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Towards Climate-Resilient Agricultural Growth in Nigeria: Can the Current Cash Reserve Ratio Help?

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Abstract

The ability of the agriculture sector, which is exposed to climate hazards, to cope with climate challenges and to strive in spite of them, is conceptualized as the resilience of agriculture. In enhancing climate-resilient agriculture, the cash reserve ratio (CRR) is generally perceived to serve two crucial functions: first, encouraging banks to allocate credit to agriculturalists for climate-resilient agricultural practices; second, enhancing agriculturalists' ability to sustain agricultural output growth in spite of climate crises. In light of this, we conducted an ex post evaluation of the effect of the currently in-use CRR on bank loans to climate-challenged Nigeria's agriculture sector for climate-resilient agricultural practices. Additionally, this study investigates the CRR's impact(s) on agricultural output growth amidst climate challenges. Other additional independent variables include monetary policy rate, government capital expenditures on agriculture, and government recurrent expenditures on agriculture, as well as temperature, precipitation, and the renewable energy supply. Using annual data from 1990 to 2022, the results from an autoregressive, distributed lag approach suggest that the standard CRR stipulated by the Central Bank of Nigeria in the present era of climate change cannot entirely sustain climate-resilient agriculture, evident in the present study's discoveries on its inability to perform its two major functions (credit and growth) in enhancing agricultural resilience. These findings highlight the need for the green differentiation of the CRR to ensure its effective utilization in enhancing climate resilience.

Keywords: climate-resilient agricultural growth; cash reserve ratio; green-differentiated reserve requirements; banks' credit allocation; agricultural output growth; Nigeria

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1. Introduction

Over the years, Nigeria has experienced accelerating incidents of climate change, such as rainfall variability, floods, rising sea levels, increasing temperature, droughts, desertification, and land degradation [1,2].

Recently, in 2012, the country faced the dual shock of severe drought in the northeast and massive flooding almost across the entire nation [3], with the agriculture sector being among the most climate-vulnerable and severely affected priority sectors [3–5]. The

negative impact of climate change on this key sector is felt especially in the sector's infrastructural damages and low productivity, posing a serious threat to Nigeria's food security and economic growth. Nigeria's agricultural sector—comprising the fishery, forestry, livestock, and crop production sub-sectors [6]—is not only vulnerable and impacted by climate challenges but also a major driver of climate change, evident in recent records that disclosed "agriculture, forestry and other land uses" as having contributed to about 66.9% (476,949 Gg CO2-eq) of Nigeria's net greenhouse gas (GHG) emissions, including removals, in 2015 [7]. However, this climate-sensitive agriculture sector has remained the backbone of Nigeria's economy [8], largely driving the country's GDP growth [9,10], similarly to documented evidence from some other countries that growth in agricultural productivity is central to overall poverty reduction, as well as economic growth and development [11–14].

As the Nigerian economy heavily depends on climate-sensitive and rain-fed agriculture, coupled with the projection that the impact of climate change will keep increasing in the future [15,16], an urgent need has arisen to build climate resilience in agriculture, in addition to climate mitigation measures, with the understanding that climate inaction in this sector would dampen not only the agricultural output but also the overall output level of the country. According to the United Nations Office for Disaster Risk Reduction [17], resilience is the "ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions". In the context of climate change, this definition implies that resilience encompasses a broader view that also involves adaptation to climate change. Therefore, building climate resilience in the agriculture sector requires equipping agriculturalists with the capacity to resist, absorb, accommodate, and recover from climate shocks, stresses, and impacts, as well as to strive in spite of climate threats in a timely, efficient, and sustainable manner. Perhaps climate resilience is a major fundamental step towards attaining sustainable growth in a country such as Nigeria, which remains within the world's ten most climate-vulnerable nations [18].

Ever since the early 1990s, Nigeria has shown dedication towards addressing climate issues, evident in the country's signing of the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992, which was ratified in August 1994. Efforts in Nigeria's strategy towards promoting climate actions and building a climate-resilient society with high-growth economic development took a key turning point with the adoption of the Nigeria Climate Change Policy Response and Strategy (NCCPRS) in 2012. In line with the requirements of the NCCPRS, banks are highly expected to play a pivotal role in restoring the climate-induced low productivity from agriculture and to support the ongoing transformation towards resilient agriculture by efficiently re-directing funds/resources towards the sector's green activities and other climate actions that would not only help the sector to survive climate shocks and impacts but also to thrive in spite of them. Mindful of this expectation, the CBN has, in addition to the introduction of the Nigerian Sustainable Banking Principles in 2012, actively continued to vary its CRR to influence banks' credit towards the nations' growth goal. To further sustain and consolidate economic recovery in agriculture and other real sectors of the economy, the monetary policy committee of the CBN initiated a program in 2018 named the "Differentiated Cash Reserve Requirement (DCRR) Regime", which incentivizes deposit money banks (DMBs) to increase the flow of affordable, direct, long-run bank credits being allocated to the agricultural, manufacturing, and other sectors, considered by the CBN to be growth stimulants [19].

Despite the above-stated advances towards promoting climate actions in the agriculture sector by Nigerian banks, difficulties are still being experienced by farmers and other agriculturalists in borrowing medium- to long-term loans from banks for climate

finance. To many farmers, especially in the southern and eastern agricultural production zones, agriculture is still being challenged by flooding, erosion, and soil loss due to increasingly frequent rainfall, resulting in substantial losses in crops, post-harvest agricultural products, and infrastructure, while farmers from the northern part of Nigeria—especially from the arid and semi-arid regions (the conventional livestock production zones)—are mostly challenged by the direct impacts of heat on livestock due to rising temperatures, resulting also in the sector's low output level, which is compounded by inaccessibility to agricultural loans from banks for necessary climate actions. This assertion is in line with the recently documented evidence on the inability of financial institutions in developing countries to finance the shift to sustainable agriculture [3]. To this end, doubts are largely circulating among Nigerians on the effectiveness of the traditional and currently in-use CRR in an increasingly climate-challenged Nigeria in directing adequate credit towards Nigeria's climate-resilient growth goals, especially in the climate-challenged agriculture sector. These doubts have resulted in many Nigerians advocating for a shift from the currently in-use CRR to green-differentiated CRR to mandate climate-resilient agricultural growth. Clearing these doubts requires empirical studies that focus on ascertaining the potency of the existing CRR in performing its two basic functions (credit and growth) with the aim of enhancing climate-resilient agriculture.

The literature has documented an abundance of empirical evidence supporting that the differentiation of reserve requirements according to the "greenness" of the activities that banks lend to is the best option for reserve requirement policies to enhance resilience in developing economies [20–22]. In Nigeria, in particular, few studies have shown evidence supporting the use of a climate-augmented CRR in encouraging green and climate-resilient growth [23,24]. However, the effectiveness of the currently in-use CRR in enhancing resilience in climate-challenged Nigeria's agriculture sector is often unknown. Prior studies that have paid attention to the nexus between the CRR and the credit allocated to agriculture [25,26] or between the CRR and the growth in the agriculture sector [27,28] have not focused on climate.

Previous CRR–climate resilience assessments in Nigeria are limited, mostly at the national level (with no focus on the agriculture sector) and are usually based either on reviews or theoretical quantitative model approaches [23,24] to assess the effectiveness of both the already-implemented CRR (and/or other monetary policy tools) and the yet-to-be introduced/implemented green-differentiated CRR (or other green monetary policy tools) in driving green and climate-resilient growth. Interestingly, the studies revealed findings that support the differentiation of the CRR (and/or other policy rules) according to banks' green lending directions, as the policy can act as a better climate action policy than the standard policy. However, before assessing the potential effects of green monetary policy tools or a green-differentiated CRR (which have yet to be implemented) on climate-resilient growth based on previous studies' research methods, first, the effectiveness of the already-implemented CRR policy tool (and/or any other policy tool) in achieving the climate-resilient growth goals needs to be assessed using an ex post evaluation approach, which is the best method as it directly assesses the real-world effects of a policy tool following its implementation, unlike the previously used theoretical quantitative model approaches that provide hypothetical forecasts based on beliefs about how the policy might have functioned, or review methods that rely solely on an analysis of existing studies, which may be prone to bias if not meticulously curated and analyzed and which could potentially limit the depth and validity of the studies' conclusions.

Therefore, this work will make an important difference to the literature by filling the two gaps created by previous studies in Nigeria, while studying the link between the CRR and climate-resilient growth. These include the focus of the present study on the

climate-challenged agriculture sector in order to fill the gap created in the study area, as the focus of prior studies is at the national level [23,24], with no focus on the agriculture sector. The few documented pieces of evidence that have focused on the agriculture sector in relation to the subject matter are concentrated mostly on the role of government or fiscal policies in enhancing agriculture growth, with no emphasis on the CRR or the monetary policy role [29,30]. Second, the gap in methodologies is filled in this study by conducting an ex post evaluation of the effectiveness of the already-implemented (currently in-use) CRR in fostering climate-resilient agricultural growth in Nigeria before using a review method to evaluate the need for a green-differentiated CRR (since Nigeria currently lacks data on yet-to-be-implemented, green-differentiated CRRs). As no prior CRR–climate resilience assessments have been conducted based on an ex post evaluation, this study aims to empirically assess the climate-resilient agricultural growth effect of the currently in-use CRR to determine whether such a policy tool can enhance resilience in agriculture or whether a green-differentiated CRR is needed in Nigeria, as proposed by the international policy fora to central banks in developing economies [31–33]. Specifically, this study aims to determine the extent to which the standard CRR has (1) channeled more credits into climate-challenged Nigeria's agriculture sector for necessary climate-resilient agricultural practices and (2) enhanced agriculturalists' ability to sustain agricultural output growth in spite of climate crises. The findings from this research pave the way for the CBN to ascertain the need for green-differentiated reserve requirements in Nigeria.

