Climate Change

To Cite:
Eze JN, Ayanniyi NN, Nwosu DJ, Salihu BZ, Isong AE. Assessing the Impact of Climate Change on Livestock Production in Nigeria Using an Econometric Approach. *Climate Change* 2026; 12: e1cc3147
doi:

Author Affiliation:
[1]National Cereals Research Institute, Badeggi, PMB 8, Bida, Niger State, Nigeria.
[2]National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Nigeria.

***Corresponding author:**
Jude Nwafor Eze,
National Cereals Research Institute, Badeggi, PMB 8, Bida, Niger State, Nigeria.
Email: zejude12@gmail.com; Phone: 08067199525

Peer-Review History
Received: 29 July 2025
Reviewed & Revised: 18/August/2025 to 07/January/2026
Accepted: 12 January 2026
Published: 21 January 2026

Peer-Review Model
External peer-review was done through double-blind method.

Climate Change
pISSN 2394-8558; eISSN 2394-8566

URL: http://www.discoveryjournals.org/climate_change

© The Author(s) 2026. Open Access. This article is licensed under a Creative Commons Attribution License 4.0 (CC BY 4.0)., which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

DISCOVERY SCIENTIFIC SOCIETY

Assessing the Impact of Climate Change on Livestock Production in Nigeria Using an Econometric Approach

Jude Nwafor Eze[1]*, Niran Nureni Ayanniyi[1], Dickson Junior Nwosu[2], Bolaji Zuluqurineen Salihu[1], Abasianyanga Edem Isong[1]

ABSTRACT

Climate change influences livestock production in two different ways, including favorable and unfavorable conditions. When the climatic conditions are favorable, it boosts livestock production, but when the conditions are unfavorable, it poses a threat to livestock sustainability and affects food security and the livelihood of livestock farmers. In this study, the researchers examined the relationship between climate change and livestock production in Nigeria from 1993 to 2024 using an Autoregressive Distributed Lag Model. The findings indicate that climate variables, including temperature, rainfall, and humidity, significantly impact livestock production. The outcome for temperature shows a positive effect in the short term but a negative impact in the long term. Meanwhile, rainfall has a bad effect in the short term but a good effect in the long term. Consequently, livestock production in Nigeria is currently being constrained by climate change, particularly the frequent occurrence of droughts. The study suggests implementing climate-resilient strategies, balancing adaptation and mitigation plans, and using more irrigation technology in areas prone to drought to ensure sufficient livestock production.

Keywords: ARDL, climate change, Climate-resilient strategies, Food security, Livestock production

1. INTRODUCTION

The relationship between livestock farming and climate change is a multifaceted issue that requires an in-depth study (Godde et al. 2021; Cheng et al. 2022). Climate change threatens the long-term success of livestock farming, causing significant drops in production (Scoones, 2023). In developing countries, the predominant population depends on agriculture, with livestock accounting for about 40% of the total farm output (Mas-Coma., 2024). Rainfall variability, high cost of feeds, and high temperature have adverse effects on livestock farming (Henry et al., 2018). Sheikh (2017) argues that unfavorable climatic variability affects animal health, productivity, and sustainability. According to the World Bank report, Nigeria has the largest population of livestock in Africa reared under traditional nomadic pastoralism. The livestock sector contributes about 20% to the farm-based GDP and 5% to the county's GDP (World Bank, 2024). Thus, extreme climate events, including heat stress, drought, desertification, and flooding, have led to the migration of farmers with their livestock, death of livestock and reduced livestock production (Bogale and Erana, 2022). Agriculture, which is the predominant source of income for the rural population, particularly livestock sector, faces multidimensional challenges due to climate change and variability.

