condition of the feed base, labor resources, and infrastructure development were systematically examined. Taking into account regional characteristics, the relationships among factors influencing farm efficiency were assessed using econometric models.

In addition, mathematical optimization methods were applied to determine the optimal ratio between production costs and revenues, with the aim of identifying economically optimal farm sizes. Regression analysis and statistical evaluation methods were used in the formation of model parameters.

Based on the research findings, scientifically grounded conclusions and practical recommendations were developed for the advancement of meat livestock farms under the conditions of the Syrdarya Region.

3. Result and Discussion

The persistently low profitability of meat production in the Syrdarya Region has long been considered one of the main threats to the development of the sector. Under current conditions, the necessity of developing effective measures to address this problem is becoming increasingly important. In this regard, one of the key instruments is the substantiation of optimal parameters for the development of the meat livestock sector. At the same time, it should be emphasized that the specific characteristics of the districts within the region also influence the development of meat livestock farming, which indicates the need for a differentiated approach that takes these territorial features into account [10].

To substantiate the optimal parameters for the development of meat livestock farming depending on natural and economic conditions, it is advisable to apply economic-mathematical methods that allow the identification of “bottlenecks” in production and the determination of factors limiting sectoral development.

The economic-mathematical model modifies the main indicators of meat livestock development across districts; therefore, the number of cattle raised and fattened for meat production under the conditions of these districts should be used as variables:

a. (X_1) – livestock population in the Boyovut district, heads;
b. (X_2) – livestock population in the Oqoltin district, heads;
c. (X_3) – livestock population in the Sayxunobod district, heads;
d. (X_4) – livestock population in the Sirdaryo district, heads;
e. (X_5) – livestock population in the Xovos district, heads.

It should also be taken into account that optimization of the meat livestock sector should not lead to significant structural changes in livestock farming in general, particularly a reduction in milk production [11]. To address this issue, an additional variable was introduced:

f. (X_6) – other cattle, heads.

To develop the economic-mathematical model, production indicators per head of livestock were used, including agricultural land area, meat production volume, direct labor costs, and the number of livestock workers, as well as financial and economic indicators such as meat production costs and revenue from meat sales. These indicators directly reflect the development of the meat livestock sector in the Syrdarya Region (Table 1) [12].

The purpose of the modeling is to reduce the level of unprofitability of meat production in the region, which predetermines the selection of the following objective function:

$$Z = \frac{\sum_{j\in J} v_{ij}x_j - \sum_{j\in J} c_{ij}x_j}{\sum_{j\in J} c_{ij}x_j} \quad (1)$$

Where:

Vij - revenue from meat sales per 1 kg, thousand UZS;

Cij - meat production costs per 1 kg, thousand UZS;

Xj - number of cattle raised and fattened for meat production, heads;

i – constraint index $(i \in I)$;

j - variable index $(j \in J)$.

Table 1. Production and Economic Indicators per Head in the Meat Livestock Sector of Syrdarya Region

Ko‘rsatkich	X1	X2	X3	X4	X5
Agricultural land per head, ha	1,39	0,727	0,442	1,283	0,251
Meat production per 1 head, centner.	0,68	0,07	0,40	0,50	0,72
Meat sales per head, centners.	180	130,1	145,9	49,5	142,6
Direct labor costs per head, thousand, person-hours	2,389	1,379	1,951	0,802	1,76
Production cost per 1 kg of meat, thousand UZS	129,57	151,43	160,03	150,87	123,12
Revenue from the sale of 1 kg of meat, thousand UZS	104,9	114,3	105,2	110,6	108,3
Number of herders per head, person	0,841	0,835	1,282	0,472	0,745

At the same time, the following constraints must be observed: the number of cattle intended for meat and milk production must not violate the overall structural proportions within the livestock sector:

$$\sum_{j=5} x_j = \sum B_j - x_6 \quad (2)$$

Where:

Xj - number of cattle reared and fattened in the meat sector, head;

X6 - other cattle, heads;
Bj - total number of cattle, head;
j – variable index ($j \in J$).

the proportion of beef cattle must be within the upper and lower limits:

$$\beta_{min} \leq \sum_{j=5} x_j \leq \beta_{max} \quad (3)$$

Where:
Xj - number of cattle reared and fattened in the meat sector, head;
βmin - the minimum allowable share of beef cattle, %;
βmax - the maximum allowable share of meat cattle, %;
j – variable index ($j \in J$).