In addition to addressing the gap in the literature in Nigeria, as has been explained above, this study adds to the body of knowledge as follows: First, it constitutes one of the first empirical studies that brings the climate finance, climate-resilient growth, and sustainable development discussions closer to the one on monetary macroeconomics dynamics in developing economies by determining the role of reserve requirements in building climate resilience in agricultural growth in Nigeria. This complements the majority of previous studies in developing economies that focus on the use of fiscal policies, government bonds, foreign aid, and grants to help achieve climate finance and climate-resilient growth goals.

Secondly, this study's focus on the agriculture sector allows for an in-depth analysis of local reserve requirements, influencing a crucial growth stimulant sector in Nigeria. The detailed documented evidence from Nigeria's agricultural sector is valuable for a better understanding of where and how climate finance should be prioritized within the country to enhance climate resilience in the economy. Lastly, by emphasizing the need for a green DCRR to prevent misaligned objectives with banks and to promote the credit allocation for green projects in the climate-challenged agriculture sector, this study provides actionable insights specifically designed to address Nigeria's unique challenges to food security due to climate change.

The remainder of this paper is arranged as follows: Section 2 briefly discusses the general overview of the CRR and its role in enhancing climate-resilient agricultural growth, particularly in Nigeria. Section 3 presents a concise review of pertinent studies, while Section 4 contains the materials and methods. Section 5 presents the findings, while a detailed discussion of the findings is presented in Section 6, and the last Section 7 delivers the conclusions, including the potential policy implications.

2. CRR and Its Role in Enhancing Climate-Resilient Agricultural Growth

This section provides a brief overview of the CRR and its role in enhancing climate-resilient agricultural growth, with a particular emphasis on Nigeria's case, especially from 1990 to 2022. It also highlights how this study analyses the relationship between the CRR and climate-resilient agricultural growth, with a detailed methodology given in Section 4.

Generally, the CRR, also called reserve requirements, maintains that a fraction of the depository institution's deposit liabilities must be kept at the central bank as reserve balances in the central bank or vault cash held by the bank. Reserve requirements (RRs) serve two major purposes: prudential and monetary purposes. The former ensures that banks have sufficient liquid resources to meet unexpected levels of deposit withdrawal. On the monetary side, the Federal Committee on Bank Reserves, in its 1931 report, viewed the control of credit as the most important function served by reserve requirements [34]. There are, however, costs to using this policy tool, as the authors of [35] observed: RRs impose a tax burden that affects the efficiency of banks. Not surprisingly, the authors of [36] observed some countries to have experienced a reduction in reserve requirement (RR) ratios and their outright elimination in Belgium, Denmark, and Sweden [35]. Some other countries remunerate their reserves, all in an attempt to limit the RR-imposed tax burden on banks and their customers, whom they have passed a significant portion of the burden onto, by raising lending rates.

Reserve requirements differ from one country to another. Some countries apply a single uniform reserve requirement ratio on deposits to influence the overall availability of credit and output growth, while some differentiate their RRs into different dimensions for different objectives. For instance, in 2008, the People's Bank of China differentiated their CRRs according to the size of the banks [22], whereas in 2010, Lebanon's central bank introduced an initiative to fund renewable energy projects by reducing the reserve requirements for banks that are providing loans under the scheme [21]. Hence, the differentiation of RRs has expanded the uses of RRs in different economies. For example, in countries that apply green-differentiated RRs, the deposit-taking institutions that direct loans towards low-carbon sectors and climate-resilient projects maintain RR ratios lower than the RR ratio maintained by their counterparts. The essence of such a practice is to facilitate green finance, thus also necessitating green and climate-resilient growth.

However, the CRR, in the context of this work, serves as a monetary policy toolkit used by the CBN to influence the lending decisions of DMBs, facilitating the achievement of the nation's growth goals. The CBN process involves reviewing developments in the economy over a specific time and setting baseline requirements and targets that would enable the economy to move toward a desired level of equilibrium. The baseline requirement, in the form of cash reserve requirements, mandates that DMBs hold a certain percentage (for instance, 45%) of their customers' deposits as reserves within the apex bank, mainly with the purpose of controlling credit within the banking system. Presently, the CRR is mathematically computed as the ratio of the cash reserve requirements to the total deposit liabilities of Nigerian banks. The base for computing the CRR was expanded from the previously demanded deposit to include all deposit liabilities, comprising savings, time, and demand deposits starting from the 1991 fiscal year. Over the years, the Nigerian monetary authority has applied an undifferentiated cash reserve ratio to bank's deposits from the private sector, even as the world economy is pressured to make and sustain finance flows toward low-GHG emissions and climate-resilient development through several global and regional climate discussions, including the 2015 Paris Agreement and others. The international policy fora [31–33], on the other end, have continued listing green reserve requirements among the monetary policy toolkit, which the CBN in developing economies can utilize to channel credit towards climate actions and building a climate-resilient society.

In enhancing climate-resilient agriculture, the CRR is generally perceived to have two basic roles: credit and growth roles. In the former, the CRR encourages banks to allocate credit to agriculturalists and to assist them in buffering against climate-related shocks, in adapting to changing climate conditions, and in recovering from adverse climate impacts. In the growth role, the CRR enhances farmers'/the agriculture sector's ability to attain

and sustain the agricultural output growth in spite of climate crises. Two major channels exist for agricultural credit allocation in Nigeria: formal and informal credit channels. Formal credit channels are institutions that provide credit according to established rules and procedures, often with government regulation and oversight. Formal agricultural credit sources/channels include commercial banks/deposit money banks, development banks, state-owned credit institutions, cooperative societies, and government agencies, while informal sources of agricultural credit include private moneylenders and self-help groups. However, it should be emphasized that the CRR in Nigeria is not specifically stipulated for informal credit channels/institutions or any other formal credit channels beside deposit money banks (DMBs).

The a priori expectation for the relationship between the CRR and each of its roles in enhancing climate-resilient agricultural growth (credit and growth) is an inverse relationship. A higher CRR reduces the funds that banks can deploy for loans, potentially leading to tight or contractionary monetary policies, as banks' lending interest rates could consequently be raised. Conversely, a lower CRR enhances banks' capacity to extend credit and could ease monetary policies (expansionary monetary policies) in the country since the bank's lending rates are reduced by such a decision. Many studies in Nigeria (though not focusing on climate) [25,26,37,38] have established a close relationship between the CRR and banks' credit allocation to agriculture, while other scholars [28] have documented evidence supporting the inverse relationship between the CRR and agricultural output growth in Nigeria. Emphasizing the agricultural climate-resilient growth roles of the CRR, Figures 1 and 2 are used to show the patterns of the CRR and the DMB credit allocated to the climate-challenged agriculture sector, respectively. In Figure 1, the CRR pattern from 1990 to 2022 reveals continuous variations, implying continuous adjustments to the standard CRR in line with the monetary policy objectives during each period. This is evident in the policy of monetary easing adopted to address the problem of liquidity shortages in the banking system and the entire economy, agriculture sector inclusive, in the wake of the global financial crisis, with the CRR reducing from 3% in 2008 to 1% in 2010 (see Figure 1). The expected effect (the a priori expectation) is a rise in the credit allocation to agriculture and agricultural productions. However, the CRR–credit inverse relationship seems to have been maintained, as agricultural credit also increased from NGN 106.35 billion in 2008 to NGN 128.41 billion in 2010 (see Figure 2). Further to the increased agricultural credit is the increase in the agricultural output. Notably, Nigeria saw severe climate incidents in the years 2012 and 2022: Nigeria was hit with double incidents of flood and drought in 2012, following which the country adopted the NCCPRS to promote climate actions in the economy, as well as another incidence of flood in 2022. However, the period from 2012 to 2022 witnessed policy tightening as the standard CRR requirements rose from 12% in 2012 to 27.50% in 2022 (see Figure 1) and to 45% in 2024 [39]. While assessing the 2012–2022 CRR policy tightening in relation to the banks' credit allocation to agriculture, we observed a positive CRR–credit role relationship, with the credit allocated to agriculture rising from NGN 316.36 billion in 2012 to NGN 1812.47 billion (see Figures 1 and 2). Not surprisingly, the CBN introduced what is called the "differentiated CRR regime program", aimed at providing more affordable credit for the development of agriculture and other real sectors of the economy in 2018.



Figure 1. Cash reserve ratio in Nigeria, 1990–2022 (%).