Some scholars have conducted research on the impact of climate change on livestock health and productivity. Research result shows that extreme weather conditions impact the output and well-being of farm animals (Ali et al. 2020; Theusme et al. 2020). Vinet et al. (2024) in their study on the effect of temperature-humidity index on the evolution of trade-offs between fertility and production in dairy cattle indicates that changes in rainfall pattern and high temperature lead to low productivity, overheating, poor feeding, and frequent illness in livestock. Scholars have predicted an increase in the demand for animal products overt time, however, greenhouse gas emission and global warming pose a great threat to livestock's long-term viability (Park, 2022). Countries in Sub-Saharan Africa account for 85% of the world's livestock production, yet they produce only 2.9% of dairy milk (Erdaw, 2023).

This research examined the dynamic effect of climate change on livestock production in Nigeria using an econometric ARDL model. Thus, understanding the effects of climate change on livestock production, this research provides insights for adapting and mitigating its impacts on the livestock sector. Therefore, having a good knowledge of the link between climate change and livestock production is crucial for developing effective adaptation and mitigation strategies. The research findings will contribute to the existing knowledge on climate change and livestock production, providing valuable insights for policymakers, farmers, and stakeholders. Consequently, by identifying the key problems and impacts of climate change on livestock production, this study will provide a basis for the development of effective adaptation and mitigation strategies to improve the resilience of the livestock production system in Nigeria.

2. METHODOLOGY

Data source

The research analyzed the effects of climate change on livestock production in Nigeria using time series from 1993 to 2024. The data on climate change and livestock production used in this study were sourced from the World Development Indicators (WDI) database and the World Bank's Climate Change Knowledge Portal. Variables used in this study are total livestock production index (lnLVSK), mean annual temperature (lnTEM), Mean annual rainfall (lnRFF), mean annual humidity (lnHum), total carbon emission (lnCO2), and cereal production (lnCRE). All these variables were transformed into natural logarithms as shown in Table 1.

Table 1: Data Sources and Climate Variables

Variable	Symbol	Description of variables use in the model	Sources of data
Total livestock production index	lnLVSK	Livestock Production Index (meat, milk, hides and skin) from all sources.	(World Bank, 2024)
Temperature	lnTEM	Mean Annual Temperature	
Humidity	lnHum	Mean Annual Humidity	
Precipitation	lnPER	Mean Annual Precipitation	
CO_2 emissions	lnCO2	Annual Carbon Dioxide (CO_2) emission	
Cereal production	lnCER	Total cereals production relate to crops harvested for dry grain only.	

Econometric Model Specification

Time series analysis was used to investigate the dynamic relationship between climate change and food production in Nigeria. The ARDL (Autoregressive Distributed Lag) model was employed to examine the short- and long-run relationships among the variables. Climate change is represented by four variables: mean annual temperature, mean annual rainfall, mean annual humidity, and mean annual carbon dioxide (CO2) emissions. Another explanatory variable that affects livestock production is cereal production.

Model Description: The general equation of this study is as follows:

$$lnLVSKt = F(\, lnTEMt, lnPERt, ln\ HUMt, lnCO2t, lnCREt) \qquad (1)$$

$$lnLVSKt = \beta_0 + \beta_1 lnTEM_t + \beta_2 lnPER_t + \beta_3 lnHum_t + \beta_4 lnCO2_t + \beta_5 lnCRE_t + \varepsilon t \quad (2)$$

Where lnLVSKt is the natural logarithm of livestock production index, lnTEMt is the natural logarithm of annual average surface temperature, $lnPER_t$ is the natural logarithm of average annual precipitation, $lnHum_t$ is the natural logarithm of annual average humidity, lnCO2 is the natural logarithm of carbon dioxide emissions, lnCRE is the natural logarithm of cereal production, and εt is the disturbance term.

