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DETERMINANTS OF AGRICULTURAL SECTOR OUTPUT IN NIGERIA: AN ANALYSIS OF CLIMATIC AND NON-CLIMATIC FACTORS

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ABSTRACT

The paper examined the macro determinants of agricultural sector output in Nigeria using annual time series data spanning from 1981 – 2022 and employs the Autoregressive Distributed Lag (ARDL) Bound tests. Two models based on climatic factors (rainfall, temperature, and carbon emission) and non-climatic factors (Government expenditure on agriculture, agricultural credit, money supply, exchange rate, and Inflation) were estimated. The empirical results for both climatic and non-climatic models showed that there exists a long-run cointegration relationship between agricultural output and selected climatic and non-climatic variables over the study period. The coefficients of rainfall and temperature (for climatic) and agricultural credit, money supply, and exchange rate (for non-climatic) significantly influence agricultural output in both the short run and long-run. Hence, the study recommends for effective management of excessive rainfall to control floods through the constructions of dams, clearance of blockage on waterways and control of human activities that results in excessive temperature in the atmosphere; Government should effectively use its macroeconomic policies (monetary and fiscal) to ensure increase credit facilities to the farmers, enhanced budgetary allocation to agricultural sector, maintenance of a stable exchange rate and single digit inflation to strengthen domestic macroeconomic environment.

Keywords: Agricultural Sector, Money Supply, Agricultural Credit, Rainfall, Farmer.

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1. Introduction

Agriculture has historically been acknowledged as the driving force of the global economy (Hanumanthappa, 2016; Phiri, 2018; Ene et al., 2022). This importance originates from the special roles played by the sector in meeting each country's demand for staple food for vibrant labour force; provision and raising the income of the farmers, thus aiding poverty alleviation; promote export, serving as prominent source of foreign exchange earnings; source of raw materials needed for industrial growth; checking the influx of rural to urban migration for avoidance of overcrowded cities and over stretched infrastructures (CBN, 2023). In fact, it was asserted that revitalizing agriculture is paramount to delivering the expected 10 per cent yearly economic growth rate within the scope of "Vision 2030" (Nwachukwu & Shisanya, 2017). UNCTAD (2015) affirmed that the level of agribusiness output explains the resource gap separating less developed nations from the developed nations (Ene et al., 2022).

Nigeria is a developing country, largely rural and agrarian in nature. Agriculture has been the traditional backbone of the economy, predating the discovery and exploration of crude oil in the 60s. The sector was described as the mainstay of the economy, exhibiting a higher growth multiplier than other sectors (Abdullahi & Marafa, 2023). It accounts for a substantial portion of the country's economic growth contributing about 24 percent in 2022 (CBN, 2023); it remains the largest single employer of labour, providing jobs and livelihood for over 70% of the population in subsistence-level agricultural production (Emeh, 2017); it source of essential raw materials to agro-based industries thereby creating linkage that drives industrial growth; it account for of total exports thereby serving as a source of foreign exchange earnings; it provide income in the rural areas thereby playing a critical role in poverty reduction; contributes to food security; creates vibrant domestic market through increased farmers income leading to increase demands for other goods and services.

Notwithstanding the significant roles of the agriculture sector in the economic life of the Nigerian economy, the sector has faced a multitude of challenges that hinder the achievement of the desired levels of growth and development in the sector, amidst rich agricultural resource endowment evident in highly diversified arable land and agro-ecological conditions (Ene et al., 2022). These challenges faced by the sector range from climatic to non-climatic problems.

Climate change plays a significant role in determining the growth of agricultural production in Nigeria. As a country with diverse climatic conditions characterized by distinct wet and dry seasons, variation in the patterns of rainfall and temperature levels throughout the year, all these have a direct impact on crop production and livestock rearing. Erratic rainfall distribution, inadequate rainfall, and prolonged droughts can lead to low crop yields, reduced pasture productivity, and limited water availability for irrigation (Oladipo et al., 2019). Insufficient rainfall not only affects rain-fed agriculture but also necessitates

increased reliance on irrigation, which can be a challenge due to limited access to water resources and infrastructure (Enete, 2017). Temperature variability is another climatic factor that affects agricultural activities in Nigeria. Extreme temperatures, such as heat waves, can cause heat stress in plants and animals, leading to reduced productivity and poor crop quality (Nwajiuba, 2013; Oladipo et al., 2019). Higher temperatures can also surge evaporation rates, which result in not only depleting soil moisture by drying up the surface water and reducing the available groundwater, but also increasing the water requirements for crops and livestock (Ufiobor, 2017). Also, with an unbearable temperature level, labourers easily get tired, and they become less productive compared to a period of mild temperature (Enete, 2017). Conversely, lower temperatures can limit the growth and development of tropical crops, affecting their overall yield potential (Oladipo et al., 2019).

Lack of sufficient financial support has impeded the sector's progress and limited its growth potential, hindering the adoption of modern farming techniques (Olomola, 2017). Supply of funds for agriculture has been paltry (Ene, et al., 2022), as farmers have limited access for bank loans due to lack collateral, double-digit interest rate charged on borrowing, absence of formal financial records, and other necessary information to qualify them for loans from banks and other financial institutions (Enete, 2017), thereby restricting their ability to invest in improved inputs, machinery, and technology, thus, limiting their productivity and profitability. Similarly, the government has failed to bridge the finance gap due to prolonged neglect as a result of the discovery of oil in commercial quantities and inconsistent fiscal policy (Emeh, 2017; Uremadu & Onyele, 2019).

Insufficient infrastructure has significant implications for the agricultural sector growth in Nigeria. Inadequate road networks affect the transportation, while poor storage facilities and processing plants affects preservation of agricultural products, thereby resulting in post-harvest losses, reduced market access, and limited value addition (Enete, 2017), and thus impeding the efficient functioning of the agricultural value chain, leading to lower incomes for farmers and limited growth of the sector. In addition, farmers often face challenges in connecting with potential buyers and accessing market information, which leads to price fluctuations and exploitation by middlemen (Enete, 2017), which hinders their ability to sell their produce at fair prices, affecting their profitability and overall motivation to invest in agriculture. More so, there is inefficient supply and distribution of modern farm inputs, as Nigerian farmers still depend on crude implements, which adversely affect their output growth (Ogundele & Okoruwa, 2014). Additionally, macroeconomic swings like the high inflation and adverse Naira-Dollar exchange rate made the acquisition of modern farm inputs very expensive for the farmers (Omekwe et al., 2018; Anyanwu, 2013).