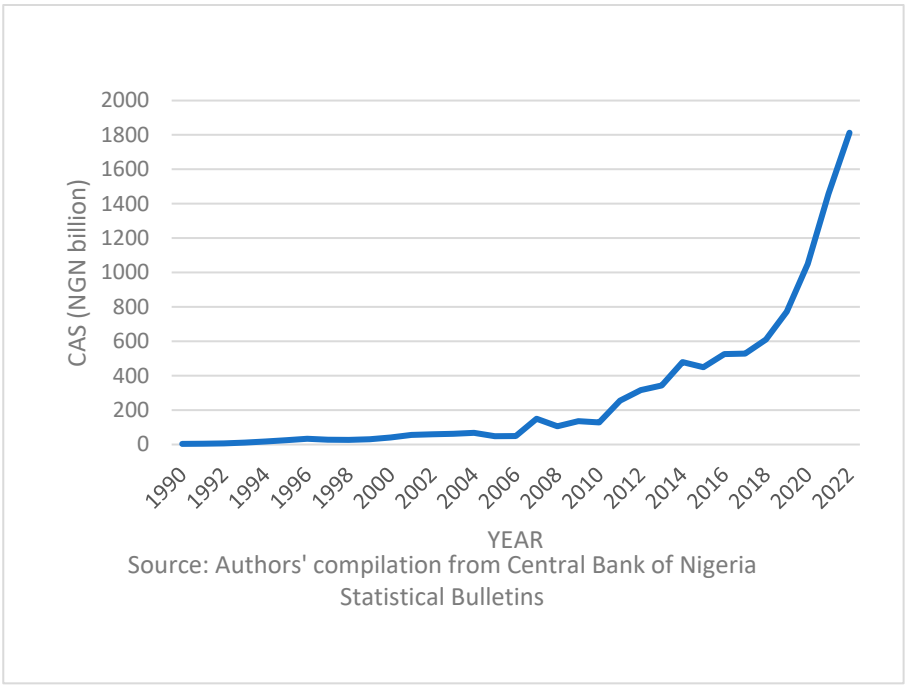

Figure 2. Deposit money bank (DMB) credit allocated to agriculture sector, 1990–2022 (NGN billion).

However, it would be premature to make conclusions about the effect of the CRR on both its credit and growth roles in enhancing climate-resilient agriculture based on the perceived relationship observed in Figures 1 and 2 without empirically assessing its relationship. Many studies have identified other variables that can affect credit for climate-resilient agricultural activities and climate-resilient agricultural output growth, such as monetary policy rates, government spending, the renewable energy supply, and climate factors, such as temperature and precipitation. On this note, this study focuses on the two major roles of the CRR in enhancing climate-resilient agricultural growth (credit and growth), while determining the effect of the currently in-use standard CRR on climate-resilient agricultural growth, with the consideration of the previously established

determinants of agricultural credits and growth. This will aid in providing an answer to the question raised in this study's title.

3. Literature Review

This section centers on a theoretical and empirical review of studies that can answer the question raised by this paper's title.

3.1. Theoretical Foundation

This study has its theoretical roots in two major theories: Keynesian theory and the theory of the "bank lending channel" of monetary policy transmission.

3.1.1. Keynesian Theory

The role of the CRR in enhancing climate-resilient agricultural growth in this study's context has its theoretical foundation in Keynesian theory, propounded by John Maynard Keynes in his book "The General Theory of Employment, Interest, and Money", published in February 1936. Keynes "general theory", which was inspired by the Great Depression that started in the 1920s and 1930s in the major industrialized economies [40], marked the beginning of contemporary macroeconomics as a systematic way to analyze economic phenomena [41]. Keynesian theory places emphasis on direct government intervention through macroeconomic policies that affect economic activities. While objecting to the "laissez faire" principle of classical theorists, Keyne [42] (p. 249) observed that "the capitalist market system seems capable of remaining in a chronic condition of sub-normal activity for a considerable period without any marked tendency towards recovery or towards complete collapse". Therefore, Keynesian theory holds the assumption that a permanent rise in the aggregate demand and the output level can result from an increase in the money supply [43], which could result from easing monetary policies. Keynesianism was initially associated with fiscalism, with monetary factors' importance being largely recognized in the late 1960s by Keynesians [41,44,45]. Notwithstanding that the Keynes approach was studied in capitalism economies, Keynes theory still remains the cornerstone of modern macroeconomics and can be applied in developing economies' macroeconomic monetary policy systems, especially in the most climate-affected economies, such as Nigeria, where farming is a business that is inherently affected by climate risks, making it challenging for farmers to obtain loans without government policy intervention. Applying Keynesian theory to this study, we assume that Nigeria's government, through its agency—the CBN—can intervene in the climate-induced depression of the agricultural economic system via the use of a reduced CRR to sustain agricultural growth amidst climate crises.

3.1.2. Theory of "Bank Lending Channel"

The effectiveness of the CRR in performing its climate-resilient agricultural growth roles depends on the transmission of the CRR. The theoretical literature has documented four major channels of monetary policy transmission—the credit channel; the bank lending channel; the statement of the financial position's (balance sheet) channel; as well as the channel of interest rates, asset prices, and exchange rates [46,47]—among which, the bank lending channel is identified as the primary transmission mechanism for the reserve requirement policy [48]. Thus, this study is also rooted in the theory of the bank lending channel. This channel refers to a credit channel of monetary policy transmission, which is based on the notion that financial intermediaries are best positioned to address the informational asymmetry issues and other imperfections in credit markets [49]. The channel was first expounded in 1988 by Bernanke and Blinder [50]. The authors of [46] outlined three essential conditions that must prevail for a distinct bank lending channel to exist. This includes the following: the supply of intermediated loans should be influenced by monetary

authorities through an adjustment of the quantity of reserves in the banking system; intermediated loans and open-market bonds are not perfect substitutes, so imperfect price adjustments must be made to prevent the neutrality of any monetary policy shock. Thus, the bank lending channel perspective posits that monetary policies influence the quantity of loans supplied to firms and households by the commercial banks, rather than the price of credit [51]. This theory holds that tight monetary policies (in the form of an increased CRR) reduce the liquidity of banks, also reducing their lending to bank-dependent economic agents [52]. Consequently, the reduced loan supply hampers the investments and output growth of bank-dependent economic agents.

The bank lending channel is more effective in developing economies such as Nigeria, where the stock market is still developing and numerous smallholder farmers have little ability to generate funds through stock markets, unlike in the case of most developed economies (with more developed stock markets), where the interest rate channel is found to be effective in affecting consumption, investment, and the real output [53–56]. Applying this theory to this study, we assumed that the CBN has, in the wake of climate crises, encouraged bank credit allocation to agriculturalists for climate-resilient agricultural activities by adjusting (decreasing) the standard CRR. However, it would be premature to hold onto this assumption without empirically ascertaining the validity of the assumption. Therefore, we formulated our first hypothesis in this regard, as shown below.

Ho_1: *The standard CRR has a non-significant effect on DMBs' credit allocation to agriculture for climate-resilient practices.*

In line with the assumption that intermediate loans and open-market bonds are not perfect substitutes, the majority of Nigeria's agriculturalists are smallholder farmers who depend largely on banks as their source of finance due to their inaccessibility to the stock market as a substitute source of finance. Thus, an increase in their bank credits can be made possible by easing the CRR and would encourage investments into climate-resilient technologies, which concurrently would enhance climate-resilient agricultural output growth. To this end, we formulated our second hypothesis, as shown below:

Ho_2: *The standard CRR has a non-significant effect on climate-resilient agricultural output growth in Nigeria.*

3.1.3. Empirical Review

Empirically, studies conducted outside of [57,58] and within [59] Nigeria, at the national level, have recorded evidence proving that the availability of bank credits is reduced by an increase in reserve requirements. In the same vein, the majority of studies in Nigeria's agriculture sector have recorded a negative relationship between the cash reserve ratio and the credit allocation to agricultural production [25,37], while a significant positive effect of the CRR on loans for agriculture was only found to have existed in the short run [26,38]. The implication is that a decrease in the ratio of cash reserve requirement increases credit to the agriculture sector in the long run. Additionally, access to agriculture finances is documented to have a positive impact on food production and total agricultural productivity in Nigeria [60].

As for the use of reserve requirements to influence agriculture output growth, studies outside Nigeria have also recorded evidence showing that tight monetary policies, including reserve requirement policies, significantly reduce agricultural production, as was discovered by Rivai [61] while focusing on the period from 1995 to 2016 in Pakistan and Indonesia. In a similar vein, Ogbuabor et al. [28] found that unanticipated monetary tightening had a detrimental impact on the agricultural industry and its sub-sectors, particularly in Nigeria.

Although both the international and domestic empirical evidence reviewed above have no climate focus, an interesting point to establish is that reserve requirements can serve as a tool for credit allocation [57] to foster development in specific sectors of the economy, particularly during stress [22], and thus can be used to enhance climate-resilient agricultural growth. On this note, many empirical works have been carried out across the globe on the use of RRs to encourage climate-focused lending and climate-resilient economic growth at the national level, with no evidence being recorded on the application of RRs in enhancing climate-resilient agricultural growth at the time of this study, to the authors' best of knowledge.

For instance, in providing credit for the transition to a green and climate-resilient society, Campiglio [21] argued for the use of green-differentiated reserve requirements in financing the shift to a low-carbon economy. Böser and Senni [62] added a green quantitative easing and green collateral framework to the green reserve requirements when proposing climate-oriented instruments of monetary policy that can mitigate climate risks and instigate cleaner technology adoption by firms. Rozenberg et al. [63] proposed the use of differentiated interest rates to provide cheaper capital to green sectors, while Liang et al. [64] recorded evidence that supports the transformation of high-polluting firms, resulting in a reduction in carbon emissions through funds allocated to green firms and industries. Using a systematic review of the literature to analyze some empirical studies on the use of monetary policies for transformation into greener economies, Aguila and Wullweber [65] concluded that monetary policies can promote a greener economy while maintaining price stability by providing less funding at higher interest rates for less-green projects and increased funding with cheap interest rates for green projects.

In using RRs to encourage green and climate-resilient economic growth, Xiaohui and Masron [22] conducted a study on the "differentiated reserve requirement ratio (DRRR) policy effect on the earthquake-stricken areas in China" and discovered the DRRR to have improved growth and development in the disaster areas. Additionally, Pan [20] used a modified Dynamic Stochastic General Equilibrium (DSGE) model to investigate the possible economic and environmental implications of China's newly implemented "green financial policies", namely lending, interest subsidies, and directed reductions in reserve ratio requirements. That study concluded that all three of the examined green financial policies are effective instruments for incentivizing green loans and have a favorable impact on the green economic transition and the environment.

