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IMPACT OF CLIMATE CHANGE ON DAIRY MILK PRODUCTION IN NIGERIA

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ABSTRACT: This study explores the impacts of climate change on milk production in Nigeria. Climate variables such as temperature, rainfall, sunshine, relative humidity and wind speed were considered as covariates in the analysis. Time-series data spanning a period of forty years obtained from the Central Bank of Nigeria and FAOSTAT database was used. The autoregressive distributed lag model was used to analyze both the short run and long run impacts of climate change on milk production. As expected, not all the variables were stationary at levels, but they were all significant at the difference suggesting the presence of cointegration. The result showed that the Bound's test F-ratio was statistically significant implies the existence of long run and short run relationships among the variables studied. Present findings revealed that temperature, rainfall and relative humidity had a negative impact on milk production, while sunlight recorded a positive impact on milk production both in the short run and long run estimates. The study concludes that milk production in Nigeria dropped as a result of climate change particularly rising temperature and prolonged rainfall. Agricultural climate smart practices were recommended to mitigate impact of climate change on milk production.

Keywords: Climate Change, Dairy Products, Production, Rainfall, ARDL model.

INTRODUCTION

On a global scale, milk production is done by over 150 million dairy homes. Smallholder dairy farmers produce milk in the majority of developing nations, and milk production has become a source of livelihood for most families around the world (Thitiya et al., 2020). From 530 million tonnes in 1988 to 843 million tonnes in 2018, the worldwide milk output has climbed by more than 59 percent (FAO, 2023). The United States of America, China, Pakistan, and Brazil are the next five countries in order of milk production output, each producing 22% of the world's total. South Asia has been the primary driver of milk production increase in the developing world since the 1970s, where production has increased rapidly (FAO, 2023). Germany, France, Australia, Ireland, New Zealand, and the United States of America have the greatest milk surpluses (OCED and FAO, 2020) while the nations with the greatest milk shortfalls are China, Italy, Russia, Mexico, Algeria, and Indonesia (Jeffrey, 2022). In many developing nations, milk productions has been limited by various factors such as health of dairy farmers, capital, and changing weather conditions combined with low genetic potential of dairy animals (Duguma, 2022). Contrary to developed nations, a large number of developing nations have hot and variant weather conditions that are unfavorable for milk production. Sudan, South Africa, Kenya, and Ethiopia are the nations in Africa that produce the most milk (Mebrate et al., 2019). Though, due to poverty and difficult climatic circumstances in Africa, milk production is experiencing a slow downturn. Nigeria produces just between 560,000 and 570,000 tonnes of fresh milk annually, against the expected industry and domestic consumption and market demand of 1.7 million tonnes (Elekwachi et al., 2021).

According to literature, In Nigeria milk production is synonymous with the northern nomads/herdsmen. The decrease in its production in Nigeria is attributed mostly to climate change and other internal and external factors (Elekwachi et al., 2021, FAO, 2023). Milk production in dairy cows is reduced as a result of heat stress brought on by excessive heat and humidity (Abbas et al., 2019, Hossain et al., 2023). The discomfort and physiological changes that result from temperatures rising above a cow's thermo neutral zone causes the animals to produce less milk (Bhimte et al., 2021, Chawicha and Mummed, 2022). Extreme heat and higher temperatures are difficult for dairy cows to tolerate, and as a result, their milk production is frequently reduced and they become more susceptible to diseases and other health issues (Das et al., 2016). Excessive rainfall subjects the dairy farm animals to extreme cold causing abnormal body functioning and inhibits fodder availability leading to a fatal drop in animal body weight and milk production (Hoffmann, 2013; hang-Fung-Martel et al., 2017). This in turn truncates the profits of dairy farmers who depend on it for economic

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livelihoods and human sustenance. It is in the light of these circumstances that Nigeria spends over 28 billion in milk importation in 2022 (NBS, 2023). These events created the gap in knowledge and led to the conceptualization of the study to ascertain the true impacts of climate change on dairy milk production in Nigeria.