- 100 hectares of agricultural land should increase livestock density:

$$\frac{\sum_{j=5} x_j}{\sum_{j=5} S_j} \geq 0 \quad (4)$$

Where:
Xj - number of cattle reared and fattened in the meat sector, head;
Sj - area of agricultural land per 1 head, ha;
j – variable index ($j \in J$).

- depending on the characteristics of the districts, it is necessary not to disrupt the existing proportions in the structure of livestock for meat-rearing and fattening cattle:

$$\sum_{j=4,5} x_j \geq W_i \sum_{j=5} x_j \quad (5)$$

Where:
Xj - number of cattle reared and fattened in the meat sector, head;
Wi - proportionality coefficient;
i – restriction index ($i \in I$);
j – variable index ($j \in J$).

- meat production in the districts should increase:

$$\sum_{i=5} a_{ij} x_j \geq 0 \quad (6)$$

Where:
Xj - number of cattle reared and fattened in the meat sector, head;
aij - meat production per 1 head of cattle in the meat sector, centners;
i – restriction index ($i \in I$);
j – variable index ($j \in J$).

- meat production should be within the upper and lower limits:

$$B_{imin} \leq \sum_{i=5} a_{ij} x_j \leq B_{imax} \quad (7)$$

Where:
Xj - number of cattle reared and fattened in the meat sector, head;
aij - production of meat per head of cattle for meat production and fattening;
Bimin - minimum meat production, c;
Bimax – maximum meat production, c.;
i – restriction index ($i \in I$);
j – variable index ($j \in J$).

- the existing ratio of the meat production structure depending on the characteristics of the districts must not be disrupted:

$$a_j x_j \geq W_i \sum_{j=5} a_{ij} x_j \quad (8)$$

Where:
Xj - number of cattle reared and fattened in the meat sector, head;
aij - meat production per head of cattle raised and fattened for meat purposes, c.;
Wi - proportionality coefficient;
i – restriction index ($i \in I$);
j – variable index ($j \in J$).

- the increase in meat sales in the districts should be:

$$\sum_{i=5} q_{ij} x_j \geq 0 \quad (9)$$

Where:

Xj - number of cattle reared and fattened in the meat sector, head;

qtj - sale of cattle meat per 1 head of meat-producing and fattening cattle, centners;

i – restriction index ($i \in I$);

j – variable index ($j \in J$).

- the established proportions of the meat sales structure, based on the specifics of the districts, must not be violated:

$$q_j x_j \geq W_i \sum_{j=5} q_{ij} x_j \quad (10)$$

Where:

Xj - number of cattle reared and fattened in the meat sector, head;

qy - sale of beef per 1 head of meat-producing and fattening cattle, c.;

W - proportionality coefficient;

i – restriction index ($i \in I$);

j – variable index ($j \in J$).

- it is necessary to minimize labor costs in meat production:

$$\sum_{i=5} p_{ij} x_j \leq P_i \quad (11)$$

Where:

Xj - number of cattle reared and fattened in the meat sector, head;

pij- labor costs per 1 head of cattle raised and fattened for meat production, thousand, man-hours;

Pi - labor costs in meat production throughout the region, thousand man-hours;

i – restriction index ($i \in I$);

j – variable index ($j \in J$).

- meat production costs must be minimized:

$$\sum_{i=5} c_{ij} x_j \leq C_i \quad (12)$$

Where:

Xj - number of cattle reared and fattened in the meat sector, head;

Cij- meat production costs per 1 head, thousand soums;

Ci - total meat production costs for the entire region, thousand soums;

i – restriction index ($i \in I$);

j – variable index ($j \in J$).

- the profit from the sale of meat must be maximized:

$$\sum_{i=5} v_{ij} x_j \leq V_i \quad (13)$$

Where:

Xj - number of cattle reared and fattened in the meat sector, head;

vij - income from the sale of meat per head, thousand soums;

Vi - total revenue from the sale of meat in the entire region, thousand soums;

i – restriction index ($i \in I$);

j – variable index ($j \in J$).

