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Quantifying the Effect of Change in Rainfall Dynamics on Agricultural Output in Nigeria

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ABSTRACT: Agricultural production has clearly gained acceptance, as a crucial approach to meeting the food consumption needs of Nigeria's growing population as well as an important requirement for achieving food security. Hence, the objective of this paper is to quantify the effect of change in rainfall dynamics on agricultural output in Nigeria employing a Dynamic Computable General Equilibrium model and using data from the 2019 Social Accounting Matrix. The results revealed that rainfall shocks had an adverse effect on the four components of agricultural output considered such as crops, livestock, fishery and forestry in the short and long term. It also had a negative effect on aggregate agricultural output compared to the baseline scenario. Therefore, public policy towards investing heavily in rain harvesters cannot be overemphasized. There is the need for policy efforts towards targeted interventions that provide an enabling environment and the necessary infrastructures for private investments in agriculture, address climatic risks and build resilience among farmers.

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The United Nations Sustainable Development Goals encompasses the crucial objectives of eradicating global hunger, enhancing nutrition, fostering sustainable agriculture, and attaining food security (Griggs *et al*., 2013). Nevertheless, the distribution of agricultural production, as well as the global markets and food supply, will be significantly impacted by human-induced climate change (Porfirio *et al*., 2016). Food systems also play a crucial role in addressing societal demands and facilitating resilience to climate change effects. However, it is important to acknowledge that these systems are also accountable for up to one-third of the total greenhouse gas emissions worldwide. In reaction, the Declaration, known as the 'COP28 UAE Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action', was unveiled during a dedicated session of the World Climate Action Summit (WCAS). Its purpose is to tackle climate change and safeguard the well-being and economic stability of farmers who are directly impacted by the effects of climate change.

Agricultural production in Nigeria relies heavily on rainfall. Consequently, the occurrence of intense rainfall patterns and/or fluctuations poses a significant risk to production (Olayide *et al*., 2016). The vulnerability of the rain-fed agricultural production system to seasonal variability, as highlighted by Venkateswarlu and Singh (2015) and Alemaw and Simalenga (2015), significantly affects the livelihood outcomes of farmers and landless laborers who rely on this particular method of agricultural production.

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Severe flooding occasioned by intense rainfall has resulted in the fatalities of more than 600 individuals and the displacement of 1.3 million from their residences, marking the most catastrophic occurrence of seasonal floods in Nigeria in the past ten years. The combination of intense rainfall and inadequate urban development heightened vulnerability to flooding (World Economic Forum, 2022). The World Bank (2021) estimated that the flooding caused significant losses and devastation, reaching approximately $17 billion in the twelve states most affected by the calamity. Moving forward to 2022, floods once again struck Nigeria, affecting 33 out of the 36 states. Notably, the agrarian and oil-producing states of Kogi, Anambra, Bayelsa, Cross River, Delta, Rivers, and the Federal Capital Territory (FCT) were particularly affected (Rewane, 2022).

Amare *et al*. (2018) identified three potential passthrough in the nexus between rainfall shocks and agricultural output. Firstly, rainfall shocks can directly influence crop production by serving as a crucial input. Secondly, the variability in rainfall can also influence farmers' decisions regarding the utilization of external inputs, thereby increasing the risk of crop loss and subsequently affecting agricultural production. Additionally, rainfall shocks have the potential to result in crop failure or changes in the choice of crops, which can divert production away from the initially planned trajectory. Hence, in nations such as Nigeria, where agricultural production heavily relies on rainfall, fluctuations in precipitation can serve as a reliable indicator for forecasting agricultural yield.

