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FORECASTS OF THE NUMBER OF CATTLE GRAZED ON PASTURES IN THE REPUBLIC OF KARAKALPAKSTAN

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Abstract: This article presents forecasts for 2027–2031 of the total cattle population and the number of cattle grazed on pastures in the Republic of Karakalpakstan. The analysis is based on annual time-series data for 2010–2026 and employs the Augmented Dickey–Fuller test, correlogram analysis and ARMAX models. A trend ARMAX (0,0,1) specification was selected for the total cattle population, while a quadratic-trend ARMAX(2,0,1) model was selected for pasture-grazed cattle. The forecast suggests that by 2031 the total cattle population may reach 1,483,420 heads and the pasture-grazed cattle population may reach 73,734 heads. The findings can be used to plan pasture load and support evidence-based livestock-management decisions.

Keywords: pastures, cattle, forecasting, time series, ARMAX model, stationarity, MAPE, Republic of Karakalpakstan.

Annotatsiya: Ushbu maqolada Qoraqalpog'iston Respublikasida qoramollar umumiy soni hamda yaylovlarda boqilayotgan qoramollar sonining 2027–2031-yillarga mo'ljallangan prognozlari taqdim etilgan. Tahlil 2010–2026-yillar bo'yicha yillik vaqt qatori ma'lumotlariga asoslanib, Augmented Dickey–Fuller testi, korrelogramma tahlili va ARMAX modellaridan foydalanilgan. Qoramollar umumiy soni uchun trendli ARMAX(0,0,1) modeli, yaylovlarda boqilayotgan qoramollar soni uchun esa kvadratik trendli ARMAX(2,0,1) modeli tanlangan. Prognozlarga ko'ra, 2031-yilga kelib qoramollar umumiy soni 1 483 420 boshga, yaylovlarda boqilayotgan qoramollar soni esa 73 734 boshga yetishi mumkin. Tadqiqot natijalari yaylov yuklamasini rejalashtirish hamda chorvachilikni boshqarish bo'yicha ilmiy asoslangan qarorlar qabul qilishda foydalanilishi mumkin.

Kalit so'zlar: yaylovlar, qoramollar, prognozlash, vaqt qatori, ARMAX modeli, statsionarlik, MAPE, Qoraqalpog'iston Respublikasi.

Аннотация: В статье представлены прогнозные значения на 2027–2031 годы по общей численности крупного рогатого скота и численности скота, выпасаемого на пастбищах Республики Каракалпакстан. Исследование основано на годовом временном ряде за 2010–2026 годы; применены расширенный тест Дики–Фуллера, коррелограммный анализ и модели ARMAX. Для общей численности выбрана трендовая модель ARMAX(0,0,1), а для пастбищного поголовья — модель ARMAX(2,0,1) с квадратичным трендом. Согласно прогнозу, к 2031 году общая численность может достигнуть 1 483 420 голов, а пастбищное поголовье — 73 734 голов. Результаты могут быть использованы при планировании пастбищной нагрузки и обосновании управленческих решений в животноводстве.

Ключевые слова: пастбища, крупный рогатый скот, прогнозирование, временной ряд, модель ARMAX, стационарность, MAPE, Республика Каракалпакстан.

INTRODUCTION

As the global need to ensure food security intensifies, the sustainable development of livestock farming has become an important direction in scientific research. Pasture-based and mixed farming systems play a crucial role in livestock production and in sustaining rural livelihoods, particularly in developing regions and humid climates. Over the past decade, livestock production has grown steadily, with global meat production increasing by nearly 26 percent and dairy production by 34 percent, reflecting the intensification and expansion of production systems [1]. Climate change, water scarcity, and intensifying desertification are increasing the urgency of the rational use of pasture resources [2]. In arid and semiarid regions, including conditions in Uzbekistan, the sustainable use of pastures is of strategic importance [3]. It is therefore necessary to deeply study the economic and ecological nature of pasture resources, develop criteria for their assessment, and improve the management system [4]. Reducing ecological pressure and land degradation, determining optimal parameters for pasture use, introducing innovative technologies in specialized livestock farms, and rationally utilizing the natural feed base are among the priority tasks of scientific research in this field.

In the Republic of Uzbekistan, particular attention is being paid to developing livestock farming, increasing the number and productivity of pedigree livestock, developing new projects for optimal resource use, and implementing them in practice. The use of digital technologies and quantitative assessment methods in these

processes serves to improve the quality of management decisions. Resolution of the President of the Republic of Uzbekistan RP-120¹, dated February 8, 2022, "On preparation for and holding of the celebration of the 35th anniversary of the state independence of the Republic of Uzbekistan," establishes as priority tasks: increasing the volume of competitive livestock production, forming value-added chains, creating a unified electronic system for monitoring natural hay fields, pastures, and irrigated cropland, and using modern technologies in the evaluation of scientific and applied research [5]. From this standpoint, developing data-driven decision-making tools for livestock enterprises, substantiating the resource capacity of products, optimizing feed rations using mathematical and econometric methods, and assessing the efficiency of pasture use are of pressing scientific and practical significance.