MATERIALS AND METHODS

This study employed time-series data (1981–2021) from two databases, FAOSTAT and the Statistical Bulletin of the Central Bank of Nigeria. The choice of the dependent and independent variables was influenced by the data that were available. The Central Bank of Nigeria Statistics Bulletin was specifically used to acquire the quantity of dairy milk produced, and the FAOSTAT database was used to obtain the climatic parameters. Table 1 displays specifics about the information and its sources. The effect of climate change on dairy milk production in Nigeria was examined using an autoregressive distributed lag (ARDL) model. The ARDL can simulate the effects of the dependent variable and independent variables over the short and long terms. It can also use the F-statistic to test for cointegration between the variables at the first and second levels. The ARDL Bound's test is typically used for cointegration tests. it's crucial to run unit root tests on time-series data to find out whether the dataset in question is stationary or has a unit root. In this study, the unit root tests were performed using the Augmented Dickey Fuller (ADF) and Phillips-Perron tests. Our model was further put to the test for missing variables, autocorrelation, homoscedasticity, heteroskedasticity, multicollinearity, and parameter stability using the LM test, F test, DW test, Ramsey reset test, White test, ARCH test, Variance Inflation Factor, and Cusum test. The amount of dairy milk produced for the research is the dependent variable, while the independent variables are mean temperature, total rainfall, sunshine, relative humidity, and wind speed. The implicit model of our autoregressive distributed lag framework is stated as follows:

$Y = f(X_1, X_2, X_3, X4, X_5, e_t)$ — eqn. 1

Where, Y = Quantity of dairy milk produced (tons); X_1 = Mean temperature (^{0}C); X_2 =Total rainfall (mm); X_3 = Sunlight (hours); X_4 = Relative humidity (%); X_5 = wind speed (km/h); e_t = error term

Transforming eqn.1 into natural logarithms, thus:

$LnY = LnX_1 + LnX_2 + LnX_3 + LnX_4 + LnX_5 + et$ eqn. 2

$LnY = LnQDMP = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + e_t$ eqn. 3

The ARDL model specification of equation (3) is expressed as unrestricted error correction model (UECM) to test for cointegration between the variables under study, this is specified as follows:

$\Delta LnQDMP_t = \phi_o + \sum_{i=0}^{t} \phi_1 \, \Delta LnQDMPt - 1 + \sum_{i=0}^{t} \phi_2 \, \Delta LnX_1 t - 1 + \sum_{i=0}^{t} \phi_3 \, \Delta LnX_2 t - 1 + \sum_{i=0}^{t} \phi_4 \, \Delta LnX_3 t - 1 + \sum_{i=0}^{t} \phi_5 \, \Delta LnX_4 t - 1 + \sum_{i=0}^{t} \phi_6 \, \Delta LnX_5 t - 1 + \beta_1 LnX_{1t-1} + \beta_2 LnX_{2t-1} + \beta_3 LnX_{3t-1} + \beta_4 LnX_{4t-1} + \beta_5 LnX_{5t-1} + e_t$ eqn. 4

Once cointegration is established, the long run relationship is estimated using the conditional ARDL model specified as:

$LnQDMP_t = \phi_o + \beta_1 QDMP_{t-1} + \beta_1 LnX_{1t-1} + \beta_2 LnX_{2t-1} + \beta_3 LnX_{3t-1} + \beta_4 LnX_{4t-1} + \beta_5 LnX_{5t-1} + e_t$ eqn. 5

The short run dynamic relationship is estimated using an Error Correction Model (ECM) specified as:

$\Delta LnQDMP_t = \phi_o + \sum_{i=0}^{t} \phi_1 \, \Delta LnQDMPt - 1 + \sum_{i=0}^{t} \phi_2 \, \Delta LnX_1 t - 1 + \sum_{i=0}^{t} \phi_3 \, \Delta LnX_2 t - 1 + \sum_{i=0}^{t} \phi_4 \, \Delta LnX_3 t - 1 + \sum_{i=0}^{t} \phi_5 \, \Delta LnX_4 t - 1 + \sum_{i=0}^{t} \phi_6 \, \Delta LnX_5 t - 1 + \Im ECMt - 1 + e_t$ eqn. 6

