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CACCI FIELD NOTES

Climate Adaptation Status and Pathways in Nigeria

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About the CACCI Field Notes

AKADEMIYA2063 CACCI Field Notes are publications by AKADEMIYA2063 scientists and collaborators based on research conducted under the Comprehensive Action for Climate Change Initiative (CACCI) project. CACCI strives to help accelerate the implementation of Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) by meeting the needs for data and analytics and supporting institutional and coordination capacities. In Africa, CACCI works closely with the African Union Commission, AKADEMIYA2063, the African Network of Agricultural Policy Research Institutes (ANAPRI), and climate stakeholders in selected countries to inform climate planning and strengthen capacities for evidence-based policymaking to advance progress toward climate goals.

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AKADEMIYA2063's work under the CACCI project contributes to the provision of technical expertise to strengthen national, regional, and continental capacity for the implementation of NDCs and NAPs. AKADEMIYA2063 is committed to supporting African countries in their efforts against climate change through the provision of data and analytics using the latest available technologies. In this Field Note, AKADEMIYA2063 scientists conduct an ex-ante analysis of Nigeria's climate change and adaptation strategies using a mix of macro- and micro-economic models to assess feasibility, achievability, and alignment with continental and global development frameworks. The authors build simulation scenarios through an exhaustive review of existing literature to collect evidence on the impacts of climate change and adaptation options on agricultural productivity, followed by an assessment of economic growth, employment, income changes, and poverty and food security outcomes.

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1. Introduction

Nigeria has a land area of 923,768 square kilometers (km^2) and 853 km of coastline (World Bank 2021). The country is located primarily within the lowland, humid tropics and is generally characterized by high temperatures throughout the year. Nigeria has three distinct climatic zones: a tropical wet climate in the south, a tropical savannah climate in most central regions, and a Sahelian hot and semi-arid climate in the north. As expected, precipitation amounts decline from the country's south to its north. The southern regions experience strong rainfall events during the rainy season from March to October, with annual rainfall amounts usually above 2,000 millimeters (mm), which can reach 4,000 mm or more in the Niger Delta. The central regions are governed by a well-defined, single rainy season (April to September) and a dry season (December to March) that is influenced by the Harmattan winds from the Sahara. Coastal areas experience a short dry season. In the north, rain falls from June to September in the range of 500 mm to 750 mm, although annual rainfall can reach up to 1,200 mm. The rest of the year is hot and dry. Northern areas have a high degree of annual variation in the rainfall regime, which can result in droughts and flooding.

The observed typical patterns across the country's climatic zones have been altering rapidly in recent years, mostly due to climate change. Dramatic variations in climatic patterns have triggered a wide range of environmental challenges for the country, negatively impacting every sector, particularly agriculture, water resources, and infrastructure. Nigeria is now classified as one of the ten most vulnerable countries to the adverse impacts of climate change and natural hazards (World Bank 2021). The country faces risks from numerous natural hazards and is prone to floods, storms, ocean surges, droughts, and wildfires. Nigeria's coastal states face extensive risks from storm surges along the entire coastline; the Niger Delta region is prone to inland flooding and wildfires, and the southeast is vulnerable to negative rainfall anomalies. The country's northern areas face chronic aridity and riverine flooding along the Sokoto River in the northwest and the Komadugu River system in the northeast, as well as transboundary flooding along the Niger and Benue rivers. The country's middle belt is at risk of high exposure to aridity – this situation is compounded by tensions between farmers and pastoralists around land rights and water access.

2. National Adaptation Policy Review and Mapping

2.1. Climate Change Impacts and Responses in Nigeria

Nigeria is highly vulnerable to climate change. The Climate Scorecard (2019) reports that Nigeria is one of the ten most climate-vulnerable countries in the world. Extreme weather events and climate variability, such as droughts, floods, erosion, and sea-level rise, all impact the West African state. Impacts of a changing climate in Nigeria include loss of life and property; damage to socio-economic infrastructure and ecological systems; exacerbation of communal conflicts as environmental resources, including freshwater, become scarce (especially in the country's marginal areas); and significant threats to the country's food security. Climate change impacts tend to be moderated by levels of socio-economic development as those communities with greater wealth are better able to invest and adapt to the extent that adaptation is possible. Nigeria's poor socio-economic development is heightening the severity of the impacts, further limiting the country's capacity to respond to the emerging challenges posed by climate change. Without serious interventions – including adaptation measures – the impacts of climate change could be even greater over time. It is therefore crucial for Nigeria to firmly focus on those activities and programs that would strengthen its resilience and adaptive capacities in terms of socio-economic development and effective management of ecosystems.

Extreme weather events such as floods, drought, and the accompanying effects of erosion and desertification now occur more frequently across the country. These have resulted in environmental degradation, especially in the semi-arid regions. In 2012, Nigeria experienced a double shock of severe drought in the northeast and widespread flooding that affected almost the entire country. The floods caused nearly US$ 17 billion in losses and damage in the 12 most affected states. Furthermore, low-income households are the most vulnerable to weather-related natural disasters as they are highly dependent on agriculture, which is the main source of income for 80 percent of the rural poor. Rapid urbanization and rising urban poverty levels also increase potential flood risks. An estimated 24 percent of Nigeria's population (approximately 41 million people) live in areas with high climate risk levels. Some of the highest overall exposure levels are concentrated in the coastal areas, including Lagos, Delta, and Rivers states, where large populations live in the cities of Lagos, Warri, and Port Harcourt. Poor households and slum areas in these cities face risks from flooding and storm surges. An estimated 27 to 53 million people may have to be relocated due to a projected 0.5 meter sea level increase, which is expected for Nigeria by the end of this century. In addition, ongoing

coastal erosion, rising seas, and oil pollution are destroying the Delta's mangrove forest, which is a major buffer against storm surges. Rising food insecurity is another concern as disasters lead to erosion and degradation of land and infrastructure, floods and heavy rains result in crop failures, and higher humidity levels cause possible nutrient leaching and fungal growth. More droughts will also likely affect water availability. Given the dependence of Nigeria's economy on climate-sensitive industries (agriculture, forestry, oil, and gas extraction), climate change inaction could cost Nigeria between 6 percent and 30 percent of her gross domestic product (GDP) by 2050, equivalent to losses of US$ 100-460 billion.