REVIEW OF LITERATURE ON THE SUBJECT

Developing agricultural production, using resources efficiently, and identifying future development trends in the agrarian sector are among the important directions of modern economic research. In particular, identifying the resource factors affecting the volume of agricultural products, econometrically assessing their degree of influence, and developing forecast indicators based on existing trends are of considerable importance for improving regional agrarian policy. Research conducted by foreign and domestic scholars has formed the theoretical and methodological foundations for assessing the efficiency of agricultural resource use and for modeling production processes.

Due to their natural characteristics, pastures perform important ecological functions in preserving biodiversity, stabilizing soil fertility, absorbing carbon dioxide, and mitigating the effects of climate change [6]. However, excessive or improper use of pastures leads to the disruption of ecological balance, land degradation, and the intensification of desertification [7]. This situation further reinforces the need to balance the economic significance of pasture resources with their ecological sustainability [8].

From an economic perspective, pasture resources belong to the category of renewable natural resources; however, their renewal directly depends on time, natural conditions, and the effectiveness of management [9]. The production potential of pastures — that is, their carrying capacity, yield, and biological composition — directly affects the cost of livestock products, profitability levels, and the economic stability of farming enterprises [10]. For this reason, analyzing the economic essence of pasture resources, assessing their value, and developing mechanisms for their efficient use are of great scientific and practical importance [11].

Ecologically, pastures constitute a complex natural system whose condition is determined by climatic factors, soil conditions, vegetation cover, and anthropogenic influences [12]. Ensuring the sustainability of pasture ecosystems requires accounting for ecological constraints in resource use, standardizing pasture load, and implementing measures aimed at preventing degradation processes [13]. Thus, the ecological essence of pasture resources is closely tied to preserving their natural regenerative capacity, biological productivity, and ecological functions [14].

Under market economy conditions, the relations governing pasture resource use are also changing [15]. The diversification of land ownership and use forms, the increasing number of entities using pastures, and the intensification of the competitive environment require improvement of the economic mechanisms of management [16]. In this context, alongside increasing the efficiency of pasture use, preserving and restoring their ecological condition should be regarded as a priority task [17].

The economic and ecological essence of pasture resources requires that they be viewed as a unified system [18]. If economic interests are prioritized while ecological factors are neglected, the production potential of pastures declines in the long term, resulting in economic losses [19]. Conversely, an approach based solely on ecological restrictions may fail to adequately ensure economic efficiency [20]. Therefore, achieving a balance between economic and ecological interests in pasture resource management is an important scientific and practical problem [21].

Climate change, water scarcity, and intensifying desertification are increasing the global strategic importance of pasture resources [22]. In arid and semi-arid regions, including conditions in Uzbekistan, the sustainable and rational use of pastures is directly linked to food security and regional ecological stability [23]. It is therefore necessary to improve the criteria for pasture assessment and to develop their management system on a scientific basis [24].

Thus, pasture resources simultaneously function as a factor of economic production and as an ecological system [25]. Determining their economic and ecological essence is an important condition for the sustainable development of the livestock sector, the rational use of land resources, and ensuring ecological safety [26].

¹ <https://lex.uz/docs/8118206>

RESEARCH METHODOLOGY

The methodological basis of the research consists of an econometric approach aimed at assessing and forecasting the dynamics of the total number of cattle and the number of cattle grazed on pastures in the Republic of Karakalpakstan. The analysis used annual statistical data compiled as of January 1 for the years 2010–2026. Methods including economic-statistical analysis, a systemic approach, comparative methods, stationarity testing of time series, correlogram analysis, and ARMAX model estimation were applied comprehensively in analyzing the data.

The complication of the ecological situation and the intensification of water scarcity in the Aral Sea region are creating the need to diversify agriculture, identify promising directions for sectoral development, and make efficient use of existing resources. According to research findings, developing livestock farming under conditions of increased water scarcity is considered one of the effective and promising directions for the region's economy [27].

From the standpoint of efficient use of existing land resources, converting biomass potential on pastures into high-value products is an important direction. This requires identifying economically and ecologically sound directions for developing pasture-based livestock farming. Available data and analysis results indicate that positive changes have been observed in this direction in recent years.

Taking into account the economic role and significance of livestock farming in the region, the issue of forming forecasts for the number of cattle was considered. Since the indicators are presented as of January 1, the analysis used data for 2010–2026.

The stationarity of the time series was tested using the augmented Dickey–Fuller test. The results obtained showed that the series is stationary when accounting for a constant and trend (Table 1).