- the profit from the sale of meat must be maximized:

$$\sum_{j \in J} v_{ij} x_j - \sum_{j \in J} c_{ij} x_j \geq 0 \quad (14)$$

Where:

Xj - number of cattle reared and fattened in the meat sector, head;

vij - income from the sale of meat per head, thousand soums;

Cij - Meat production costs per 1 head, thousand soums;

i – restriction index ($i \in I$);

j – variable index ($j \in J$).

Thus, in the economic-mathematical model, the following constraints are included:

a. Number of cattle in meat and dairy production systems, heads;
b. Maximum allowable share of meat cattle, %;
c. Minimum allowable share of meat cattle, %;
d. Livestock density per 100 hectares of agricultural land, heads;
e. At the regional level, 78.3% of meat cattle are concentrated in the Oqoltin District and Sayxunobod District, heads;

f. Total meat production, c;
g. Maximum meat production, c;
h. Minimum meat production, c;
i. In the Oqoltin District, meat production accounts for 46% of total regional output, c;
j. In the Sayxunobod District, meat production accounts for 31.7% of total regional output, c;
k. In the Sirdaryo District, meat production must account for at least 9.5%;
l. Meat sales, c;
m. The share of the Boyovut District in total meat sales must not be lower than 3.47%, c;
n. The share of the Xovos District in meat sales must be higher than 8.7%, c;
o. Number of livestock workers, persons;
p. Direct labor costs per head of cattle for meat production, thousand person-hours;
q. Total production costs for meat, thousand UZS;
r. Revenue, thousand UZS;
s. Profit, thousand UZS.

The simulation was carried out in MS Excel using the simplex method. The optimal structure of the number of animals for meat production and fattening by districts in the Syrdarya Region is presented in Table 2 [12].

As a result, it was determined that to ensure optimal development of the meat livestock sector in the Syrdarya Region, the number of fattening cattle should be increased by 258 heads. In particular, the number of meat cattle should be increased by 59 heads in the Boyovut District, by 62 heads in the Oqoltin District, and by 137 heads in the Sirdaryo District. It should be noted that compared to the available land area allocated for meat cattle production, the number of livestock is higher in the Sayxunobod District (171 heads) and the Xovos District (86 heads) [13].

Table 2. Optimal structure of livestock composition for meat production in the districts of the Syrdarya region, head

District name	2025 year	Optimal value	Deviation
Bayaut	55	114	-59
Akaltyn	740	802	-62
Saykhunabad	502	331	171
Syrdarya	150	287	-137
Khavast	138	52	86
By region	1585	1586	-1

Thus, the structure of livestock undergoes significant changes (Figure 1). After optimization, in the Syrdarya Region, the largest share of animals raised and fattened for meat production belongs to the cattle herd of the Oqoltin District, accounting for 50.57% of the total livestock population.

The share of the Sayxunobod District in the total meat cattle structure is 20.87%, the share of the Sirdaryo District is 18.09%, the share of the Boyovut District is 7.19%, and the share of the Xovos District is 3.28%.

According to the optimization results, the smallest proportion of animals raised and fattened for meat production should be attributed to the population of the Oqoltin district, where the share amounts to only 8.38%.

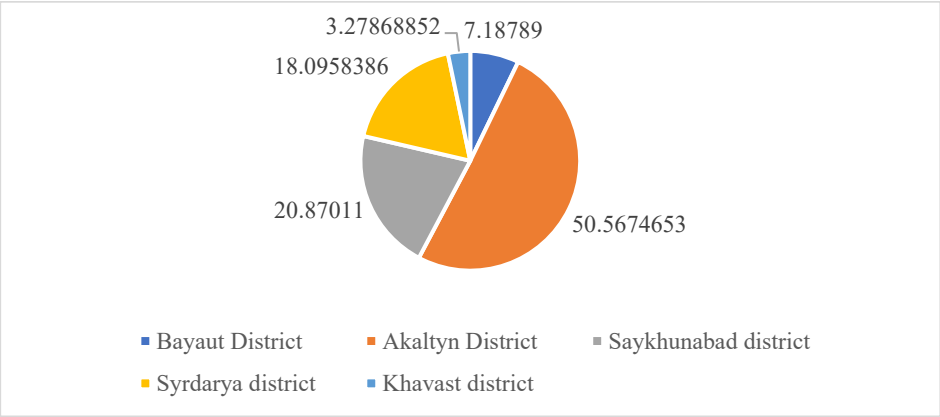

Figure 1. Structure of meat-rearing and livestock stocks in the districts of the Syrdarya region after optimization, %

In the Saykhunabad and Khavast districts, such a decrease in livestock leads to a decrease in meat production from 8% to 30%. However, in the Syrdarya region, the growth in meat production increased by 85.39 tons, totaling 372.01 tons (Fig. 2).

