
Study of the Impact of Environmental and Resource Constraints on Livestock Development in the Kingdom of Saudi Arabia

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Abstract

This study aims to measure the impact of environmental and resource constraints on livestock development in the Kingdom of Saudi Arabia during the period 1990–2023 using econometric analysis. The results indicate that the key environmental and resource constraints affecting livestock development include climate change, animal diseases, water scarcity and its impact on the area and production of green fodder (alfalfa and Rhode's grass), the importation and processing of feed grains (barley, maize, and sorghum), as well as loans and investments allocated to the livestock sector.

The study shows that a 10% increase in fodder crop production, rainfall levels, and manufactured feed quantity leads to an increase in the number of livestock units by 4.47%, 4.46%, and 3.54%, respectively. The results also reveal an inverse relationship between green fodder production and the number of livestock units during the study period, due to the decline in the area and production of water-

intensive green fodder and the gradual shift toward cultivating seasonal fodder within a period not exceeding three years.

Furthermore, the number of livestock units is expected to increase from 8.01 million units in 2026 to 12.56 million units in 2030. In light of water scarcity and the decline and fluctuations in rainfall rates in sedimentary-ridge regions, the study recommends protecting livestock resources by reconsidering the loan distribution policy to increase livestock numbers in the Arabian Shield regions (Makkah, Madinah, Jazan, Al-Baha, Asir, and Najran), which are characterized by higher rainfall levels and the presence of natural rangelands.

Keywords: Climate Change, Water Scarcity, Animal Diseases and Control, Loans and Investments, Feed Grain Imports.

1. Introduction

Livestock production in the Kingdom of Saudi Arabia has transitioned from traditional grazing to the adoption of specialized modern practices supported by technology and private investment, with a focus on achieving self-sufficiency and food security in meat production. The main developments in the livestock sector in Saudi Arabia can be summarized as follows: (1) Adoption of modern technologies, such as the use of the Internet to monitor animal health, enhance productivity, and implement modern management models in livestock farms; (2) Genetic improvement of animals to enhance production efficiency and reduce disease incidence; (3) Expansion of the dairy and poultry sectors to increase domestic production and reduce reliance on imports; (4) Support for small-scale breeders through financing programs aimed at boosting productivity and improving income levels; (5) Expansion of integrated livestock cities, including barns, feed mills, veterinary hospitals, and modern slaughterhouses; (6) Implementation of programs to develop traditional livestock production and integrate it with economic development; (7) Diversification of investment in veterinary medicine and related services, attracting

both domestic and foreign direct investment (Al-Nafea, 2022; Al-Shahrani, 2025).

The state has provided both direct and indirect support for livestock development, with the Agricultural Development Fund adopting the initiative for sheep multiplication and improvement. The total value of loans allocated for sheep breeding and fattening reached 879.7 million SAR from the establishment of the fund up to 2022 (Agricultural Development Fund, 2024).

Saudi Arabia possessed a livestock population of 33.93 million head in 2023, including 20.6 million sheep, 7.42 million goats, 2.21 million camels, and 502,000 cattle. Thus, the total number of livestock (sheep, goats, camels, and cattle) amounted to 30.73 million head, representing 90.57% of the total livestock population, while traditional poultry, birds, rabbits, horses, cats, gazelles, and dogs collectively accounted for no more than 9.43% in 2023 (Ministry of Environment, Water and Agriculture, 2023). The livestock production index (2004–2006 = 100) increased from 65.39 in 2000 to 164.71 in 2022 (World Bank, 2025). The increase in livestock numbers requires an expansion in the importation of feed grains (barley, maize, and sorghum), in addition to higher water requirements for livestock breeding and fattening, as well as for red meat production.

Several economic studies have addressed livestock development and its impact on self-sufficiency, food security, and water consumption in the Kingdom of Saudi Arabia. The study by Ghanem et al. (2014) indicated that relying on domestic agriculture to achieve food security entails several economic risks, the most important of which are: (1) Depletion of relatively scarce water resources; (2) A decline in the economic size of the agricultural sector due to allocating part of the water resources to crops with low water productivity; (3) A reduction in the cultivated area of other dominant crops in the cropping pattern; (4) Limited benefit from virtual water obtained through imports and Saudi agricultural investments abroad.

Regarding water consumption, the study by Almojel et al. (2024) examined the effect of food sovereignty in red meat on water use in the agricultural sector. The study found that the total volume of water used for red meat production reached 46.68 billion m³, representing 10.14% of total agricultural water use during the period 1995–2022. The amount of water used in red meat production depends on several factors, the most important of which are the ratio of fodder crop area to total cultivated area, and the ratio of green fodder area to total fodder crop area. A 10% increase in estimated water usage for red meat production leads to only a slight 0.22% increase in total agricultural water use. This is attributed to the reduction of green fodder areas on the one hand and the Agricultural Development Fund's initiative for sheep multiplication and improvement on the other. To achieve sustainable development under water scarcity, the following measures are required: (1) Continuing the halt of green fodder cultivation to conserve water for future generations; (2) Utilizing virtual water obtained through imports and Saudi agricultural investments abroad to meet local consumption needs and ensure food security in red meat.

The study by Ghanem et al. (2025) focused on estimating the current and projected water requirements for livestock in the Kingdom of Saudi Arabia up to 2030. The study revealed that water requirements for livestock increased to 137.54 million m³, valued at 66.29 million SAR in 2023. These water needs represent 1.12% of the total water used for agricultural purposes, which amounted to 12.3 billion m³ in 2023. The study projects that water requirements for livestock will rise from 131.90 million m³ in 2026 to 206.66 million m³ in 2030. The study recommended preserving livestock resources by having the Agricultural Development Fund reconsider its loan distribution policy, aiming to expand livestock numbers in the Arabian Shield regions, characterized by higher rainfall and the presence of natural rangelands.

