International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
NAAS Rating (2025): 4.49
Maths 2025; 10(10): 01-05

https://www.mathsjournal.com
Received: 02-08-2025
Accepted: 04-09-2025

Tanko Gambo
Department of Statistics, Yakubu Gowon University (University Of Abuja), P.M.B 117, Abuja, Nigeria

Dr. Zubair MA
Department of Statistics, Yakubu Gowon University (University Of Abuja), P.M.B 117, Abuja, Nigeria

Corresponding Author:
Tanko Gambo
Department of Statistics, Yakubu Gowon University (University of Abuja), P.M.B 117, Abuja, Nigeria

Modelling the impact of maize and sorghum production on Nigeria's economic growth: An ARDL approach

Tanko Gambo and Zubair MA

DOI: https://www.doi.org/10.22271/maths.2025.v10.i10a.2170

Abstract
This study investigates the impact of maize and sorghum production on Nigeria's economic growth using the Autoregressive Distributed Lag (ARDL) modelling approach. Agricultural productivity remains a cornerstone of Nigeria's economy, yet the specific contributions of key staple crops like maize and sorghum to GDP growth have received limited empirical attention. The study utilizes annual time series data from (1960-2024), sourced from national bureau of statistics. After conducting unit root tests to determine the stationarity properties of the variables, the ARDL bound testing approach to cointegration is employed to assess both the short-run dynamics and long-run relationships between crop production and economic growth The results revealed that, in the short-run, the ECM(-1) coefficient of maize is -1.120, which is negative and statistically significant with a p-value of 0.000145(less than 0.01) at 5% level of significance, indicating that there is indeed short-run adjustment in the relationship between maize production and economic growth, however, the relationship between GDP and sorghum production captured by the variable X.t for ΔGDP(6.58e-09) is positive but very small, with a marginally significant t-value. In the long-run, the F-statistic value (8.678) is greater than the upper bound critical value at the 5% significance level (5.73), indicating the presence of a long-run co-integration relationship among the variables (maize and GDP), however, the long-run coefficient (1.374e+08) reveals that an increase in sorghum production positively influences GDP at 5% level of significance. This suggests that over time, higher sorghum production contributes to economic growth. The findings suggests that increased investment in agriculture, support for maize and sorghum farmers, and agricultural policy formulation can contribute to economic growth of Nigeria.

Keywords: Maize production, sorghum production, economic growth, Nigeria, ARDL model (Autoregressive distributed lag)

1. Introduction
According to (Praburaj, *et al*., 2018; Pawlak and Kołodziejczak, 2020) [12, 19], agriculture is directly proportional to economic growth, development and industrialization, most especially among the developing nations of the world including Nigeria. Mgbakor *et al*. (2014) [20], also said that no relevant development can take place in a developing country without the proper building of the agricultural sector as this will bring about adequacy in food production and decline in the governments' annual spending on food importation. It has been revealed that over 80% of the farmers in Nigeria are persistent farmers who cultivate few hectares of land, plant crops, and harvest but yet play a crucial role in the country's food security and yet remain poor (FAO, 2015; Mgbenka and Mbah, 2016) [21, 22]. According to MA Zubair, S.O Adams, and KS Aniagolu (2022) [8], the Nigerian government should make local products better to meet international needs so as to minimize total imports. Maize is an essential staple food crop in Nigeria where it plays a major role in the food basket of the country (Anderson *et al*., 2017) [23]. Maize is an important cereal crop occupying second place after rice in the diet of most households in Nigeria. It is a high yielding crop with so many uses ranging from food source in the human diet, a principal ingredient in livestock feed production and raw material to many agro-allied industries. In addition, maize is also employed in beer and starch production (IITA, 2007; Ogunniyi, 2011) [24, 11]. Maize is majorly where carbohydrate is gotten from and also other nutrient elements like minerals, protein, vitamin B and iron. For there to be an invigorate rise of Nigeria's economy through an expansion in human limit improvement, the

government need to increment monetary designation to the power area and instructive (SO Adams, MA Zubair, TG Olatunde-Aiydun, 2022) [8].

According to (Sadiq *et al*., 2013) [14], human food needs and livestock feeds has caused a competitive demand for maize in Nigeria. Sorghum is one of the principal cereal crops mostly grown in Nigeria, and a very essential staple food but now is being replaced by other crops such as barley, wheat, rice and maize for the people. Tashkalma *et al*. (2010) [18], submitted that this crop is one of the main source of energy and is the fifth major crop grown for human consumption in the world being surpassed only by corn, rice, and barley.