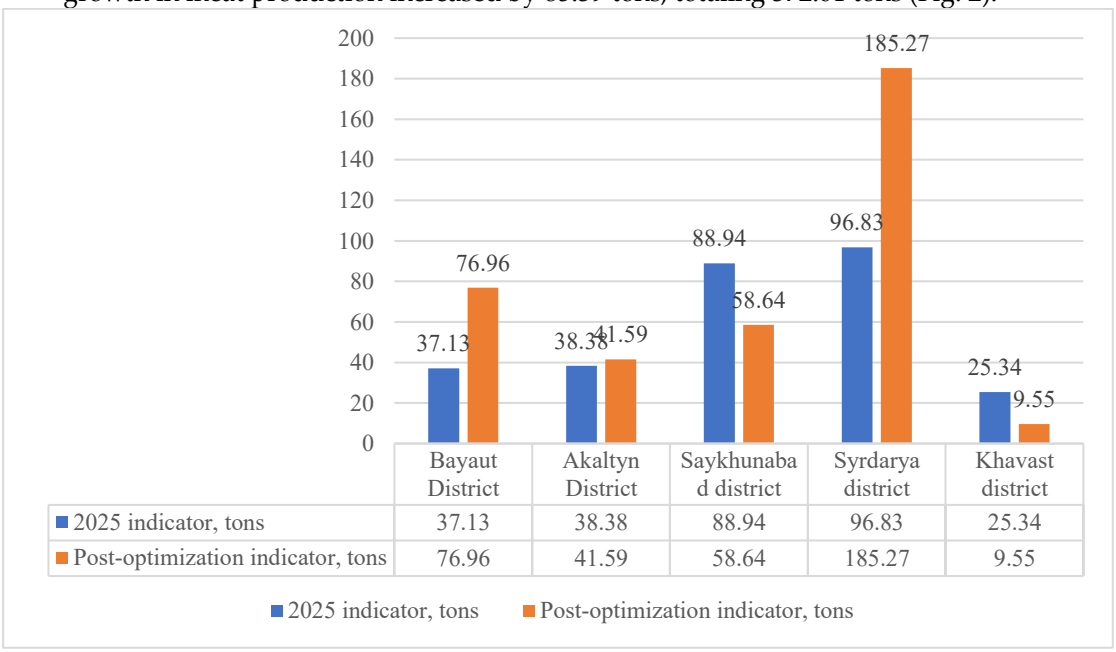

Figure 2. Meat production in the districts of the Syrdarya region after optimization, tons

Achieving this indicator will be ensured by increasing meat production in the Bayaut district by 207.27% or up to 39.83 tons, as well as in the Yakaltyn district by 108.36% (up to 3.21 tons) and the Syrdarya district by 191.33% (up to 88.44 tons) [14].