Finally, another study by Ghanem et al. (2025) examined the impact of livestock

development on water consumption in the agricultural sector of the Kingdom of Saudi Arabia. The study found that the amount of water required for livestock and red meat production increased from 1.53 billion m³ (representing 8.52% of total agricultural water consumption in 2000) to 2.86 billion m³ (representing 23.23% of total agricultural water consumption in 2023). It is projected that total water requirements for livestock and red meat production will rise from 2.77 billion m³ in 2024 to 3.32 billion m³ in 2030. Similarly, water consumption in the agricultural sector is expected to increase from 12.39 billion m³ in 2024 to 15.95 billion m³ in 2030, thereby affecting strategic water reserves and lowering groundwater levels, especially in sedimentary-ridge regions. The study ultimately recommended regulating livestock numbers to ensure continued water conservation and sustainability for future generations.

2. Research Objectives

This study aims to measure the impact of environmental and resource constraints on livestock development in the Kingdom of Saudi Arabia during the period 1990–2023 through the following specific objectives:

1. To examine the current status of environmental and resource constraints affecting livestock in the Kingdom of Saudi Arabia.
2. To assess the impact of environmental and resource constraints on livestock numbers in the Kingdom of Saudi Arabia.
3. To forecast livestock numbers in light of environmental and resource constraints up to the year 2030.

3. Study Methodology

This study relies on secondary data published by: (1) Websites of international organizations, most notably the World Bank Group and the Food and Agriculture Organization (FAO); (2) The Livestock Statistics Bulletin issued by the General

Authority for Statistics; (3) The Statistical Yearbook published by the Ministry of Environment, Water and Agriculture.

To estimate the annual growth rate of environmental and resource constraints affecting livestock development during the period 1990–2023, the study employed both exponential and quadratic growth models, which can be expressed by the following equations:

Exponential Model:

$$\ln Y = B_0 + B_1 T \dots \dots \dots (1)$$

The above equation can be written as follows:

$$Y = e^{B_0+B_1T} \dots \dots \dots (2)$$

Whereas: e represents the base of the natural logarithm and equals 2.71828, B₁ represents the annual growth rate, which is obtained by taking the first derivative of the model and then dividing by Y, as follows (Ismail, 2001):

$$\frac{dY}{dT} = B_1 e^{B_0+B_1T} \dots \dots \dots (3)$$

$$r = \frac{dY}{dT} \div Y = B_1 \dots \dots \dots (4)$$

Quadratic Model:

$$Y = a_0 + b_1 T + b_2 T^2 + e \dots \dots \dots (5)$$

The annual growth rate of livestock numbers (livestock units) is obtained by taking the first derivative of the model and then dividing by \bar{Y} , as follows (Ismail, 2001):

$$\frac{dY}{dT} = b_1 + 2 b_2 T \dots \dots \dots (6)$$

$$r = \left(\frac{dY}{dT} \div \bar{Y} \right) \times 100 \dots \dots \dots (7)$$

Due to the differences in the nature and characteristics of the animals, they were converted into livestock units using the following conversion rates: cattle = 1, camels = 1.25, sheep = 0.20, goats = 0.15. A stepwise multiple regression analysis was employed to study the determinants of livestock unit numbers during the period 2000–2023. The model used can be expressed by the following equation:

$$Y = a_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + e \dots \dots \dots (8)$$

Whereas:

- Y represents the total number of livestock units (in million units).
- X₁ represents the production of feed grain crops (barley, maize, sorghum) in thousand tons.
- X₂ represents the production of green fodder crops (in million tons).
- X₃ represents the rainfall rate (in millimeters) for natural rangeland development.
- X₄ represents the quantity of Saudi imports of feed grain crops (in million tons).
- X₅ represents the quantity of manufactured feed (in thousand tons).

Other variables, such as the value of loans allocated for livestock development, were excluded despite their relative importance in influencing livestock unit numbers. This exclusion was due to their discontinuity over most years, as no loans were allocated for sheep and calf breeding and fattening during 2000, 2002–2003, 2005, 2008–2009, 2011, 2013–2017, and 2022 (Agricultural Development Fund, 2024).

The model was estimated in linear, logarithmic, and semi-logarithmic forms using the Ordinary Least Squares (OLS) method, and comparisons were made between these forms. Since the model relies on time series data, there is a potential issue of autocorrelation in the residuals, which was examined using several tests, the most important of which are: (1) Durbin-Watson (DW) test, with values ranging between 0 and 4 ($0 \leq DW \leq 4$), (2) Breusch-Godfrey Serial Correlation LM test, where a p-value greater than the significance level (α) indicates no autocorrelation in the random errors, while a p-value less than the significance level indicates the presence

of autocorrelation in the residuals (Gujarati, translated and reviewed by Odeh and Al-Dash, 2015).

4. Research Findings

4.1 The Current Status of Environmental and Resource Constraints Affecting Livestock Development in the Kingdom of Saudi Arabia:

There are no doubt that environmental and resource constraints influence agricultural production in the Kingdom of Saudi Arabia in general, and livestock development in particular. These constraints include climate change, animal diseases, water scarcity and its impact on the cultivated area of water-intensive crops most importantly green fodder along with loans and investments allocated for livestock development, as well as the importation and processing of feed grains.

Climate Change:

Climate change refers to long-term shifts in weather patterns and global temperatures. Although climate change can occur due to natural factors, its pace has accelerated at an unprecedented rate due to the burning of fossil fuels (oil, gas, and coal), deforestation, and industrial activities. Climate change results in rising global temperatures, melting polar ice, and extreme weather events such as heat waves, floods, and droughts. It also poses threats to biodiversity, contributes to the extinction of some species, and leads to economic and health impacts such as reduced agricultural production and the spread of diseases (William et al., 2022). Data presented in Figure 1 show that the magnitude of temperature change on Earth during the months of June, July, and August in the Kingdom of Saudi Arabia ranged between a minimum of 1.0°C in 2004 and a maximum of 2.9°C in 2017. In practice, temperature changes tend to affect wildlife more than farm animals, due to the ability to mitigate heat stress in livestock production systems by installing fans and air-conditioning units inside barns and stables.