Based on the foregoing, it became pertinent to achieve the desired levels of growth and development of the Nigerian economy. It is, therefore, crucial to periodically examine the determinants of agricultural output so as to determine the degree of their influence, to enable informed policy recommendations to ensure

sustainable development of the agricultural sector. Hence, this paper examined the determinants of agricultural output in Nigeria. The next section presents the literature review, while the dataset and method are explained in Section Three. Section four presents the analysis of the results, while Section five concludes the paper and draws some policy recommendations.

Research Question

- a) What is the short-run and long-run relationship between climatic factors and agricultural sector output in Nigeria?
- b) What is the short-run and long-run relationship between non-climatic factors and agricultural sector output in Nigeria?

Objective of the Study

The broad objective of the study is to examine the determinants of agricultural sector output in Nigeria. To achieve that, the following specific objectives were pursued:

- a) To examine the short-run and long-run relationship between climatic factors and agricultural sector output in Nigeria.
- b) To investigate the short-run and long-run relationship between non-climatic factors and agricultural sector output in Nigeria.

2. Literature Review

2.1 Conceptual Literature

Agricultural output: Agricultural output refers to the measure of individual output in the agricultural sector. It encompasses various aspects, including livestock enterprise output, crop enterprise output, by-products, forage and cultivations, and other outputs that fall under the agricultural activities category but are neither livestock nor crop enterprise outputs (Onwioduokit, 2013; Marafa, 2021). Agricultural output of a country is a key indicator of the performance of the sector and its contribution to the national economy (Marafa, 2021). Determining agricultural output encompasses the evaluation of the connection between the quantity of agricultural inputs and the outputs involved in agricultural production. These inputs involved various resources/factors that directly (climatic) or indirectly (non-climatic) influence the output growth, which is determined by how efficiently these inputs are managed to generate outputs.

Any effort to advance agricultural development and output growth must involve the implementation of strategies, policies, and programs that improve productivity and efficiency of farming practices by supporting the farmers, providing incentives for innovation, facilitating research and development, encouraging collaboration between public and private sectors, and promoting sustainable farming practices by various levels of governments, policymakers, and international organizations.

Climatic Factors- also called climatic variables or meteorological factors- refer to the elements of climate that have a direct influence on various aspects of the environment and human activities, including

agriculture. Important climatic factors that can significantly affect agricultural output include rainfall, temperature, and carbon dioxide, among others, which play a critical role in shaping the climate patterns of a specific area, and their interactions determine the overall weather conditions experienced over a given period and agricultural planning (IPCC, 2013). Departure from normal climate/rainfall and temperature, individually or collectively, could alter agricultural output (Nwachukwu & Shisanya, 2017; Enete, 2017). From theory, *ceteris paribus*, a positive relationship is expected between rainfall and agricultural output, while a negative relationship is expected between temperature and agricultural output (Abdullahi & Marafa, 2023).

Rainfall: Rainfall is indexed by total annual rainfall in an area. Rainfall is crucial for sustaining ecosystems, agriculture, and human activities as it replenishes water sources, supports plant growth, and ensures an adequate water supply for various purposes, including drinking, irrigation, and industrial use (IPCC, 2014). Variation in rainfall patterns over the years is an indication of weather variability, and can lead to droughts or floods, affecting water availability, crop yields, and ecosystem functioning (Knutson et al., 2019). From theory, a positive relationship is expected between rainfall and agricultural productivity (Abdullahi & Marafa, 2023).

Temperature: This represents the measure of the average kinetic energy of molecules in the air. It is a physical quantity that expresses quantitatively the perceptions of hotness and coldness expressed in terms of any of several arbitrary scales and indicating the direction in which heat energy will spontaneously flow. Temperature variations influence the growth and development of plants, animals, and microorganisms, as well as the functioning of ecosystems. Extreme temperatures like heat waves or extreme cold can have detrimental effects on crop, livestock, and human health (Knutson et al., 2019). It also affects the rate of evaporation and water availability, further impacting the hydrological cycle and water resources (IPCC, 2014). A negative relationship is expected between temperature and agricultural output.

Carbon-Emission: Carbon emission is the release of carbon compounds into the atmosphere (greenhouse gas emissions), which are the main contributors to climate change. Since greenhouse gas emissions are often calculated as carbon dioxide equivalents, they are often referred to as “carbon emissions” when discussing global warming or the greenhouse effect. Since the industrial revolution, the burning of fossil fuels has increased, which directly correlates to the increase in carbon dioxide levels in our atmosphere and, thus, the rapid increase of global warming. A negative relationship is expected between carbon emission and agricultural output (Abdullahi & Marafa, 2023)

Non-Climatic Factors: These include various factors that indirectly influence the agricultural output growth. These include government expenditure on agriculture, agricultural credit, inflation, exchange rate, money supply in the economy, and many others.

- **Government Expenditure on Agriculture:** This is a government allocation of budgetary funds to the agricultural sector with the aim of boosting agricultural productivity and output, thereby inciting economic growth. It comprises expenses on sector policies and programs, construction of flood control, irrigation, and drainage systems, operation or support of extension services or veterinary services to farmers, pest control services, crop inspection services, provision of grants and subsidies to farmers, etc. Investing in agriculture is one of the most effective ways of promoting agricultural output growth, raising real incomes, reducing poverty and food insecurity, and enhancing

environmental sustainability (FAO, 2016). The agricultural public expenditures in Nigeria are mainly classified as capital (development) and recurrent (CBN, 2023). The recurrent expenditures are further classified as wage and non-wage/personnel and overhead costs, while the capital public agricultural capital expenditures in Nigeria were dominated by two dominant activities - Project coordinating unit (PCU) and Fertilizer market stabilization (subsidy) (Mogue et al, 2008). A positive relationship is expected between government expenditure on agriculture and agricultural output.