Where, Δ = First difference operator; Ln = Natural logarithm; φo = Constant term; φ1—φ5 = Short run elasticities (coefficients of the first-differenced explanatory variables); β1—β5 = Long run elasticities (coefficients of the explanatory variables); ECMt -1 = Error correction term lagged for one period; ʒ = Speed of adjustment; p = Lag length

Table 1 - Type of variable and data source

Variable	Source
Diary milk quantity	CBN
Temperature	FAOSTAT
Rainfall	FAOSTAT
Sunlight	FAOSTAT
Relative humidity	FAOSTAT
Wind speed	FAOSTAT

RESULTS AND DISCUSSION

Descriptive statistics of variables used

Table 2 presents the descriptive statistics of the variables used which comprises of the dependent and independent variables. From the Table, the mean diary of milk produced in Nigeria during the study period was 478.93 metric tons which is far less of 1.7 million metric tons expected per annum (Elekwachi et al., 2021). The minimum and maximum range further showed that Nigeria is producing less of its expected outcome. The mean temperature had a value of

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25.09⁰C with a high standard deviation of 7.09 indicating that temperature was not normally distributed during the study period. Rainfall mean had a value of 999.03mm, which possibly indicates high showers of rainfall during the study period. Its standard deviation was 0.54 showing moderately distributed. Sunlight had a minimum and maximum value of 101.91 and 487.23 with a mean of 371.03, its maximum value reflects high intense of sunrays. The mean relative humidity was 71.03; this value indicates a relatively unfair distribution of relative humidity with its skewness and kurtosis values being negatively related. Wind speed average was 56.03 and ranges between 40.00 and 110.03 respectively.

Table 2 - Descriptive statistics of variables

Variable	N	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
Diary milk quantity	40	101.28	765.93	478.93	4.90	-0.57	-0.29
Temperature	40	22.09	28.05	25.09	7.09	-0.91	-0.45
Rainfall	40	671.01	1457.61	999.03	0.54	-0.48	0.12
Sunlight	40	101.91	487.23	371.03	2.94	0.45	0.31
Relative humidity	40	55.00	99.61	71.03	0.39	-0.25	-1.01
Wind speed	40	40.00	110.03	56.03	0.69	-0.81	-0.41

Unit Root Test using Augmented Dickey-Fuller and Phillips–Perron Test

The unit root test utilizing the Augmented Dickey-Fuller and Phillips-Perron tests are shown in Table 3. They were used to establish the stationary nature of the dependent and independent variables. The amount of dairy milk produced and temperature were not steady under the Augmented Dickey-Fuller test when integrated with order zero [I (0)]; this suggests the presence of the unit root that characterizes the null hypothesis. Yet, all of the variables became stationary at the first difference [I (1)], indicating that they were all integrated at order one. This supports the existence of the alternative hypothesis, which characterizes time series as stationary, and further refutes the null hypothesis. The amount of dairy milk produced, the temperature, and the amount of rainfall were also not stationary under the Phillips-Perron Test when integrated at order zero [I (0)], but became stationary at the first difference [I (1)]. The test for co-integration is justified since this suggests that the variables under consideration were not integrated in the same order under the Augmented Dickey-Fuller and the Phillips-Perron tests (Onyeneke et al., 2022).

