Gershon, Obindah; Mbajekwe, Chinua

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Investigating the Nexus of Climate Change and Agricultural Production in Nigeria

Obindah Gershon*, Chinua Mbajekwe

Department of Economics and Development Studies, Covenant University, Nigeria. *Email: obindah.gershon@covenantuniversity.edu.ng

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ABSTRACT

This study examined the relationship between climate change and agricultural production (crop and livestock) in Nigeria using time series data from 1981-2017. Variables used to depict climate change are mean annual rainfall, temperature and carbon dioxide emissions. Data on crop yield was collated for 17 major crops produced in Nigeria with the livestock production index of Nigeria. Econometric analysis was carried out using autoregressive distributed lag (ARDL). The results showed that there is a long run relationship between climate change and crop production while no long run relationship exists between climate change and livestock production. Furthermore, evidence is provided that rainfall and CO_2 emissions have a positive and significant effect on crop yield in the long run while temperature has a negative and significant effect on crop yield in the long run. It also was seen that four period lagged rainfall has a positive and significant effect on livestock production; two period lagged temperature had a negative significant effect and one period lagged CO_2 emissions had a negative significant effect on livestock production in Nigeria. Consequently, policy recommendations are offered for the government to meet its sustainable development goals.

Keywords: Agriculture, CO_2 Emissions, Climate Change, Sustainable Development Goals, Livestock Production
JEL Classifications: Q54, Q15, Q56, Q18

1. INTRODUCTION

Climate change and failure in the mitigation/adaption measures are the leading threats to the global economy, after COVID-19 (World Economic Forum, 2020). Available data shows that the last decade has been the warmest ever recorded with 2016 being the warmest year during the period (National Aeronautics and Space Administration, 2020). Furthermore, the data indicates that since the late 19th century, the average temperature of the earth's surface increased by over 1.62°Fahrenheit (0°C). Consequently, increasing concentration of greenhouse gases in the atmosphere is changing precipitation patterns, raising temperature, spurring frequent extreme weather events, and shifting growing seasons (Egbetokun et al., 2020; IPCC, 2014; MFA, 2010).

Meanwhile, Nigeria's agriculture and agro-allied industries could potentially drive the economy's growth and diversification from crude oil (Gershon et al., 2019). However, it is largely climate fed - depends mainly on rainfall and temperature. Moreover, infrequent fluctuations in rainfall and temperature patterns have distorted the standard April-October rainfall period and October-March harmattan weather or dry season. On the one hand, untimely rainfall and climatic extremes could threaten potential agricultural investment (Gershon and Patricia, 2019). Excessive rainfall, on the other hand, can prompt the development of many pest and diseases which affect crop yields and animal breeding. Increasing temperature also provides a conducive atmosphere for the breeding of pests which damage crops. More so, the outbreak and spread of Corona Virus disease, popularly known as COVID-19, has proven that the Nigeria cannot rely on crude oil as its main source of revenue. Global oil prices which recently plunged to a 17-year low creating a gloomy macroeconomic outlook for most oil-exporting countries – including Nigeria. Reviving the dwindling economy requires deliberate and strategic action to fully reap the benefits of agriculture and minimize its vulnerability to climate change and/or COVID-19. In 2019, the sector accounted for 25.16% of real GDP growth. Crop production and livestock farming remain the major drivers of the sector as they accounted for 85% and 8% respectively of agricultural GDP in 2019. (National Bureau of Statistics, 2019).

Against the above background, this paper sought to: (a) ascertain the types of the relationship that exists at the nexus of climate change, crop and animal production in Nigeria; (b) determine the difference between climate change's effects on crop yields and livestock production. The autoregressive distributed lag (ARDL) estimation technique is applied with data from 1981-2016 (36 years) to analyze the variables of interest. This seeks to highlight possible actions to minimize the vulnerability of Nigeria's agricultural sector to climate change towards achieving sustainable development goals 2 and 13 which remain critical for economic progress. Farmers and agro-allied businesses could be incentivized to benefit from potential positive effects of climatic factors and guard against negative effects. To highlight the relevance of this work, a review of relevant literature is presented hereafter. Subsequent three sections contain respectively, methods; result presentation with discussions; as well as, the conclusion with recommendations.