Nigeria submitted its Third National Communication in 2020 and its Nationally Determined Contribution (NDC) to the UN Framework Convention on Climate Change (UNFCCC) in 2016. In 2021, the country submitted its Updated NDC. These documents outline the country's efforts to promote sustainable, climate-resilient development. Efforts outlined in the documents include adaptation and mitigation actions that are economically efficient, socially beneficial, and also effectively address climate change and its expected impacts. These policies aim to alleviate poverty, increase social welfare and inclusion, and improve individual well-being while ensuring a healthy environment. Nigeria has identified its adaptation priorities, which include sustainable land use and water resource management for food security, inclusive urban development, preservation of biodiversity and ecosystem services, development of social protection mechanisms, infrastructural resilience, improved health, and disaster risk reduction measures for reduced vulnerability across the country.

2.2. Climate Change Adaptation Actions

Adaptation is defined as the process of adjusting to climate change impacts by seeking to moderate or avoid harm and exploiting beneficial opportunities should these arise. Climate change adaptation may further be regarded as the behavioral adjustments needed to protect people, their families and property, and the overall economy from the adverse impacts of a changing climate. Countries are required to submit a National Adaptation Plan (NAP) to the UNFCCC, but Nigeria has yet to do so. While the country prepares its NAP for submission, its national mitigation and adaptation measures are guided by the National Climate Change Policy. Nigeria recently submitted its NAP framework document in June 2020 to manage the country's medium- and long-term adaptation needs coherently and coordinatedly. The country has also set the goal of providing a broad-based framework to effectively address the development of its NAP. In May 2021, Nigeria submitted its final updated Nationally Determined Contribution (NDC) to the UNFCCC, which replaced the NDC document submitted in 2016. Continued adaptation efforts are focused on the country's most vulnerable sectors: **agriculture and food security, forests and biodiversity, water resources, energy and infrastructure, health, human settlements, industry and commerce, transportation and communication.** These adaptation measures and efforts aim to increase the country's resilience capabilities and strengthen its social and economic structures against vulnerability. The country's adaptation strategies and policies for the twelve priority sectors in Table 1 are based on the information captured in the National Adaptation Strategy and Plan of Action for Climate Change in Nigeria, NASPA-CCN (2011), the NAP Framework (2020), and the 2021 Nigeria Climate Change Policy Response and Strategy (NCCPRS).

Table 1: Nigeria's National Adaptation Strategies, Policies, and Action Plans

S/N	Sector	Adaptation Strategies
	Agriculture: Crops and Livestock	• Adopt improved agricultural systems for both crops and livestock (e.g., diversify livestock and improve range management). • Increase access to drought-resistant crops and livestock feeds, adopt better soil management practices, and provide early warning and meteorological forecasts and related information. • Implement strategies for improved resource management. These include, for instance, increasing the use of irrigation systems that use low amounts of water, increasing rainwater and sustainable groundwater harvesting for use in agriculture, increasing the planting of native vegetation cover and the promotion of re-greening efforts, intensifying crop and livestock production in place of slash-and-burn approaches. • Focus on agricultural impacts in the savanna zones, especially the Sahel and other areas that are likely to be most affected by the impacts of climate change. • Promote efficient, gender-responsive, socially inclusive, climate-smart crop production, fisheries, and livestock development practices. • Promote and support effective research and knowledge development and management to connect farmers, policymakers, businesses, and researchers to work on adapting to dynamic current and future climate scenarios. • Develop and apply improved production and risk management technologies in agriculture. • Increase the uptake of adaptation measures at the farm and community levels. • Reinvigorate extension services, capacity-building, and technology transfer approaches to provide support to a wider group of farmers, including women and youth. • Strengthen adaptation measures based on indigenous knowledge. • Facilitate an enabling environment for enhanced public and private-sector participation and financial investments to achieve adaptation at scale. • Increase access to adaptation finance through economic incentives and value chain initiatives. • Strengthen regulatory and institutional capacity to implement and disseminate technical solutions in agricultural adaptations.

S/N	Sector	Adaptation Strategies
	Freshwater Resources, Coastal Water Resources, and Fisheries	• Initiate a national program for integrated water resource management at the watershed level. • Intensify programs to survey water quality and quantities for ground and surface water. • Implement programs to sustainably extend and improve water supply and management infrastructure. • Explore water efficiency and water demand management, particularly in the Sahel and Sudan savanna areas. • Enhance artisanal fisheries and encourage sustainable aquaculture as adaptation options for fishing communities. • Strengthen integrated water resources management (IWRM) for multi-layered development of the nation's water resources infrastructure. • Develop gender-responsive, socially inclusive, and resilient water and sanitation infrastructure. • Invest in small-scale earth dams for multi-purpose use. • Promote alternative water supplies, including inter- and intra-basin water transfers. • Strengthen river basin governance and scale up regional cooperation, particularly along the major river basins and catchment areas. • Increase the density of hydrometric networks for early warning forecasting. • Strengthen appropriate policy, regulatory, and institutional reforms and provide economic instruments for water supply and demand management. • Strengthen the capacity for smart water management. • Promote investment in the sector, including enhanced public and private-sector participation. • Deploy renewable energy sources for water infrastructure.