The Autoregressive Distributed lag (ARDL) model

This article used the ARDL bound test to look at the relationship between variables in the long run. The simplified model is as follows

$$\Delta lnLVSK_t = \varphi_0 + \sum_{i=1}^{r} \varphi_1 \Delta lnLVSK_{t-i} + \sum_{i=1}^{r} \varphi_2 \Delta lnTEM_{t-i} + \sum_{i=1}^{r} \varphi_3 \Delta lnPER_{t-i} + \sum_{i=1}^{r} \varphi_4 \Delta lnHum_{t-i} + \sum_{i=1}^{r} \varphi_5 \Delta lnCO2_{t-i} + \sum_{i=1}^{r} \varphi_6 \Delta lnCRE_{t-i} + \emptyset_1 lnLVSK_{t-i} + \emptyset_2 lnTEM_{t-i} + \emptyset_3 lnPER_{t-i} + \emptyset_4 lnHum_{t-i} + \emptyset_5 lnCO2_{t-i} + \emptyset_6 lnCER_{t-i} + \varepsilon t \quad (3)$$

Where Δ represents the first difference of all variables lnLVSK, lnPER, lnTEM, lnCER, lnHum, and lnCO2. Whereas, the variables imply the value of optimum lag length, Schwarz's Bayesian Information Criterion (SBIC), the value, and the estimated coefficient of the long and short run model. For annual time series data, the optimum lag length determination (Pesaran et al, 2001). This bound F-statistic was applied to each variable, treating the endogenous variables as endogenous and the others as exogenous. The null and alternative hypotheses for the bound test are given below.

$$Null\ hypothesis\ H_0 := \emptyset_1 = \emptyset_2 = \emptyset_3 = \emptyset_4 = \emptyset_5 = \emptyset_6 = 0$$

$$Alternative\ hypotheiss\ H_1 := \emptyset_1 \neq \emptyset_2 \neq \emptyset_3 \neq \emptyset_4 \neq \emptyset_5 \neq \emptyset_6 \neq 0$$

The above hypothesis is accepted or rejected based on the estimated F-statistic and the critical value. Correspondingly, the long-run relationship between the variables, specified using the ARDL model, is presented below.

$$\Delta lnLVSK_t = \varphi_0 + \sum_{i=1}^{r} \delta_1\, lnLVSK_{t-i} + \sum_{i=1}^{r} \delta_2\, lnTEM_{t-i} + \sum_{i=1}^{r} \delta_3\, lnPER_{t-i} + \sum_{i=1}^{r} \delta_4\, lnHum_{t-i} + \sum_{i=1}^{r} \delta_5\, lnCO2_{t-i} + \sum_{i=1}^{r} \delta_6\, lnCER_{t-i} + U_t \quad (4)$$

Based on the above equation, the coefficient of long-run variability of the model is denoted. Further, to estimate the short-run relationship between the variables, the ARDL error-correction model (ECM) was developed as follows.

$$\Delta lnLVSK_t = \varphi_0 + \sum_{i=1}^{r} \rho_1 \Delta lnLVSK_{t-i} + \sum_{i=1}^{r} \rho_2 \Delta lnTEM_{t-i} + \sum_{i=1}^{r} \rho_3 \Delta lnPER_{t-i} + \sum_{i=1}^{r} \rho_4 \Delta lnHum_{t-i} + \sum_{i=1}^{r} \rho_5 \Delta lnCO2_{t-i} + \sum_{i=1}^{r} \rho_6 \Delta lnCER_{t-i} + \epsilon_t \quad (5)$$

In equation 5 above, the short-run relationship between food production and other explanatory variables is evaluated using an error relationship model with a value coefficient. The value coefficient of the error correction term (ECT) measures the time required for the adjustment of disequilibrium.