2. LITERATURE REVIEW

Adedeji et al. (2017) employed regression analysis to show that rainfall has a positive and significant effect on rice yield while temperature was found to affect rice yield negatively. However, greenhouse gas emissions which are the primary causes of climate change apart from the natural variations in temperature and rainfall were not included in the model. Ayinde et al. (2011) demonstrated that rainfall and temperature have positive and negative effects on agricultural productivity respectively using descriptive statistics and co-integration technique. It was also observed that the previous year's rainfall has a negative, significant effect on current year agricultural productivity.

Agba et al. (2017) using time series data showed that rainfall had a positive, significant on crop output in the short and long run while temperature and carbon dioxide emissions had a negative, significant effect on crop production only in the long run. Aondoakaa (2012) demonstrated that a weak, positive significant relationship exists among temperature, rainfall and crop yield during a 10 year period in Abuja. Using correlation and regression analysis. A longer and wider dataset should have been collected to account for annual changes in temperature and rainfall. Other factors that affect crop yield such as soil fertility, land, irrigation should also be included in the model.

Exenberger et al. (2014) also showed that middle and low income countries are affected by increased temperature, changes in precipitation, frequency of droughts and these adverse effects are more pronounced in Sub-Sahara Africa. Conversely, climate change rarely affects agricultural production in high income countries. The results also revealed that technological heterogeneity is a reason for cross-country differences regarding how climate change affects agricultural production.

Ekpenyong and Ogubagu (2015) concluded that in the long run, agricultural productivity is affected by increased carbon emissions. The ARDL was employed for analysis using 1984-2014 as the time period. Ejemeyovwi et al. (2018) applied Fully Modified OLS and found out that a positive, significant long-run relationship exists between crop production and CO_2 emission. This implies that increase in carbon dioxide emissions will increase crop production over time. The result obtained here differs from that of other studies as CO_2 emissions had a positive, long run effect on crop production in spite of its usual notion of pure negativity. This is also in contrast to existing hypothesis that rising CO_2 levels in a tropical country (like Nigeria) negatively impact crop production. Reasons for obtaining this result could be due to types and seasonal properties of crops used in determining the crop production index which was used as the dependent variable.

Climate change factors examined in the reviewed studies above include rainfall, temperature and carbon dioxide emissions. Measures of agricultural production popularly examined include crop production and agricultural productivity. Climate change affects on livestock production has received limited attention in Nigeria - probably due to its complex nature and peculiarity of nomadic farming in the country.

3. METHODOLOGY

3.1. Data Sources

The data used in this study were sourced from World Bank Development Indicators; Food and Agricultural Organization; CBN Statistical Bulletin and World Bank Climate Change Portal.

3.2. Model Specification

Following the works of Iheoma (2014), and Agba, et al. (2017), the modified model to examine the effect of climate change on crop production is specified as;

$$Y = f\,(MAR, MAT, CO_2E, AL, CMA, AGE) \tag{1}$$

Where f= functional relationship
Y = Crop yield (dependent variable)
MAR = Mean annual rainfall
MAT = Mean annual temperature
CO_2E = Carbon dioxide emissions
AGE = Agricultural government expenditure
AL = Arable Land
CMA = Crop manure application

Independent variables; MAR, AGE, AL, CMA are expected to positively influence crop yield while MAT and CO_2E are expected y to have negative effects on crop yield

Following the work of Iheoma (2014), the modified model to examine the effect of climate change on livestock production is given as;

$$LPI = f\,(MAR, MAT, CO_2E, AGE) \tag{2}$$

Where:
F = functional relationship
LP1 = Livestock production index (dependent variable)
MAR = Mean annual rainfall
MAT = Mean annual temperature
CO_2E = Carbon dioxide emissions
AGE = Agricultural government expenditure

Dependent variables MAR and AGE are expected to positively influence the livestock production while MAT and CO_2E are expected to negatively nfluence livestock production.i

Stating eq 1 in its non-linear form gives;

$$YIELD = MAR^{\beta 1}\ MAT^{B2}\ CO_2E^{\beta 3}\ AL^{\beta 4} CMA^{\beta 5}\ AGE^{\beta 6} \quad (3)$$

Stating eq 2 in its non-linear form gives;

$$LPI = MAR^{\gamma 1} MAT^{\gamma 2}\ CO_2E^{\gamma 3}\ AGE^{\gamma 4} \quad (4)$$

In order to state the econometric form eq (3) model, it has to be linearized.