2. Materials and Methods

The study will utilize a quantitative approach to model the impact of maize and sorghum production on Nigeria's economic growth. The study will adopt an econometric technique to examine the relationships between maize and sorghum production and economic growth over time. The study employed a well-known approach by Pesaran *et al*. known as the Autoregressive Distributed Lag (ARDL) model.

2.1 Data collection

This study employs a secondary source of data. The yearly time series data are collected from the National Bureau of Statistics (NBS) covering 1960- 2024.

2.2 Model specification

This study will focus on an ARDL model that captures the relationships between maize and sorghum production and economic growth. The autoregressive distributed lag (ARDL) model suggested by (Pesaran, Shin, 1999) and (Pesaran *et al*., 2001) [25, 26] is adopted here. The agricultural products for this study are maize (MZ) and sorghum (SM).

The representation of the model specification is as follows:

$$EG=\phi(MZ,SM);\phi_1,\phi_2 <0 \quad (2.1)$$

2.3 Model I: ARDL Model for Economic Growth (EG) and Maize (MZ).

$$\Delta EG_t= \beta_0 + \beta_1 \mathrm{R(EG)}_{t-1} +\beta_2 R(MZ)_{t-1}+ \sum_{i=1}^{j} \theta_{1i}\, \Delta R(EG)_{t-i}+\sum_{i=1}^{j} \theta_{2i}\, \Delta R(MZ)_{t-i} +\mathcal{E}_t \quad (2.2)$$

2.4 Model II: ARDL Model for Economic Growth (EG) and Sorghum (SM).

$$\Delta R(EG)_t=\beta_0 + \beta_1 \mathrm{R(EG)}_{t-1} +\beta_2 R(SM)_{t-1}+ \sum_{i=1}^{j} \theta_{1i}\, \Delta R(EG)_{t-i}+\sum_{i=1}^{j} \theta_{2i}\, \Delta R(SM)_{t-i} +\mathcal{E}_t \quad (2.3)$$

2.5 Model III: ARDL Model for all Variables

$$\Delta R(EG)_t=\beta_0+\beta_1 \mathrm{R(EG)}_{t-1}+\beta_2 R(MZ)_{t-1}+\beta_3 R(SM)_{t-1} + \sum_{i=1}^{j} \theta_{1i}\, \Delta R(EG)_{t-i} + \sum_{i=1}^{j} \theta_{2i}\, \Delta R(MZ)_{t-i}+\sum_{i=1}^{j} \theta_{3i}\, \Delta R(SM)_{t-i} + \mathcal{E}_t \quad (2.4)$$

3. Results and Discussions

Table 3.1: Summary of Unit Root Test (ADF Test at Level and First Difference)

Variable	ADF Test Statistics (Level)	P-value (Level)	Stationarity at Level	ADF Test Statistic (First Difference)	P-Value (First Diff)	Stationarity at First Diff
Maize	-2.490	0.3001	Not Stationary	-6.210	0.0167	Stationary
Sorghum	-2.015	0.4165	Not Stationary	-6.663	0.01	Stationary
GDP	-2.252	0.4882	Not Stationary	-6.130	0.0199	Stationary

Table 3.1 shows that all the variables MAIZE, SORGHUM, and GDP are non-stationary at level since their p-values are greater than 0.05. However, after first differencing, all variables became stationary, as their p-values fell below the 5% significance level. Thus, the series are integrated of order one, I (1).

Table 3.2: VAR Lag Selection Summary

Variable	Selected Lag (based on AIC)
Dmaize	10
Dsorghum	2
Dgdp	1

AIC: Akaike Information Criterion

Table 3.2 reveals that the optimal lag lengths selected by the Akaike Information Criterion (AIC) are 10 lags for dmaize, 2 lags for dsorghum, and 1 lag for dgdp. This suggests that the dynamics of MAIZE prices require a longer memory compared to SORGHUM and GDP.

Table 3.3: ARDL Model Diagnostic Tests for Maize and Economic growth

Test	Statistic	p-value	Conclusion
Serial Correlation LM Test	$Chi^2(1) = 1.39$	0.2383	No serial correlation
Heteroskedasticity Test (Breusch-Pagan)	$Chi^2 = 13.99$	0.4999	Homoskedastic
Jarque-Bera Normality Test	JB = 3.85	0.1471	Residuals are normal
RESET Test (Model Specification)	F(1,21) = 2.77	0.1194	Model is well specified

Table 3.3 reveals that the ARDL model passes all diagnostic tests, including tests for serial correlation, heteroskedasticity, normality of residuals, and model specification. Therefore, the estimated model is statistically reliable and adequate for analysis.