Table 1
Results of the UNITROOT test for checking the stationarity of the
time series of the number of cattle in the Republic of Karakalpakstan²

Augmented Dickey-Fuller test for d_YQ
testing down from 4 lags, criterion AIC
sample size 15
unit-root null hypothesis: $a = 1$
test without constant
including 0 lags of $(1-L)d_YQ$
model: $(1-L)y = (a-1)*y(-1) + e$
estimated value of $(a - 1)$: -0.210639
test statistic: $\tau_{nc}(1) = -1.44636$
p-value 0.1329
1st-order autocorrelation coeff. for e: -0.204
test with constant
including 0 lags of $(1-L)d_YQ$
model: $(1-L)y = b_0 + (a-1)*y(-1) + e$
estimated value of $(a - 1)$: -0.818019
test statistic: $\tau_{c}(1) = -2.75376$
p-value 0.08847
1st-order autocorrelation coeff. for e: 0.019
with constant and trend
including 4 lags of $(1-L)d_YQ$
model: $(1-L)y = b_0 + b_1*t + (a-1)*y(-1) + \dots + e$
estimated value of $(a - 1)$: -2.67048
test statistic: $\tau_{ct}(1) = -8.46251$
asymptotic p-value 5.207e-014
1st-order autocorrelation coeff. for e: -0.763
lagged differences: $F(4, 4) = 8.955 [0.0282]$

² Source: Prepared by the author.

ANALYSIS AND RESULTS

The results of the correlogram analysis showed that it is appropriate to use the ARMAX(0,0,1) model for the total number of cattle. A comparative evaluation of various model specifications confirmed that the selected model is the most optimal for the forecasting task.

(1)

Where: YQ — the total number of cattle in the Republic of Karakalpakstan, head.

To verify the statistical reliability of the selected model and the significance of the estimated coefficients, the main diagnostic criteria were calculated; the results are presented in Table 2.

Equation (1) itself didn't come through in the text you pasted (likely a formula/image that didn't extract), so I've left the numbering placeholder as in the original — you may want to paste the actual equation separately if you need it translated or formatted.

The model output table (coefficients, standard errors, t-ratios, p-values, etc.) also appears to be cut off — if you have that data, send it over and I'll translate/format the table headers and any accompanying diagnostic terms (e.g., «R-squared,» «Durbin-Watson,» «Akaike criterion») into their standard academic English equivalents (Table 2).

Table 2

Results of the model developed for calculating the forecast of the number of cattle in the Republic of Karakalpakstan³

Model 11: ARMAX, using observations 2010–2026 (T = 17)

Dependent variable: YQ Standard errors based on Hessian

	Coefficient	Std. Error	z	p-value	
const	697787	14878.6	46.90	<0.0001	***
theta_1	0.842361	0.303334	2.777	0.0055	***
time	35710.6	1435.09	24.88	<0.0001	***
Mean dependent var	1021161		S.D. dependent var		184290.4
Mean of innovations	226.5119		S.D. of innovations		16813.51
R-squared	0.991159		Adjusted R-squared		0.990570
Log-likelihood	-190.1481		Akaike criterion		388.2961
Schwarz criterion	391.6290		Hannan-Quinn		388.6274
	Real	Imaginary	Modulus	Frequency	
MA					
Root 1	-1.1871	0.0000	1.1871	0.5000	

According to the results of the regression analysis, the absolute value of the z-statistic exceeds 1.96 for all estimated coefficients in the model, with corresponding p-values below 0.05. The high value of the coefficient of determination ($R^2 = 0.991159$) indicates that the model provides a strong fit to the observed data. Accordingly, this model can be used to generate forecast values.

The growing attention to the development of pasture-based livestock farming in recent years, together with the rapid increase in the number of cattle grazed on pastures since 2018, underscores the need to develop a separate forecast for this indicator. Based on existing trends and the results of a comparative analysis of various model specifications, the following model was found to be the most optimal for calculating forecast values for the number of cattle grazed on pastures in the Republic of Karakalpakstan.

(2)

Where: YQY — the number of cattle grazed on pastures in the Republic of Karakalpakstan, head. The z-statistics of all coefficients in the selected model differ sufficiently from the critical value, with their p-values below 0.001. The coefficient of determination ($R^2 = 0.987792$) indicates that the model provides a high degree of fit to the observed data (Table 3).

³ Source: Prepared by the author.