The linearized crop production model is given as;

$$YIELD = \beta_0 + \beta_1 MAR + \beta_2\ MAT + \beta_3 CO_2E + \beta_4 AL + \beta_5 CMA + \beta_6 AGE + \mu \quad (5)$$

Where;
β_0 = constant/intercept parameter
$\beta_1 - \beta_6$ = Slope coefficients
μ = Stochastic error term

Whereas the linearized livestock production model is given as;

$$LPI = \gamma_0 + \gamma_1 MAR + \gamma_2 MAT + \gamma_3 CO_2E + \gamma_4 AGE + \mu \quad (6)$$

Where;
γ_0 = constant/ intercept parameter
$\gamma_1 - \gamma_1$ = Slope coefficients

3.3. Estimation Technique

This research study employs the Auto regressive Distributed lag to determine the type of the relationship exists between climate change and agricultural production in Nigeria. The econometric techniques to be performed are briefly discussed below.

3.3.1. Augmented dickey fuller (ADF) unit root test

Economic data collected overtime tend to be non-stationary and if used for analysis may yield spurious regression results. Hence there is need to test data for stationarity prior to model estimation. The augmented dickey fuller (ADF) unit root test is used to detect stationarity or the presence of a unit root in a time series data at a level of significance (1%, 5% or 10%) between variables

3.3.2. ARDL model estimation

This is one of various methods to estimate a model taking into account information regarding the long run and short run relationship between the variables in the model. In an ARDL model, the present value of the dependent variable is expressed as a function of current and lagged values of the independent variable(s) as well as lagged values of the independent variable. The optimal lag length of variables in the may be determined by a number selection criteria. The main steps involved in co-integration technique are ARDL Bound's Test, ARDL Co-integration Test and Vector Error Correction.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

From Table 1, the mean is the value average of the series and summarizes the whole time series data over a single period with a single variable. It is a measure of central tendency while the standard deviation is a measure of dispersion. The standard deviation measures how much the series deviate from the mean. There is the likelihood of a large coefficient if the mean is larger than the standard deviation. On the other hand, there is the likelihood of a large coefficient of variation if the mean is smaller than the standard deviation.

The median is the middle of the series and is often seen as a social measure as its value is better reporting income than the mean. The mean of crop yield provides that average crop yield of Nigeria's 17 majorly produced crops is 91.42 million which appears quite low when compared to the maximum value of 159.05 million, although crop yield has been substantial on average. Increased crop yields will certainly aid Nigeria to boost her agriculture production in light of her significant agriculture resources. The mean of AGEXP is relatively low when compared to its maximum value suggesting

Table 1: Descriptive statistics of variables

Descriptive Statistics	CY (In Millions)	LPI	COE (In Kilotonnes)	CMA (In Thousands)	AL (In Millions)	AGEXP (In Billions)	MAR (in millimetres)	MAT in (degrees centigrade)
Mean	91.42	87.05	72927.57	8818.81	30.98	49.51	91.95	27.17
Median	93.91	86.29	73505.02	8645.08	33.10	15.49	92.70	27.20
Maximum	159.05	123.65	106068.0	12350.12	37.00	180.10	111.78	27.83
Minimum	30.76	51.64	35199.53	6337.10	16.47	1.35	72.68	26.46
Standard Deviation	36.997	24.17	24916.98	1790.66	5.476	54.37	9.33	0.34
Skewness	−0.157	0.136	−0.213	0.569	−1.437	0.735	−0.356	−0.0906
Kurtosis	2.072	1.503	1.499	2.315	4.165	2.184	2.713	2.457
Observations	37	37	37	37	37	36	37	37

Source: Researchers' Compilation 2020

Table 2: Results of augmented dickey fuller unit root test of variables

Variables	Series at levels			Series at first difference			Order of integration
	ADF statistic	Critical value at 5%	Remarks	ADF statistic	Critical value at 5%	Remarks	
CY	−0.808	−2.951	Not Stationary	−3.130	−2.951	Stationary	I(I)
LPI	−1.639	−3.540	Not Stationary	−5.989	−3.544	Stationary	I(I)
AGEXP	−2.999	−3.544	Not Stationary	−7.111	−3.548	Stationary	I(I)
AL	−1.920	−3.540	Not stationary	−4.575	−3.548	Stationary	I(I)
MAT	−5.283	−3.540	Stationary	8.550	−3.548	Stationary	I(0)
MAR	−3.889	−3.540	Stationary	−6.946	−3.552	Stationary	I(0)
CMA	−2.938	−3.540	Not stationary	−7.685	−3.544	Stationary	I(1)
CO_2E	−1.838	−3.540	Not stationary	−5.908	−3.204	Stationary	I(1)

Source: Researchers' Compilation 2020

that agriculture government expenditure has been low on average over the period of 1981 to 2017. All other variables, LPI, COE, CMA, AL, MAR and MAT have all been high on average as their mean values are quite high relative to their maximum values.