In Nigeria, few empirical studies have documented evidence on the climate-augmented economic effect of RRs with a focus on the national level. For example, Oye [24] used an environmental DSGE model to analyze the impact of green fiscal (carbon tax) and monetary tools (green lending rate) on Nigeria's macroeconomic indicators and the environment, as well as to examine the volatility of climate-augmented fiscal and monetary policy rules compared to normal rules. The results from impulse responses showed that carbon taxes and lower green loan rates resulted in lower pollution and emissions in the economy, while the carbon tax and green lending policies had a contradictory effect on the macroeconomy, resulting in a decreased output and increased inflation due to shocks.

However, in Nigeria, no previous study has researched climate-focused RRs and climate-resilient agricultural enhancements. Even the few studies at the national level (empirical and otherwise) only employed either a review or a theoretical quantitative model approach; instead of the use of an ex post evaluation technique that directly assesses the real-world effects of the RR policy tool following its implementation, at least in assessing the effect of the already-implemented CRR, currently in use in the wake of climate change, on climate-augmented economic growth, as Nigeria currently lacks data on yet-to-be-implemented, green-differentiated RRs. Thus, this research attempts to fill

the gap by assessing the effect that the CRR requirements have on, first, Nigerian banks' credit allocation to climate-challenged agriculture and, second, climate-resilient agricultural output growth to determine if a green-differentiated CRR is needed.

4. Materials and Methods

4.1. Data and Variables' Descriptions

The annual data series for all the variables used in this study was selected from 1990 to 2022 largely due to data unavailability. Furthermore, the early 1990s marked the starting point of Nigeria's active participation in international climate discussions, with the country's signing of the UNFCCC, particularly in 1992; therefore, we chose 1990 to be our starting point for the covered periods. The year 2022 was the study's end period, which was wholly due to the unavailability of data for the later years. The data on the two major categories of variables utilized in this study—independent and dependent variables—were obtained from the CBN statistical bulletins, the World Bank's World Development Indicators, and the World Bank climate change knowledge portal for the periods covered herein. The data on all the utilized variables are completely accessible from these sources; thus, no issues of missing values were encountered. Our choice of data collection method/sources is justified on the basis of the authenticity of the data sources at both the national and international levels. At the national level, the CBN is the only monetary authority and the highest regulatory authority of banks in Nigeria, at the time of this study; thus, it contains more authentic and complete data on any monetary indices and on all the banks under its watch in its official documents. At the international level, the World Bank is a prominent source of data collection that is well known for its authenticity.

This study uses the cash reserve ratio requirements stipulated in Nigeria's climate change periods (the CRR) as the independent variable. However, the authors of [22] have maintained that the effect of reserve requirements should not be explored in isolation but in conjunction with other policy actions, while some other studies have argued for the use of multiple independent variables to improve the robustness of the parameter estimates [66,67]. In light of this, we included monetary policy rates (MPRs); the federal government recurrent expenditure on agriculture (GREA); the federal government capital expenditure on agriculture (GCEA), using federal government capital expenditure on economic services as a proxy; temperature (TEMP); precipitation (PRE); and the renewable energy supply (RES) as the study's additional independent variables, which were used to control for the effect of other monetary and fiscal policy, climate, and agricultural technological progress factors on our dependent variables. The choice of the additional independent variables above is informed by theoretical and empirical studies on credit and/or output growth analysis in general and specifically on the relationship between the CRR and its roles (credit and growth) in enhancing climate-resilient agricultural growth. At the theoretical end, Keynesian economists have identified fiscal and monetary policies as the primary tools for encouraging output growth in a depressed economic system, while the theory of the bank lending channel sees the CRR as the major determinant of the credit available for lending to banks' economic agents (see the details in Section 3). Based on established studies [25,26,28], MPRs were added to account for the influence of the CBN's cost of lending to DMBs on the agricultural sector's access to affordable bank credits, as well as on climate-resilient agriculture output growth, while the GREA and the GCEA were used to account for the fiscal policies' effect on climate-resilient agricultural growth with reference to existing studies [68,69]. TEMP and PRE were added to account for the effect that changes in temperature and precipitation patterns have on the dependent variables, based on prior studies [70,71]. Additionally, the RES was incorporated as a factor for building climate-resilient agriculture, with reference to [72].

The dependent variable, climate-resilient agricultural growth in Nigeria (CRAG), is proxied by the DMB's credit that was allocated for climate-resilient agricultural practices, quantified herein using the DMB credit allocated to the climate-challenged agriculture sector during the period that we studied Nigeria's climate change (CAS), and the agricultural output growth during climate hazards, quantified herein using the annual percentage growth rate of the agriculture, forestry, and fishing value added during the studied periods of climate change in Nigeria (AFFVA). The selection of the above dependent variable's proxies is based on the two important roles of reserve requirements in enhancing climate-resilient agriculture: the credit and growth roles.

All the variables were further transformed into their logarithmic forms to ensure an improvement in our models' performance, to stabilize variances, to make our data more interpretable, and to mitigate the impact of any possible outliers [73,74]. Hence, Table 1 provides the variables' pertinent information, including detailed descriptions, units of measurement, and data sources.

Table 1. Descriptions and data sources for the study's variables.

Variables	Detailed Description	Units of Measurement	Data Sources
CRR	Log of cash reserve ratio requirements on private sector's deposits during the studied period of Nigeria's climate change.	Percentage	*
MPR	Log of monetary policy rates during the studied period of Nigeria's climate change.	Percentage	*
GREA	Log of federal government recurrent expenditure on agriculture during the covered period of climate hazards in Nigeria.	NGN Billion	*
GCEA	Log of Federal government capital expenditure on agriculture during the covered period of climate hazards in Nigeria	NGN Billion	*
TEMP	Log of observed annual average mean surface air temperature in Nigeria for the covered periods.	Degree Celsius (°C)	**
PRE	Log of observed annual precipitation in Nigeria during the studied periods.	Millimeters (mm)	**
RES	Log of renewable energy supply.	Percentage of Energy Supply	***
CAS	Log of DMB credits to climate-hit agriculture sector (DMBs' sectoral distribution of credits: agriculture) at times of climate hazards studied.	NGN Billion	*
AFFVA	Log of annual percentage growth of agriculture, forestry, and fishing value added during the studied period of climate change in Nigeria.	Annual % Growth	***

Note: (1) * represents CBN annual statistical bulletin. Available online: https://www.cbn.gov.ng/documents/Statbulletin.html. (2) ** represents WB Climate change knowledge portal. Available online: https://climateknowledgeportal.worldbank.org/country/nigeria/climate-data-historical. (3) *** denotes WB World development indicators, https://databank.worldbank.org/source/world-development-indicators/Type/TABLE/preview/on (30 June 2025). (4) MPR as previously known as minimum rediscount rate.

4.2. Empirical Model

In this sub-section, we present the study's basic theoretical credit and growth model, as well as the econometric technique used to estimate the empirical models.

4.2.1. The Credit and Growth Model

In line with the bank lending channel, as discussed earlier, this study employs a regression model based on the assumption of a credit function given in terms of DMBs' credit allocation to the climate-challenged agriculture sector (CAS), wherein the CRR is explicitly incorporated as a determinant of the amount of credit available to DMBs for lending to the severely climate-impacted agriculture sector. Thus, Equation (1) below is used to show the functional relationship.

$$CAS = f(CRR) \quad (1)$$

where the variables are as explained in Table 1.

As we stated earlier, the effect of the CRR should be explored in conjunction with other policy measures [22], as well as with various potential determinants of banks' credit for climate-resilient agricultural practices, as the robustness of the parameter estimates have been questioned by several studies, arguing that they are often sensitive to many other conditional variables. In light of this, a core set of factors that have robustly and consistently impacted credit for climate-resilient agricultural growth, as established by several studies (see Section 4.1), were included in the vector of our independent variable to improve the robustness of the parameter estimates. This includes MPR, GREA, GCEA, TEMP, PRE, and RES. Thus, we can investigate the credit role of the CRR using Equation (2), as given below:

$$CAS = f(CRR, MPR, GREA, GCEA, TEMP, PRE, RES) \quad (2)$$

where the variables are as explained in Table 1.

Taking into account the crucial role of reserve requirements in not only improving the sector's access to credits for adapting to and recovery from climate losses but also enhancing the agricultural economic activities and growth in spite of climate hazards, we also estimate the following reduced-form equation of output growth, with consideration of Keynesian theory (see Section 3) and other determinants of climate-resilient agricultural output growth (see Section 4.1), as shown in Equation (3).

$$AFFVA = f(CRR, MPR, GREA, GCEA, TEMP, PRE, RES) \quad (3)$$

where the variables are as explained in Table 1.

Specifying Equations (2) and (3) in their econometric terms, with all the variables expressed in their natural logarithm-transformed form, the models become as follows:

$$LCAS_t = \alpha + \beta_1 LCRR_t + \beta_2 LMPR_t + \beta_3 LGREA_t + \beta_4 LGCEA_t + \beta_5 LTEMP_t + \beta_6 LPRE_t + \beta_7 L\,RES_t + \varepsilon_t \quad (4)$$

$$LAFFVA_t = \alpha + \beta_1 LCRR_t + \beta_2 LMPR_t + \beta_3 LGREA_t + \beta_4 LGCEA_t + \beta_5 LTEMP_t + \beta_6 LPRE_t + \beta_7 LRES_t + \varepsilon_t \quad (5)$$

where α represents a constant term and β_1–β_7 refer to coefficients of the regressors. LCAS is the logarithm function of the credit allocation to the agriculture sector during climate hazards, while AFFVA is the logarithm function of the annual percentage of growth in the agriculture, forestry, and fishing value added during climate hazards in Nigeria. The subscript "εt" refers to a white noise disturbance term, and t denotes periods covered in this study. LMPR, LGREA, LGCEA, LTEMP, LPRE, and LRES are as explained in Table 1.