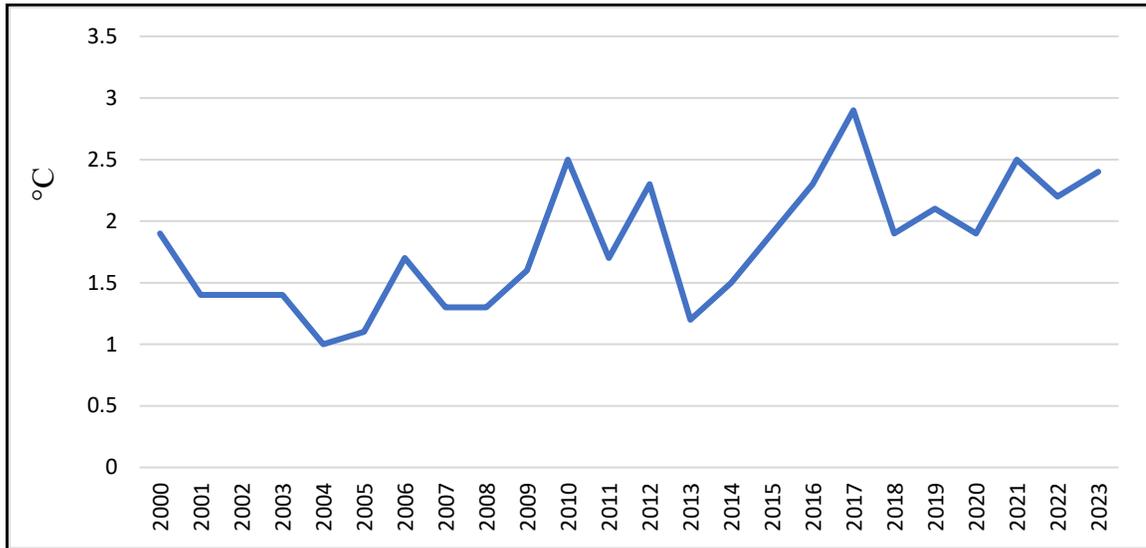


Figure 1: Magnitude of Temperature Change on Earth During the Months of June, July, and August in the Kingdom of Saudi Arabia During the Period 2000–2023- Source: Prepared by the researcher based on data published on the Food and Agriculture Organization (FAO) website.

Diseases Affecting Livestock and Their Treatment:

Livestock are vulnerable to a range of natural disease hazards, the most important of which include foot-and-mouth disease, infectious bronchitis, sheep and camel pox, bovine and small ruminant plague, as well as rabies in farm animals. The Ministry of Environment, Water and Agriculture plays a significant role in maintaining animal health by producing veterinary vaccines and immunizing animals against brucellosis. The Animal Wealth Department has treated large numbers of animals across various regions of the Kingdom of Saudi Arabia during the period 2000–2023. Data presented in Table 1 and Figure 2 show that the total number of treated animals increased from 7.21 million in 2000 to 61.79 million, with an annual average of 10.62 million animals during the study period. Sheep represented the largest share of treated animals, accounting for 67.97%, followed by goats at 27.39%, while camels and cattle accounted for 3.91% and 0.73%, respectively.

Table 1: Number of Treated Animals (in Thousands) during the Period 2000–2023. Source: Ministry of Environment, Water, and Agriculture, Animal Wealth Department, Period 2000–2023.

Year	Sheep	Goats	Camels	Cattle	The Total
2000	4419	2405	332	51	7207
2001	6971	2208	59	67	9305
2002	3633	1883	354	37	5907
2003	3633	1659	353	37	5682
2004	2793	2156	370	32	5351
2005	4668	2577	488	61	7794
2006	4754	3172	633	94	8653
2007	6024	4124	770	99	11017
2008	6834	3554	453	145	10986
2009	4790	2630	556	57	8033
2010	413	2434	507	69	3423
2011	1304	2125	250	31	3710
2012	2961	1567	339	31	4898
2013	6727	1520	296	25	8568
2014	7474	4543	931	84	13032
2015	1207	6951	36	115	8309
2016	3699	5524	630	101	9954
2017	7161	4439	566	127	12293
2018	4265	854	353	23	5495
2019	4179	2226	400	67	6872
2020	4722	1531	363	45	6661
2021	54721	6290	416	365	61792
2022	13236	1712	258	46	15252
2023	12638	1714	248	64	14664
Average	7217.8	2908.3	415.0	78.0	10619.1
%	67.97	27.39	3.91	0.73	100

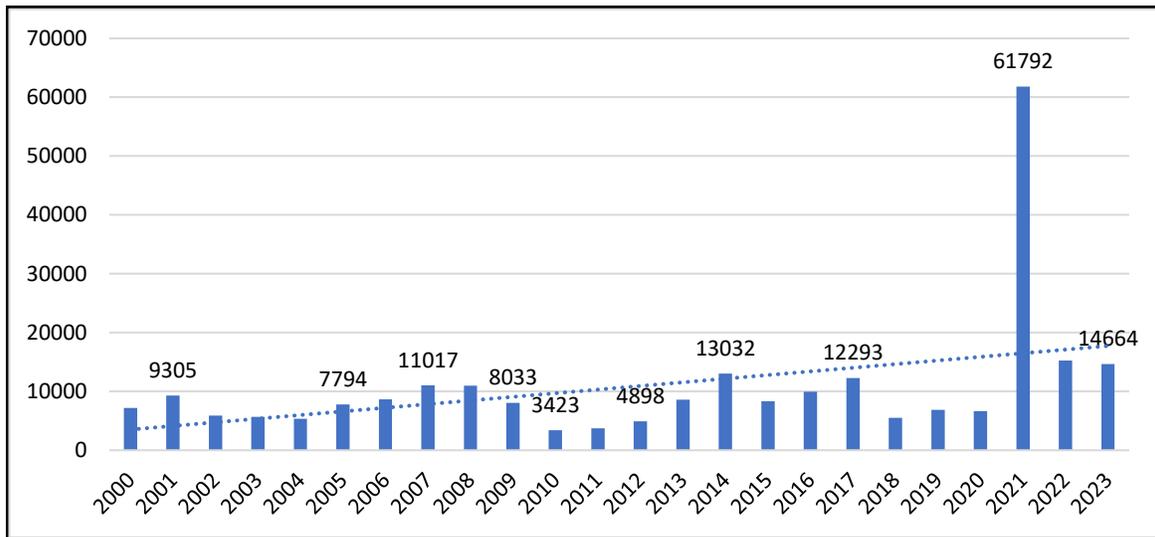


Figure 2: Total Number of Treated Animals (in Thousands) During the Period 2000–2023. Source: Data reported in Table 1.