S/N	Sector	Adaptation Strategies
	Forests and Biodiversity	• Strengthen implementation of the national Community-Based Forest Resources Management Programme. • Support review and implementation of the National Forest Policy. • Develop and maintain a frequent forest inventory system to facilitate the monitoring of forest status and initiate a research program on a range of climate change-related topics, including the long-term impacts of climatic shifts on closed forests. • Provide extension services to civil society organizations (CSOs), communities, and the private sector to help establish and restore community and private natural forests, plantations, and nurseries. • Improve the management of forest reserves and enforce low-impact logging practices. • Support the active implementation of the National Biodiversity Strategy and Action Plan (NBSAP), especially those strategic actions that address climate change impacts. • Support the recommended climate change adaptation policies and programs in sectors that affect biodiversity conservation, including agriculture, forestry, energy, and livelihoods. • Support and implement programs for alternative livelihoods to reduce unsustainable resource use that contributes to biodiversity losses. • Treat forests as resources that must be properly accounted for. • Strengthen the management of forests and expand tree cover through gender-responsive, socially and environmentally responsible reforestation and restoration initiatives. • Facilitate sustainable regulatory frameworks, incentives, and financial mechanisms for implementing the REDD+ Strategy and the Great Green Wall Initiative. • Mainstream climate change adaptation into forest management. • Enhance forest capacity for adaptation by reducing ecosystem vulnerability and reducing exposure of ecosystems to extreme events.

S/N	Sector	Adaptation Strategies
	Health and Sanitation	• Undertake research to better understand the health impacts of climate change in Nigeria. • Strengthen disease prevention and treatment for those diseases expected to increase as a result of climate change. • Reinforce programs to build and maintain wastewater and solid waste management facilities. • Promote and facilitate the adoption of practices and technologies that reduce exposure to and health impacts from extreme heat. • Establish early warning and health surveillance programs. • Strengthen adaptation strategies for the health sector and align them with the National Adaptation Plan (NAP) Framework. • Strengthen surveillance programs for monitoring human health under a changing climate. • Promote climate-resilient infrastructural development and maintenance in the health sector. • Promote policies to retain qualified health personnel to enhance health sector resilience. Create a functional, effective, and transparent program for their retention. • Promote community hygiene and general cleanliness in all sectors. • Promote preparedness in all areas of primary healthcare delivery and responses to climate-induced diseases and pandemics.
	Human Settlements and Housing	• Develop climate change adaptation action plans for urban areas, particularly those exposed to the greatest risks. • Assist communities in reducing vulnerability through participatory land use and housing planning. • Discourage building and urban encroachment into vulnerable, high-risk, low-lying areas. • Discourage maladaptive housing and settlement practices in the face of climate change. • Strengthen rural settlements to reduce migration. • Support main settlements in developing and undertaking ambitious climate change adaptation actions. • Strengthen institutional capacity for urban development and the promotion of climate-resilient cities. • Strengthen socially inclusive and gender-responsive land use planning and promote urban renewal. • Strengthen regulatory and institutional frameworks to ensure resilient settlements.

S/N	Sector	Adaptation Strategies
	Energy	• Include increased protective margins in the construction and placement of energy infrastructure (i.e., higher standards and specifications). • Undertake risk assessment and reduction measures to increase the energy sector's resilience. • Strengthen existing energy infrastructure, in part through early efforts to identify and implement all possible 'no-regrets' actions. • Develop and diversify secure energy backup systems to ensure that both civil society and security forces have access to emergency energy supplies. • Expand sustainable energy sources and decentralize transmission to reduce the vulnerability of energy infrastructure to climate impacts. • Climate-proof the energy sector for resilience. • Invest in protective energy infrastructure to reduce loss and damage caused by climate-related extreme events. • Promote decentralized energy systems to increase resilience, with an emphasis on mini-grids and stand-alone systems. • Improve access to energy, particularly in rural areas. • Improve energy and water efficiency and demand-side management to alleviate supply constraints. • Invest in early warning systems, including reliable and timely weather and hydrometeorological observations combined with forecast models.

S/N	Sector	Adaptation Strategies
	Transportation and Communications	• Include increased protective margins in the construction and placement of transportation and communications infrastructure (i.e., higher standards and specifications). • Undertake risk assessment and risk reduction measures to increase the resilience of the transportation and communication sectors. • Strengthen existing transportation and communications infrastructure, in part through early efforts to identify and implement all possible 'no-regrets' actions. • Develop and diversify secure communication backup systems to ensure that both civil society and security forces have access to emergency communication methods. • Make provisions for diverse transportation options, such as pedestrian, bicycle, and transit routes. • Ensure a functional, socially inclusive, gender-responsive, culturally appropriate, and adaptable transport system. • Revise and adapt standards and guidelines for the construction, maintenance, and exploitation of transport infrastructure under different climatic scenarios. • Promote and support research on the impacts of climate change on transport demand and supply. • Undertake a comprehensive evaluation of the vulnerability of transport networks and identify response strategies. • Mainstream adaptation into transport planning, decision-making, and implementation. • Promote public and private-sector investment in climate-proofed and climate-resilient transport infrastructure. • Ensure the diversification of transport modes with appropriate adaptive capacities.