Therefore, this study examined the effect of rainfall disturbances on agricultural output in Nigeria. This study builds on recent studies examining the effects of rainfall variability on agricultural output (such as Bhanumurthy & Kumar, 2018; Torres *et al*., 2019; Adamu & Negeso, 2020; Talib *et al*., 2021; Ogunbode *et al*. 2022; Kotz *et al*., 2022). It highlights the significant dependence of agriculture on rainfall pattern as also shown by (Lemi, 2005; Beyer *et al*., 2016; Ogenga *et al*., 2018). This study contributed to the existing literature by investigating the short and long-term consequences of rainfall variability on agricultural production in Nigeria. Our study was motivated by the need to extend the insights provided by anecdotal literature at the country-specific level, which shed light on the impacts of rainfall variability on agricultural output (Olayide *et al*., 2016; Beyer *et al*., 2016; Saha *et al*., 2018; Kyei-Mensah *et al*., 2019; Siddig *et al*., 2020; Chandio *et al*., 2020; Antony, 2021; Bessah *et al*., 2021; Delacrétaz *et al*., 2023). Policies designed to enhance resilience to climate change and ensure food security are typically implemented on a larger scale (national level) rather than at the level of individual households and communities (IPCC, 2015). Therefore, this study presents empirical evidence on the impact of rainfall on agricultural output by considering both the overall agricultural sector and some specific agricultural sectors (such as crops, livestock, fisheries, and forestry). The study employed the dynamic computable general equilibrium approach, which provided both static and dynamic evidences.

Previous studies have shown that variations in rainfall have diverse effects on agricultural yields. Wang *et al*. (2024) which employed the Spatial Precipitation Index (SPI) to evaluate rainfall patterns utilized fixed effects methods to examine the impact of extreme rainfall shocks on rural households. Employing panel data from China's 2006-2015 National Rural Fixed-Point Survey, the results showed that both drought and rainstorm shocks had a negative effect on agricultural yield and income. Duffy and Masere (2015) utilized simulations to explore the impact of different within-season daily rainfall distributions on potential maize yields. The findings indicate that these distributions can indeed influence maize yields during periods of low rainfall, with the use of fertilizer also playing a crucial role. However, in seasons with average or above-average rainfall, the within-season variance has minimal impact on maize yields. This suggests that the effects of within-season distributions on crop yields are more pronounced in low-rainfall seasons. Sangkhaphan and Shu (2019) examined the effect of rainfall on GDP growth in Thailand at the provincial level from 2004 to 2015 using the FGLS estimator. The findings revealed that rainfall had a positive effect on economic growth in the northeastern and northern regions, particularly in the agricultural sector and its subsectors. The fishing subsector experienced a greater economic boost from rainfall compared to the farming subsector. Torres *et al.* (2019) presented a new hydro-economic model that examines how the timing and intensity of rainfall impact the productivity of a partially irrigated agricultural system in Brazil. The findings indicated that the timing of rainfall plays a crucial role as an economic factor, and models that only consider yearly shifts may underestimate the effects of water scarcity on agricultural revenue. Bortz and Toftum (2023) examined the long-term effects of climate change, specifically changes in rainfall, on a developing country like Argentina. The study utilized rainfall variations as an instrumental variable to assess the export performance of the country's main agricultural sectors between 2003 and 2019. Employing an instrumental variable methodology, the study investigated the influence of rainfall fluctuations on foreign exchange reserves, while controlling for economic indicators, capital flows, and debt repayments. The findings showed a significant correlation between reduced rainfall in January and February and decreased accumulation of reserves by the central bank.

Demeke *et al*. (2011) examined the impact of rainfall shocks on food security and vulnerability of rural households in Ethiopia. A time-variant household food security index was created through principal components analysis to categorize households into different food security groups and analyze their socioeconomic disparities. The preliminary findings indicated that households with higher food security levels typically had male and literate household heads, a larger number of economically active members, more livestock, better rainfall outcomes, and participation in local savings groups. By employing a fixed effects instrumental variable regression model with the food security index as the dependent variable, the study identified rainfall variability as a significant determinant of food security over time. The results from a multinomial logistic regression model further supported these findings by highlighting the importance of rainfall level and variability in determining persistent food insecurity and vulnerability.

Investigating the effect of climate change on agricultural output in Ethiopia from 1980 to 2016, Adamu and Negeso (2020) utilized the ARDL approach to examine both the long-run and short-run effects. Average temperature was found to have an insignificant effect on output in the short run. In the long run, both mean annual rainfall and average temperature had significant effects on agricultural output, with mean annual rainfall positively influencing output and average temperature exerting a negative effect. Bessay *et al*. (2021) used the statistical downscaling model (SDSM-DC) performance at a 2m spatial resolution for simulating rainfall in Ghana during the base period of 1981–2010. The study also examined the anticipated changes in seasonal rainfall patterns across various agro-ecological zones in Ghana for the twenty-first century under RCP 4.5 and 8.5 emission scenarios. The ensemble mean of simulated rainfall data (2011–2099) from 43 GCMs in the Coupled Model Intercomparison Project Phase 5 (CMIP5) served as the foundational elements for generating local future climate scenarios. The findings suggested a heightened risk of flooding across Ghana in the twenty-first century, with significant implications for the agricultural sector, which plays a substantial role in Ghana's GDP. Epule *et al*. (2012) investigated the effect of rainfall on cereal production in Cameroon. The research utilized a combination of fieldwork and desk-based analysis, which included the distribution of 200 questionnaires and conducting focused group discussions. The desk-based component involved an extensive literature review and the examination of Normalized Difference Vegetation Index (NDVI) satellite images depicting vegetation changes and rainfall patterns sourced from the Global Precipitation Climatology Project (GPCP). The findings revealed a decrease in cereal production despite a 30-40% increase in rainfall over the past decade within the study area.