Table 3.4: Error Correction Model (ECM) Result

Variable	Coefficient	Standard Error	t-Statistic	p-value
ECM(-1)	-1.120	0.124	-9.04	0.000

Table 3.4 presents the coefficients from the ECM, which reveals the short-run dynamics and speed of adjustment between maize production and economic growth in Nigeria. The key result is the ECM(-1) coefficient, which indicates the speed at which the system returns to equilibrium after a shock. If the ECM(-1) coefficient is significant and negative, it implies that there is a short-run relationship between the variables, and the system adjusts towards the long-run equilibrium. In this case, the ECM(-1) coefficient is -1.120, and it is statistically significant with a p-value of 0.000145 (less than 0.01), indicating that there is indeed short-run adjustment in the relationship between maize production and economic growth.

Table 3.5: ARDL Bounds Test for Cointegration

F-statistic	5% Lower Bound	5% Upper Bound	Co-integration Status
8.678	4.94	5.73	Co-integrated

Table 3.5 shows that the F-statistic value (8.678) is greater than the upper bound critical value at the 5% significance level (5.73), indicating the presence of a long-run cointegration relationship among the variables.

Table 3.6: Long-Run Coefficients from ARDL Model

Variable	Coefficient	Standard Error	t-Statistic	p-value
MAIZE	1.014×10^8	2.589×10^7	3.91	0.001
GDP(-1)	-1.120	0.124	-9.04	0.000

Table 3.6 reveals that in the long run, an increase in MAIZE output is associated with a significant and large positive impact on GDP. Furthermore, the negative sign on GDP lagged confirms the necessary condition for model stability and error correction.

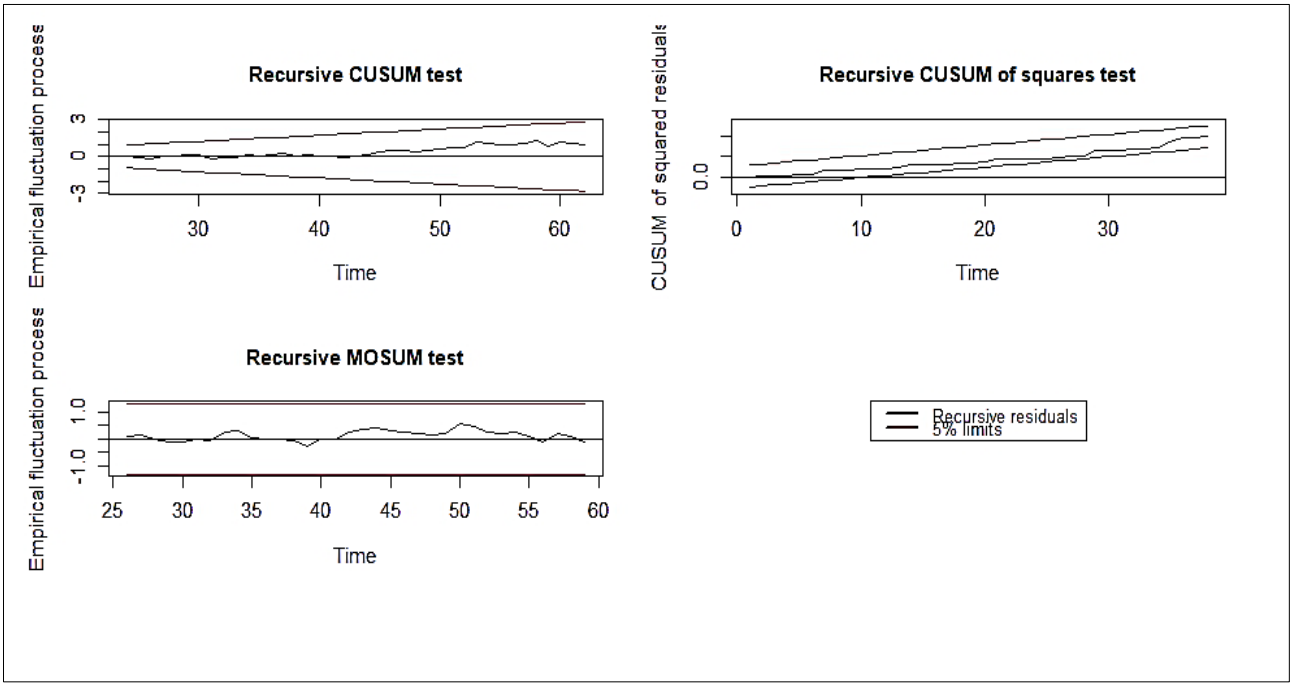

Fig 3.1: Plot of Recursive CUSUM, CUSUM of Squares, and MOSUM Tests for the Stability of the ARDL Model Parameters