Water Scarcity and Its Impact on the Area and Production of Green Fodder:

The Kingdom of Saudi Arabia suffers from significant water scarcity due to low rainfall rates, with precipitation ranging from a minimum of 41.6 mm in the Tabuk Region to a maximum of 291.6 mm in Al-Baha Region in 2023 (Figure 3). The Kingdom is generally characterized by low and highly variable rainfall, particularly in the sedimentary plateau areas (Riyadh, Eastern Region, Qassim, Al-Jouf, Hail, Tabuk, and the Northern Borders).

As a result, the available renewable surface and groundwater resources are insufficient to meet the increasing demand for water used for domestic, industrial, and agricultural purposes.

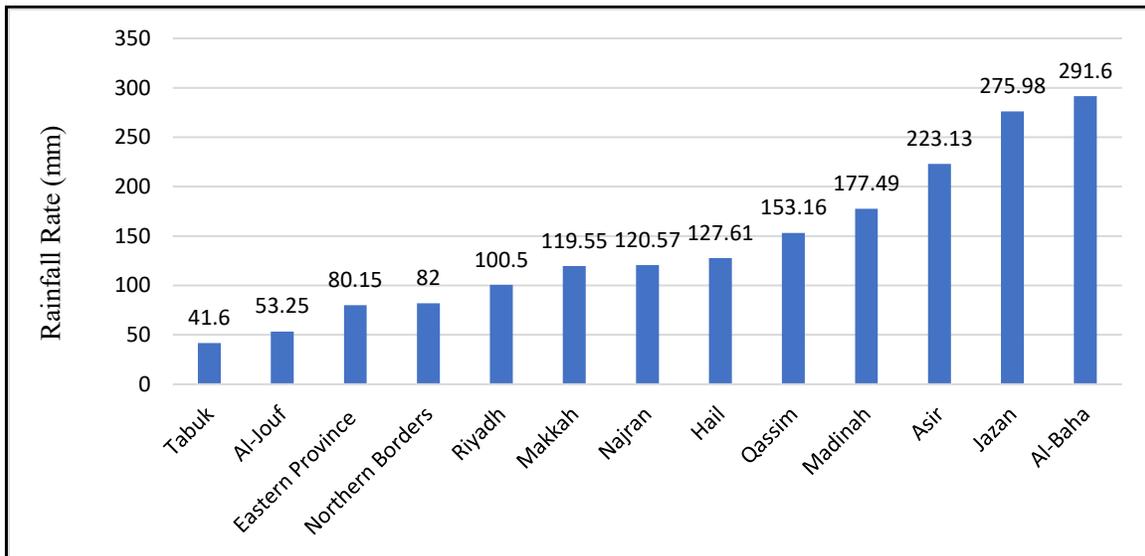


Figure 3: Average Rainfall Rate across the Regions of the Kingdom of Saudi Arabia in 2023. Source: Prepared by the researcher based on data published in the Statistical Yearbook issued by the Ministry of Environment, Water and Agriculture.

A study by Alrwis et al. (2021) investigated the impact of water scarcity on agricultural economic development in the Kingdom of Saudi Arabia. The study revealed that a 10% change in available water resources leads to a 5.1% change in the cultivated area in the same direction. Furthermore, a 10% change in the estimated cultivated area results in a 1.5% change in the total value of agricultural output. Thus, reduced water availability in the agricultural sector diminishes the cultivated area, negatively affecting agricultural output value and, ultimately, the country's Gross Domestic Product (GDP).

Given the scarcity of water resources and the declining levels of non-renewable groundwater, the per capita share of renewable internal freshwater dropped from 950 m³ per person in 1961 to 148.0 m³ per person in 2000, and further declined to 75.0 m³ per person in 2022 (World Bank, 2025). To address this challenge, the Ministry of Environment, Water and Agriculture has implemented measures to rationalize and

sustain water consumption by restructuring the crop pattern, following decisions to halt wheat and green fodder cultivation. As a result, water use in the agricultural sector decreased from 18.0 billion m³ in 2000 to 12.3 billion m³ in 2023 (Figure 4).

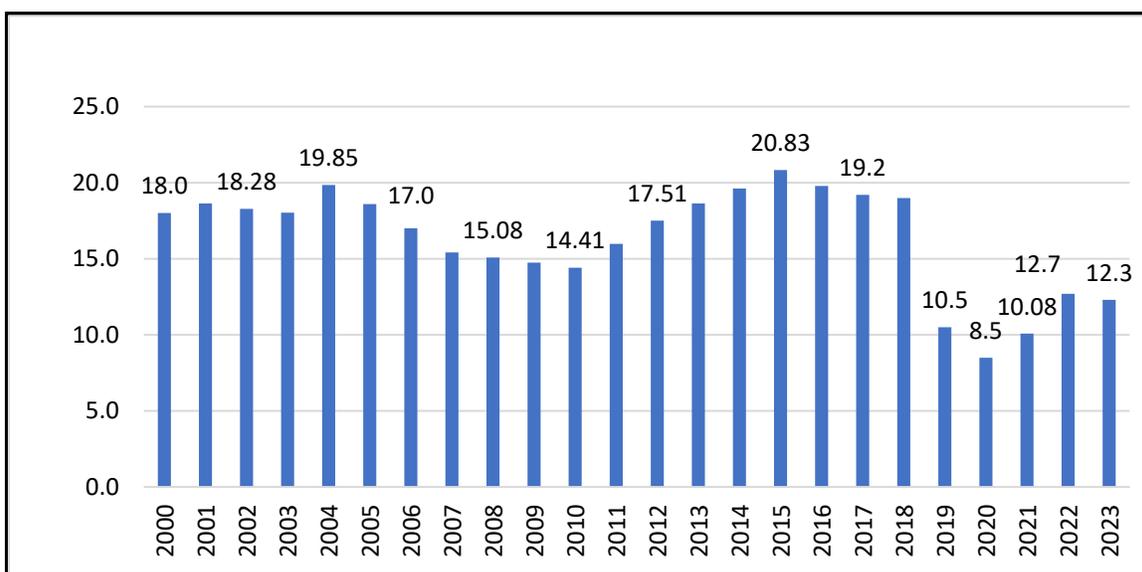


Figure 4: Water Consumption in the Agricultural Sector (billion m³) during the Period 2000–2023.
Source: Prepared by the researcher based on data published in the Statistical Yearbook issued by the Ministry of Environment, Water, and Agriculture.