Further, from the table above, we see that the mean is greater than the standard deviation for all variables except AL, indicating a possibility of small coefficient of variation. However, the standard deviation of AL is greater than the mean indicating the possibility of a large coefficient of variation. Skewness is the extent to which a distribution differs from a normal distribution. A long right tailed distribution indicates positive skewness while a long left tailed distribution indicates negative skewness. From the table above, we observe that LPI, CMA, AGEXP have a long right tail while MAR, MAT, CO_2E and CY have a left tail. The skewness of a normal distribution is zero.

Kurtosis measures how flat or peaked a distribution is. If the kurtosis of a distribution is greater than 3, it is peaked; if it is <3, the distribution is flat. From the table above, it is observed that AL is the only variable with a peaked distribution while the others have a relatively flat distribution.

4.2. Econometric Results

4.2.1. Unit root test results

The Augmented Dickey-Fuller test was used to check for the stationarity of the variables in this research (see results in Table 2). If ADF t-stat is greater than the absolute critical value at 5%, the variable is stationary but if it is less than the critical value, it is not stationary. The results of the test are presented in Table 3 below.

The results above shows that the variables are a combination of I(0) and I(1) variables. MAT and MAR were stationary at the level while CY, LPI, AL, CMA, CO_2 and AGEXP were stationary after first differencing. This necessitated the use of bounds test for cointegration.

4.2.2. Bound's test crop production

From Table 3 the F-statistic (10.59235) is greater than the upper bound of 3.61 at the 5% level of significance. As such one concludes that a long run relationship exists between CY and its respective independent variables, MAT, MAR, CO_2E, AL, CMA and AGEXP.

4.2.3. Livestock production

The ARDL bounds test was also used to check for cointegration between climate change and livestock production. From the results presented in Table 4 the F-statistic (1.055450) is lower than the

Table 3: Test for counteraction result for relationship between crop production and climate change

ARDL bounds test		
Null hypothesis: No long-run relationships exist		
Test statistic	**Value**	
F-statistic	10.59235	
Significance	Lower Bound I(0)	Upper Bound I(1)
10%	2.12	3.23
5%	2.45	3.61
2.5%	2.75	3.99
1%	3.15	4.43

Source: Researchers' Compilation 2020

upper bounds of 4.01 at 5%. It is, therefore, conclusive that there is no long run relationship between the dependent variable LPI and its respective explanatory variables, MAT, MAR, CO_2E, and AGEXP.

4.2.4. ARDL results for crop production

The ARDL results indicating the cointegrating relationship between crop production and climate change are presented in Table V and subsequently discussed in section 4.3.

4.3. Interpretation of Long Run Coefficients for Crop Production

From the Table 5, the coefficient of mean annual rainfall (MAR) is 11.476. A unit increase in mean annual rainfall will lead to an 11.476 increase in crop yield. It is statistically significant. The coefficient of mean annual temperature (MAT) is −30.443. A unit increase in mean annual temperature will result in a −30.443 decrease in crop yield. It is however statistically insignificant. The coefficient of carbon dioxide emissions (COE) is 2.427. A unit increase in carbon dioxide emissions will cause a 2.427 increase in aggregate crop yield. It is statistically significant.

The coefficient of crop manure application (CMA) is 14.580. A unit increase in crop manure application will lead to a 14.580 increase in crop yield. It is also statistically significant. The coefficient of arable land (AL) is 1.433. This means that a unit increase in arable land will result in a 1.433 increase in crop yield. It is statistically significant. The coefficient of agricultural expenditure (AGEXP) is -2.370. A unit increase in agricultural expenditure cause a -2.370 decrease in crop yield. It is also statistically significant.