- **Agricultural Credit:** This involves all forms of financial services ranging from short, medium, and long-term loans covering the entire agricultural value chain, such as leasing, insurance, input supply, production and distribution, wholesaling, processing, and marketing of agricultural produce. It is the provision of multiple types of financial services dedicated to supporting both on-and-off-farm agricultural activities and the industrial sector (Anyanwu et al, 1997; Marafa, 2021). It is a type of financing, such as loans, letters of credit, or bankers' acceptances, provided to individuals or businesses for use in the production activities related to the production, storage, and distribution of agricultural produce. Its importance lies in the fact that farmers need to adopt improved technologies, which usually involve a higher cost of production, in addition to the purchase of seeds, fertilizers, pesticides, farming tools and equipment, feed for livestock, water, etc. The availability of these basic inputs would increase the productivity of farmers. Thus, credit is an essential ingredient in the growth strategy of the agricultural sector.
- **Money Supply:** This is the total currency and other liquid assets of a country at a particular period. This represents the stance of the monetary authority and the availability of financial resources within the economy. A sufficient money supply is an indication that lending to farmers is affordable and available, which can positively influence agricultural output by improving farmers' purchasing power and their ability to invest in agricultural inputs and technologies. A positive relationship is expected between money supply and agricultural output.
- **Exchange Rate:** The real exchange rate is the purchasing power of a currency relative to another currency. It serves as a policy variable to bring in the effect of a country's macroeconomic and trade policies. The real exchange rate is a macro price and affects both the prices of imported inputs and tradable outputs. A volatile exchange rate could affect the importation of necessary agricultural inputs from technologically advanced countries (Muraya & Ruigi, 2017). The relationship between the exchange rate and agricultural productivity is rather uncertain.
- **Inflation Rate:** This is a sustained general increase in price levels of goods and services, measured in terms of the consumer price index over time. For prices of agricultural outputs, the relationship between price level and agricultural output is expected to be positive, while for prices of agricultural inputs, the relationship is expected to be negative. An unstable inflation rate could influence domestic consumption as low agribusiness output accompanies a low supply of agricultural products due to instability in food prices.

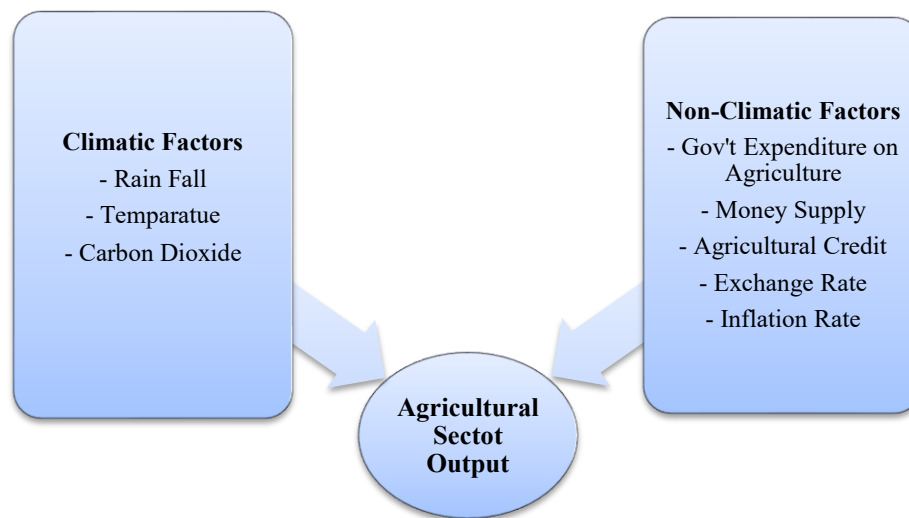


Figure 1: Determinants of Agricultural Output

2.2 Theoretical Literature

This study is based on two main theories- the Cobb-Douglas production function and the Endogenous Growth Theory. According to the Cobb-Douglas production function, output is a function of two or more inputs (particularly labour and physical capital). The Cobb-Douglas production function is expressed as:

$$Q(L, K) = AL^{\beta}K^{\alpha} \dots \dots \dots (1)$$

Where Q = Output quantity, L = labour input, K = physical capital, A = the total factor of productivity, and α and β reflect the output elasticity.

Endogenous Growth Theory, on the other hand, argues that to achieve long-run growth, government interventions are required in the form of policies to manage macroeconomic factors such as the inflation rate, exchange rate, and money supply, among others, to affect output growth (Lucas, 1988). Enete (2017) argued that agricultural output is strongly affected by climatic factors such as rainfall, temperature, and carbon dioxide, among others. Therefore, incorporating the components of the Endogenous Growth Theory and climatic factors, the Cobb-Douglas production function can be expressed as:

$$Q(L, K, M, C) = AL^{\beta}K^{\alpha} M, C \dots \dots \dots (2)$$

Where M = macroeconomic factors, and C = climatic factors

In equation (2), the sum of exponents ($\alpha + \beta$) measures returns to scale, while output elasticity measures the response of agricultural output to a change in climatic (rainfall, temperature, and carbon dioxide) and

non-climatic factors (government expenditure on agriculture, agricultural credit, exchange rate, inflation rate, and money supply).

2.3 Empirical Literature

Kakar et al. (2016) examined the determinants of productivity in the agricultural sector in Pakistan with annual data ranging from 1990 to 2017 and the ARDL framework. The study found that the application of fertilizer, the size of area under cultivation, loans to the farmers, and average rainfall exerted a significant positive impact on agricultural productivity, while the use of pesticides and labour engaged had a positive but statistically insignificant influence on agricultural output in the long run.

Building upon the findings from Pakistan, Maniriho and Bizoza (2016) estimated the Cobb-Douglas production function to determine the factors influencing crop production in Rwanda. Using a structured questionnaire to collect data from a survey of randomly selected 107 farmers in Musanze and employing the ordinary least squares technique, the study found that crop production was positively linked to fertilizer application, labour supply, availability of seeds and pesticides, with high significance in labour supply, fertilizer application, and seeds.

Enete (2017) examined the impact of climatic factors on agricultural productivity in Enugu state, Nigeria, using descriptive statistics and correlation techniques on primary data collated from Enugu State Agricultural Development Programme (ENADP) and secondary data on rainfall for the period between 1981 and 2010 sourced from Nigerian Meteorological Agency. The result indicated that there was a significant change in seasonal rainfall and that the traditional crops, except cassava and pepper, experienced a significant decrease as rainfall continued to diminish.

The determinants of agricultural production in Kenya were investigated by Nwachukwu and Shisanya (2017) using secondary data spanning from 1970 to 2012. Using the quadratic equation, the log of the equation showed that agricultural production in Kenya was principally affected by labour, precipitation, and the availability of arable land for farming.