Table 3

Results of the model developed for calculating the forecast of the number of cattle grazed on pastures in the Republic of Karakalpakstan⁴

Model 24: ARMAX, using observations 2010-2026 (T = 17)

Dependent variable: YQY

Standard errors based on Hessian

	Coefficient	Std. Error	z	p-value	
const	28383.2	684.589	41.46	<0.0001	***
phi_1	1.67004	0.0561173	29.76	<0.0001	***
phi_2	-0.953761	0.0432997	-22.03	<0.0001	***
theta_1	-1.00000	0.165024	-6.060	<0.0001	***
t2	95.2428	6.25707	15.22	<0.0001	***
Mean dependent var	39295.47		S.D. dependent var	10030.05	
Mean of innovations	96.86786		S.D. of innovations	1082.038	
R-squared	0.987792		Adjusted R-squared	0.984975	
Log-likelihood	-146.0908		Akaike criterion	304.1817	
Schwarz criterion	309.1810		Hannan-Quinn	304.6786	
	Real	Imaginary	Modulus	Frequency	
AR					
	Root 1	0.8755	-0.5310	1.0240	-0.0868
	Root 2	0.8755	0.5310	1.0240	0.0868
MA					
	Root 1	1.0000	0.0000	1.0000	0.0000

To assess the forecast accuracy of the model, the MAPE indicator was calculated. Its value of 2.64 percent indicates a low forecast error and confirms that this model can be used to generate future indicators.

For the model of the total number of cattle, the MAPE indicator amounted to 1.24 percent. This result indicates that the model has a high level of forecast accuracy. The forecast values calculated on the basis of the model for 2027–2031 are presented in Table 4 (Table 4).

Table 4

Forecast values for the number of cattle in the Republic of Karakalpakstan⁵

For a 95% confidence interval: $z(0.025) = 1.96$

Years	Forecast values	Growth rate, %	Standard error	95% confidence interval
2027	1 312 440	103,7	16813,5	(1 279 490; 1 345 400)
2028	1 376 290	104,9	21983,8	(1 333 200; 1 419 380)
2029	1 412 000	102,6	21983,8	(1 368 910; 1 455 090)
2030	1 447 710	102,5	21983,8	(1 404 620; 1 490 800)
2031	1 483 420	102,5	21983,8	(1 440 330; 1 526 510)

According to the forecast results, the positive growth trend in the total number of cattle in the Republic of Karakalpakstan is expected to be maintained. According to the calculations, the indicator will reach 1,483,420 head as of January 1, 2031. This implies an average annual growth rate of approximately 3.2 percent over the forecast period, representing a 1.17-fold increase relative to the current level.

Based on the second model, forecast values for the number of cattle grazed on pastures in the Republic of Karakalpakstan were calculated for the next five years; the results are presented in Table 5 (Table 5).

⁴ Source: Prepared by the author.

⁵ Source: Prepared by the author.

Table 5

Forecast values for the number of cattle grazed on pastures in the Republic of Karakalpakstan⁶Aor a 95% confidence interval: $z(0.025) = 1.96$

Years	Forecast values	Growth rate, %	Standard error	95% confidence interval
2027	55 746	102,0	1082,04	(53 624,8; 57 866,3)
2028	58 101	104,2	1302,48	(55 548,4; 60 654,0)
2029	62 025	106,8	1314,69	(59 448,0; 64 601,5)
2030	67 393	108,7	1372,14	(64 703,9; 70 082,7)
2031	73 734	109,4	1601,93	(70 593,8; 76 873,2)

CONCLUSIONS AND SUGGESTIONS

During the forecast period, the growth rate of the number of cattle grazed on pastures is expected to accelerate, with annual growth increasing from 2.0 percent to 9.4 percent. As a result, the indicator is forecast to reach 73,734 head by 2031, representing a 1.35-fold increase relative to the current level. The analysis showed that this indicator has been characterized by high growth rates since 2018, with the growth rate slowing after 2023. Nevertheless, according to the forecast results, a renewed acceleration in the growth rate of livestock numbers is expected starting from 2028.

The observed and forecast changes can be explained by a number of factors. In particular, a shift is being observed in the composition of entities engaged in cattle farming: the share of farmer (private subsidiary) farms, which have historically led the sector, declined from 98.1 percent in 2010 to 92.9 percent in 2026. In addition, a number of legal and regulatory documents aimed at regulating pasture use were adopted in 2019. Specifically, Law of the Republic of Uzbekistan № LRU-538⁷ "On pastures" was adopted on May 20, 2019. Resolution No. 689⁸ of the Cabinet of Ministers of the Republic of Uzbekistan, dated August 19, 2019, "On approval of the regulations on permissible limits for livestock grazing on pastures and the procedure for maintaining and managing pasture rotation" established the maximum permissible norms for livestock grazing on pastures, as well as the procedure for pasture rotation and management. These institutional changes have contributed to improving pasture management practices. Furthermore, the fact that cattle grazed on pastures are predominantly attributable to farming enterprises and organizations engaged in agricultural activities, and that their share in livestock farming continues to grow, may also be regarded as an important contributing factor.

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⁶ Source: Prepared by the author.

⁷ <https://lex.uz/en/docs/6906956>

⁸ <https://lex.uz/docs/7269443>

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