The coefficient of the constant is -12.254 which connotes that the value of crop yield will decrease by -12,254 when the independent variables are kept constant. The lag of the error correction term

Table 4: Test for relationship between livestock production and climate change

ARDL bounds test		
Null hypothesis: No long-run relationships exist		
Test statistic	Value	
F-statistic	1.055450	
Significance	Lower bound I(0)	Upper bound I(1)
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Source: Researchers' Compilation 2020

Table 5: ARDL regression results for crop production

ARDL Co-integrating and long run form				
Dependent variable: CY				
Variables	Coefficient	Standard error	t-statistic	Prob.
D(CY(-1))	0.310	0.142	2.183	0.0606
D(CY(-2))	1.235	0.171	7.234	0.0001
D(CY(-3))	0.274	0.189	1.454	0.1839
D(MAR)	15.562	10.625	1.465	0.1812
D(MAR(-1))	−3.251	1.442	−2.254	0.0543
D(MAR(-2))	−4.421	1.380	−3.204	0.0164
D(MAT)	−3.864	1.160	3.332	0.0000
D(COE)	5.159	0.889	5.801	0.0004
D(CMA)	5.986	1.974	3.032	0.0163
D(CMA(-1))	−5.475	1.522	−3.597	0.0010
D(CMA(-2))	−10.475	2.446	−4.282	0.0027
D(AL)	1.659	0.678	2.448	0.0401
D(AL(-1))	2.573	0.839	3.068	0.0154
D(AL(-2))	−3.021	0.602	−5.014	0.0010
D(AGEXP)	4.572	3.371	1.3565	0.2121
D(AGEXP(-1))	−3.769	2.937	−1.284	0.2352
D(AGEX(P-2))	9.638	3.582	2.691	0.0275
CointEq(-1)	−0.969	0.126	−7.664	0.0001
Cointeq = CY - (11.476*MAR -30.443*MAT + 2.427*COE + 14.580*CMA + 1.433*AL -2.370*AGEXN -12.254)				
Long run coefficients				
Variable	Coefficient	Standard error	t-statistic	Prob.
MAR	11.476	2.779	4.130	0.0033
MAT	−30.443	22.670	−1.343	0.2162
COE	2.427	0.439	5.533	0.0006
CMA	14.580	1.134	12.859	0.0000
AL	1.433	0.464	3.090	0.0149
AGEXP	−2.370	0.825	−2.873	0.0037
C	−12.254	4.843	−2.530	0.0084

Number of Observations: 32. Source: Researchers' Compilation 2020

(Cointeq(-1)) is -0.969 and is statistically significant which indicates that 96.90% of errors in the previous period are corrected in the current period. This is a high speed of adjustment of the estimated ARDL Error correction model.

4.4. ARDL Results for Livestock Production

4.4.1. Interpretation

The R squared of the model above is 0.7938 which connotes that 79.3% of the variation in the dependent variable, Livestock production index is explained by the explanatory variables (Table 6). The probability of F- statistic which measures the joint significance of the variables is 0.000000 which indicates that the estimated ARDL model is correctly specified. The Durbin-Watson statistic of 2.017181 indicates that there is no serial correlation in the above model.

Table 6: ARDL regression results for livestock production

Dependent variable: LPI				
Method: ARDL				
Variables	Coefficient	Std. Error	t-statistic	Prob.*
LPI(-1)	0.765394	0.083093	9.211273	0.0000
MAR	−0.186498	0.099755	−1.869567	0.0842
MAR(-1)	0.146404	0.084880	1.724836	0.1082
MAR(-2)	−0.060954	0.085504	−0.712872	0.4885
MAR(-3)	−0.014887	0.083074	−0.179203	0.8605
MAR(-4)	0.416262	0.108797	3.826039	0.0021
MAT	1.639287	2.976973	0.550656	0.5912
MAT(-1)	4.610707	3.482983	1.323781	0.2084
MAT(-2)	−10.03760	3.358915	−2.988347	0.0105
MAT(-3)	3.096976	2.613098	1.185174	0.2572
COE	−8.17E-05	6.84E-05	−1.194843	0.2535
COE(-1)	0.000185	7.76E-05	2.382175	0.0332
COE(-2)	−4.11E-05	8.32E-05	−0.494190	0.6294
COE(-3)	−0.000114	7.57E-05	−1.504086	0.1565
AGEXP	0.0794	0.029642	2.679315	0.0077
AGEXP(-1)	0.009903	0.030779	0.321743	0.7528
AGEXP(-2)	−0.003390	0.030222	−0.112155	0.9124
AGEXP(-3)	0.0763	0.0269	2.833	0.007
C	11.07838	187.0626	0.059223	0.9537
R-squared	0.793875	Mean dependent var		89.79281
Adjusted R-squared	0.685395	S.D. dependent var		22.87967
S.E. of regression	2.765048	Akaike info criterion		5.158707
Sum squared resid	99.39138	Schwarz criterion		6.028987
Log likelihood	−63.53930	Hannan-Quinn criter.		5.447180
F-statistic	117.1966	Durbin-Watson stat		2.017181
Prob(F-statistic)	0.000000			