Confirming this result, Muraya and Ruigi (2017) applied the Cobb-Douglas production function and the OLS estimation approach technique to identify the determinants of agricultural productivity in Kenya. The study found that annual rainfall, increase in government agricultural expenditure, and rainfall were responsible for the increase in agricultural output. The long-run results indicated an inverse impact on inflation and exchange rate on agricultural output, while rainfall, labour force, and government agricultural expenditure exerted a positive influence on agricultural productivity.

Omekwe et al. (2018) investigated the determinants of agricultural output in Nigeria with data spanning from 1985 – 2016, using the Johansen cointegration test and error correction mechanism. The results indicated the existence of a long-run relationship and that agricultural credit, government agricultural funding, and climate change are mainly responsible for agricultural output.

Epule et al. (2018) analyzed the climatic and non-climatic determinants of crop yields in Uganda. The study involved a systematic approach using multiple linear regression, and the result indicated that non-climatic determinants of crop yields, like wood fuel, dynamics in forest area, and usage of tractors, were significant determinants of crop production more than climatic fundamentals such as temperature, CO₂ emissions, and precipitation.

Dennis and Lyabode (2020) investigated the impact of agricultural production determinants on agricultural output in Nigeria using the OLS and Granger causality techniques. The result of the OLS model indicated that agricultural funding, exchange rate, and agricultural credits positively influence agricultural output, while the Granger causality test showed that agricultural funding, agricultural credit, and exchange rate granger caused agricultural production output. The study recommended adequate budgetary provisions and provision of credit facilities for the agricultural sector.

Ene et al (2022) examined the climatic and non-climatic determinants of agribusiness output in Nigeria using the ARDL technique and data covering the period 1981 – 2018. The result indicated that agribusiness output was mainly determined by temperature level, exchange rate, capital, and labour employed in the long run, while both climatic and non-climatic factors were significant determinants of agribusiness output in Nigeria in the short run.

3. Methodology

The study used secondary data on an annualized basis obtained from the Central Bank of Nigeria (CBN) statistical bulletin and the publications of the National Bureau of Statistics (NBS) covering the period from 1981 to 2022. The dependent variable is agricultural output proxied by agricultural share of GDP, while the dependent variables are climatic factors: rainfall, temperature, and carbon emission, and non-climatic factors: government expenditure on agriculture, money supply, agricultural credit, inflation, and exchange rate.

This study adapts the Cobb-Douglas production function and endogenous growth model, which states that production is a function of labour and capital, and government intervention is needed to achieve long-run growth in output. In adapting this theoretical framework, the study follows Ene et al. (2022), who studied the determinants of agribusiness output in Nigeria, with some modifications. The functional model in their study was specified as:

$$ABO = f(RNF, TRP, FMZ, EXR, IFR, MPR, CAP, LAB) \dots\dots\dots (3)$$

Where ABO is agribusiness output, RNF is average rainfall, TPR is average annual temperature, FMZ is farm size, EXR is exchange rate, IFR is inflation, MPR is monetary policy rate, CAP is capital for agribusiness, and LAB is labour force. The model used in Ene et al. (2022) was modified by breaking the model into two climatic and non-climatic models. More so, this study includes carbon Emission which is increasingly becoming a global concern recently, and the disaggregation of capital into government expenditure and bank loans to agriculture to differentiate between public sector and private sector investment in agriculture. Additionally, money supply is introduced to account for investment in agriculture, coming as a result of growth from other sectors of the economy. Thus, the models used for this study are specified as:

Model for Climatic Factors (Model I):

$$AGO = f(RF, TEM, CO2F) \dots\dots\dots (4)$$

In an explicit form, the functional and econometric relationship is specified as:

$$AGO = \beta_0 + \beta_1 RF + \beta_2 TEM + \beta_3 CO2F + \mu t \dots\dots\dots (5)$$

The log-linear form of the model can be specified as:

$$\log AGO = \beta_0 + \beta_1 \log RF + \beta_2 TEM + \beta_3 \log CO2F + \mu t \dots (6)$$

Model for Non-climatic Factors (Model II):

$$AGO = f(GEA, AGC, MS, EXR, INF) \dots\dots\dots (7)$$

In an explicit form, the functional and econometric relationship is specified as:

$$AGO = \beta_0 + \beta_1 GEA + \beta_2 AGC + \beta_3 MS + \beta_4 EXR + \beta_5 INF + \mu t \dots (8)$$

The log-linear form of the model can be specified as:

$$\log AGO = \beta_0 + \beta_1 \log GEA + \beta_2 \log AGC + \beta_3 \log MS + \beta_4 EXR + \beta_5 INF + \mu t \dots (9)$$

Where:

AGO = Agricultural Output

RF = Rainfall,

TEM = Temperature,

CO2F = Carbon Emission

GEA = Government Expenditure on Agriculture,

AGC = Agricultural Credit,

MS = Money supply

EXR = Exchange rate.

INF = Inflation

Log=logarithm

β_0 = Constant terms/ intercept;

$\beta_1 - \beta_5$ = coefficient of the explanatory variables.

μ = the error term

A diagnostic test is first performed on the dependent and independent variables by way of descriptive statistics. The variables used in the study were analyzed to examine their stochastic properties and to aid in the selection of the right econometric framework for analysis. The traditional Augmented Dickey-Fuller (ADF) unit root test was employed, and complemented by the Phillips-Perron (PP), based on the premise that it is commonly regarded as having superior consistency than the ADF owing to its heftiness amid serial correlation and heteroskedasticity (Hamilton, 1994). Rejecting the null hypothesis of the unit root test, which implies that the time series variable is I(1) or non-stationary. The test was performed using constant and trend specification as indicated in equations (10).

$$x_t = \beta_0 + \beta_1 x_{t-1} + \beta_2 t + \varepsilon_t \dots \dots \dots (10)$$

where x represents the variable of interest, ε_t is the residual, β_0 is the constant, $\beta_1 x_{t-1}$ is the lag values of the variables of interest, and $\beta_2 t$. A stationary time series is a variable with constant mean and variance ($\beta < 1$), while a non-stationary series has different properties over time ($\beta = 1$) or is explosive and non-stable ($\beta > 1$). The null hypothesis of the ADF and PP states that there is a unit root in the series. If the p-value of the series is greater than 5% critical value ($p > 0.05$), we cannot reject. Second, the Autoregressive Distributed Lag (ARDL) bound testing method established by Pesaran and Shin (1999) and Pesaran et al. (2001) was used to examine whether there exists a long-run relationship exists between the series. The ARDL superiority lies in the flexibility to incorporate both I(0) and I(1), making it suitable for small sample sizes and ensuring unbiased estimates of long-run parameters (Harris & Sollis, 2003). The long-run form of the model can be specified as:

Model I:

$$\begin{aligned} \Delta \log AGO_t = & \beta_0 + \sum_{t=1}^k \beta_1 \Delta \log AGO_{t-1} + \sum_{t=1}^k \beta_2 \Delta \log RF_{t-1} + \sum_{t=1}^k \beta_3 \Delta TEM_{t-1} \\ & + \sum_{t=1}^k \beta_4 \Delta \log CO2F_{t-1} + \gamma_1 AGO_{t-1} + \gamma_2 RF_{t-1} + \gamma_3 TEM_{t-1} + \gamma_4 CO2F_{t-1} + \varepsilon \\ & + \varepsilon_{2t} \dots \dots \dots (11) \end{aligned}$$

Model II:

$$\begin{aligned}
\Delta \log AGO_t = & \beta_0 + \sum_{t=1}^k \beta_1 \Delta \log AGO_{t-1} + \sum_{t=1}^k \beta_2 \Delta \log GEA_{t-1} + \sum_{t=1}^k \beta_3 \Delta \log AGC_{t-1} \\
& + \sum_{t=1}^k \beta_4 \Delta \log MS_{t-1} \\
& + \sum_{t=1}^k \beta_5 \Delta EXR_{t-1} + \sum_{t=1}^k \beta_6 \Delta INF_{t-1} + \gamma_1 AGO_{t-1} + \gamma_2 GEA_{t-1} + \gamma_3 AGC_{t-1} \\
& + \gamma_4 MS_{t-1} + \gamma_5 EXR_{t-1} + \gamma_6 INF_{t-1} + \varepsilon_{1t} \dots \dots \dots (12)
\end{aligned}$$

Δ This is the first difference. β_0 and ε are constant and the error term, respectively. Equations (11) and (12) test the null hypothesis $H_0: y_1 = y_2 = y_3 = y_4 = 0$, and $H_0: y_1 = y_2 = y_3 = y_4 = y_5 = y_6 = 0$, there is no cointegration between the variables against the alternative hypothesis $H_0: y_1 \neq y_2 \neq y_3 \neq y_4 \neq 0$, and $H_0: y_1 \neq y_2 \neq y_3 \neq y_4 \neq y_5 \neq y_6 \neq 0$ using the bounds testing procedure, respectively. First, the top optimal lag length for the model will be chosen, and then the F-test will be used to give the upper and lower bounds critical values. The test's decision rule is that if the F-statistic is greater than the upper boundary, we reject the null hypothesis of no cointegration. When a long-run cointegration exists, the conditional ARDL model is estimated using the ordinary least squares method (OLS) determined by a given information criterion in the second phase. The short-term relationship can be estimated using the error correction model. The short-run form of the model can be specified as:

Model I:

$$\begin{aligned}
\Delta \log AGO_t = & \beta_0 + \sum_{t=1}^k \beta_1 \Delta \log AGO_{t-1} + \sum_{t=1}^k \beta_2 \Delta \log RF_{t-1} + \sum_{t=1}^k \beta_3 \Delta TEM_{t-1} \\
& + \sum_{t=1}^k \beta_4 \Delta \log CO2F_{t-1} + \delta ETC_{t-1} + \varepsilon_{2t} \dots \dots (13)
\end{aligned}$$

Model II:

$$\begin{aligned}
\Delta \log AGO_t = & \beta_0 + \sum_{t=1}^k \beta_1 \Delta \log AGO_{t-1} + \sum_{t=1}^k \beta_2 \Delta \log GEA_{t-1} + \sum_{t=1}^k \beta_3 \Delta \log AGC_{t-1} \\
& + \sum_{t=1}^k \beta_4 \Delta \log MS_{t-1} \\
& + \sum_{t=1}^k \beta_5 \Delta EXR_{t-1} + \sum_{t=1}^k \beta_6 \Delta INF_{t-1} + \delta ETC_{t-1} + \varepsilon_{2t} \dots \dots \dots (14)
\end{aligned}$$

where, δ is the coefficient of the ECT (the error correction term), which quantifies the haste of conjunction of the series to the long-run equilibrium and represents the residual. For short-run convergence to occur, the coefficient should be statistically significant and negative.

4. Results and Discussions

4.1 Presentation of the Results

Table 1: Result of the Descriptive Statistics

	AGO	CO2	RF	TEM	AGC	GEA	MS	INF
Mean	8,473.149	89985.02	1460.725	0.739707	3,220,109.0	20.69444	8126.415	19.75146
Median	5,024.542	90060.00	1450.700	0.766000	728,545.4	7.537355	1269.322	13.67000
Maximum	18,738.41	120,337.0	1,808.600	1.559000	12,456,251	76.60099	40,318.29	76.76000
Minimum	2,303.505	59,020.00	1,145.180	-0.412000	24,654.90	0.012770	14.47117	0.220000
Std. Dev.	5,702.712	16,656.32	147.0557	0.415924	3,898,679.	24.38010	11,875.70	17.59854
Skewness	0.496468	-0.091603	0.123651	-0.391495	0.856914	0.916470	1.362983	1.752641
Kurtosis	1.687839	2.038801	3.192281	3.178217	2.297717	2.523509	3.560473	5.146527
Jarque-Bera	4.625633	1.635676	0.167639	1.101591	5.860276	6.127299	13.23107	28.86158
Probability	0.098982	0.441385	0.919597	0.576491	0.053390	0.046717	0.001339	0.000001
Observations	41	41	41	41	41	41	41	41

Source: Authors' Computation.

Table 1 above presents the results of descriptive statistics. Given the overlap of variables between models I and model II, the descriptive statistics of the variables are discussed jointly. The results indicated that the series were consistent as their mean and median values were within their minimum and maximum values. The AGC has the highest standard deviation of 3,898,679, while TEM has the lowest standard deviation of 0.415924 in the series. This shows the amount of variation or dispersion of the set of values. A low standard of deviation indicates that the values tend to be close to the mean of the set, while a high standard deviation indicates that the values are spread out over a wider range. Two variables, CO2 and TEM, have a negative skewness, which indicates that the tail of the distribution is longer on the left side and the mean is lower than the median and mode. Four variables, AGO, AGC, GEA, and CO2, have kurtosis lower than 3; the distribution of these series is platykurtic. Except for AGO, RF, and TEM, the Jarque-Bera probability of the other series shows that they are normally distributed based on the null hypothesis at 5% significance level.