Cultivated Area and Crop Yield:

The cultivated area refers to the total land used for producing and harvesting crops within a single agricultural year. It includes the areas planted with both winter and summer seasonal crops, as well as fruit orchards. Figure 5 shows that the cultivated area decreased from approximately 1.12 million hectares in 2000 to 534.23 thousand hectares in 2022, before rising again to 893.4 thousand hectares in 2023. This decline is mainly attributed to the reduction in wheat cultivation following Ministerial Decision No. 335, as well as the decrease in the area planted with water-intensive green fodder crops in accordance with the regulations implementing Cabinet Resolution No. 66 dated 25/2/1437 H, which mandated the cessation of perennial

green fodder cultivation.

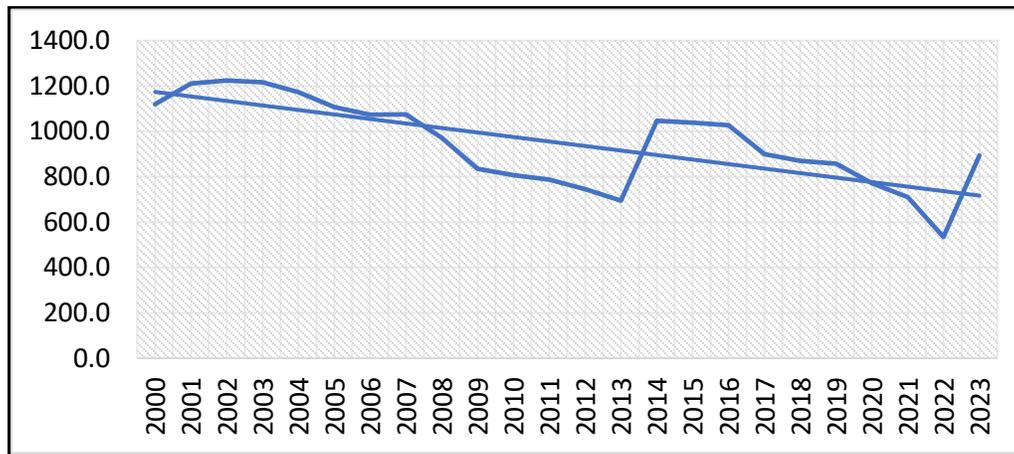


Figure 5: Cropped area (in thousand hectares) during the period 2000–2023. Source: Prepared by the researcher based on data published in the Statistical Yearbook issued by the Ministry of Environment, Water and Agriculture.

Import and Processing of Feed Grains:

To rationalize water consumption and safeguard livestock resources, the Kingdom of Saudi Arabia has expanded its imports of feed grains primarily barley, maize, and sorghum. Data in Table 2 show that Saudi barley imports increased from 5.34 million tons, valued at 669.12 million USD in 2000, to 15.5 million tons, valued at 3,249.59 million USD in 2013, before declining to 2.08 million tons, valued at 730.03 million USD in 2023. Similarly, Saudi maize imports rose from 1.26 million tons, valued at 170.83 million USD in 2000, to 4.6 million tons, valued at 1,456.58 million USD in 2022, and then decreased to 3.20 million tons, valued at 1,007.84 million USD in 2023. As for sorghum, only small quantities were imported due to its cultivation being concentrated in the Arabian Shield regions, which receive relatively higher rainfall. Consequently, Saudi Arabia achieved a high self-sufficiency rate for sorghum no less than 90% during the period 2000–2023.

Based on the data presented in Figure 6, the total quantity of Saudi imports of feed grains (barley, maize, and sorghum) increased from 6.60 million tons, valued at

839.95 million USD in 2000, to 12.66 million tons, valued at 3,935.67 million USD in 2013, before declining to 5.28 million tons, valued at 1,738.12 million USD in 2023. The recent decline in Saudi feed grain imports is attributed to a shift toward utilizing these grains in feed manufacturing rather than providing them as whole grains for direct animal consumption. This shift reduces visible grain losses in animal waste and enhances overall utilization efficiency.

Table 2: Quantity and Value of Saudi Imports of Fodder Grains the Period 2000- 2023. Source: Food and Agriculture Organization (FAOSTAT), 2000–2023.

year	Barley		Maize (Corn)		Sorghum	
	Quantity million tons	Value million dollars	Quantity million tons	Value million dollars	Quantity thousand tons	Value thousand dollars
2000	5.34	669.12	1.26	170.83	0.05	48.0
2001	3.24	413.96	1.08	146.74	0.08	35.0
2002	3.79	489.62	1.16	144.71	0.01	6.0
2003	5.65	962.28	0.89	131.18	0.17	92.0
2004	2.89	553.57	0.79	146.88	0.21	110.0
2005	5.98	1048.25	1.23	189.18	0.37	147.0
2006	7.59	1214.26	1.34	213.64	0.23	109.0
2007	7.10	2143.35	1.83	466.39	2.22	1038.0
2008	7.65	2984.26	1.68	415.08	0.00	0.0
2009	5.96	1258.65	1.54	377.93	0.00	0.0
2010	7.24	1917.23	1.93	471.49	0.00	0.0
2011	6.35	1958.75	1.65	611.38	0.00	0.0
2012	8.32	2514.09	1.91	629.27	0.00	0.0
2013	10.55	3249.59	2.11	685.72	1.00	364.0
2014	7.55	1993.32	2.57	680.97	0	0
2015	6.49	1469.67	2.32	532.80	0.52	485.0
2016	8.49	1679.74	3.24	691.97	0.11	137.0
2017	8.60	1655.31	3.71	748.03	0.04	30.0
2018	7.66	1037.14	3.01	640.89	0.01	33.0
2019	3.91	882.88	3.26	715.32	0.16	72.0
2020	2.90	616.14	3.07	654.19	0.29	59.0
2021	5.38	1458.43	2.94	909.41	0.08	31.0
2022	3.79	1401.21	4.60	1456.58	6.25	3273.0
2023	2.08	730.03	3.20	1007.84	0.49	250.0
Average	6.02	1429.20	2.18	534.93	0.51	263.29