3. RESULTS AND DISCUSSION

In Table 2, the descriptive statistics for all the variables used in this study are presented. The results indicate that the highest mean value, 16.487, is for cereal production (InCER), followed by carbon dioxide emission ($InCO_2$) at 15.716. Also, the annual average temperature has a value of 3.123, which is the lowest among the variables used. Cereal output gave a maximum value of 17.26, whereas the mean annual carbon dioxide emission has a maximum value of 16.873. Humidity and Temperature recorded lower standard deviations from their mean values, with values of 0.041 and 0.016, respectively. The above results agree with the research results conducted by Erdaw (2023)

Table 1 : Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
lnLVSK	30	4.361	.342	3.787	4.845
lnTEM	30	3.123	.016	3.095	3.154
lnPER	30	6.751	.094	6.573	6.955
lnHum	30	3.962	.041	3.875	4.028
lnCO_2	30	15.716	.686	14.603	16.873
lnCRE	30	16.487	.571	15.475	17.269

The integration order of each variable was determined using a unit root test. Also, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were used (David and Dickey, 1979; Perron, 1988). Table 3 indicates that all other variables used in this study are not stationary at the level, except temperature and precipitation.

Table 2: Unit root test evaluation

Variables	Augmented Dickey-Fuller (ADF)				Phillips-Peron (PP)			
	At level		Frist difference		At level		Frist differences	
	T-Stat.	Prob.	T-Stat.	Prob.	T-Stat.	Prob.	T-Stat.	Prob.
lnLVSK	-1.266	0.1081	-2.485**	0.031	-2.091	0.551	-4.343***	0.000
lnTEM	-3.022	0.002***	-2.187***	0.009	-4.925	0.003	-4.934 ***	0.003
ln PER	-4.079*	0.0002	-2.925***	0.003	-5.739	0.000	-5.759***	0.000
lnHum	-1.240	0.235	-6.891***	0.000	-.889	0.532	-8.331***	0.000
lnCO2	-0.918	0.1834	-5.495***	0.000	-4.031	0.007	-5.572***	0.000
lnCER	-1.148	0.1306	-8.433***	0.000	-1.401	0.051	-8.852***	0.000

Note *, **, *** represents 10%, 5% and 1%

It is worth noting that all variables are stationary at their first differences, meaning that the variables used in this study are all integrated of order one (Perron, 1988). Moreover, after conducting a unit root test, the research further examined the optimal lag length for the model (Perron, 1988). The research results corroborate the work of David and Dickey (1979). Table 4 presents the optimal lag selection. Consequently, the model selected lag 4, which is free from diagnostic test error, as a better lag value.

Table 3: Lag selection and bund test

Lag	LL	LR	df.	P	FPE	AIC	HQIC	SBIC
0	165.446		1.9e-13	-12.2651	12.1815	-11.9748		
1	242.937	154.98	36	0.000	8.5e-15	-15.4567	-14.8714	-13.4244
2	288.062	90.251	36	0.000	7.0e-15	-16.1586	-15.0718	-12.3843
3	434.394	292.67	36	0.000	8.7e-18	-24.6457	-23.0572	-19.1295
4	2876.72	4884.6*	36	0.000	5.6e94*	-209.748*	-207.657*	202.489*

Also, the cointegration bound test was carried out to determine the long-run relationship between climate change variables and livestock production in Nigeria (Narayan and Smyth, 2005). Table 5 results show a long-run relationship among the variables. In addition, the bound test for cointegration shows that the null hypothesis was rejected by comparing the calculated F and t values with their critical values. The rejection of the null hypotheses indicates a long-run relationship among all variables. The research result aligns with a study by Bogale and Erena (2022).

Table 4: Bounds test result

	K	10%		5%		1%	
		I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F- value	12.299	2.26	3.35	2.62	3.79	3.41	4.68
T- value	-7.193	-2.57	-3.86	-2.86	-4.19	-3.43	-4.79

Table 6 presents diagnostic test results. The diagnostic test was carried out, and the model passed all tests, including the Jarque-Bera test for normality, the autoregressive conditional heteroskedasticity (ARCH) test, the Breusch-Pagan-Godfrey test for heteroskedasticity, the Ramsey RESET test for omitted variables, and the Breusch-Godfrey LM test for autocorrelation.