Kyei-Mensah *et al*. (2019) investigated the correlation between the production of key crops and the distribution of rainfall in the Worobong Agroecological Area (WAA). The data covered a 30-year timeframe, divided into three decades of 10 years each. The study found that the variability in rainfall during the major seasons across the three decades was lower compared to the minor seasons. Moreover, the results revealed a decline in yields for three specific crops over the studied period.

Investigating the effects of dry spells on food production in Homa Bay County, Ogenge *et al*. (2018) specifically focused on rainfed agriculture. Using data for a sample size of 384 households and secondary data from 2007 to 2016 obtained from the Ministry of Agriculture of the County Government of Homa Bay, the study employed Chi–Square estimation method. The results showed that during dry spells, the annual crop yield for maize and beans fell below the average of 1.44 tons/ha and 0.78 tons/ha, respectively, while sorghum and millet exceeded the average with 0.94 tons/ha and 1.61 tons/ha, respectively. The livestock production was significantly affected, with a 48% decrease in weight and a 23.8% reduction in milk output. These findings highlight the severe impact of rainfall variability and dry spells on food security in Homa Bay County, leading to substantial crop failure and diminished livestock production, including fatalities. Cabral (2014) examined the effect of rainfall shocks on poverty in Burkina Faso and Senegal using the computable general equilibrium model. The study employed an index to measure the consequences of rainfall fluctuations and found that Senegal was projected to have a reduction in poverty due to an anticipated rise in annual rainfall. Conversely, Burkina Faso was projected to experience an increase in poverty rate and a declining trend in rainfall. The study also found that the implementation of mitigating policies in Burkina Faso had the potential to influence the rate of poverty increase. However, future rainfall patterns were anticipated to have a positive effect on poverty in Senegal and negative effect in Burkina Faso.

Sassi and Cardaci (2013) examined the effect of potential changes in rainfall on food availability and access in Sudan. The study employed an integrated approach that combined a stochastic method with a CGE model. The findings of the study revealed a detrimental effect on both dimensions of food security that were considered. This was primarily attributed to a decrease in cereal supply, a significant increase in cereal prices, and a contraction in income. The negative effects were particularly pronounced among the poorest households. The study also found a decline in economic performance as a result of these changes. Talib *et al*. (2020) investigated the long-term effect of temperature and precipitation on agricultural growth in 32 sub-Saharan African countries. The study employed the augmented autoregressive distributed lag (ARDL) modeling technique and panel estimators with multifactor error structures. The results showed that increasing temperatures had a significant negative effect on agricultural growth in Sub-Saharan Africa over the long term. However, the long-run effect of precipitation was insignificant in most of the estimations. Olayide *et al*. (2016) examined the effect of rainfall and irrigation on agricultural productivity in Nigeria. They utilized a time series dataset spanning 43 years and applied an Autoregressive Integrated Moving Average (ARIMA) model along with the GMM technique. The findings revealed that while precipitation had a positive effect on agricultural output, it was insignificant.

Olayide (2018) investigated the potential impact of rainfall variability on the average rice yield in Nigeria over a 22-year period from 1992 to 2013. The researcher conducted an analysis of the mean annual rainfall data from key rice-producing states and the national average rice yields using the ordinary least squares estimation techniques. The findings of the study indicated a notable disparity in mean annual rainfall levels across different vegetation zones, with the highest levels observed in swamp forests and the lowest in the Sudan savanna. The mean rainfall was deemed sufficient for rice cultivation in all vegetation zones except the Sudan savanna, where the rainfall fell below the recommended threshold for optimal rice production. While a positive correlation between rainfall and rice yield was observed in all vegetation zones except the Sudan savanna, this relationship was not statistical significance at the 5% level.