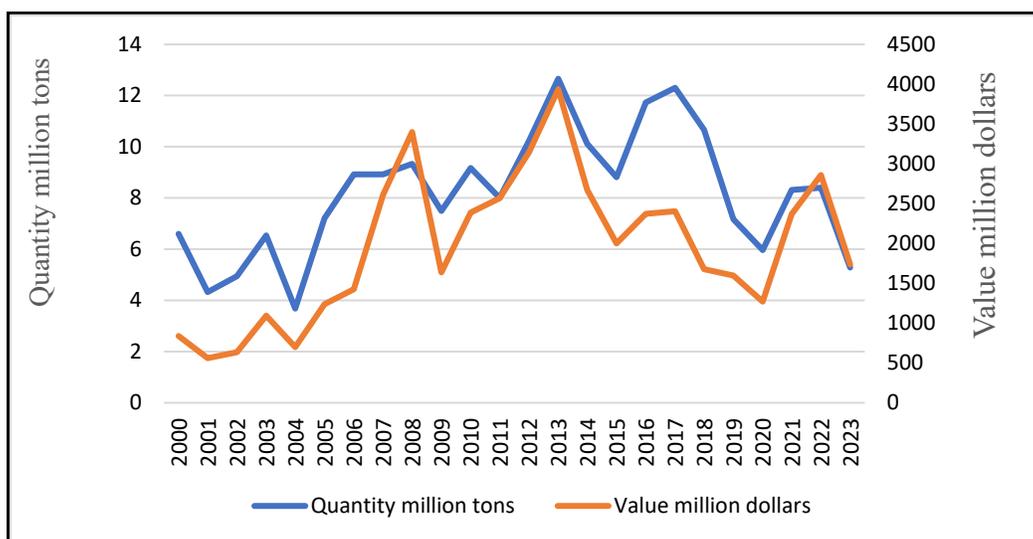


Figure 6: Quantity and value of Saudi imports of feed grains during the period 2000–2023. Source: Data Reported in Table 2.

Loans and Investments Allocated for Livestock Development:

An examination of the development of sheep and calf fattening projects funded by the Agricultural Development Fund during the period 2000–2023 indicates that the total number of financed breeding and fattening projects reached 19, with loans amounting to SAR 183.24 million (Figure 7). Within the framework of the Sustainable Rural Development Program, the Ministry of Environment, Water, and Agriculture provided subsidies to livestock breeders totaling SAR 930.36 million for 24.27 million heads of livestock, distributed across the various production regions in 2023. The Asir region received 20.62% of the total subsidies, followed by Makkah with 15.4%, and subsequently Najran, Jazan, Riyadh, Madinah, and the Eastern Province with 13.22%, 11.94%, 9.25%, 6.91%, and 5.41%, respectively. Collectively, these seven regions accounted for 82.76% of the total subsidies allocated to livestock breeders, while the remaining production regions together represented no more than 17.24% in 2023 (Figure 8).

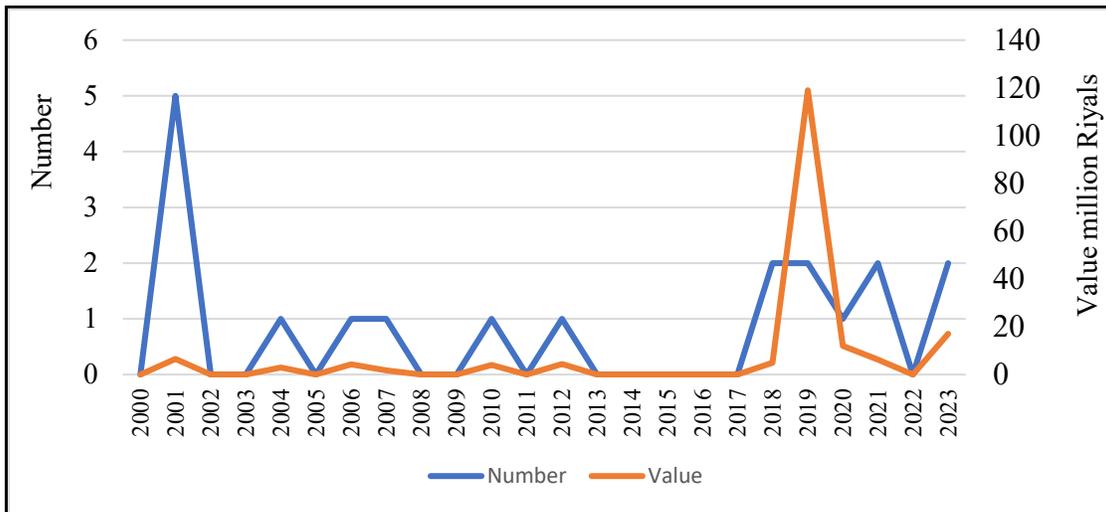


Figure 7: Number of Sheep and Calf Breeding and Fattening Projects and Loans Funded by the Agricultural Development Fund during the Period 2000–2023. Source: Agricultural Development Fund (2024). Sixty-first Annual Report for the Fiscal Year (1445-1446 H).