The results of the Recursive CUSUM, Recursive CUSUM of Squares, and Recursive MOSUM tests indicate that the ARDL model is structurally stable over the sample period. All test statistics remained within the 5% significance bounds, suggesting that the parameter estimates do not suffer from structural breaks, variance instability, or gradual parameter shifts.

Table 3.7: ARDL Model Diagnostic Tests for Sorghum and Economic growth

Test	Statistic	p-value	Conclusion
Serial Correlation LM Test (Breusch-Godfrey)	$Chi^2(1) = 0.5996$	0.4422	No serial correlation
Serial Correlation Test (Ljung-Box)	$X^2(1) = 0.2525$	0.6153	No serial correlation
Heteroskedasticity Test (Breusch-Pagan)	$Chi^2(6) = 10.625$	0.1007	Homoskedastic
Normality Test (Shapiro-Wilk)	W = 0.9582	0.0385	Residuals are not normal
RESET Test (Model Specification)	F(2,52) = 3.6685	0.0323	Model may be misspecified
ARDL Bounds Cointegration Test	F = 32.99	—	Cointegration exists

Table 3.7 presents the diagnostic tests conducted on the ARDL model. it confirmed several key aspects of model adequacy. First, the results from the Breusch-Godfrey Serial Correlation LM test ($Chi^2(1) = 0.5996$, $p = 0.4422$) and the Ljung-Box Q-test ($X^2(1) = 0.2525$, $p = 0.6153$) both indicate that there is no evidence of serial correlation in the residuals, as their p-values are greater than the 5% significance level. This suggests that the residuals are independent over time, satisfying an important assumption for time series regression. Similarly, the Breusch-Pagan test for heteroskedasticity yields a $Chi^2(6)$ statistic of 10.625 with a p-value of 0.1007, indicating that the null hypothesis of homoskedasticity cannot be rejected. Therefore, the residuals exhibit constant variance, implying that the model does not suffer from heteroskedasticity problems. However, the Shapiro-Wilk test for normality reports a W statistic of 0.9582 with a p-value of 0.0385, which is below the 5% threshold. This result suggests that the residuals are not normally distributed. Although normality is desirable for small-sample inference, its violation does not necessarily invalidate the model, especially in large samples where the Central Limit Theorem provides some robustness. The Ramsey RESET test, used to detect model misspecification, produces an F-statistic of 3.6685 with a p-value of 0.0323. Since the p-value is less than 0.05, there is evidence that the model may be misspecified, potentially due to omitted variables or an incorrect functional form. This indicates the need for caution when interpreting the model's results and suggests that further model refinement may be necessary. Finally, the ARDL Bounds Test for cointegration shows an F-statistic of 32.99, which is substantially higher than the critical values at the 1%, 5%, and 10% levels. This strongly confirms the presence of a long-run equilibrium relationship between the variables, justifying the use of the ARDL approach in this study.

Table 4.2: ARDL Model Results for Sorghum Production and Economic growth

Variable	Coefficient Estimate	Std. Error	t-Value	p-Value
Short-Run Coefficients				
(Intercept)	-0.2047	0.145	-1.392	0.1697
X.t (ΔGDP)	6.58e-09	3.29e-09	2.000	0.0549
X.1 (ΔSORGHUM)	1.008e-09	5.46e-10	1.85	0.0734
Y.1 (SORGHUM Lagged)	-0.4461	0.147	-3.04	0.0042
Y.2 (SORGHUM Lagged 2)	-0.8102	0.153	-5.29	0.0001
Long-Run Coefficients	Coefficient Estimate	Std. Error	t-Value	p-Value
dsorghum.1 (SORGHUM)	1.374e+08	5.98e+07	2.30	0.0255
dgdp.1 (GDP)	-1.238	0.404	-3.06	0.0025

Table 3.8 presents the short-run coefficients from the ARDL model. It shows that the relationship between GDP and sorghum production (captured by the variable X.t for ΔGDP) is positive but very small, with a marginally significant t-value. This suggests that short-run fluctuations in GDP have a small but significant effect on changes in sorghum production. The lagged coefficients (Y.1 and Y.2 for past sorghum production) show a significant negative effect on the current economic growth, indicating that the effects of past agricultural performance may persist and hinder economic growth in the short run. The significant negative relationship between lagged sorghum production and GDP implies that changes in sorghum production from the previous periods may still have a lingering impact on economic performance. The long-run coefficients reveal that in the long term, an increase in sorghum production positively influences GDP. This suggests that over time, higher sorghum production contributes to economic growth. The long-run relationship between GDP and sorghum production (coefficient = -1.238) indicates that, over time, GDP has a negative effect on sorghum production. This could reflect structural shifts in the economy as GDP grows, potentially leading to a decline in agricultural sector reliance.