4.2.2. The Econometric Technique: The ARDL Approach

The search for a suitable regression model, with more robust econometric methods, further prompted this study's application of the autoregressive distributed lag (ARDL) modeling approach, advanced by [75]. Our choice of the ARDL approach is justified by the

following reasons: First, it is a least squares regression that can be used as a cointegration test, both to establish if a long-run relationship exists between the model's explanatory and explained variables (ARDL bound test) and to estimate the direction and significance of the long-run relationship or otherwise (an ARDL coefficient analysis in the long run, simply termed the ARDL long-run form). Additionally, the ARDL bound-testing method can be used to estimate the unrestricted error correction model, which captures the short-run dynamics of the variables, explaining also the speed at which the variables adjust to deviations from the long-run equilibrium (the ARDL-based error correction model approach). Thus, this study benefits from all the stated features of ARDL.

ARDL has an advantage over other cointegration techniques as it can be used regardless of whether all the variables have a mixed level of integration or are stationary at level (I(0)) or at the first difference (I(1)), unlike traditional approaches [76–78] that require all series to have identical orders of integration. Secondly, it is relatively more reliable and effective in small samples with 30 to 80 observations [75]; thus, its use in this study with the small sample size of 33 observations is justified. Furthermore, the ARDL approach typically yields unbiased estimates of the long-run model and valid t-statistics, even when the regressors are endogenous [75,79–81], unlike traditional cointegration techniques, which may encounter issues of endogeneity. Additionally, the appropriateness of using an ARDL model lies in the fact that it is based on a single-equation framework. Thus, the application of ARDL in this study is justified due to all these advantages over other standard cointegration techniques.

In this study, we provide two separate ARDL models: one is used to investigate the credit effect of CRR and other independent variables, while the other is used for investigating the growth effect of the independent variables. The specified ARDL models are shown in Equations (6) and (7) below.

$$\begin{aligned}\Delta LCAS_t = {} & \alpha \sum_{i=2}^{p} b_{1i}\Delta LCAS_{t-i} + \sum_{i=2}^{p} b_{2i}\Delta LCRR_{t-i} + \sum_{i=2}^{p} b_{3i}\Delta LMPR_{t-i} + \sum_{i=2}^{p} b_{4i}\Delta LGREA_{t-i} + \sum_{i=2}^{p} b_{5i}\Delta LGCEA_{t-i} + \sum_{i=2}^{p} b_{6i}\Delta LTEMP_{t-i} \\ & + \sum_{i=2}^{p} b_{7i}\Delta LPRE_{t-i} + \sum_{i=2}^{p} b_{8i}\Delta LRES_{t-i} + \beta_1 LCAS_{t-2} + \beta_2 LCRR_{t-2} + \beta_3 LMPR_{t-2} + \beta_4 LGREA_{t-2} + \beta_5 LGCEA_{t-2} \\ & + \beta_6 LTEMP_{t-2} + \beta_7 LPRE_{t-2} + \beta_8 LRES_{t-2} + \varepsilon_t \end{aligned} \quad (6)$$

$$\begin{aligned}\Delta LAFFVA_t = {} & \alpha \sum_{i=1}^{p} b_{1i}\Delta LAFFVA_{t-i} + \sum_{i=1}^{p} b_{2i}\Delta LCRR_{t-i} + \sum_{i=1}^{p} b_{3i}\Delta LMPR_{t-i} + \sum_{i=1}^{p} b_{4i}\Delta LGREA_{t-i} \\ & + \sum_{i=1}^{p} b_{5i}\Delta LGCEA_{t-i} + \sum_{i=1}^{p} b_{6i}\Delta LTEMP_{t-i} + \sum_{i=1}^{p} b_{7i}\Delta LPRE_{t-i} + \sum_{i=1}^{p} b_{8i}\Delta LRES_{t-i} \\ & + \beta_1 LAFFVA_{t-1} + \beta_2 LCRR_{t-1} + \beta_3 LMPR_{t-1} + \beta_4 LGREA_{t-1} + \beta_5 LGCEA_{t-1} + \beta_6 LTEMP_{t-1} \\ & + \beta_7 LPRE_{t-1} + \beta_8 LRES_{t-1} + \varepsilon_t \end{aligned} \quad (7)$$

where Δ represents a change, $t-1$ is a period lag, $t-2$ is a two-period lag, b is the coefficient in the short run, and β denotes the corresponding long-run multiplier of the underlying ARDL model.

5. Results

This section presents the results of both the descriptive statistics and econometric model estimations that were employed. The description of the individual variables in relation to each other in the dataset are summarized with the descriptive analytics, while ARDL econometric model estimation was utilized for the data analysis. Before presenting the estimated models' results, we present the results of the conducted pre-estimation tests, while a series of diagnostic tests performed to assess the robustness of the estimated models are presented in conjunction with the concerned estimated model's results.

5.1. Descriptive Statistics

Table 2 shows the descriptive statistics of the variables used in this study. The results show that the LCRR, LMPR, LGREA, LGCEA, LTEMP, LPRE, LRES, LCAS, and LAFFVA have means of 2.12569, 2.58205, 2.45910, 5.18219, 3.30738,7.07236, 3.89644, 4.58194, and 1.42293, respectively, with standard deviations of 0.87986, 0.28910, 1.75605, 1.63090, 0.01095, 0.05798, 0.09096, 1.65301, and 0.62999, respectively. The LCRR, LMPR, LGREA, LGCEA, LTEMP, LPRE, and LCAS have negative skewness values of −0.57140, −0.65999, −0.84141, −1.43811, −0.41219, −0.51133, and −0.05305, respectively, meaning that they are skewed to the left, while the LRES and the LAFFVA are skewed to the right, with their respective positive skewness values of 0.12006 and 2.02832, respectively. The LCRR, LGREA, LPRE, LRES, and LCAS individually have kurtoses of 2.70628, 2.55765, 2.51302, 1.97235, and 2.11267, respectively, which is less than three, meaning that they are less peaked and have a lighter tail, while the LMPR, LGCEA, LTEMP, and LAFFVA have kurtoses of 4.67897, 4.33609, 3.10059, and 9.72157, respectively, which are greater than three, meaning they are more peaked and have a heavier tail.

Table 2. Descriptive statistics.

	LCRR	LMPR	LGREA	LGCEA	LTEMP	LPRE	LRES	LCAS	LAFFVA
Mean	2.12569	2.58205	2.45910	5.18219	3.30738	7.07236	3.89644	4.58194	1.42293
Median	2.27213	2.60269	3.11085	5.57984	3.30908	7.07908	3.88321	4.21568	1.36771
Maximum	3.31419	3.25810	4.40513	7.22232	3.32899	7.16752	4.05370	7.50245	4.01779
Minimum	0.00000	1.79176	−1.56065	0.85015	3.27941	6.93984	3.73218	1.43984	0.62818
Std. Dev.	0.87986	0.28910	1.75605	1.63090	0.01095	0.05798	0.09096	1.65301	0.62999
Skewness	−0.57140	−0.65999	−0.84141	−1.43811	−0.41219	−0.51133	0.12006	−0.05305	2.02832
Kurtosis	2.70628	4.67897	2.55765	4.33609	3.10059	2.51302	1.97235	2.11267	9.72157
Observations	33	33	33	33	33	33	33	33	33

5.2. ARDL Econometric Model Estimation

This section aims to answer the question "Does the current CRR aid climate-resilient agricultural growth in Nigeria?" and presents the results of the estimated models, namely the ARDL credit and growth models used to test hypotheses one and two, respectively, which helps answer the query raised in this paper's title.

However, before estimating the ARDL models, the unit root test needs to be conducted to ensure the variables' stationarity and to affirm the non-existence of second- or greater-order variables in our equations, since the ARDL cointegration test is not suitable for variables that are stationary at the second difference, I(2), or more. An augmented Dickey–Fuller (ADF) test was employed for the unit root test. The results, as disclosed in Table 3, show all the variables to be stationary at the first difference, with the exception of LTEMP, LPRE, and LAFFVA, which are stationary at level.

Following the order of integration in our empirical models' variables, the ARDL bound test for cointegration among the variables was conducted using the appropriate lag length. Therefore, the appropriate lag length needs to be determined before conducting the bound test. The Vector Auto-Regressive (VAR) lag order selection approach was utilized to determine the optimal lag order of the ARDL-specified models. Using Akaike's information criterion (AIC) and the final prediction error (FPE), lags 2 and 1 were found to be the optimal lag lengths for our ARDL models for the credit and growth functions, as specified in Equations (6) and (7), respectively. The results are presented in Tables 4 and 5. The AIC and FPE are particularly well-suited for small samples, such that they minimize the chance of under estimation while maximizing the chance of recovering the true lag length [82]. Thus, their use in this study with a sample size of 33 observations is justified.

Table 3. ADF unit root test.