Amare *et al*. (2018) examined the effects of rainfall shocks on agricultural productivity and crop-specific agricultural land productivity. The research also analyzed the repercussions of negative rainfall shocks on household consumption, taking into account the distributional impact based on initial wealth and geographical zones. The data utilized in this study were obtained from the Nigerian Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) for the years 2010, 2012, and 2015. An instrumental variables regression method was employed, with agricultural land productivity being instrumented with negative rainfall shocks. The findings revealed that a negative rainfall shock led to a 37% decrease in agricultural productivity, subsequently reducing household consumption. Moreover, the study highlighted varying impacts of rainfall shocks on household consumption depending on the initial wealth levels and geographical locations. Specifically, rainfall shocks had a more pronounced negative effect on household consumption for asset-poor households compared to nonpoor households. Ciccone and Ismailov (2022) investigated the effect of rainfall on agricultural productivity and democratization in the most agriculturally dependent nations worldwide. The research utilized a Least Squares method with Heteroscedastic and Autocorrelation-Consistent (HAC) standard errors to account for arbitrary heteroscedasticity and serial correlation. The findings revealed a curvilinear relationship between rainfall and agricultural output, indicating that extreme weather conditions such as droughts and excessive rainfall can negatively affect agricultural productivity.

Kinda and Badolo (2019) conducted an analysis on the impact of rainfall variability on food security across 71 developing nations spanning from 1960 to 2016. Therefore, the objective of this study was to as to quantify the effect of change in rainfall dynamics on agricultural output in Nigeria utilizing ordinary least square (OLS), fixed effects (FE), and random effects (RE) in a Dynamic Computable General Equilibrium model making use of data from the 2019 Social Accounting Matrix

METHODS AND MATERIALS

Model Specification: This study employed a Dynamic Computable General Equilibrium (DCGE) model to examine the effect of rainfall shocks on agricultural output in Nigeria. These models are firmly rooted in microeconomic theory, specifically the principles of utility and profit maximization, as well as the equilibrium of product and factor markets. The parameterization of the model is typically designed to capture medium to long-term adjustments to external shocks, such as variations in rainfall, while being less suitable for representing year-to-year adjustment processes.

Using data from the 2019 Social Accounting Matrix (SAM) for Nigeria, the study applied the recursive dynamic CGE models based on Decaluwé *et al*., (2013). The key behavioural equations adopted from the model are outlined in equations 1 to 5.

$$VA_{j,t} = v_j XST_{j,t} \qquad (1)$$

$$CI_{j,t} = io_j XST_{j,t} \qquad (2)$$

$$VA_{j,t} = B_{j,t}^{VA} \left[B_{j,t}^{VA} LDC_{j,t}^{-\rho_j^{VA}} + \left(1 - B_{j,t}^{VA}\right) KDC_{j,t}^{-\rho_j^{VA}} \right]^{-\frac{1}{\rho_j^{VA}}} \qquad (3)$$

$$LDC_{j,t} = \left[\frac{B_{j,t}^{VA}}{1 - B_{j,t}^{VA}} \frac{RC_{j,t}}{WC_j, t} \right]^{\sigma_j^{VA}} KDC_{j,t} \qquad (4)$$

$$DI_{i,j,t} = aij_{i,j,t} CI_{j,t} \qquad (5)$$

Where: $VA_{j,t}$ = value added of industry *j*; $B_{j,t}^{VA}$ = total Factor Productivity of industry *j*; $LDC_{j,t}$= composite demand for labour of industry *j*; $KDC_{j,t}$ = composite demand for capital of industry *j*; $XST_{j,t}$: = Total aggregate output of industry *j* ; *io j* = Coefficient (Leontief – intermediate consumption); *vj* = Coefficient (Leontief – value added); *DIi,j* = Intermediate consumption of commodity *i* by industry *j*; $CI_{j,t}$ = Total intermediate consumption of industry *j*

Model Closure: The study adopted the premise of full employment of factor endowments and perfect competition, which implies zero economic profits, by utilizing a specific model closure. Although these assumptions may not accurately capture the unique characteristics of the Nigerian economy, they serve the purpose of narrowing down the focus of our analysis. Moreover, we consider the ease of movement for production factors such as capital and labor across sectors, while acknowledging that factors like land and natural resources exhibit less mobility. Additionally, we consider Nigeria as a small economy, which implies that global prices are determined externally and are not influenced by domestic factors. The real exchange rate is considered to be flexible, meaning it is determined by market forces, and the current account balance is treated as an exogenous variable. Furthermore, we maintain the base-year level of the distribution of factor income and foreign institutions throughout the study.