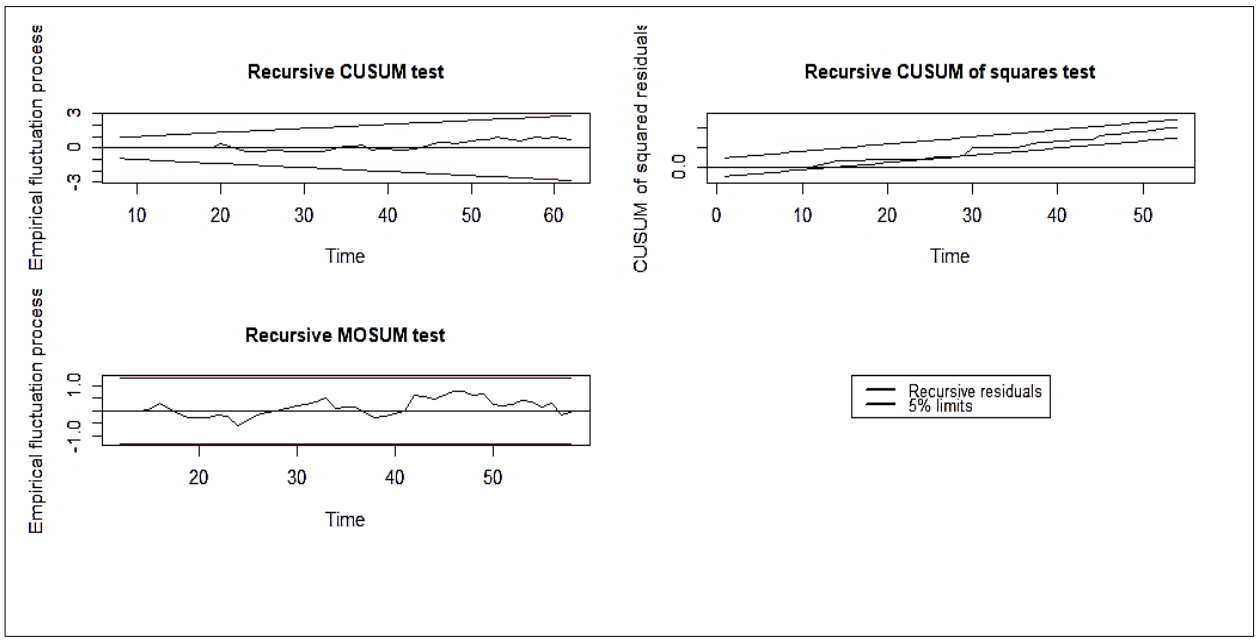

Fig 3.2: Plot of Recursive CUSUM, CUSUM of Squares, and MOSUM Tests for the Stability of the ARDL Model Parameters

Fig 3.2 indicates that the model is generally stable over the sample period. The residuals fluctuate within the critical bounds at the 5% significance level, suggesting that the model's parameters remain stable over time. There is no clear evidence of structural breaks or instability, supporting the reliability of the ARDL model's estimates for both short-run and long-run analysis.

Conclusion

The study has provided valuable insights into the impact of maize and sorghum production on Nigeria's economic growth. Based on the results obtained, I therefore concludes that there is indeed short-run adjustment in the relationship between maize production and economic growth. There exist the presence of a long-run cointegration relationship among the variables maize production and economic growth. There is a short-run fluctuations in GDP which has a small but significant effect on changes in sorghum production. In the long-run, there is an increase in sorghum production that positively influences GDP, but over time, GDP has a negative effect on sorghum production.

Recommendations

Based on the findings of the study, the following recommendations are made;

1. Further research should be conducted to examine the impact of other agricultural commodities on economic growth in Nigeria.
2. Policymakers should provide support to maize and sorghum farmers, including access to credit, extension services, and market information
3. The government and private sector should increase investment in agriculture to improve productivity and efficiency.
4. Policymakers should formulate policies that promote the development of maize and sorghum subsectors.