Table 3 - Unit root test using Augmented Dickey-Fuller and Phillips–Perron test

Variable	At level I (0) *t*-statistic	Remark	At first difference I (1) *t*-statistic	Remark	Decision: *H0*	Order of integration
Augmented Dickey – Fuller test						
Y	-1.267	Non-Stationary	-2.679**	Stationary	Reject	I (1) at 5%
X_1	-1.309	Non-Stationary	-2.821**	Stationary	Reject	I (1) at 5%
X_2	-2.403**	Stationary	-3.853***	Stationary	Reject	I (0) at 1%
X_3	-3.462***	Stationary	-4.143***	Stationary	Reject	I (0) at 1%
X_4	-3.852***	Stationary	-3.426***	Stationary	Reject	I (0) at 1%
X_5	-4.934***	Stationary	-4.521***	Stationary	Reject	I (0) at 1%
Phillips – Perron test						
Y	-1.409	Not stationary	3.734***	Stationary	Reject	I (1) at 1%
X_1	-1.056	Not stationary	3.982***	Stationary	Reject	I (1) at 1%
X_2	-1.034	Not stationary	2.582**	Stationary	Reject	I (1) at 5%
X_3	-3.983***	Stationary	4.532***	Stationary	Reject	I (0) at 1%
X_4	-2.321**	Stationary	5.821***	Stationary	Reject	I (0) at 1%
X_5	-4.733***	Stationary	4.624***	Stationary	Reject	I (0) at 1%

** and *** indicate significance at 5% and 1% levels, respectively; *H0* = series have a unit root

ARDL-Bounds Test for Cointegration

Table 4 presents the ARDL-bounds test for cointegration. Cointegration is a vital method for analyzing time series data' long-term connections. Co-integration is used to look at non-stationary variables' correlations and the long-term effects of explanatory factors on dependent variables. The table demonstrates that the F-statistics for the dependent and independent variables were significant at the 1% and 5% level of probability for both the lower and higher boundaries. As a result, the alternative hypothesis, which indicates the presence of cointegration, was accepted and the null hypothesis of no cointegration was rejected. This further supports the existence of both short- and long-term relationships among the dependent and independent variables under investigation. According to the findings of (Gershon and Mbajekwe, 2020 and Emenekwe et al. 2022), even though these factors may diverge in the near term, their correlations are predictable over

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the long term. Thus, the estimation of an autoregressive distributed lag ECM model is justified by the presence of cointegration among the variables.

Table 4 - ARDL-bounds test for cointegration

Critical value	F-Statistic lower bound	F-Statistic upper bound	Remark
1%	3.06***	4.72***	Reject H0
5%	2.43**	2.08**	

Long and short run ARDL estimates on impact of climate change on diary milk production

Table 5 presents the ARDL estimates on impact of climate change on diary milk production. Temperature had a long-term negative correlation with milk production, according to the coefficient of temperature, which was negative and significant at the 1% level. Thus, a 1% rise in the average temperature will result in a 96% reduction in milk output. Cows that produce a lot of milk are sensitive to heat and tend to produce less milk as the temperature rises (Yano et al., 2014). Once more, dairy cows under heat stress have physiological body changes and decreased dry matter intake, which lower milk output. Rainfall had a negative coefficient that was statistically significant at the 1% level, suggesting that rainfall has a long-term negative impact on milk output. According to this, a change in the pattern of rainfall will result in a proportional decline in the output of dairy milk. Milk output is predicted to plummet by 85% as precipitation rises. Prolonged droughts are brought on by seasonal variations in rainfall patterns, which have a negative effect on the production of dairy milk. Increased infestations of cow diseases brought on by excessive rain damage the animals' health and result in a sharp decline in milk output (Somoza et al., 2018). Due to the animals' low health, this equally causes poor reproduction and abortion. Lack of rain hinders the optimal growth of dry matter feed or dairy fodder, which results in a shortage of feed and thus increases the mortality of calves and cows. These aberrations inevitably cause dairy cow animals to produce less milk. The correlation between sunshine and milk production is positive and significant at the 1% level, this suggests that a 1% increase in sunshine would result in a 76% rise in milk output. Cows that are exposed to sunshine react favorably to the physiological processes of the environment, increasing milk output. Sunlight aids dairy farm animals' physical development, which increases milk quality and output (Lim et al., 2021). Moreover, sunlight enhances dairy cows' consumption of dry matter and water, which improves the quality and amount of milk produced. The coefficient for relative humidity was negative and statistically significant at the 5% level, suggesting that relative humidity has a long-term detrimental impact on milk production. This implies that any rise in relative humidity will immediately result in a drop in milk output. Relative humidity increases the amount of microbial activity in dairy cows, which lowers milk quality and output. This is in conflict with Abbaya et al. (2022) and supports Bohmanova et al. (2007) and Xiaoyan et al. (2020). The results of the short-run ARDL estimates, however, were consistent with those of the long-run ARDL estimates, with the exception that the coefficient of wind speed turned positive and significant at the 5% level, which indicates that a 1% increase in wind speed will result in a corresponding increase in milk production of 71%. Wind speed reduces dairy cows' heat stress, keeping their ability to operate normally and maintaining a healthy balance, which results in the production of high-quality milk (Hill and Wall, 2015). The calculated error correction coefficient, which is -0.899, has the predicted sign, highly significant at the 1% level, and it suggests that equilibrium returns reasonably quickly following a shock. 90% of the disequilibria caused by the shock of the previous year converge to the long-term equilibrium in the current year. This further suggests that there was a considerable and steady adjustment process for the examined variables during the course of the relationship.