S/N	Sector	Adaptation Strategies
	Industry and Commerce	• Increase knowledge and awareness of climate change risks and opportunities. • Undertake and implement risk assessments and risk reduction measures. • Incorporate climate change into ongoing business planning. • Review and enforce land use plans in industrial areas in light of climate change. • Encourage the relocation of high-risk industries, facilities, and markets. • Promote and market opportunities emerging from climate change. • Encourage informal savings and insurance schemes and arrange for the availability of medium-term credit (especially for industries in crisis). • Promote a value chain-based approach for climate-resilient industries. • Harness the potential of clean technologies for climate-resilient industrial development. • Foster innovation and strengthen entrepreneurship to develop new capacities for wealth creation while safeguarding the environment and promoting sustainable climate-resilient industrial development. • Facilitate international partnerships to reinforce cooperation for climate resilience in the sector.

S/N	Sector	Adaptation Strategies
	Disaster, Migration, and Security	• Strengthen capacity to anticipate disasters and impacts on internal migration and security. • Strengthen response capacity through information and awareness, training, equipment, plans and scenarios, and communication. • Strengthen individual and community-based emergency preparedness and response capacity in high-risk areas. • Strengthen rural infrastructure and the availability of jobs to discourage out-migration. • Integrate climate change into national and regional security strategies. • Strengthen the capacities of security agencies and institutions to mainstream gender-based perspectives and climate risk considerations in security planning and operations. • Strengthen capacity to anticipate and respond to disasters and impacts on internal migration and security. • Develop robust projections in terms of climate change impacts for the formulation of appropriate policies toward reducing vulnerability. • Promote open and constructive dialogue for coordinated multilateral mechanisms to address climate risks and the development of effective policy responses and strategies on climate change-related security issues. • Institutionalize inclusive, participatory decision-making processes to reflect the voices of women, girls, and youth as ecosystem managers under increasing insecurity. • Develop and implement strategies that allow for the better management of climate variability and lessen its impacts on livelihoods and agricultural production to enhance security. • Strengthen rural infrastructure and promote sustainable rural livelihoods. • Minimize the existence of ungoverned spaces. • Integrate migration and human displacement issues into national climate change planning.
	Livelihoods	• Develop a replicable approach or model that uses intermediate non-governmental organizations (NGOs), community members, and radio to disseminate climate change adaptation approaches and information and to gather feedback on adaptation actions focused on livelihoods. • Build a network of intermediate NGOs capable of working on climate change and livelihood issues, with these NGOs supporting a number of communities in high-risk states. • Reach communities with appropriate engagement methods in order to elicit and document needs and vulnerabilities related to climate change and livelihoods. • Use or reinforce available (indigenous) community resources to reduce vulnerability and build livelihood-linked capacities to adapt to climate change. • Encourage community participation and active roles by both genders in all livelihood development initiatives.

S/N	Sector	Adaptation Strategies
	Vulnerable Groups (from NASPA-CCN, 2011)	• Create awareness among government staff, including disaster and emergency management personnel, about climate change impacts and how these impacts affect vulnerable groups. • Provide basic training for government staff on gender awareness tools to enhance implementation capacities. • Adapt government programs, including emergency response plans and programs directed at vulnerable groups, to better address the impacts of climate change on these groups. • Adapt public service facilities, including school buildings, to withstand storms and excess heat. • Intensify the immunization of children and youth to provide protection against diseases that are expected to become more prevalent with climate change. • Retrain health workers to appreciate emerging climate change challenges within the context of immunization delivery and other comprehensive healthcare delivery. • Encourage faith-based and civil society organizations to provide social welfare programs and other forms of support to address the climate change-induced needs of vulnerable groups.
	Education	• Provide evidence-based information to raise awareness and trigger climate change adaptation actions that will protect present and future generations. • Develop skills-based curricula in subjects such as science, geography, social studies, language arts, environmental education, and technology that will empower children to better respond to the threats of climate change. • Train teachers on climate change adaptation teaching strategies and techniques at pre-primary, primary, secondary, and tertiary levels of education.

Nigeria's adaptation actions and policies outlined above appear far-reaching and are close to exhaustive. Surprisingly, however, the NDC document is silent on the funders, implementation agencies, and timeframe, as well as associated financing needs or cost estimates for the implementation of these adaptation actions. These gaps represent significant drawbacks to the country's adaptation measures outlined in the submitted NDC. The document also does not highlight the overall and sectoral adaptation priority actions.

There are, however, climate targets for the country at both economy-wide and sectoral levels. The Grantham Research Institute on Climate Change and the Environment at the London School of Economics (LSE) has a rich database covering climate and climate-related laws for all countries and regulations and policies promoting low-carbon transitions. These reflect the relevance of climate policies across various sectors, including energy, transport, land use, and climate resilience. The Grantham database shows that Nigeria has two key climate change-related legislations, 18 climate-related national policies, and 32 climate targets (six in the 2016 Intended Nationally Determined Contribution (INDC) document and 26 in national laws and policies). The climate targets and their source documents are listed below in Table 2.