Variables	ADF Statistic	*p*-Value	5% Critical Value	Order of Integration
LCRR	−5.33680	0.00010	−2.96041	I(1)
LMPR	−6.76469	0.00000	−2.96041	I(1)
LGREA	−5.85225	0.00000	−2.96397	I(1)
LGCEA	−6.24507	0.00000	−2.96041	I(1)
LTEMP	−3.66222	0.04010	−3.55776	I(0)
LPRE	−2.96031	0.05000	−2.96041	I(0)
LRES	−5.64383	0.00010	−2.96397	I(1)
LCAS	−6.39274	0.00000	−2.96041	I(1)
LAFFVA	−3.42042	0.01760	−2.95711	I(0)

Note: The variables are as defined previously (see Section 4).

Table 4. VAR lag order selection criteria for ARDL model 1 (see, Equation (6)).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	77.11	NA	1.60	−4.46	−4.09	−4.34
1	204.17	180.34 *	3.14	−8.53	−5.20 *	−7.44
2	287.23	75.03	2.36 *	−9.76 *	−3.47	−7.71 *

Note: * indicates the lag order selected by the criterion (we utilized AIC and FPE).

Table 5. VAR lag order selection criteria for ARDL model 2 (see, Equation (7)).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	66.33	NA	3.21	−3.76	−3.39	−3.64
1	176.69	156.64 *	1.85 *	−6.75 *	−3.42 *	−5.67 *
2	238.21	55.57	5.58	−6.59	−0.30	−4.54

Note: * indicates the lag order selected by the criterion (we utilized AIC and FPE), LR denotes the sequentially modified LR test statistic (each test at 5% level), the FPE represents the final prediction error, AIC is the Akaike information criterion, SC denotes the Schwarz information criterion, and HQ is the Hannan-Quinn information criterion.

At lags 2 and 1, the ARDL bound test was performed to establish if a long-run equilibrium relationship exists between the variables in our models (see Equations (6) and (7)). The results of the bound tests, as disclosed in Table 6, reveal the presence of a long-run equilibrium relationship between the explanatory and explained variables in both Equations (6) and (7) because the F-value at 3.53 exceeds the upper bound critical value at both 5% and 10% and the F-value at 3.21 exceeds the upper bound critical values at 10% in Equation (6) and Equation (7) respectively. Therefore, we proceeded to estimate the ARDL models for the credit and growth effects.

Table 6. Summary of bound test results.

Dependent Variable	F-Statistics	Significant Level	Lower Bound I(0)	Upper Bound I(1)
LCAS	3.53	10%	1.92	2.89
		5%	2.17	3.21
		1%	2.73	3.90
LAFFVA	3.21	10%	1.92	2.89
		5%	2.17	3.21
		1%	2.73	3.90

5.2.1. The Credit Function: The Long- and Short-Run Models' Results

In this sub-section, the estimation results for Equation (6) used in testing hypothesis 1 are presented and interpreted. Specifically, Table 7 presents the results from the ARDL long-

(ARDL long-run form) and short-run (ECM) model estimations performed to determine the long- and short-term effects of the CRR on banks' credit allocation to the climate-challenged agricultural sector.

Table 7. The long- and short-run ARDL model results: the credit role.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ARDL long-run form results.				
LCRR	0.63746 **	0.21587	2.95296	0.01830
LMPR	−3.11637 *	0.69407	−4.49000	0.00200
LGREA	0.36776	0.28135	1.30716	0.22750
LGCEA	0.23145	0.33867	0.68340	0.51370
LTEMP	−63.87826 *	19.83314	−3.22079	0.01220
LPRE	4.02726	2.36997	1.69929	0.12770
LRES	−7.91372 *	2.21428	−3.57394	0.00730
C	223.03160 **	77.65692	2.87201	0.02080
Short-run model (ECM) results.				
Δ(LCRR(-1))	−0.36754 *	0.08224	−4.46913	0.00210
Δ(LMPR(-1))	0.99262 *	0.28443	3.48989	0.00820
Δ(LGREA(-1))	−0.07411	0.06221	−1.19143	0.26760
Δ(LGCEA(-1))	−0.05815	0.07920	−0.73417	0.48380
Δ(LTEMP(-1))	21.21854 *	5.49806	3.85928	0.00480
Δ(LPRE(-1))	0.05298	0.57604	0.09198	0.92900
Δ(LRES(-1))	3.22379 *	0.83198	3.87482	0.00470
ECT(-1) *	−0.84707 *	0.10630	−7.96903	0.00000
Statistical tests	Values			
R-squared	0.84690			
Adjusted R-squared	0.71294			
F-statistics	91.56572			
Prob(F-statistic)	0.00000			
Durbin–Watson stat.	2.39851			
Model diagnostic tests				
Breusch–Godfrey serial correlation LM test #	0.06670			
Breusch–Pagan–Godfrey heteroskedasticity test #	0.71420			
Jarque–Berra	1.27431			
Prob(Jarque–Berra)	0.52880			
CUSUM stability test	See Figure 3			
CUSUMSQ stability test	See Figure 4			
Dependent variable: LCAS				

Note: # denotes that we reported only the *p*-value for the F-statistics in the diagnostic tests. Δ represents change. ECT is the error correction term (adjustment coefficient). Significance at the 1% and 5% significance levels is represented with * and **, respectively. All the variables are as defined in Section 4 (see Table 1).

In the long and short runs, the findings, as Table 7 discloses, show significant positive and significant negative impacts of the cash reserve ratio (LCRR) on banks' credit allocation to the agricultural sector during climate hazards (LCAS), respectively. The coefficient of the LCRR showed that a 1% decrease in reserve requirements significantly reduces and increases the agricultural sector's access to bank credits (necessary for building climate resilience) by 0.637% and 0.368% in the long and short runs, respectively. Therefore, the study's first hypothesis, which states that the standard CRR has a non-significant effect on DMBs' credit allocation to agriculture for climate-resilient practices, is rejected. Furthermore, the cash reserve ratios' significant positive and negative impacts on banks' credit allocation to the climate-challenged agricultural sector for the long and short runs,

respectively, as stated above, mean that easing the monetary policy action in form of a reduced LCRR decreases the LCAS in the long-run, while increasing it in the short-run.

Regarding the study's additional independent variables, the MPR has, in the long and short runs, disclosed significant negative and positive impacts on credit allocation to the agriculture sector during climate hazards, with coefficients of −3.11637 and 0.99262, respectively, implying that the CBN could enhance banks' credit allocation to the climate-challenged agriculture sector by easing the MPR in the long run, though this effect was not felt during the initial (short-run) periods. Both the government capital and recurrent expenditure on agriculture have non-significant positive and negative impacts on banks' credit allocation to agriculture during climate challenges in the long and short runs, respectively. Their coefficient results revealed that a 1% increase in the GREA and the GCEA would increase the CAS by 0.368% and 0.232%, respectively, in the long run, while a percentage increase in the GREA and the GCEA would, in the short run, decrease the CAS by 0.074% and 0.058%, respectively. The significant negative effect of climate change on the agricultural credit from banks was only established in the long run by the climate factor, temperature changes (TEMP), with its coefficient of −63.87826. This means that in the long run, a 1% increase in temperature changes would consequently decrease the credit allocation to agriculture by 63.878%, while in the short run, TEMP revealed a significant positive effect on the CAS. A non-significant positive effect was found to exist between precipitation and the CAS, both in the long and short runs. The RES discloses a significant negative and positive relationship with the CAS in the long and short runs, respectively.

Furthermore, the R-squared value shows that approximately 85% of all changes in bank credits to the climate-challenged agriculture sector are explained by the studied independent factors, with an unexplained variation of 15%. This suggests that the change in the endogenous variable cannot be explained solely by the explanatory variables. The Durbin–Watson test, showing a value of 2.39851, signifies that the data are free of autocorrelation. The overall significance of the model is affirmed by the F-stat value (91.56572) and its significant value of 0.00000. The ECT coefficient is negative and statistically significant, as expected, with its approximate value of 84.7%, meaning that the system corrects its previous disequilibrium period at a speed of 84.7% and thereby validates that the variables in the credit model have a long-run equilibrium relationship.

Furthermore, to assess the robustness of our estimated model for credit allocation (see the results in Table 7), we conducted a series of model diagnostic tests, including tests for serial correlation, heteroskedasticity, normality, and model parameter stability. The results of the Breusch–Godfrey Lagrange Multiplier (LM) test performed to check for serial correlation, as presented in Table 7, disclose a lack of sufficient evidence to reject the null hypothesis of there being no serial correlation. Therefore, issues of serial correlation do not exist in our estimated model regarding credit function. For the heteroskedasticity check, the results of the conducted Breusch–Pagan–Godfrey heteroskedasticity test show that our model has no problem of heteroscedasticity. The Jarque–Bera test, conducted to test for the normality of the residuals of our model regarding credit roles, confirms the normality of the residuals, as we could not also find enough evidence to reject the null hypothesis that "errors are normally distributed" in said specified model.

Moreover, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests were conducted to assess the stability of the estimated coefficients in our model (see Equation (6)). The stability tests, as depicted in Figures 3 and 4, reveal that the CUSUM and CUSUMSQ plots are within the 5% critical bound, indicating that the parameters did not experience any structural instability over the study period.