Table 5 - ARDL estimates on impact of climate change on diary milk production

Variables	Coefficient	T-values	Std. Error
Long-run Estimates			
LnX_1	-0.956	-3.939***	0.243
LnX_2	-0.848	-3.710***	0.228
LnX_3	0.758	4.081***	0.186
LnX_4	-0.934	-2.023**	0.462
LnX_5	-0.352	-1.028	0.342
Short-run Estimates			
ECM (-1)	-0.899	-4.921***	0.183
ΔLnX_1	-0.931	-3.201***	0.291
ΔLnX_2	-0.845	-3.011***	0.281
ΔLnX_3	0.671	3.610***	0.186
ΔLnX_4	-0.801	-2.220**	0.189
ΔLnX_5	0.710	2.205**	0.322
Constant	0.566	3.670***	0.154

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Diagnostic Statistical Test

Table 6 presents the diagnostic statistical test. The result of variance inflation factor (VIF) was less than 5; this indicates the absence of multicolinearity among the independent variables. LM test was not significant showing that no serial correlation exists among the explanatory variables. ARCH test and the white test values was not significant indicating the absence of homoscedasticity and heteroskedasticity among the variables. Ramsey RESET test shows that the model is free from omitted variables. R^2 value of 0.8902 indicates that 89.02% of the total variation in diary milk production was explained by the climatic variables investigated. F-statistic was highly significant at 1% level showing the overall fitness of the model. DW-Statistic value of 1.8063 was higher than the value of R^2 indicating that the result is not spurious and absence of absence of autocorrelation among the variables. Cusum test further confirmed the goodness of fit of the model used and establish that the econometric model is structurally stable (Onyeneke et al., 2022).

Diary milk production in Nigeria (1981 to 2021 in metric tons)

Figure 1 presents the trend analysis showing the trend pattern of milk produced in Nigeria during the period covered. It could be seen that milk production in Nigeria is unstable and fluctuates arbitrarily per year.

Diary milk consumption in the six geo-political zones in Nigeria

Table 7 presents the diary milk consumption in the six geo-political zones in Nigeria. The Table shows that a total of 266 litres of milk was consumed in the north with the north central having the highest consumption rate. While the south had a total of 302 litres with outstanding consumption in the south east. The total litres of milk consumed (568) in both the north and south regions implies that milk consumption in Nigeria is generally low probably due to climate change impacts on dairy cows (FAO, 2020).