Table 2: Climate Change Adaptation Targets for Nigeria

No.	Description	Base year	Target year	Source	Sector
	20% (unconditional) to 45% (conditional) reduction in greenhouse gas (GHG) emissions by 2030 compared to the business-as-usual (BaU) scenario	2021	2030	Nigeria's INDC (2016)	Economy-wide
	By 2030, reducing GHG emission intensity will impact GDP by 20% relative to the base period 2010-14. This is conditional; the reductions in intensity will increase to 45% depending on conditions such as climate finance and capacity building	2010-2014	2030	Nigeria's National Action Plan to reduce short-lived climate pollutants (2019)	Economy-wide
	To phase out 10% of hydrofluorocarbons (HFCs) by 2030, 50% by 2040 and 80% by 2045		2045		Economy-wide
	Blending 10% by volume of Fuel-Ethanol with Gasoline (E10); blending 20% by volume of Biodiesel with Petroleum Diesel (B20) for transportation fuels			Nigeria's INDC (2016)	Economy-wide
	Attain 2% energy efficiency improvements per year				Energy
	Elimination of kerosene lighting by 2030	2021	2030		Energy
	End gas flaring by 2030		2030		Energy
	Reduce the contribution of flaring to total oil and gas emissions to less than 10% in 2020 from 80%.		2030	Nigeria's National Action Plan to reduce short-lived climate pollutants (2019)	Energy
	Generate 30% of electricity from renewables by 2030		2030		Energy
	Attain a 50% improvement in energy efficiency in the industrial sector by 2050		2050		Energy
	Achieve a 50% reduction in methane emissions from oil and gas by 2030		2030		Energy
	Ensure that 20% of households are using biomass stoves by 2030		2030		Energy
	Reduce oil and gas emissions in line with the Kyoto Protocol by 2043		2043	National Integrated Infrastructure Master Plan (2021)	Energy
	Increase share of alternative energy to 30% by 2023 and 35% by 2043		2043		Energy
	Create 250,000 jobs in the energy sector and provide solar power to 5 million households by 2023		2023	Nigeria Economic Sustainability Plan (2020)	Energy

	Reduce energy consumption levels by 20% by 2020 and 50% by 2030 through energy efficiency	2015	2030	National Policy on Climate Change and Climate Change Policy Response and Strategy (2023)	Energy
	End flaring by 2030 and reduce the contribution of flaring to total oil and gas emissions to less than 10% in 2020 from 80%		2030		Energy
	Create 250,000 jobs and power 5 million households by 2023 with solar energy		2023	Nigeria Economic Sustainability Plan (2020)	Energy
	Attain a 30% reduction in methane emission intensity from enteric fermentation by 2030		2030	Nigeria's National Action Plan to reduce short-lived climate pollutants (2019)	Agriculture
	Achieve a 50% reduction in anaerobic digestion by 2030		2030		Agriculture
	Attain a 50% reduction in the fraction of crop residues burned in fields by 2030		2030		Agriculture
	Ensure that 50% of all cultivated land will adopt Alternate Wetting and Drying (AWD) management by 2030		2030		Agriculture
	Ensure that 50% of methane is recovered from landfills and achieve a 50% reduction in open burning of waste by 2050		2050		Waste
	All vehicles to meet Euro IV limits by 2030		2030		Transport
	Convert 25% of all buses to compressed natural gas (CNG) by 2030		2030	Nigeria's National Action Plan to reduce short-lived climate pollutants (2019)	Transport
	Attain 12% forest cover by 2015 and 18% by 2020	2015	2020	Nigeria Vision 2020	Forest

There is no statistical evidence to indicate whether the country has attained the 2020 delivery targets. Realization of the 2023 targets is also not in view, which means that the possibility of achieving the other targets, given this trend of non-attainment, is doubtful. This further highlights the need to link climate adaptation and mitigation measures in the country to funder, implementation agency, and implementation timeframe, as well as to estimate the associated implementation costs of these adaptation actions.

2.3. Innovativeness and Context-specificity of the Proposed Actions

This sub-section examines Nigeria's proposed adaptation actions, which may be considered innovative. These are actions that differ from general development interventions and are also different from the adaptation actions proposed in the *Cancun Adaptation Framework (CAF)* for countries. The objective here is to facilitate the learning of valuable lessons among peer countries. This sub-section also reviews the context-specificity of the proposed adaptation actions to situate the proposed actions and interventions within a specific context, such as agroecological sectors or value chains.

Nigeria's adaptation actions are still evolving as the country has yet to submit a National Adaptation Plan to the UNFCCC. Currently, each official policy document on climate adaptation strategies, actions, and targets in the country is full of numerous actions and interventions; little or no consideration is given to harmonizing these adaptation

actions and strategies. Despite these concerns, there are several innovative proposed adaptation actions across the Agriculture, Forestry and Land Use (AFOLU) and Education sectors which are highlighted below:

1. Focus on agricultural impacts in the savanna zones, especially the Sahel, and other areas that are likely to be most affected by the impacts of climate change.
2. Reinvigorate extension services, capacity building, and technology transfer approaches to provide support to a wider group of farmers, including women and youth.
3. Strengthen adaptation measures based on indigenous knowledge.
4. Facilitate an enabling environment for enhanced public and private sector participation and financial investments to achieve adaptation at scale.
5. Implement programs to sustainably extend and improve water supply and water management infrastructure.
6. Enhance artisanal fisheries and encourage sustainable aquaculture as adaptation options for fishing communities.
7. Deploy renewable energy sources for water infrastructure.
8. Develop and maintain an updated forest inventory system to facilitate monitoring of forest status and initiate a research program on a range of climate change-related topics, including the long-term impacts of climatic shifts on closed forests.
9. Support and implement programs for alternative livelihoods to reduce unsustainable resource use that contributes to biodiversity losses.
10. Treat forests as resources that must be properly accounted for.
11. Develop skills-based curricula in subjects such as science, geography, social studies, languages, arts, environmental education, and technology that will empower children to better respond to the threats of climate change.