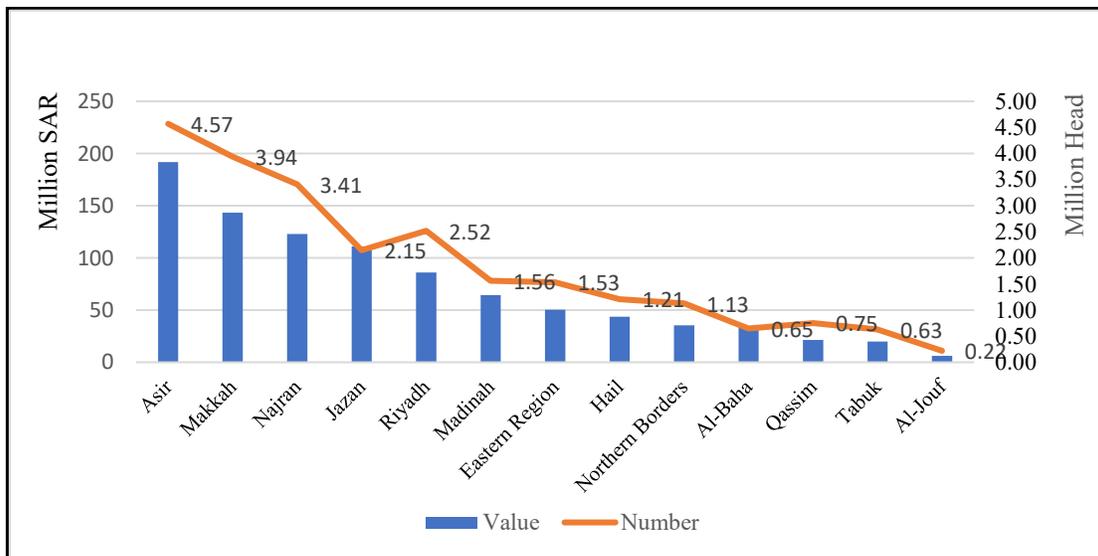


Figure 8: Value of Subsidies for Livestock Farmers According to the Rural Development Program in 2023. Source: Ministry of Environment, Water and Agriculture, Statistical Yearbook 2023.

4-2 Measuring the Impact of Environmental and Resource Determinants on Livestock Numbers in the Kingdom of Saudi Arabia:

To study the impact of various determinants on livestock numbers (goats, sheep, cattle, and camels), these were converted into animal units for the period 2000–2023. Data in Table 2 show that the total number of animal units ranged from a minimum of 2.18 million units in 2012 to a maximum of 8.49 million units in 2023, with an annual average of 4.43 million units. The production of feed grain crops ranged from a minimum of 209.0 thousand tons in 2010 to a maximum of 967.3 thousand tons in 2014, with an annual average of 447.01 thousand tons. Similarly, the production of green fodder ranged from a minimum of 2.37 million tons in 2006 to a maximum of 10.70 million tons in 2014, with an annual average of 6.37 million tons during the study period.

Rainfall rates in the Kingdom of Saudi Arabia ranged from a minimum of 56.6 mm in 2012 to a maximum of 151.9 mm in 2023, with an annual average of 89.29 mm. Likewise, Saudi imports of feed grain crops (barley, maize, and sorghum) ranged from a minimum of 3.67 million tons in 2004 to a maximum of 12.65 million tons in 2013, with an annual average of 8.20 million tons. The quantity of manufactured feed also varied, ranging from zero in 2008 to 737.89 thousand tons in 2022, with an annual average of 345.34 thousand tons during the study period. Both the number of animal units, rainfall rates, and Saudi imports of feed grain crops exhibited relative stability, whereas the production of feed grain crops, green fodder, and manufactured feed showed instability due to the high coefficients of variation of these variables over the study period.

Table (2): Descriptive Analysis of the Determinants of Animal Units During the Period 2000–2023.
Source: Collected and calculated from: (1) Ministry of Environment, Water and Agriculture, Statistical Yearbook, 2000–2023; (2) Food and Agriculture Organization (FAOSTAT) website, 2000–2023.

Item	Number of animal units (million units)	Production of feed grain crops (thousand tons)	Production of green fodder (million tons)	Rainfall rate (mm)	Imports of Feed Grains (million tons)	Manufactured feed (thousand tons)
Minimum	2.18	209.00	2.37	56.60	3.67	0.00
Maximum	8.49	967.30	10.70	151.9	12.65	737.89
Mean	4.43	447.01	4.77	89.29	8.20	345.34
Standard Deviation	1.45	209.41	2.76	21.02	2.42	203.24
Coefficient of Variation (%)	32.73	46.85	57.86	23.54	29.51	58.85

The correlation matrix among the determinants of the number of animal units was estimated. Data in Table 3 show that all correlation coefficients between the independent variables are below 0.80. Therefore, there is no problem of multicollinearity, which could otherwise lead to large standard errors and imprecise regression coefficients, potentially rendering the effect of an independent variable statistically insignificant (Gujarati, translated and reviewed by Odeh and Al-Dash, 2015).

Table 3: Correlation Matrix of the Determinants of Animal Units During the Period 2000–2023. Source: Collected and calculated from the data presented in Table (2).

Variable	Y	X ₁	X ₂	X ₃	X ₄	X ₅
Y	1.000	-0.392	-0.359	0.499	-0.389	0.405
X ₁	-0.392	1.000	0.718	-0.093	0.194	0.103
X ₂	-0.359	0.718	1.000	-0.152	0.509	0.481
X ₃	0.499	-0.093	-0.152	1.000	-0.364	-0.013
X ₄	-0.389	0.194	0.509	-0.364	1.000	0.254
X ₅	0.405	0.103	0.481	-0.013	0.254	1.000

By estimating the relationship between the total number of animal units (as the dependent variable) and its determinants using stepwise multiple regression in linear, logarithmic, and semi-logarithmic forms for the period 2000–2023, it was found that the semi-logarithmic model best represents the data used in the estimation. This relationship can be expressed by the following equation:

$$\ln \hat{Y} = 1.098 + 0.001X_1 - 0.125X_2 + 0.005X_3 + 0.001X_5 \dots \dots \dots (9)$$

$$(4.26)^{**} \quad (2.09)^{*} \quad (-3.91)^{**} \quad (2.98)^{**} \quad (4.58)^{**}$$

$$R^2 = 0.70, F = 11.19, D.W. = 2.02, Lm \text{ test} = 0.32, Arch \text{ test} = 0.006$$

The estimated model indicates that the most important determinants of the number of animal units are the production of feed crops (barley, maize, and sorghum), the production of green fodder (alfalfa and Rhode's grass), rainfall rates for natural rangeland development, and the quantity of manufactured feed. These variables explain approximately 70% of the variation in the number of animal units, while the remaining 30% is attributed to other factors not included in the estimated model.

By estimating the relative impact (elasticity) of the explanatory variables, it is evident that a 10% increase in feed crop production, rainfall rates, and manufactured feed leads to an increase in the number of animal units by 4.47%*, 4.46%, and 3.54%, respectively. An inverse relationship was observed between green fodder production and the number of animal units during the study period, due to the reduced area and production of water-intensive green fodder and the gradual shift to seasonal fodder cultivation within a maximum duration of three years.