Table 2: Result of ADF Unit Root Test (Model I and II)

Climatic Factor Model (Model I)					
Variables	LEVELS		1ST DIFFERENCE		Order of Integration
	T-Stat	P-Values	T-Stat	P-Values	
LAGO	-1.821734	0.6754	-5.926947	0.0001*	I(1)
LCO2F	-3.155963	0.1079	-7.564672	0.0000*	I(1)
LRF	-5.890910	0.0001*	-	-	I(0)

TEM	-5.469107	0.0003*	-	-	I(0)
Non-Climatic Factor Model (Model II)					
Variables	LEVELS	P-Values	1ST DIFFERENCE		Order of Integration
	T-Stat		T-Stat	P-Values	
LAGO	-1.821734	0.6754	-5.926947	0.0001*	I(1)
LAGC	-1.163044	0.9046	-5.687117	0.0002*	I(1)
LGEA	-2.075226	0.5433	-6.940594	0.0000*	I(1)
LMS	-0.088538	0.9934	-4.213863	0.0099*	I(1)
EXR	0.068481	0.9958	-4.776618	0.0023*	I(1)
INF	-4.164558	0.0113**	-	-	I(0)

Note: *, and ** represent 1% and 5% significance, respectively.

Source: Authors' Computation.

Table 2 presents the results of the ADF unit root test conducted separately for both Model I and Model II. The results showed that two variables - LAGO and LCO2F in model I and five variables - AGO, LAGC, LGEA, LMS, and EXR in model II are non-stationary at the level, hence, we failed to reject the null hypothesis of the unit root test. However, the variables become stationary after the 1st difference. While two variables - LRF and TEM in Model I and one variable – INF in Model II indicated that they are stationary at levels, as such, we reject the null hypothesis of the unit root test. In all, and irrespective of the model, the variables showed a mixed order of integration (i.e., I(0) and I(1) variables, hence, justification for the use of the ADRL approach.

Table 3: ARDL Bound Test Approach to Cointegration (Model I and II)

	Model I (Climatic Model)		Model II (Non-Climatic Model)	
F-statistics	8.225488		6.232645	
Significance	I0 Bound	I1 Bound	I0 Bound	I1 Bound
10%	2.26	3.35	2.72	3.77
5%	2.62	3.79	3.23	4.35
2.5%	2.96	4.18	3.69	4.89
1%	3.41	4.68	4.29	5.61

Source: Authors' Computation.

Table 3 presents the result of the ARDL Bound test for both Model I and II. The F-statistic for Model I is 8.23, exceeding 1 % critical value for the upper bound. Similarly, the bounds test F-statistic for Model II is 6.23 higher than the 1% critical value for the upper bound. These results suggest that we reject the null hypothesis of no long-run relationship, implying that cointegration exists among the variables included in both models.

Table 4: Long Run Coefficient for Model I and II

Model I (Climatic Model)		Model II (Non-Climatic Model)	
Variable	Coefficients	Variable	Coefficients

LCO2F	0.150143 (1.617927)	LAGC	0.111953 (4.043650) *
LRF	-0.180008 (-2.247342) **	LGEA	-0.035630 (-1.445751)
TEM	-0.393759 (-3.378604) **	LMS	0.151223 (3.109405) **
C	53.364926 (1.853613) ***	EXR	0.001436 (6.256004) *
		INF	-0.002125 (-1.713719)
		C	6.225331 (25.010293) *

Note: Figures in parentheses are t-statistics. *, **, and *** indicate 1%, 5% and 10% level of significance, respectively.

Source: Authors' computation.

Table 4 presents the result of the ARDL long-run analysis for Model I and II estimated with restricted constant using (1, 1, 4, 4) and (4, 3, 4, 2, 4, 4) selected based on the Akaike Information Criterion (AIC), respectively. The long-run coefficients of carbon emission show a positive and statistically insignificant relationship with agricultural output. The coefficient of rainfall is negative and statistically significant at 5% level, implying that a unit increase in this variable will decrease agricultural output by -0.180008 equivalents to 18.0% in the long-run. The coefficient of temperature is negative and statistically significant at 1%, implying that a unit increase in this variable will decrease agricultural output by -0.393759, equivalent to 13.9% in the long run.

The long-run coefficients of agricultural credit show a positive and significant relationship with agricultural output at the 1% level. This means that a unit change in the variable increases agricultural output by 0.111953, or about 1.11% in the long run. The long-run coefficients of Government expenditure on agriculture indicated a negative and insignificant relationship with agricultural output. The long-run coefficients of Money supply demonstrated a positive and statistically significant relationship with agricultural output at 1% level. This implies that a unit change in money supply increases output by 0.151223, or 1.51%, in the long run. The long-run coefficient of the exchange rate has a positive and significant effect at 1%, so a unit appreciation in the Naira increases output by 0.001436, or 0.01%. The coefficient of Inflation, however, shows a negative and insignificant long-run relationship with agricultural output.

Table 5: Short Run Coefficient and ECT for Model I and II

Model I (Climatic)		Model II (Non-Climatic)	
Variable	Coefficients	Variable	Coefficients
D(LCO2F)	-0.063302 (-0.462128)	D(LAGO(-1))	0.150594 (1.058903)
D(LRF)	0.077587 (0.682076)	D(LAGO(-2))	0.205831 (2.195196)**
D(LRF(-1))	0.284337 (2.574558)*	D(LAGO(-3))	0.336556 (2.664999)**
D(LRF(-2))	0.065484 (0.592033)	D(LAGC)	-0.042501 (-1.647970)
D(LRF(-3))	0.443025 (3.906142)*	D(LAGC(-1))	-0.027494 (-1.796618)
D(TEM)	-0.048913 (-1.113369)	D(LAGC(-2))	-0.046695 (-2.568330)**
D(TEM(-1))	-0.054271 (-1.362530)	D(LGEA)	-0.015641 (-1.470907)

D(TEM(-2))	-0.024035 (-0.610562)	D(LGEA(-1))	0.017857 (1.782436)
D(TEM(-3))	-0.120790 (-2.912774)*	D(LGEA(-2))	-0.038989 (-3.623563)*
CointEq(-1)	-0.116892 (-2.266430)**	D(LGEA(-3))	-0.011621 (-0.909890)
		D(LMS)	0.051813 (0.667750)
		D(LMS(-1))	0.155321 (2.547077)**
		D(EXR)	0.000292 (0.956668)
		D(EXR(-1))	0.001144 (2.144658)**
		D(EXR(-2))	-0.002431 (-4.849541)*
		D(EXR(-3))	0.000660 (1.562988)
		D(INF)	0.000056m (0.113298)
		D(INF)	-0.000498 (-1.265724)
		D(INF)	0.000286 (0.688675)
		D(INF)	0.001634 (3.190096)*
		CointEq(-1)	-0.909709 (-5.410763)*

Note: Figures in parentheses are t-statistics. *, **, and *** indicate 1%, 5% and 10% level of significance, respectively.