In terms of context-specificity, the proposed actions and interventions may be situated primarily within the relevant agroecological and sectoral contexts.

2.4. Feasibility of Proposed Adaptation Measures and Target Achievability

Adaptation actions and targets that countries propose should be feasible and achievable. The technological and financing needs for adaptation must also be within the country's reach. There should also be in-built safeguards to prevent these actions from becoming maladaptive over time. An evaluation of the country's progress in the implementation of its adaptation actions will require a review of some key performance indicators, such as trends in food supply and agricultural productivity.

The feasibility of Nigeria's proposed adaptation measures and the achievability of its targets may not be in view if agricultural production and productivity are regularly declining despite all the adaptation measures that the country has put in place over the years. Table 3 shows the trends in agricultural production between 2000 and 2020. Except for 'Roots and Tubers,' the selected commodity groups recorded declining outputs between 2010 and 2019. While the decline in 2020 from 2019 levels may be explained by the nationwide lockdowns necessitated by the COVID-19 pandemic, the decline in output for most agricultural commodities between 2010 and 2019 may partly be due to poor implementation of existing climate change adaptation measures. As expected, there is an observed productivity decline for these commodities (except for 'Fruits-Primary') during the same period. Agricultural land by use increased marginally during the same period. However, the share of area equipped for irrigation in agricultural land remained stable for most of the period under review.

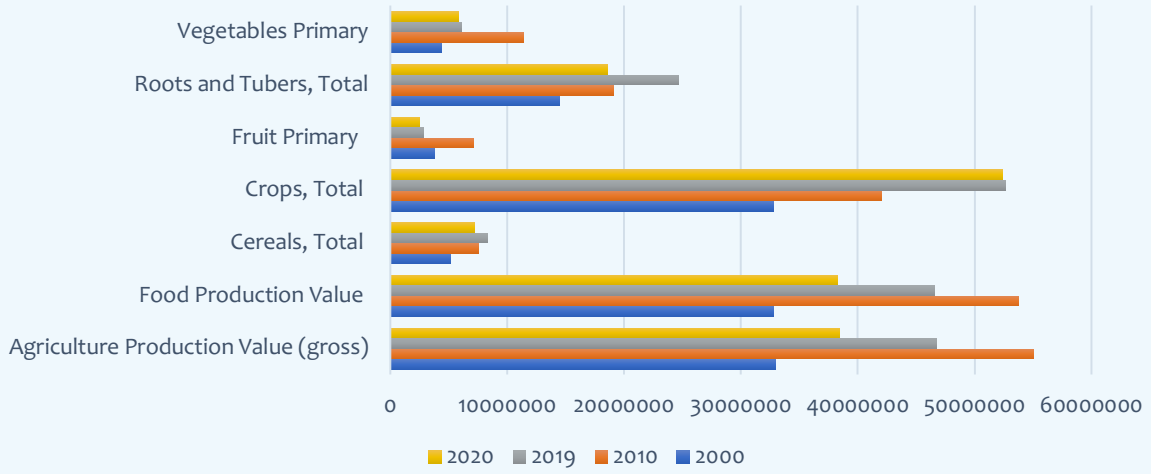
2.5. Alignment, Similarity, and Coherence of Nigeria's Adaptation Measures with National, Regional and Global Development Goals

The mainstreaming of climate change into the national development agenda requires a legal framework to facilitate coordination and alignment of climate change response goals with other relevant development aspirations such as the Sustainable Development Goals (SDGs), Agenda 2063, and the Sendai Framework on Disaster Risk Reduction. In line with this, Nigeria recently enacted the Climate Change Act (2021), making it the first West African country to

pass such a bill into law. The Climate Change Act seeks to provide a legal and institutional framework for achieving low greenhouse gas (GHG) emissions, identifying the major climate risks and vulnerabilities facing the country, and mainstreaming climate change actions into national plans and programs. Section 1(3) provides for **mainstreaming climate change actions in line with national development priorities**. Nigeria has already started integrating current adaptation measures into its 2021-2025 Economic Recovery and Growth Plan (ERGP). Further, the NAP Framework looks to align the NAP process with existing policies (e.g., ERGP, NASPA-CCN, National Climate Change Policy Response and Strategy (NCCP-RS)).

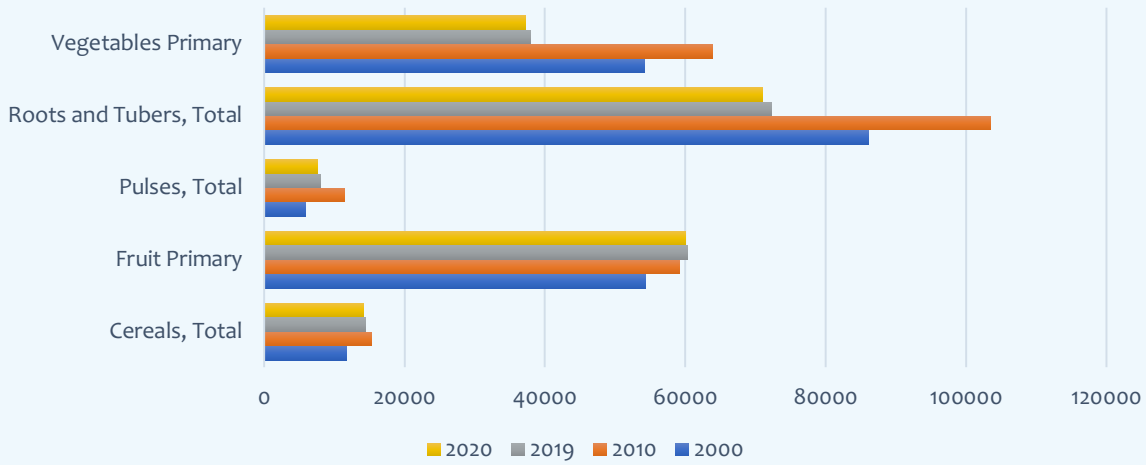
2.5.1 Nigeria's Food Supply and Productivity Patterns