Data: In order to analyze the impact of rainfall shocks, we make use of the 2019 Nigerian Social Accounting Matrix (SAM) developed by Equilibria Consult, a Nigerian economic research consulting firm based at the University of Ibadan, Ibadan, Nigeria. (Cicowiez *et al*., 2021). The 2019 SAM offers a detailed breakdown of Forty-Six (46) sectors and commodities, with a majority of them falling under the agricultural category. The data for the 2019 Nigeria SAM was gathered from various sources and publications including the National Bureau of Statistics, the 2010 supply-and-use table, the Central Bank of Nigeria Statistical Bulletin, the Federal Inland Revenue Services (FIRS), and the World Integrated Trade Solutions of the World Bank.

The Scenario: The analysis involved a scenario where a simulation was conducted to introduce the effect of a 15% increase in rainfall and examine the effect on agricultural output. The 15% increase in rainfall caused a decline in agricultural productivity by 1.23% as estimated by Amare and Balane (2023). The 1.23% decline in agricultural productivity is thus introduced into the model and the effect on agricultural output is presented in the results. The baseline scenario presents the data as at 2019, which is the base year.

RESULTS AND DISCUSSION

Employing a dynamic computable general equilibrium model, the effect of a rainfall shock of 15% on agricultural output was estimated for both short term and long-term effects.

Short-Term Effect of a Change in Rainfall on Agricultural Output: The static (short-term) effect implies that the results presented are the effects for the current year 2023. The results are presented in Table 1. The results showed that a 15% increase in rainfall caused crop production, livestock, forest stock and fish production to decline by 2.18%, 1.37%, 1.08% and 1.62%, respectively when compared to the 2019 base year. The 15% increase in rainfall also had a negative effect on agricultural output, precisely causing a decline of -1.56% in the aggregate agricultural output in the short run, which is the weighted sum of variations in crop yield (-2.18%), livestock (-1.37%), forest stock (-1.08%), and fish production (-1.62%). This implies that the increase in rainfall caused actual agricultural output to decline below its potential output, resulting in an agricultural output gap in the short run. This shows the heavy volatility of the Nigerian agricultural sector to the vicissitudes associated with increasing rainfall and underscores the need for the country to reduce its vulnerability to rainfall changes by building a better water sustainability framework.

The result can be explained by the fact that intense rainfall, resulting in floods, are detrimental to the optimal growth of crops, animals (livestock and fish), and forest products. High levels of rainfall can cause waterlogs, potentially resulting in the loss of soil texture and agricultural products. Moreover, key factors in the agricultural sector, such as labor, may become demotivated and shift to less climate-sensitive sectors. The result is similar to Epule *et al.* (2012) and Amare *et al.* (2018). However, it contradicts the findings of Sangkhaphan and Shu (2019), which found that an increase in rainfall led to a boost in agricultural productivity.

Table 1: Simulation Results of Effect of a Change in Rainfall on Agricultural Output (Short term)

S/N	*Variables*	*2019 Base Year Value (N'Million)*	*Simulation Effect*
1	***CPN***	37,621,864.76	-2.18
2	***LSK***	6,046,291.26	-1.37
3	***FTY***	376,490.78	-1.08
4	***FHY***	2,039,263.37	-1.62
5	***Aggregate Agricultural Output***	46,083,910.17	-1.56

Source: Author's Computation based on simulation results from GAMS; Note: The simulation effect represents percentage changes from 2019 reference scenario; Agg=Aggregate CPN: Crop, LSK: Livestock, FTY: Forestry, FHY: Fishery.