Source: Authors' computation.

Table 5 shows the result of the ARDL short-run analysis for Models I and II. The result shows that the coefficient of the error term is negative and significant at 1% level. The value of the ECT is -0.116892, which implies that the previous period deviation from the long-run equilibrium is corrected in the current period at an adjusted speed rate of 1.68 percent. This has further reaffirmed the result of the ARDL Bound test.

The short-run coefficient of carbon dioxide shows a negative and statistically insignificant relationship with agricultural output. The coefficient of rainfall is positive and statistically significant at 1% level, implying that a unit increase in this variable will increase agricultural output by 0.284337, equivalent to 2.84%. The coefficient of temperature is negative and statistically significant at 3 lags, implying that a unit increase in this variable will decrease agricultural output by -0.120790, equivalent to 1.21% in the short run.

The short-run coefficient of the agricultural credit shows a negative and significant relationship with agricultural output after 2 lags, implying that a unit change in the variable will decrease agricultural output by -0.046695, equivalent to 0.47 after 2 years' lags. The coefficient of government expenditure on agriculture shows a negative and significant relationship with agricultural output after 2 lags, implying that a unit change in the variable will decrease agricultural output by -0.038989, equivalent to 0.39% after 2 years' lags. The coefficient of money supply shows a positive and significant relationship with agricultural output after 1 lag, implying that a unit change in the variable will increase agricultural output by 0.155321, equivalent to 1.55% after a year lag. The coefficient of exchange rate shows a positive and significant relationship with agricultural output after 1 lag, implying that a unit appreciation in the Naira exchange will increase agricultural output by 0.001144, equivalent to 0.01% after 1 year lag. INF shows a positive and

significant relationship with agricultural output at 1%, implying that a unit change in the variable will increase agricultural output by 0.001634, equivalent to 0.02% in the short run.

The CUSUM (cumulative sum of recursive residuals) and the CUSUMSQ (cumulative sum of recursive residuals) graphs are used to test the stability of the parameters for Mode I and II as suggested by Pesaran and Pesaran (1997). The null hypothesis is that the regression equations are correctly specified with stable parameters. The lines are well within the confidence bands, indicating that the models are relatively stable and consistent (see Figures 2 and 3). Therefore, the null hypotheses of stability are not rejected.

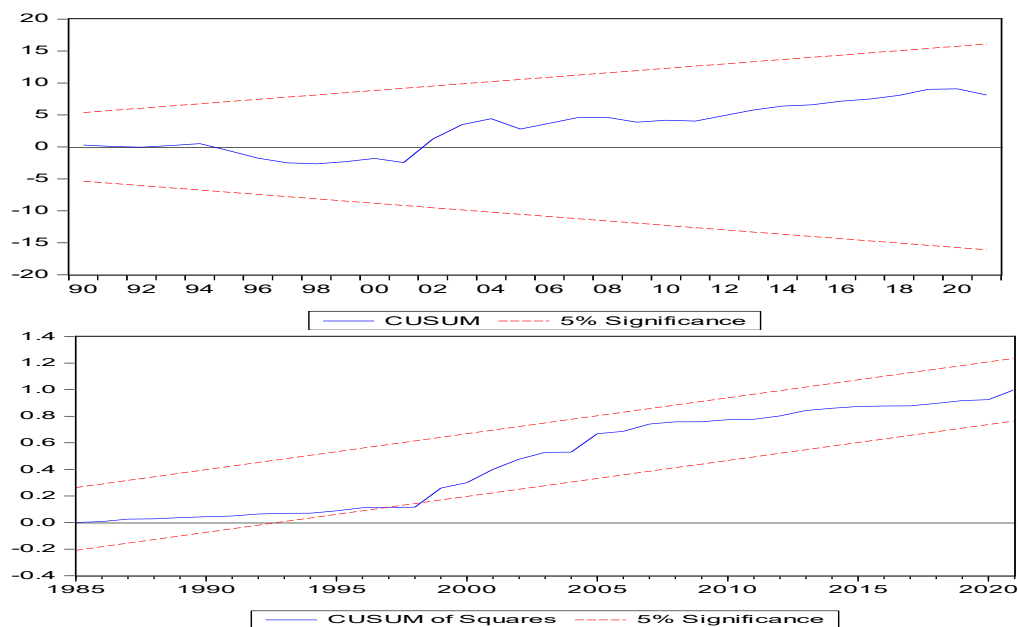


Figure 2: The CUSUM Stability Test (Model 1)

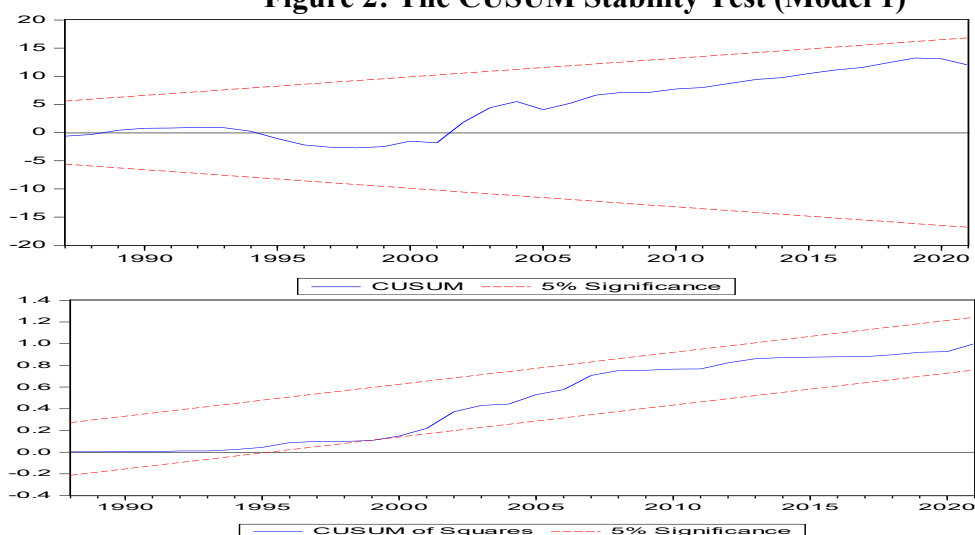


Figure 3: CUSUM Stability Test (Model 2)

The study further conducts diagnostic tests on the residuals. The results showed, in Table 6, that the residuals of the ARDL models are free from autocorrelation, heteroskedasticity, and abnormality in the residuals.