Table 5: Diagnostic statistics tests

Diagnostic statistics tests	**Prob > chi2**
Breusch Godfrey LM test	0.2383
Breusch-Pagan-Godfrey test	0.8762
Autoregressive conditional heteroskedasticity (ARCH)	0.6254
Ramsey RESET test	0.2115
Jarque-Bera Test	0.365

In Table 7, the short-run and long-run dynamic models are presented. The results show that in the short-run, temperature has a significant favorable effect on livestock production, whereas in the long-run, temperature has a significant unfavorable effect on livestock production. Studies have shown that higher temperatures accelerate the growth of fodder for animal grazing (Singh and Ukey, 2024). Therefore, temperature has a positive effect on livestock production in the short run up to a certain point. In general, a rise in temperature has an adverse effect on livestock production due to heat stress, which reduces livestock reproduction and increases the spread of disease (Singh and Ukey, 2024; Vinet et al., 2024).

Table 6: Long and short run dynamic model results

Variables	**Coefficient**	**Std. err.**	**T**	**P>t**
Long run estimates				
lnTEM	-15.559^{***}	4.124	-3.770	0.013
lnPER	3.179^{***}	0.331	9.610	0.000
lnHum	-6.335^{***}	0.680	-9.320	0.000
$lnCO_2$	-0.248^{**}	0.114	-2.180	0.031
lnCRE	0.641^{**}	0.205	3.120	0.026
Short run estimates				
ΔlnTEM	19.09^{***}	4.083	4.680	0.005
$\Delta lnTEMt_{-1}$	16.33^{***}	2.543	6.420	0.001
$\Delta lnTEMt_{-2}$	9.885^{***}	2.437	4.060	0.010
ΔlnPER	-0.974^{***}	0.247	-3.940	0.011
$\Delta lnPERt_{-1}$	-0.023	0.214	-0.110	0.920
$\Delta lnPERt_{-2}$	0.310	0.177	1.760	0.139
ΔlnHum	5.068^{***}	0.499	10.150	0.000
$\Delta lnHumt_{-1}$	3.642^{***}	0.361	10.080	0.000
$\Delta lnHumt_{-2}$	3.111^{***}	0.378	8.220	0.000
$\Delta lnCO_2$	0.191^{**}	0.064	3.000	0.030
$\Delta lnCO2t_{-1}$	0.091	0.051	1.790	0.133
$\Delta lnCO2t_{-2}$	-0.060	0.045	-1.340	0.238
ΔlnCRE	-0.444^{**}	0.131	-3.390	0.019

$\Delta lnCREt_{-1}$	-0.769**	0.206	-3.720	0.014
$\Delta lnCREt_{-2}$	-0.917***	0.165	-5.550	0.003
ECT(-1)	-0.750***	0.081	-9.230	0.000
Cons	37.58***	7.421	5.060	0.004

Note, *** p<0.01, ** p<0.05, * p<0.

Precipitation has a positive and significant effect on livestock production in the short run but an adverse significant effect in the long run. This implies that in the short run, moderate rainfall creates a good environment for high fodder production. The conducive environment leads to high livestock productivity (Emediegwu and Ubabukoh, 2022). On the other hand, extreme precipitation reduces grazing land area due to flooding and land degradation, leading to a scarcity of fodder for livestock. Moreover, flooding resulting from high rainfall also increases the risk of vector-borne diseases, which affect livestock productivity (Emediegwu and Ubabukoh, 2022; Leweri et al., 2021).

Humidity has a positive significant effect on livestock production in the short run but an adverse significant effect in the long run. Optimal humidity can enhance livestock productivity, comfort, and health. Optimal humidity helps maintain moisture in the respiratory system, thus reducing frustration and the risk of respiratory disorders caused by dry air (Xiong, 2017). Inhalation of dust particles may result in respiratory problems. Therefore, maintaining the relative humidity in the atmosphere would enhance the reduction in the amount of dust particles available in the air. An environment with moderate relative humidity enhances the reproduction rate of livestock (Rojas-Downing et al., 2017; Cheng et al., 2022; Xiong, 2017).