Long-Term Effect of a Change in Rainfall on Agricultural Output: The dynamic (long-term) effect implies that the results are a period beyond 2023 precisely from 2023 to 2032. The results are presented in Table 2. The results showed a negative effect of an increase in rainfall on agricultural production in the long run period. The result indicates that a 15% increase in rainfall will cause crop yield, livestock production, forest stock and fishing to decrease by 2.20%, 1.44%, 1.16% and 1.71%, respectively when compared to the baseline scenario of 2019. The results presented in Table 4.18 demonstrate the negative impact of increased rainfall on agricultural output in the long term. Specifically, it is projected that a 15% increase in rainfall will result in a decline of 1.63% in aggregate agricultural output in the long term. The decline in aggregate agricultural output is the weighted sum of variations in crop yield (-2.20%), livestock (-1.44%), forest stock (-1.), and fish production (-1.71%). The result showed that an increase in rainfall will amount to an agricultural productivity gap. Nigeria's susceptibility is evident due to the fact that a significant number of its crops are situated near the limits of rainfall thresholds, leading to a decrease in yields. There is therefore the need for deliberate plans and actions to mitigate the adverse effects of high rainfall levels such as floods, water logging and salination, which may lead to poor crop yields due to the washing away of crops and a huge land surface. This reduces the availability of pasture for livestock grazing thus causing a low rate of livestock survival. Heavy rain also causes rivers to overflow their banks and this is unhealthy for fish. These negative consequences ultimately reduce agricultural output. The result is similar to Adamu and Negeso (2020), and Kyei-Mensah *et al*. (2019), which found that increased rainfall caused a decline in agricultural output. The result is however contrary to Adamu and Negeso (2020), which showed that rainfall had a positive effect on agricultural output. The result also supports the extended Solow growth theory by Nordhaus and Yang (1996), which attributed reductions in output to climatic factors such as temperature rise, increased precipitation, droughts, floods, and pest infestations.

Table 2 Simulation Results of Effect of a Change in Rainfall on Agricultural Output (Long Term)

T	**CPN**		**LSK**		**FTY**		**FHY**	
	2019 Base Year Value (N'Million)	**Effect**	**2019 Base Year Value (N'Million)**	**Effect**	**2019 Base Year Value (N'Million)**	**Effect**	**2019 Base Year Value (N'Million)**	**Effect**
1	37,621,864.76	-2.18	6,046,291.26	-1.37	376,490.78	-1.08	2,039,263.37	-1.62
2	38,750,520.71	-2.18	6,227,680.00	-1.39	387,785.51	-1.10	2,100,441.27	-1.64
3	39,913,036.33	-2.19	6,414,510.40	-1.40	399,419.07	-1.12	2,163,454.51	-1.66
4	41,110,427.42	-2.19	6,606,945.71	-1.42	411,401.64	-1.14	2,228,358.14	-1.68
5	42,343,740.24	-2.19	6,805,154.08	-1.43	423,743.69	-1.15	2,295,208.89	-1.70
6	43,614,052.45	-2.20	7,009,308.71	-1.45	436,456.00	-1.17	2,364,065.16	-1.72
7	44,922,474.02	-2.20	7,219,587.97	-1.46	449,549.68	-1.19	2,434,987.11	-1.74
8	46,270,148.24	-2.21	7,436,175.61	-1.47	463,036.17	-1.20	2,508,036.72	-1.76
9	47,658,252.69	-2.21	7,659,260.87	-1.49	476,927.26	-1.22	2,583,277.82	-1.78
10	49,088,000.27	-2.22	7,889,038.70	-1.50	491,235.08	-1.23	2,660,776.16	-1.80
Ave.	43,129,251.71	-2.20	6,931,395.33	-1.44	431,604.49	-1.16	2,337,786.92	-1.71

Source: Author's Computation based on simulation results from GAMS
Note: Effect represent percentage changes from 2019 base year / reference scenario
T=Time period (from 2023-2032, with 2019 being the base-year); Ave=Average CPN: Crop, LSK: Livestock, FTY: Forestry, FHY: Fishery

Conclusions: This study examined the effect of rainfall shocks on agricultural output in Nigeria using data from the 2019 Social Accounting Matrix and employing the dynamic computable general equilibrium model. The study estimated both short term and long-term effects of a 15 percent increase in rainfall and the results revealed that increased rainfall shocks had an adverse effect on the four components of agricultural output considered such as crops, livestock, fish and forest production in the short and long term. It also had a negative effect on aggregate agricultural output compared to the base year value in

2019. Therefore, plans and actions towards providing road, drainages and water harvesters for water management is important for preventing agricultural output reduction.

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