Table 6: Result of the Diagnostics Test

Test	Model I		Model II	
	t-statistics	probability	t-statistics	probability
Normality Test (Jarque-Bera Statistics)				
	1.781627	0.4103	0.754662	0.7219
Serial Correlation Test (Breusch-Godfrey LM test)				
	0.124425	0.8837	2.212868	0.1718
Heteroskedasticity Test (White Heteroskedasticity)				
	1.188762	0.3462	1.157379	0.4239

Source: Author's computation.

4.2 Discussion of the Findings

The results of the ARDL Bound tests for both models suggested that we reject the null hypothesis of no long-run relationship, implying that cointegration exists among the variables included in both models. This indicates that the variables included in both models move together. This result is consistent with findings in Omekwe et al. (2018), Ene et al. (2022), Abdullahi and Marafa (2023) for Model I, and Oparinde et al (2017), Olowofeso et al (2017), and Marafa (2021) for Model II.

In the long-run, carbon emission has a positive and statistically insignificant relationship with agricultural output, which is contrary to expectation and in agreement with the result found in Abdullahi and Marafa (2023). Rainfall has a negative and statistically significant relationship with agricultural output, implying that an increase in rainfall to a certain level will lower agricultural output. This explains the series of crop destruction due to flooding, root rot, and crop failure as a result of excessive rainfall in some states recently. This result is in agreement with the findings of Abdullahi and Marafa (2023) and Muraya and Ruigi (2017) but is contrary to Ene et al. (2022) and Enete (2017). Temperature is negative and statistically significant relationship with agricultural output. Excessive temperature could hinder agricultural output as a myriad of crops and animals might not thrive under such harsh weather conditions. This is consistent with Omekwe et al. (2018) and Ene et al. (2022).

The long-run coefficients of agricultural credit show a positive and significant relationship with agricultural output. This means that increases in agricultural output are linked to fund availability, enabling farmers to purchase inputs and expand cultivatable area for growth. These findings are consistent with our expectations and with Dennis and Lyabode (2020) and Kakar et al. (2016). Government expenditure on agriculture shows

a negative and insignificant relationship with agricultural output. This might be because those who benefited from government funding through subsidies or schemes are not real farmers - a common political practice in the country. The Money supply demonstrates a positive and significant relationship with agricultural output. More money available in an economy encourages investment in different sectors, including agriculture. This is consistent with theory as an increase in money supply stimulates output growth. The exchange rate has a positive and significant effect on output growth. A likely reason for this is that a higher exchange rate makes agricultural imports expensive, causing consumers to rely more on domestic products and boosting output. Inflation, however, shows a negative and insignificant long-run relationship with agricultural output.

The short-run coefficient of carbon dioxide shows a negative and statistically insignificant relationship with agricultural output. The sign is in agreement with our expectations. The coefficient of rainfall is positive and statistically significant. This is consistent with our expectation, as rainfall is a primary driver of agricultural output in rain-fed systems. This is consistent with the results in Muraya and Ruigi (2017), Enete (2017), and Kakar et al. (2016). The coefficient of temperature is negative and statistically significant at 3 lags. This is consistent with our expectation, as rising temperatures generally have a detrimental impact on output. This is in agreement with Ene et al (2022).

The short-run coefficient of the agricultural credit shows a negative and significant relationship with agricultural output after 2 lags. This may primarily be due to high interest rates that discourage borrowing, misapplication or diversion of funds by farmers, and bureaucratic bottlenecks that delay loan disbursement until after the planting season. The coefficient of government expenditure on agriculture indicated a negative and significant relationship with agricultural output. This is inconsistent with our theoretical expectation. Possible reasons for this could be when funds are misallocated, poorly implemented, or foster dependency rather than productivity, late release of funds and subsidies, corruption, etc. The coefficient of money supply indicated a positive and significant relationship with agricultural output. This is consistent with theory as money supply boosts short-run output by lowering interest rates, which reduces the cost of borrowing to the farmers for the purchase of essential outputs like fertilizer, seeds, machinery, and agrees with the result found in Kakar et al. (2016) and Dennis and Lyabode (2020). The coefficient of exchange rate indicated a positive and significant relationship with agricultural output. This is consistent with our expectation, as an increase in the exchange rate (currency depreciation can boost short-run output by making exports cheaper and more competitive for international buyers, which stimulates output. The coefficient of inflation indicated a positive and significant relationship with agricultural output. This is expected as short-run higher output prices will boost farmers' revenue, and by incentivizing farmers to expand production to take advantage of the rising price. This result confirmed the results in Dennis and Lyabode (2020).

5. Conclusion and Recommendations

5.1 Conclusion

The study examines the determinants of agricultural sector output in Nigeria using the ARDL Bound tests. Annual time series data for climatic factors (rainfall, temperature, and carbon emission) and non-climatic factors (Government expenditure on agriculture, agricultural credit, money supply, exchange rate, and Inflation) over the period 1981 to 2022 are used. The empirical results for both climatic and non-climatic models show that there exists a long-run cointegration relationship between agricultural output and selected climatic and non-climatic variables over the study period. Specifically, rainfall and temperature (for climatic) and agricultural credit, money supply, and exchange rate (for non-climatic) significantly influence agricultural output in both the short run and long run.

5.2 Recommendations

The study recommends for the following: Effective management of excessive rainfall to control floods through the constructions of dams, clearance of waterways blockage and control of human activities that results in excessive temperature in the atmosphere; Government should effectively use its macroeconomic policies (monetary and fiscal) to ensure increase credit facilities to the farmers, enhanced budgetary allocation to agricultural sector, maintenance of a stable exchange rate and single digit inflation to strengthen domestic macroeconomic environment.

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