The shift to seasonal fodder cultivation is limited to a maximum of 50 hectares per licensed farmer. The suspension applies to all farmers licensed to cultivate green fodder in the sedimentary plateau regions, in accordance with Cabinet Resolution No. 66 dated 25/2/1437H, which prohibits the cultivation of green fodder. To implement the crop rotation cycle, those licensed to cultivate wheat, under Cabinet Resolution No. 192 dated 4/4/1440 H, are allowed to obtain a license to cultivate seasonal fodder on the same area as that licensed for wheat cultivation (Ministry of Environment, Water and Agriculture, 2025).

It is also evident that the estimated model is free from the problem of autocorrelation

in the residuals, according to the D.W. value, and the F-value for the Breusch-Godfrey serial correlation LM test, which is 0.32, is not significant. Additionally, there is no heteroscedasticity in the series variance, as the F-value for the ARCH test, 0.006, is not significant. The estimated model also demonstrates good efficiency in representing the data used in the estimation, according to model efficiency indicators, most notably Theil's inequality coefficient (U-Theil), which approaches zero (Table 4).

Table 4: Indicators for Measuring the Efficiency of the Estimated Model during the Period 2000–2023.
Source: The econometric model estimated in this study.

Indicator	Value
Root Mean Square Error (R.M.S.E.)	0.154
Mean Absolute Error (M.A.E.)	0.105
Mean Absolute Percentage Error (M.A.P.E.)	8.310
Theil's Inequality Coefficient (U-Theil)	0.053

4-3 Forecasting the Number of Animal Units in the Kingdom of Saudi Arabia up to the Year 2030:

The number of animal units was forecasted up to the year 2030 using the econometric model estimated in this study, based on predicting the values of the independent variables and then substituting them into the estimated model. According to the trend equations presented in Table 5, the production of feed grain crops (barley, maize, and sorghum), which amounted to 292.1 thousand tons in 2023, is expected to remain unchanged through 2030 due to the low and statistically insignificant annual growth rate of these crops. The production of green fodder is expected to increase from 7.67 million tons in 2026 to 9.07 million tons in 2030. Rainfall levels supporting natural rangeland development are also projected to rise from 135.43 mm in 2026 to 171.44 mm in 2030, aided by the cloud-seeding system implemented in Saudi Arabia. Furthermore, the quantity of manufactured feed is expected to increase from 972.63 thousand tons in 2026 to 1,416.58 thousand tons in 2030. Finally, the number of

animal units is projected to rise from 8.01 million units in 2026 to 12.56 million units in 2030 (Table 6).

Table 5: General Trend Equations for the Most Important Variables Determining Livestock Numbers (Animal Units) During the Period 2000–2023. Source: Data presented in Table 2.

Equation	R^2	F	Annual growth rate (%)	Statement
$\hat{Y}_1 = 5.998 - 0.498T + 0.023T^2$ (9.39)** (-4.24)** (5.01)**	0.60	15.86	1.74	Number of animal units
$Ln\hat{X}_1 = 5.969 + 0.003T$ (30.72)** (0.20) ^{ns}	0.002	0.04	-	Production of feed grains ¹
$Ln\hat{X}_2 = 0.903 + 0.042T$ (5.29)** (3.54)**	0.36	12.51	4.20	Production of green fodder
$\hat{X}_3 = 115.797 - 6.482T + 0.267T^2$ (9.51)** (-2.89)** (3.06)**	0.31	4.76	0.22	Rainfall rates
$Ln\hat{X}_5 = 4.342 + 0.094T$ (8.93)** (2.77)**	0.26	7.67	9.40	Quantity of manufactured feed

¹Feed crops include barley, sorghum, and maize.

** Significant at the 1% probability level; * Significant at the 5% probability level.

Table (6): Forecast of Animal Units in the Kingdom of Saudi Arabia up to the Year 2030. Source: Collected and calculated from: the estimated equations in Table 5, the econometric model estimated in this study.

Year	Production of feed grain crops (thousand tons)	Production of green fodder (million tons)	Rainfall rate (mm)	Manufactured feed (thousand tons)	Number of animal units (million units)
2026	292.10	7.67	135.43	972.63	8.01
2027	292.10	8.00	143.63	1068.49	8.82
2028	292.10	8.34	152.37	1173.80	9.81
2029	292.10	8.70	161.64	1289.49	11.03
2030	292.10	9.07	171.44	1416.58	12.56
Average	292.10	8.35	152.90	1184.20	10.04

5- Conclusion

Livestock production in the Kingdom of Saudi Arabia has transitioned from traditional grazing to the adoption of specialized modern practices supported by technology and private investment. By examining the environmental and resource-related determinants affecting livestock development in Saudi Arabia, it is evident that livestock numbers declined in 2012. This decrease is attributed to several key

factors: (1) drought, water scarcity, and limited natural rangelands; (2) rising feed costs; (3) the spread of animal diseases and inadequate veterinary services (including vaccines, medicines, and veterinary centers); and (4) rural-to-urban migration, which weakened the rural labor force.

The government has prioritized livestock development, and the number of livestock (animal units) increased, reaching 30.71 million head in 2023. This growth is due to increased investments dedicated to livestock development, support for small-scale livestock breeders, and the expansion of imports of feed grains (barley, maize, and sorghum) as well as feed manufacturing.

The Livestock Department at the Ministry of Environment, Water, and Agriculture treated infected animals, with an annual average of 10.62 million animals treated during the period 2000–2023. Most of these were sheep (67.97%), followed by goats (27.39%). In light of the determinants influencing livestock numbers (animal units), it is expected that livestock numbers will increase from 8.01 million animal units in 2026 to 12.56 million animal units by 2030.

Given the scarcity of water and the decline and fluctuation of rainfall in the sedimentary plateau regions, this study recommends the need to preserve livestock resources by revisiting loan distribution policies. Such measures would help increase livestock numbers in the Arabian Shield regions (Makkah, Madinah, Jazan, Al-Baha, Asir, and Najran), which experience higher rainfall rates and offer better opportunities for natural rangeland development.

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