Carbon dioxide emissions into the atmosphere without plant sequestration are highly detrimental to the environment, with a global effect. Xiong (2017) states that high concentrations of carbon dioxide in the atmosphere raise the temperature within the milieu, which also affects the health of livestock. Despite the adverse effects of carbon dioxide on livestock production, it plays an important role in agricultural growth, particularly in livestock sustainability.

An increase in atmospheric carbon dioxide concentration supports photosynthesis, leading to higher crop yields for livestock feed. Carbon dioxide improves water use efficiency in plants, enabling them to survive with less water (Scoones, 2023). Carbon dioxide plays an important role in global crop and livestock production (Ainsworth et al., 2020). Cereal production directly affects livestock production. This is because cereal production serves as a primary source of energy and nutrients for livestock. Cereals such as maize, millet, sorghum, rice, and wheat provide energy and support the growth and maintenance of livestock.

4. CONCLUSION

Livestock production is the predominant source of livelihood among the rural population in Nigeria, particularly in Northern Nigeria. However, livestock production is highly affected by climate change. This paper conducted a comprehensive ARDL study on livestock production and the climate change index in Nigeria from 1993 to 2024. The research outcomes indicate that livestock production is adversely affected in the short-run by rainfall but positively influenced in the long-run. Besides, constant exposure to humid air and the dissolving of Carbon dioxide in the air put pressure on livestock production. Meanwhile, cereals have a positive impact. To achieve sustainable livestock production in Nigeria, climate change adaptation and mitigation strategies are essential. The strategies include developing climate-resilient livestock feeding options, effective water management, early warning systems, heat-tolerant livestock breeds, and promotion of climate-resilient crops used in livestock feed production. Implementing mitigation strategies, such as (a) Climate-smart manure management (manure storage and treatment, anaerobic digestion, composting, nutrient management) to reduce greenhouse gas emissions, improve water quality, improve livestock health, and productivity. (b) Improved animal diets (feed optimization, alternative feed sources, forage-based diets, feed additives) to reduce greenhouse gas emissions, improve feed efficiency, enhance animal health, and productivity. Climate adaptation and mitigation are important in achieving food security, economic sustainability, and environmental conservation.

Acknowledgement

The authors acknowledge the World Bank's World Development Indicators (WDI) database and Climate Change Knowledge Portal for Providing the data used in this study. We sincerely appreciate the World Bank's commitment to open data and knowledge sharing which facilitated this research on climate change impacts on livestock production in Nigeria

Authors contributions

Jude Nwafor Eze was involved in conceptualization, methodology, data collection and analysis, and writing the original draft

Niran Nureen Ayanniyi was involved in data curation, investigation, validation, writing – review and editing

Dickson Junior Nwosu focused on methodology, software handling, visualization, writing – review and editing of the daft

Bolaji Zuluqurneen Salihu carried out the literature review aspect, data Interpretation, and also was involved in writing – review and editing

Abasianyanga Edem Isong was involved in the conceptualization, supervision of the research work, writing – review and Editing

Informed consent

Not applicable.

Ethical approval

Not applicable. This article does not contain any studies with human participants or animals performed by any of the authors.