Number of Observations: 32

The coefficient of LPI(-1) IS 0.7653 implying that a unit change in one period lagged livestock production index will result in a 0.7653 unit change in current period livestock production index and it is statistically significant. The coefficient of MAR is -0.1865 suggesting that a unit change in current period mean annual rainfall will lead to a 0.4162 change in the livestock production index. It is also statistically significant.

The coefficient of MAT is 1.6392 implying that a unit change in current period mean annual temperature will bring about a 1.6392 unit change in the livestock production index and it is statistically significant. The coefficient of COE is 0.000185 meaning that a unit increase in current period carbon dioxide emissions will result in a 0.000185 unit increase in the livestock production index. It is statistically significant. The coefficient of AGEXP is 0.0794 which shows that a unit change in current period agricultural expenditure will bring about a 0.0794 unit change in livestock production index. It is statistically significant. The coefficient of the constant term C is 11.0784 meaning that the value of livestock production will increase by 11.0784 keeping all explanatory variables constant.

5. DISCUSSION OF RESULTS

The bounds testing confirms the study's hypotheses of a long run relationship between climate change and crop yield but, no long run relationship between climate change and livestock production. Furthermore, ARDL cointegration test results showed that climate change affects both agricultural subsectors differently and through different channels. Specifically, rainfall has a positive and significant effect on both crop yield and livestock production, while temperature has a negative effect on both subsectors - though insignificant for crop production. Also, CO_2 emissions affects crop production positively while it affects livestock production negatively.

The ARDL results for crop production showed that a long run relationship exists between climate change and crop production. Mean annual rainfall and CO_2 emissions significantly influence crop yield while mean annual temperature had an insignificant effect on crop yield. The non-climatic variables (agricultural expenditure, crop manure application and arable land) also affect the yield of 17 major crops produced in Nigeria significantly in the long run. Furthermore, the results provide evidence of the economic significance of the coefficients of each variable.

Meanwhile, the mean annual rainfall had a positive effect on aggregate crop yield in Nigeria in line with the *apriori* expectation and existing literature (Adedeji et al, 2017; Agba et al., 2017; Aondoakaa, 2012; Ayinde, 2011). As such, increased rainfall due to climate change will lead to increased crop yield particularly in dryland areas with poor irrigation systems. In contrast, Enete (2014), Jönsson (2011) and Nwachukwu et al. (2012) observed a negative relationship between rainfall and crop yield. However, mean annual temperature had a negative effect on crop yield. This implies that increased temperature caused by increased greenhouse gas emissions will reduce aggregate crop yield in Nigeria. Adedeji et al. (2017), Ajetemobi et al. (2015), Apata, (2011), Ayinde et al. (2011) and Jönsson (2011) arrived at similar results. On the other hand, Aondoakaa (2012), Nwachukwu et al. (2012) concluded a positive relationship exists between temperature and crop yield.

CO_2 emissions has a positive effect on crop yield. This goes against the *apriori* expectation and results from existing literature. Possibly, CO_2 emissions do not affect crop yield directly, but causes higher temperature and reduced rate of photosynthesis which negatively affects aggregate crop yield in Nigeria. Ejemeyovwi et al. (2018) obtained similar result while Agba et al. (2017) concluded that CO_2 emissions has a negative effect on crop production.

Arable land showed a positive effect on crop yield. This is in line with the *apriori* expectation and existing literature as increased availability of arable land enables farmers to grow more crops which in turn increases crop yield. Crop manure application showed a positive effect on crop yield too in line with the *apriori* expectation and as manure is used to fertilize towards increased crop yield. Contrary to *apriori* expectation, government's agricultural expenditure showed a negative effect on crop yield. Previous research outcomes indicate increased government expenditure on the agricultural sector is meant to boost yield of crops by making farm implements and funds available for farmers. This could be indicating that increases in government expenditures require better channels or more effective distribution mechanism to achieve the expected result. Perhaps, government expenditure into the agricultural sectors is leaking away or being diverted inappropriately.