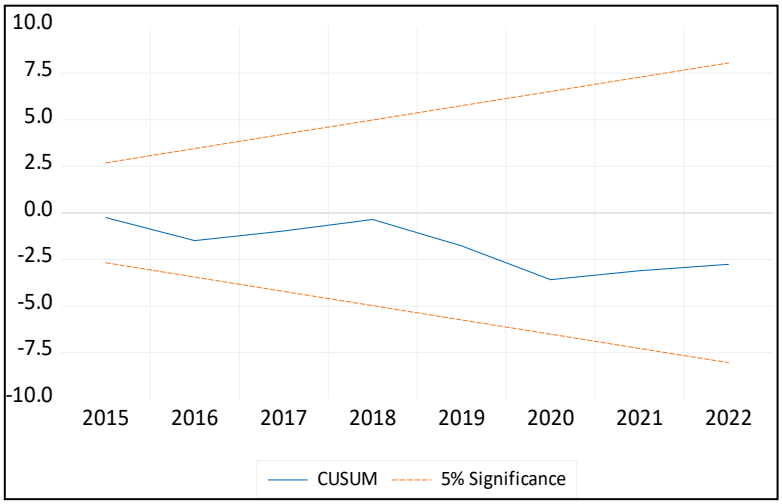

Figure 3. The CUSUM parameter stability test in relation to the ARDL model estimated in Table 7.

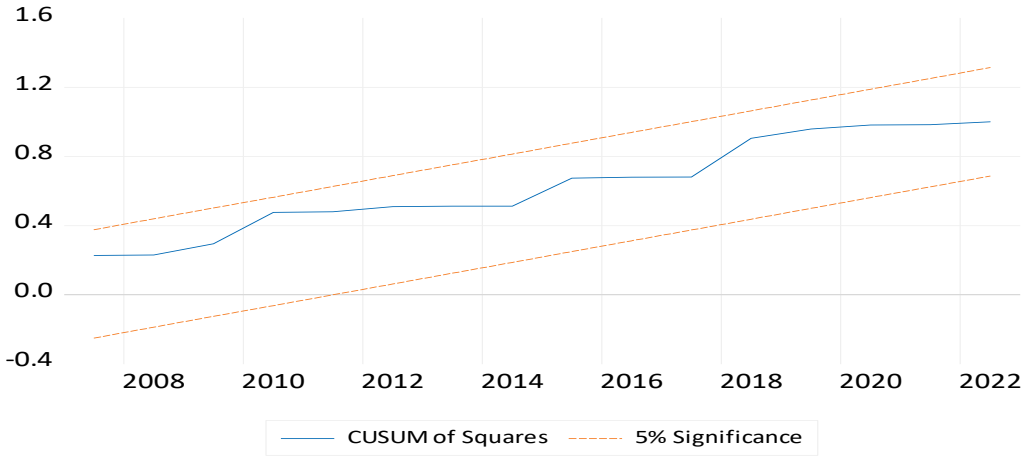

Figure 4. The CUSUMSQ parameter stability test in relation to the ARDL model estimated in Table 7.

5.2.2. The Growth Role: The Long- and Short-Run Models' Results

This section presents and interprets the results of the estimated ARDL model on the role of the current LCRR in promoting agricultural output amidst climate challenges, which was used to test the study's hypothesis 2. Table 8 is specifically utilized to present the results.

Based on the outcomes in Table 8, the second hypothesis of the present study (see Section 3) is also rejected as a significant negative relationship was found between the current cash reserve ratio requirements and the agricultural output growth during climate hazards in Nigeria, both in the long and short runs. These results are demonstrated by the coefficient of the LCRR, which showed that a 1% decrease in reserve requirements significantly increases agricultural output growth during climate challenges (measured with LAFFVA) by 0.894% and 0.485% (with −0.89423 and −0.48474 as their coefficient values, respectively, at an optimum lag length of one) in the long and short runs, respectively.

The monetary policy rate has, in the long and short runs, disclosed significant and non-significant positive impacts on agricultural output growth during climate hazards, respectively. While LGREA has a non-significant negative and positive effect on the LAFFVA, the LGCEA revealed non-significant positive and negative effects on agricultural output growth amidst climate crises. With regard to the climate factors, the coefficient of change in precipitation discloses that an increase in climate change due to precipitation has a detrimental effect on agricultural output growth during climate hazards in the long

and short runs, though this effect is only significant in the short run. The results on the changes in the average surface air temperature did not provide any evidence that increased temperature due to climate change would reduce the agricultural output growth, either in the long or short run. The LRES has a non-significant negative relationship with the LAFFVA, both in the long and short runs.

Table 8. The long- and short-run ARDL model results: the growth role.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ARDL long-run form results.				
LCRR	−0.89423 **	0.36839	−2.42738	0.02740
LMPR	2.92800 **	1.13437	2.58116	0.02010
LGREA	−0.30763	0.30305	−1.01510	0.32520
LGCEA	0.70754	0.41900	1.68862	0.11070
LTEMP	20.69238	29.86375	0.69289	0.49830
LPRE	−4.64769	4.16713	−1.11532	0.28120
LRES	−1.20045	3.01986	−0.39752	0.69620
C	−37.98511	118.01720	−0.32186	0.75170
Short-run model (ECM) results.				
Δ(LCRR)	−0.48474 **	0.23027	−2.10505	0.05140
Δ(LMPR)	0.61476	0.50564	1.21579	0.24170
Δ(LGREA)	0.16645	0.13115	1.26921	0.22250
Δ(LGCEA)	−0.14932	0.17410	−0.85769	0.40370
Δ(LTEMP)	23.88853 *	8.67252	2.75451	0.01410
Δ(LPRE)	−2.01139 ***	1.05339	−1.90945	0.07430
Δ(LRES)	−0.13724	1.28348	−0.10693	0.91620
ECT(-1) *	−0.88862 *	0.13508	−6.57849	0.00000
Statistical tests	Values			
R-squared	0.69484			
Adjusted R-squared	0.60583			
F-statistics	1.93474			
Prob(F-statistic)	0.10089			
Durbin–Watson stat.	2.10952			
Model diagnostic tests				
Breusch–Godfrey serial correlation LM test #	0.68080			
Breusch–Pagan–Godfrey heteroskedasticity test #	0.34700			
CUSUM stability test	See Figure 5			
CUSUMOQ stability test	See Figure 6			
Dependent variable: LAFFVA				

Note: # denotes that we reported only the *p*-value for the F-statistics in the diagnostic tests. Δ represents change. ECT is the error correction term. Significance at the 1%, 5%, and 10% significance levels are represented with *, **, and ***, respectively. All the variables are as defined in Section 4 (see Table 1).

The goodness of fit of the estimated model is shown with the R-squared values, indicating that about 69.5% of the total change in the agricultural output growth amidst climate crises is explained by the studied independent variables, while only 30.5% of the aggregate variation is explained by other variables that are not included in our independent variables. The results of the Durbin–Watson test shows no issues of autocorrelation. The ECT coefficient is negative and statistically significant, as expected, with an approximate value of 88.9%, meaning that the system corrects its previous disequilibrium period at a speed of 88.9% and thereby validates that the variables in the growth model have a long-run equilibrium relationship.

Furthermore, the results of the Breusch–Godfrey serial correlation LM test and the Breusch–Pagan–Godfrey heteroskedasticity test, shown in Table 8, disclose that issues of serial correlation and heteroskedasticity do not exist in our estimated model for the growth role. The stability tests, as depicted in Figures 5 and 6, reveal that the CUSUM and CUSUMSQ plots are within the 5% critical bound, indicating that the parameters did not experience any structural instability over the study period.

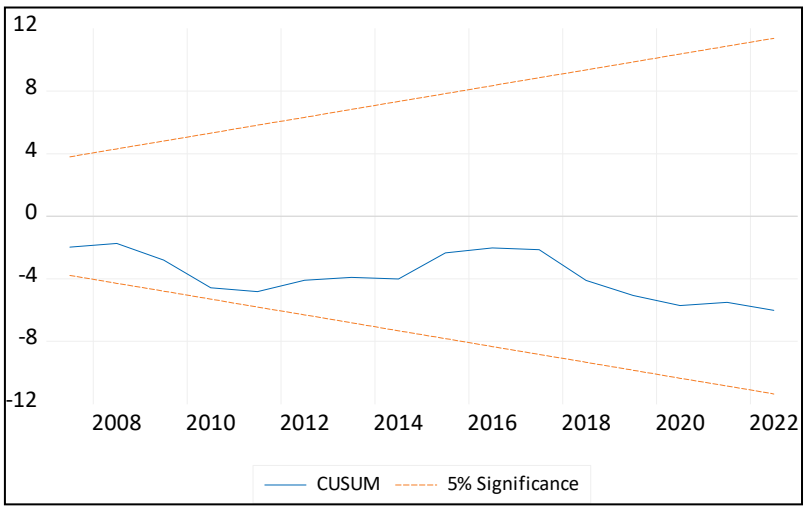

Figure 5. The CUSUM parameter stability test in relation to the ARDL model estimated in Table 8.

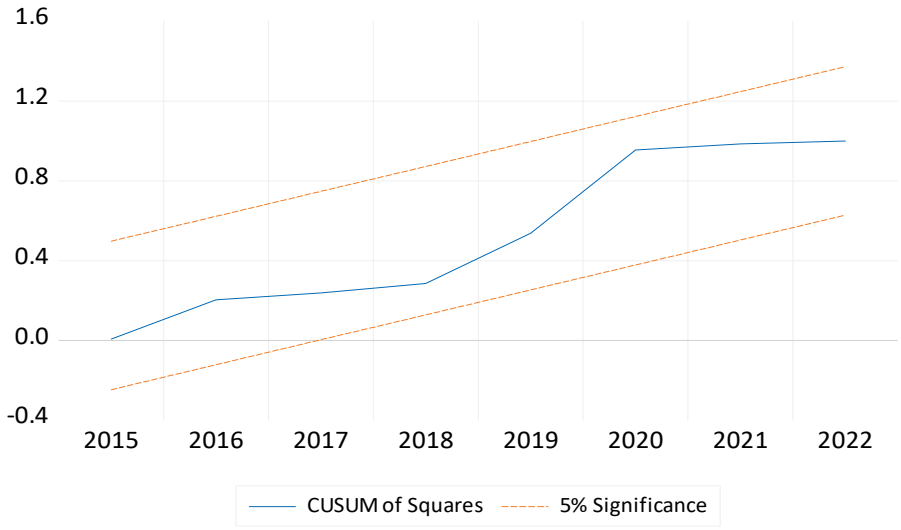

Figure 6. The CUSUMSQ parameter stability test in relation to the ARDL model estimated in Table 8.