Conflicts of interests

The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Funding

This research did not receive any external funding like specific grant from funding agencies in the public, commercial, or nonprofit sectors.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Ainsworth EA, Lemonnier P, Wedow JM. The Influence of Rising Tropospheric Carbon Dioxide and Ozone on Plant Productivity. Plant Biol. 2020; 22(S1):5–11.
2. Ali MZ, Carlile G, Giasuddin M. Impact of Global Climate Change on Livestock Health: Bangladesh Perspective. Open Vet J. 2020;10(2):178–88.
3. Bogale GA, Erena ZB. Drought vulnerability and impacts of climate change on livestock production and productivity in different agro-Ecological zones of Ethiopia. J Appl Anim Res 2022; 50(1):471–89.
4. Cheng M, McCarl B, Fei C. Climate Change and Livestock Production: A Literature Review. Atmosphere (Basel). 2022; 13(1):140. doi: 10.3390/atmos13010140
5. David A, Dickey WAF. Distribution of the Estimators for Autoregressive Time Series with a Unit Root. Journal of the American Statistical Association 1979; 74(366) 427-431. doi: 10.1080/01621459.1979.10482531
6. Emediegwu LE, Ubabukoh CL. Re-examining the impact of annual weather fluctuations on global livestock production. Ecol Econ 2022; 204(PA):107662. doi: 10.1016/j.ecolecon.107662
7. Erdaw MM. Contribution, prospects and trends of livestock production in sub-Saharan Africa: a review. Int J Agric Sustain. 2023; 21(1). doi: 10.1080/14735903.2023.2247776
8. Godde CM, Mason-D'Croz D, Mayberry DE. Thornton PK, Herrero M. Impacts of climate change on the livestock food supply chain; a review of the evidence. Glob Food Sec 100488. 2021; doi: 10.1016/j.gfs.2020.100488
9. Henry BK, Eckard RJ, Beauchemin KA. Review. Adaptation of ruminant livestock production systems to climate changes. Animal. 2018; 12(s2):S445–56.
10. Leweri CM, Msuha MJ, Treydte AC. Rainfall variability and socio-economic constraints on livestock production in the Ngorongoro Conservation Area, Tanzania. SN Appl Sci 2021; 3(1):1–10. doi: 10.1007/s42452-020-04111-0
11. Mas-Coma S, Valero MA, Bargues MD. Effects of climate change on animal and zoonotic helminthiases. OIE Rev Sci Tech. 2024; 27(2):443–57.
12. Park SO. Application strategy for sustainable livestock production with farm animal algorithms in response to climate change up to 2050: A review. Czech J Anim Sci 2022; 67(11):425–41. doi: 10.17221/172/2022-CJAS

13. Rojas-Downing MM, Nejadhashemi AP, Harrigan T, Woznicki SA. Climate change and livestock: Impacts, adaptation, and mitigation. Clim Risk Manag. 2017; 16:145–63. doi: 10.1016/j.crm.2017.02.001
14. Scoones I. Livestock, methane, and climate change: The politics of global assessments. Wiley Interdiscip Rev Clim Chang. 2023; 14(1):1–8.
15. Sheikh AA, Bhagat R, Islam ST, Dar RR, Sheikh SA, Wani JM, et al. Effect of climate change on reproduction and milk production performance of livestock: A review. J Pharmacogn Phytochem 2017;6(6):2062–4.
16. Singh SV, Ukey AK. Climate change trends and their impacts on bovine productivity: Precision livestock 2024;63:20–30.
17. Theusme C, Avendaño-Reyes L, Macías-Cruz U, Correa-Calderón A, García-Cueto RO, Mellado M. Climate change vulnerability of confined livestock systems predicted using bioclimatic indexes in an arid region of México. Sci Total Environ 2021; doi: 10.1016/j.scitotenv.2020.141779
18. Perron P. Testing for a unit root in time series regression. 1988; 75(2):335–46.
19. Narayan PK, Smyth R. Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. Energy Policy 2005;33:1109–16.
20. Vinet A, Mattalia S, Vallée R, Bertrand C, Barbat A, Promp J. Effect of temperature-humidity index on the evolution of trade-offs between fertility and production in dairy cattle. Genet Sel Evol. 2024; 56(1):1–15. doi: 10.1186/s12711-024-00889-4
21. Xiong Y, Meng Q Shi, Gao J, Tang X Fang, Zhang H Fu. Effects of relative humidity on animal health and welfare. J Integr Agric 2017; 16(8):1653–8. doi:10.1016/S2095-3119(16)61532-0
22. World Bank. From Uruguay to Ethiopia: Innovations in Sustainable Livestock Practices. 2024; Url: https://www.worldbank.org/en/news/feature/2024/07/03/etiopia-el-gigante-ganadero-africano-que-quiere-aprender-de-uruguay