5.1. Livestock Production

The ARDL results showed that no long run relationship exists between climate change and livestock production. The findings for each variable are discussed below. The four-period lagged mean annual rainfall has a positive and significant effect on the livestock production index. This is in accordance with the *apriori* expectation and existing literature as rainfall provides water for livestock and growing of forage crops to feed livestock. The two-period lagged temperature has a negative and significant effect on the livestock production index, confirming the *apriori* expectation from existing theory. Increased temperature causes heat stress in livestock, dries up water bodies that provide water for livestock and increases the spread of pests and diseases which negatively affect livestock production.

The current period lagged CO_2 emissions has a negative effect on livestock production index, as expected but the estimate is not statistically significant. Government's expenditure on agriculture in the current period has a positive and significant effect on livestock production in Nigeria. This outcome appears to supports existing government-backed herders-support programmes and justifies proposed rangeland management initiatives to address the herders-farmer disputes in Nigeria (Chiluwa and Chiluwa 2020; Chukwuma, 2020; Mbih, 2020).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Climate change is a major reality for all countries of the world including Nigeria. It has significant influence on various sectors of Nigeria's economy, one of which is agriculture as examined here with extended linkage to farmers-herders dispute. This is because, as has been shown here, climate change impacts on agricultural outputs (of farmers and herders) - crop yields and livestock production. Both outputs are central to the Nigerian economy given their contribution to food security in Nigeria and the government's initiatives to diversify away from petroleum sector (Fubara et al. 2019).

So far, this paper has examined the effect of climate change on agricultural production in terms of crop yield and livestock production in Nigeria over the period 1981 to 2016. The findings of the study revealed that a long run relationship exists between climate change measured by (rainfall, mean annual temperature and CO_2 emissions) and crop yield. However no long run relationship exists between climate change measured by mean annual rainfall and temperature, CO_2 emissions) and livestock production. Meanwhile, results here suggest that the effect of climate change on agriculture depends on the measure of agriculture production and climate change employed in studies.

This study has contributed to literature in two ways: firstly, it employs aggregate output of 17 crops main produced in Nigeria

- cassava, cocoa, groundnuts, kolanut, maize, melon, millet, oil palm, plantain, rice, rubber, sorghum, soybeans, yam, cashew, sesame and potatoes. As such, it offers a more representative sample of aggregate crop production in Nigeria. Secondly, the study uses the livestock productivity index to ascertain the effect of climate change on the Nigeria's agricultural sectors. Thereby, it has uniquely highlighted an underlying factor (climate change), previously acknowledged, in Nigeria's farmers-herders clashes which has claimed many lives.

This study was limited by lack of data on the emissions of other greenhouse gases and livestock production values in Nigeria (offering better representation than the index). Future studies on climate change and agriculture could investigate how other greenhouse gases (apart from carbon dioxide) affect crop yield and livestock production in Nigeria and across West Africa. Additionally, further endeavours could analyze the comparative effect of climate change on the yields of individual crops produced in Nigeria's six geopolitical regions. This study could be extended to cover selected states in Nigeria where climate change impacts on rainfall and temperature are perceived as more severe for agriculture.

6.2. Recommendations

Based on the empirical results obtained in this study, businesses, policymakers and government agencies could consider the following suggestions:

1. Implementation of climate change mitigation and environmental sustainability measures to reduce their carbon footprint and curb greenhouse gas emissions. The trend analysis of carbon dioxide emissions shows that these emissions have increased considerably since 2000. Strategies that can be employed include: charging taxes on carbon emissions, promoting greater use of renewable energy resources, promoting sustainable agricultural practices through reduced use of inorganic fertilizers, as well as, encouraging afforestation and the use of organic manure.
2. Adaptation: This focuses on measures which are based on reducing vulnerability to the effects of climate change on agriculture in Nigeria. They include farmers growing crops and raring animals that are resistant to adverse weather conditions; government incentive support for research and technological innovations to boost crop yield (such as biotechnology). To overcome the effect of rainfall uncertainty, it is recommended that agricultural firms partner with energy companies (and/or government) to invest in combined hydro power and irrigation project – especially, in drought-prone areas.
3. The government should increase its expenditure on agriculture (both capital and recurrent) to especially support farmers and agro-allied companies who have been affected by the COVID-19 shutdown. This could increase the level of mechanized farming with modern equipment, farming implements and enhanced seedlings which are resilient to climate change to boost crop and livestock yield.
4. National orientation programmes aimed at enlightening farmers and herders about emerging changes in climate extremes.

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