Figure 1a: Trends in Food Production (Current US$, 000s)



Source: Authors' computations based on the FAOSTAT online database.

Figure 1b: Crop Yields (tonnes/ha)



Source: Authors' computations based on the FAOSTAT online database.

The UNDP (2020) noted that the country has already started developing a national toolkit to integrate the Nationally Determined Contributions (NDCs) into its Economic Recovery and Growth Plan (ERGP), Agenda 2030 and the SDGs, and the Sendai Framework for Disaster Risk Reduction.

Some of the specific measures taken by the Nigerian government to integrate climate change measures into national policies, strategies, and planning include:

i. Establishment of the Department of Climate Change, under the Federal Ministry of Environment, to coordinate the country's climate action agenda.

ii. The adoption in 2012 of a comprehensive strategy policy on climate change, i.e., the 'Nigeria Climate Change Policy Response and Strategy.

iii. The Climate Change Act (2021) was enacted to provide a comprehensive legal framework and enabling environment for the implementation of the country's climate action agenda.

It is, however, necessary to develop a comprehensive costing system for adaptation measures in the proposed NAP sectoral action plans to allow for mainstreaming of these climate change actions into the various development priorities. Developing community ownership of the NAP design and implementation process is vital to the success of the adaptation plan at all levels of society.

The requirement to align Nigeria's adaptation measures with continental and global development goals stems from the need to harmonize efforts and activities to fight climate change at a global scale. This was also emphasized in the SDG Summit of 2019, where countries were urged to mainstream the UN 2030 Agenda into their national planning instruments, policies, and strategies (UN 2022). African countries also need to integrate their adaptation measures and policies into continental priorities, including the African Union Agenda 2063 and the African Union Climate Change and Resilient Development Strategy and Action Plan – AUCCaRD (2022-2032).

Table 4: Alignment or Similarity of Nigeria's Adaptation Measures with Continental and Global Development Agendas

Nigeria's adaptation measures and targets	Agenda 2063 Goals	SDG Goals	AUCCaRD
The NDC pledge of 45% emissions reduction by 2030		• SDG 7– Renewable energy development • SDG 15 - Forest improvement	
Development of skills-based curricula in subjects like science, geography, social studies, language arts, environmental education, and technology	7. Environmentally sustainable and climate-resilient economies and communities	• SDG 13 – Climate action	3. Enhancing the means of implementation toward climate-resilient, low-emission development, incl. climate finance
Encourage informal savings and insurance schemes to make medium-term credit available to vulnerable groups and industries in crisis	1. Well-educated citizens and skills revolution underpinned by science, technology, and innovation	• SDG 1 – End poverty	3. Enhancing the means of implementation toward climate-resilient, low-emission development, incl. climate finance
Develop and maintain an updated forest inventory system to facilitate monitoring of forest status and initiate a research program on a range of climate change-related topics, including long-term impacts of climatic shifts on closed forests		• SDG 15–Forest improvement	

2.6. Key Programs and Projects Designed for the Implementation of Nigeria's Adaptation Measures

The Africa Policy Research Institute (APRI) has provided a list of the most comprehensive adaptation projects in Nigeria in recent years that are designed to support the implementation of adaptation measures. These include:

1. The World Bank assisted the **Nigeria Erosion and Watershed Management Project (NEWMAP)**, which was designed in collaboration with the Federal Ministry of Environment to tackle the hazard of gully erosion in south-eastern Nigeria and other forms of land degradation in northern Nigeria. The project was approved in 2012, and the World Bank committed approximately US$ 500 million (EUR 500 million). It was implemented in nineteen Nigerian states and consisted of three main components: (a) Gully Rapid Action and Slope Stabilization (GRASS), (b) Integrated watershed management, and (c) Adaptive livelihoods.

2. The **Building Nigeria's Response to Climate Change (BNRCC) project** was a five-year project that started in 2007 and undertook research on vulnerability (current and future) and awareness. It also incorporated pilot projects and included gender mainstreaming throughout the project lifecycle. The BNRCC cost US$ 4.9 million (EUR 4.9 million), was funded by the Canadian International Development Agency (CIDA), and resulted in the development of the National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) in collaboration with the Federal Ministry of Environment. The pilot projects were developed with the following goals: utilizing improved varieties to improve food security, providing fuel-efficient wood stoves, developing aquaculture as an alternative source of income, weaning communities off forest products, improving access to water sources, and rehabilitating ecosystems by planting trees.