Table 6 - Diagnostic Statistical Test

Diagnostic statistical test	Statistical values
VIF Test	2.903
LM Test	0.867
ARCH Test	0.762
White Test	1.045
Ramsey RESET test	1.221
R^2	0.8902
F-statistic	4.934
DW-Statistic	1.8063
Cusum Test	Stable

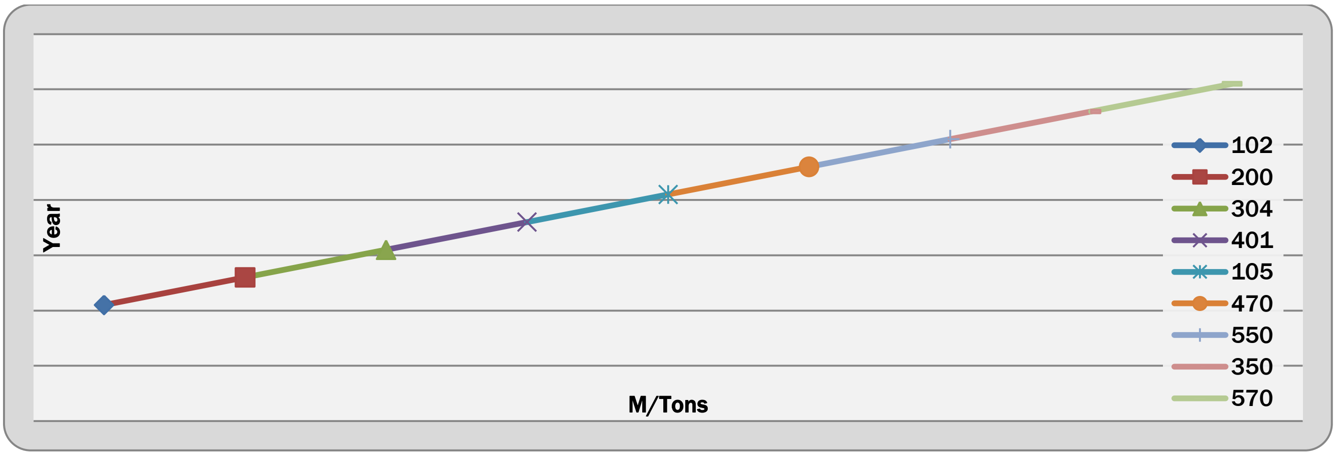

Figure 1 -Diary milk production in Nigeria (1981 to 2021 in metric tons)

Table 7 - Diary Milk Consumption in the Six Geo-political Zones in Nigeria

Zones	Diary milk consumption
North East	78
North Central	101
North West	87
South East	116
South South	104
South West	82

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CONCLUSION

The average amount of milk produced in Nigeria during the course of the study was 478.93 metric tons, far less than the 1.7 million metric tons anticipated annually. Climatic variables including temperature, rainfall, and relative humidity negatively impacted milk production both in the long and short run. Heat stress brought on by a rise in temperature causes dairy cows to consume less dry matter, which lowers milk quality and output. Prolonged droughts have a negative effect on the production of dairy milk. Increased infestations of cow diseases brought on by excessive rain damage the animals' health and result in a sharp decline in milk output. Low milk quality and quantity are caused by dairy cows' increased microbial activity when relative humidity is high. Cows exposed to sunlight retain healthy physiological attributes which improves dairy cows' milk output. The ECM value indicated the rapid response of milk production to climate change shocks. Increasing milk production in Nigeria to meet the market demand requires prompt and engaging actions in checkmating climate change.

DECLARATIONS

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Authors' contribution
E. Osuji = Conceptualization, model design, data analysis, section writing and proof-read.
C. Igberi = Data analysis, results editing, proof-reading and grammar checking.
C. Enyia = Conceptualization, result design, section writing, reference sorting and editing.
E. Nwachukwu = Questionnaire design, methodology design, section writing, editing and proof-read.
R. Nwose, A. Adeolu, A. Tim-Ashama, G. Nkwocha, A. Eleazar and D. Gabriel = Data collection, data processing, data curation, data sorting, and data coding.

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Conflict of interest
The authors declare that no conflict of interest exists.

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