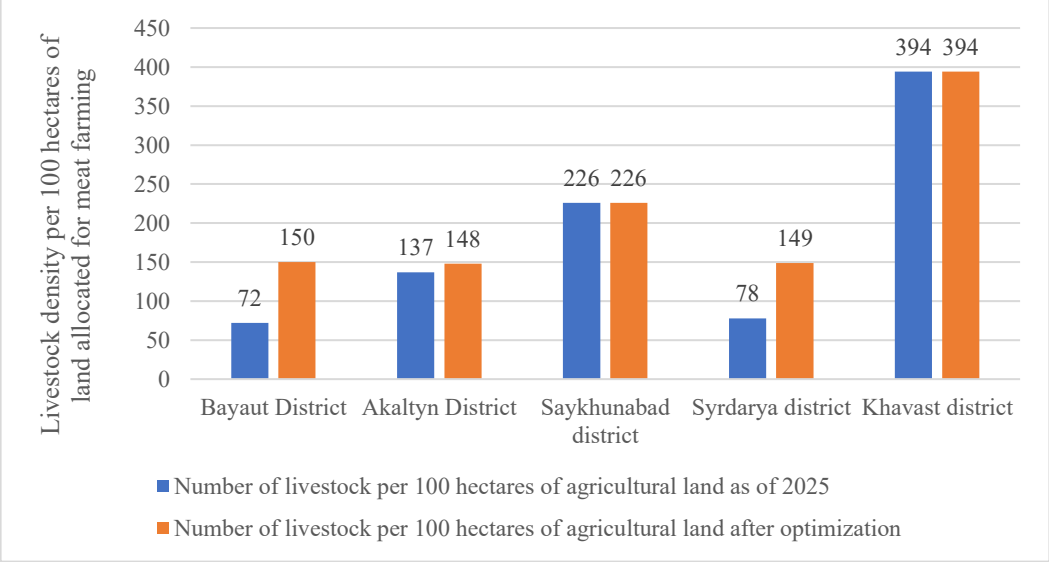

Figure 3. After optimization, the density of livestock per 100 hectares of agricultural land in the districts of the Syrdarya region, head

In the districts of the Syrdarya Region, the livestock density per 100 hectares of agricultural land changes in a manner similar to the changes in the number of animals raised and fattened for meat production after optimization (Figure 3).

As a result of optimization, the livestock density per 100 hectares of agricultural land in the Syrdarya region increased by 16.28%, reaching an average of 173 heads. This growth is explained by increases of 208.3% in the Boyovut District, 108% in the Oqoltin District, and 191.02% in the Sirdaryo District [15].

For any economic-mathematical model, an important criterion of optimization consistency is achieving a certain level of economic efficiency. Considering the previously identified high level of unprofitability in meat production in the Syrdarya Region and its persistent upward trend, we consider that the main criterion of economic efficiency for optimization should be the reduction in the level of losses in meat production.

Table 3. Financial results of optimizing the structure of the livestock population for meat production and fattening in the Syrdarya region

Indicator	2025	Optimal value	Deviation (+; -)
Total expenses for meat, million soums	37 125,54	42 587,62	5 462,08
Revenue from the sale of meat, million soums	38 293,07	45 568,75	7 275,68
Rentability of meat production, %	3	6	3

As a result of optimization, the profitability of meat production in the Syrdarya region as a whole will increase by 3 percentage points and amount to 6%, which will increase sales revenue by 18% and amount to 45,568.75 million soums.

The profitability of meat production in the districts after optimization is presented in Table 4 [16][17].

Table 4. Profitability of meat production after optimization in certain districts of the Syrdarya region, %

District name	2025	Optimal value	Deviation (+; -)
Bayaut District	2,4	6,6	4,2
Akaltyn District	3,2	5,9	2,7
Saykhunabad district	5,3	6	0,7
Syrdarya district	3,7	6,2	2,5
Khavast district	5,9	6,1	0,2

4. Conclusion

The results of the study show that the optimization of meat livestock farming in the Syrdarya Region based on economic-mathematical modeling enables a significant increase in production efficiency. In particular, it was found that improvements in profitability in the Boyovut District, Oqoltin District, and Sirdaryo District can be achieved through the rational use of regional resources and optimization of the production structure. Overall, the implementation of the proposed optimal parameters for meat cattle farming can increase the average regional profitability by approximately 3 percentage points.

Based on these findings, the following scientific and practical recommendations were developed:

First, it is necessary to specialize meat livestock farms in the Syrdarya Region in accordance with local natural and economic conditions and to gradually establish their optimal farm sizes.

Second, in order to improve production efficiency, it is essential to strengthen the feed base, ensure the full and rational use of available resources, and modernize livestock infrastructure.

Third, it is advisable to widely implement decision-making practices in the livestock sector based on economic-mathematical modeling.

Fourth, state support mechanisms should be adapted to regional conditions and effectively targeted to further increase the profitability of livestock enterprises.

In general, the proposed approaches contribute to the sustainable development of meat livestock farming in the Syrdarya Region, the improvement of economic efficiency, and the strengthening of food security.

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