6. Discussion of the Results

The findings from this study are discussed in line with the two specific objectives of this work, resulting from the two crucial roles of cash reserve ratio requirements in enhancing climate-resilient agricultural growth. Although this study has reported the outcomes of other factors that influence banks' credit allocation for climate-resilient agricultural growth, as well as the agricultural output growth, this section focuses mostly on the findings related to assessments of CRR–climate resilient agricultural growth to provide a deep understanding of the currently in-use, standard CRR's interplay with climate resilience, which is vital in ascertaining whether a green-differentiated CRR is needed, in line with the recommendations of the international policy fora.

Specifically, this study firstly aimed to determine the extent to which the standard cash reserve ratio (LCRR) has channeled more credits to climate-challenged Nigeria's agriculture sector for necessary climate-resilient agricultural practices (LCAS). The results, in Table 7, for the long run revealed a significant positive effect of the LCRR on banks' credit allocation to the agricultural sector during climate hazards (LCAS), while a significant negative impact of the LCRR on the LCAS was found in the short run. These results imply that, in the wake of climate challenges on the agriculture sector in Nigeria, as the CBN applies an easing (reduction) of the CRR monetary policy tool with the intention of enhancing climate-resilient agricultural credit from banks based on theoretical expectations (see the bank lending channel theory in Section 3), their intended goals would only be achieved for a short period, and the reverse becomes the case in the long run.

The findings of this study conform with the theory of the bank lending channel in the short run but not in the long run. The theory of bank lending channel suggests that tight monetary policies (in the form of increased CRRs) reduce the liquidity of banks, thus also reducing their ability to lend to bank-dependent economic agents [52]. In relation to previous studies, contrary findings have been reported in prior studies on the CRR and the CAS nexus in Nigeria, though these studies did not focus on climate [25,37,38]. Prior studies [25,37] found a negative and significant effect between the CRR and the agricultural sector's bank credits, while the authors of [38] found a significant positive effect between the CRR and the CAS.

The findings of the present study, which focuses on climate, in relation to the findings of previous studies in Nigeria, conducted without a focus on climate, suggest that the standard CRR applied during climate challenges is not a suitable reserve requirement policy option to boost credit for climate-resilient agriculture, as it is used to boost banks' credit allocation to agriculture when climate challenges are not considered. This conclusion is made based on the long-run results, since climate challenges will continue to exist for a very long period, requiring a long-term assessment that can inform a long-term solution. Furthermore, our study establishes a long-run relationship among the variables of our estimated models, and any deviation from the long-run relationship is corrected back to its long-run equilibrium with an error correction term.

In the face of climate variability and extremes, banks in Nigeria always see farmers as unattractive customers, due largely to the varying weather patterns and the challenges of other natural elements that have always posed hazards to farms. However, the impotency of the current CRR in serving its credit function towards climate-resilient agricultural growth could result from the lack of "greenness" in the standard CRR, which, if in existence, would have ensured banks' commitment towards the provision of more credit for green activities and climate-resilient practices.

The second objective was to determine the extent to which the standard CRR has enhanced agriculturalists' ability to sustain agricultural output growth in spite of climate crises. From the outcomes presented in Table 8, a significant negative relationship can be seen between the current CRR and agricultural output growth during climate hazards in Nigeria, both in the long and short runs. This means that a reduction in the cash reserve ratio by the CBN with aim of increasing the agricultural output during climate challenges (based on a theoretical expectation) would increase the climate-resilient output, as expected, both in the long and short runs. These findings are in agreement with the Keynesian view on monetary policies. In line with Keyne's theory, an increase in the money supply due to reduced rates of monetary policy instruments should lead to a fall in interest rates, which in turn leads to increased investments in agriculture and, consequently, increases in the agricultural output. This result conforms with the results of previous studies that revealed

that tightening monetary policies (CRR, inclusive) have detrimental effects on agricultural output growth [28].

7. Conclusions

This study employed an ARDL approach to carry out an ex post evaluation on the effectiveness of the current CRR in enhancing the climate-resilient agricultural sector in Nigeria by focusing on two key elements: the impact on farmers'/the agricultural sector's access to credit for climate-resilient agriculture and the impact on agricultural production growth in spite of climate crises. This answers the questions of "Could the current CRR aid climate-resilient agricultural growth in the face of climate variability and extremes?" and "Is there a need for green differentiation of the CRR?" as "green" policies may not necessarily result in growth in the conventionally measured output or the GDP [68,69]. To improve the robustness of the parameter estimates, we included the MPR, GREA, GCEA, TEMP, PRE, and RES in the vector of our independent variable.

In particular, the present study specified two separate equations for two ARDL models, one for the credit effect and another for the growth effect, and as such, employed the ARDL bound-testing approach, ARDL long-run form, and ARDL error correction modeling approach to establish the existence of a long-run relationship between our models' explanatory and explained variables; to estimate the direction and magnitude of the long-run relationship; and to capture the short-run dynamics of the variables, explaining also the speed at which the variables adjust to deviations from the long-run equilibrium. The bound test results show the presence of a long-run relationship between the study's independent variables and each of the dependent variables, as contained in both models. In relation to the credit effect, the long- and short-run ARDL model estimation results show that a 1% decrease in reserve requirements significantly reduces and increases the agricultural sector's access to bank credits (necessary for building climate resilience) by 0.637% and 0.368% in the long and short runs, respectively.

With regard to the growth effect, the results disclose that a percentage decrease in reserve requirements significantly enhances the agricultural output in spite of climate crises by 0.894% and 0.485% in the long and short runs, respectively. In contrast, our results demonstrated that a percentage decrease in the CRR would not sustain climate-resilient agricultural credit, while it would sustain agricultural output growth amidst climate challenges.

The ECM regression results additionally confirmed the long-run equilibrium relationship among the two types of variables utilized in our study, in the models for the credit and growth roles, as the error correction terms in both models showed the variables to have adjusted to deviations from the long-run equilibrium at speeds of 84.7% and 88.9%, respectively. In response to the question posed by this paper's title, the current CRR cannot fully sustain climate resilience in the agriculture sector, evident in the present study's results on its inability to perform its credit functions in addition to its ability to perform its growth function in enhancing agricultural resilience.

An interesting result regarding policy implication is that the conventional CRR applied by the CBN during climate challenges is not a suitable reserve requirement policy option for boosting credit for climate-resilient practices as it encourages output growth in spite of climate threats in the agriculture sector. In the face of climate variability and extremes, adding to the speculation that their impacts will continue to be felt in Nigeria's agriculture sector—as Nigeria practices rain-fed agriculture, with other climate factors being largely depended upon by the country's agricultural system—farmers' access to credit is a critical resource needed for enhancing climate-resilient agriculture practices, such as the diversification of crops and farming practices, including drought-resistant crops and water-efficient

irrigation systems. The authors of [83] have also documented evidence supporting that increasing agricultural production with increased formal credit is not unique to Nigeria, yet many private smallholder farmers today are worse off due to inadequate agricultural credit access. This could largely be a result of the substantial autonomy given to private banks in their green/climate-related lending decisions, made possible by a lack of the green differentiation of the CRR. Hence, banks channel more of the credit made possible from easing reserve requirements to sectors other than the climate-challenged agriculture sector, and agriculturalists use such funds provided from easing the CRR to encourage climate-resilient growth for other purposes that are sub-optimal from a climate perspective.

Therefore, the CBN needs to differentiate the CRR according to banks' green/climate-resilient lending decisions. Thus, we recommend such a policy option to the CBN. In this reserve requirement policy option, the CBN would require different cash reserve ratios to be maintained by different banks based on their lending decisions. DMBs that direct loans towards low-carbon sectors, climate actions, and climate-resilient practices and investment projects would be required to maintain a CRR lower than that of others. Such a practice would ensure the effective utilization of the CRR in boosting credit to climate-affected agriculture. The actionability of our recommendation is discussed regarding accountability/transparency, equity, and coordination. The "greenness" in the differentiated CRR conveys a commitment that the credit availability made possible by the reduced CRR will be used effectively and transparently by banks and farmers for green and climate-resilient activities. With regard to equity, the recommended reserve system should be designed and monitored by the CBN to ensure that all farmers, including smallholders and urban and rural resident farmers, have access to the benefits of the green-differentiated CRR, so far as their reason for requiring credit is green/climate-oriented. Lastly, close coordination is needed between the CBN, DMBs, farmers/the agriculture sector, and other stakeholders for the recommended CRR to work effectively.

This study has one major limitation: the applicability of this study's results to other countries. However, the findings offer valuable insights for Nigeria and its agriculture sector. Therefore, future research could benefit from comparative studies involving multiple countries' agricultural sectors for deeper insights.

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Abbreviations

NBS	National Bureau of Statistics
NEMA	National Emergency Management Agency
UNDP	United Nations Development Program
NCCP	National Climate Change Policy
BNRCC	Building Nigeria's Response to Climate Change
UNEP	United Nations Environment Program
UNCTAD	NU Trade and Development

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