Acknowledgement

I acknowledge God Almighty for His infinite mercy to complete this research work.

References

1. Adamu HD, Baba SA. Economic impact of maize technology on farmers in Nigeria. Journal of Fisheries and Agriculture. 2025;5(1).
2. Alimi T. Resource use efficiency in food crop farming in Oyo of Nigeria. Journal of Agriculture and Environment. 2000;1(1):1-7.
3. Altuntas Y, Comert Z, Kocamaz AF. Breeding strategies for tropical maize. SciELO Brazil. 2019. https://www.scielo.br
4. Fakayode SB, Rahji MA, Oni OA, Adeyemi MO. Household food security among different wealth groups. Science and Education Publishing. Available from: https://www.sciepub.com
5. Garcia Santillan M, Mantalvo, Pajares. Automatic detection of curved and straight crop rows from images in maize fields. ScienceDirect. 2017. https://www.sciencedirect.com
6. Huang S, Fan XF, Sun L, Shen YL, Suo XS. Maize seed appearance quality assessment based on machine vision. Frontiers. 2019. https://www.frontiersin.org
7. Javanmardi H, Martynenko. A literature study on development of maize seed. TOJSAT. 2020. Available from: https://www.tojsat.net
8. Zubair MA, Adams SO, Aniagolu KS. Economic impact of some determinant factors of Nigerian inflation rate. Journal of Economics and Financial Analysis. 2022;5(2):23-41.
9. Mgbenka RN, Mbah EN. A review of smallholder farming in Nigeria. American Journal of Water Resources. 2022;10(2):35-48.
10. Nyagumbo, Mainassara Zaman-Allah. Maize kernel abortion recognition and classification. MDPI. 2020. Available from: https://www.mdpi.com
11. Ogunniyi LT. Determinants of profit efficiency among small scale maize farmers in Oyo State. IOSR Journal. 2011. Available from: https://www.iosrjournals.org
12. Praburaj I. Role of agriculture in the economic development of a country. International Journal of Commerce. 2018;6(3):1-5.
13. Romer PM. Increasing returns and long-run growth. Journal of Political Economy. 1986;94:1002-37.
14. Sadiq A, *et al*. Economics of small scale maize production in Toto local government area. SciSpace. 2013. Available from: https://scispace.com
15. Sani S, Sanni, Damisa, Oladimeji. Analysis of sorghum production and its effect on food security. Ahmadu Bello University. 2017. https://kubanni.abu.edu.ng
16. Adams SO, Zubair MA, Olatunde-Aiydun TG. Economic growth and environment sustainability (EGNES). EGNES. 2022;1(2):41-46.
17. Olajuwon S, Olayide, Heady EO. Introduction to agricultural production economics. Ibadan: Ibadan University Press; 1982.
18. Tashkalma, *et al*. Economic analysis of sorghum production. TERAS. 2010. https://teras.ng
19. Pawlak K, Kołodziejczak M. The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production. Sustainability. 2020 Jul 7;12(13):5488.
20. Ugwu JN, Mgbakor MN, Chitor CC. Assessment of value addition in rice production and processing in Adani in Uzouwani Local Government Area of Enugu State, Nigeria. International Journal of Agricultural Sciences and Veterinay Medicine. 2014;2:53-68.
21. McGuire S. FAO, IFAD, and WFP. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO, 2015. Advances in nutrition. 2015 Sep 1;6(5):623-4.
22. Mgbenka RN, Mbah EN, Ezeano CI. A review of smallholder farming in Nigeria: Need for transformation. International Journal of Agricultural Extension and Rural Development Studies. 2016 May;3(2):43-54.
23. Anderson SF, Kelley K, Maxwell SE. Sample-size planning for more accurate statistical power: A method adjusting sample effect sizes for publication bias and uncertainty. Psychological science. 2017 Nov;28(11):1547-62.
24. Nkamleu GB, Coulibaly O, Sanogo D, Manyong VM, Alene AD. Ex post impact assessment of agricultural research in sub-Saharan Africa: the IITA experience. Assessing the Impact of Agricultural Research on Rural Livelihoods: Achievements, Gaps, and Options. 2007:27.
25. Pesaran MH, Shin Y, Smith RP. Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American statistical Association. 1999 Jun 1;94(446):621-34.
26. Pesaran MH, Shin Y, Smith RJ. Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics. 2001 May;16(3):289-326.