3. **The Great Green Wall** is currently being implemented across twenty-two countries and encompasses the forestry, water management, and energy sectors. The program's overarching goal is to tackle persistent droughts, food insecurity, migration, and conflict by growing 8,000 km of forest across 100 million hectares of degraded land by 2030. Launched by the African Union (AU), it is currently being implemented by a partnership of the United Nations Convention to Combat Desertification (UNCCD), the Food and Agriculture Organization (FAO), the World Bank, the Global Environment Facility (GEF), the International Union for Conservation of Nature (IUCN), the Green Climate Fund (GCF) and several other organizations. The Africa Development Bank's (AfDB) newly launched US$ 25 billion (EUR 25 billion) **Africa Adaptation Acceleration Program (AAAP),** in collaboration with the Global Centre on Adaptation (GCA), aims to unlock financing from African governments, investors, and foundations through resilience bonds and debt-for-climate adaptation swaps.

4. **Adapting to climate change in the Lake Chad Basin** was funded by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The five-year project undertaken from 2013 to 2018 specifically targeted improvements in food security through the provision of adaptation solutions and best practices to 1,100 villages in the region and bordering countries.

5. In 2021, the World Bank launched a successor to NEWMAP dubbed the **Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL)** project. This is a US$ 700 million (EUR 700 million) project targeted at improving landscape management in northern Nigeria. The project consists of four sequentially phased components that aim to address the challenges of large-scale watershed degradation in northern Nigeria, improve community climate resilience, strengthen institutional capacity, and enable institutional and policy foundations for multisectoral integrated landscape management and climate resilience. Lastly, the project will install a financing mechanism that will be made available to borrowers on investment project financing operations to enable the quick deployment of uncommitted funds in response to crises or emergencies.

3. Economic Impacts of Climate Change and Adaptation Strategies

3.1. Methodology

Economic simulation models are practical tools used to support evidence-based planning and implementation of development programs. They establish a relationship between program inputs and expected outputs and outcomes, as well as facilitate the prioritization of public interventions and investments. Ex-ante analysis of climate change and adaptation strategies is carried out using a mix of macro- and micro-economic models. The macro-economic model captures issues related to growth, employment, and income generation, while the micro-economic model addresses income distribution, poverty, food security, and nutrition issues. The two models communicate in a top-down fashion through a set of interrelated variables available in both of them. These models are applied to the Nigerian economy using the most recent macro- and micro-economic databases.

The methodology is implemented using a stepwise approach. First, simulation scenarios are built through an exhaustive review of existing literature to collect evidence on the impacts of climate change and adaptation options on agricultural productivity. Second, evidence on the productivity effects of climate shocks is fitted into the macro-model to assess economic growth, employment, and income changes by production factor and household category. Third, income changes from the macro model are fitted into the micro-model to evaluate the poverty and food security outcomes.

Review of Climate Change Impacts on Agricultural Yields

Existing literature provides evidence of the likely impacts of climate change on African agriculture. The first step in implementing the methodology entails conducting an extensive review of evidence on the impacts of climate change on the agricultural sector in Nigeria, West Africa, and Africa. The review covers several agricultural activities, i.e., crops, livestock, forestry, and fisheries. Predictions on the likely effects of climate change on yields are documented in annexed Tables A.3 to A.8.

Management practices at the farm level, such as the use of irrigation, crop protection with chemicals and fertilizers, and adjusting sowing dates, have been proven to improve crop adaptation to climate change. The review also collects existing evidence on how farm-level practices contribute to mitigating the effects of climate change on agricultural yields in Nigeria.

Modeling the Macro-Economic Impacts of Climate Change

The ex-ante analysis of climate change and adaptation pathways primarily uses a Computable General Equilibrium (CGE) model customized to the Nigerian economy based on a Social Accounting Matrix (SAM). The CGE model is a macroeconomic model that combines economic theory and empirical data to capture the effects of economic policies and shocks. These models consider the interdependencies between different sectors, agents, and markets in the economy. They can, therefore, shed light on the wider economic impacts of policies and shocks, occasionally revealing their indirect or unintended effects. Considering the long-term outlook of climate change shocks, this analysis uses a static CGE model with long-term macroeconomic closure rules.

Key features of the model are borrowed from the static version of the CGE model developed by Decaluwé et al. (2013). This standard CGE model is modified for use in climate change analysis by adopting a long-term closure rule to consider the time dimension more accurately. This means that labor, agricultural land, and other forms of capital are fully mobile between economic activities as the economy has time to adjust in such a long-term scenario. Current public expenditures and the fiscal balance are fixed relative to GDP. The integration of a compensatory mechanism through taxes or subsidies on gross household income enables the capturing of the effects of government income variations following climate shocks, on household welfare. Nigeria is a small country in terms of its trade links with the rest of the world, i.e., the country has no influence on international prices of both imported and exported products, which remain fixed in the model. The current account balance of foreign trade is kept fixed relative to GDP, effectively linking external financing to the country's economic performance. The volume of investment is also kept fixed relative to GDP through household savings. Thus, the model is investment-driven in the sense that total investments determine total savings, i.e., the sum of private, government, and foreign savings. This closure rule allows the capture of the full effects of climate shocks. Stated differently, inter-generational welfare transfers are not allowed. Flexible prices equilibrate the demand and supply of domestically marketed local output, and the exchange rate is the numeraire in the model.

Many studies use a deterministic approach to assess the effects of climate change on agriculture. However, deterministic shocks ignore the uncertainties associated with climate change and its implications on yield, as depicted in annexed Tables A.3 to A.8. In this analysis, we use a stochastic approach to consider the uncertainties in the evolution of climate change and their effects on agricultural yields. Climate change shocks are translated into variations in the productivity of agricultural activities and, consequently, are transmitted through the agricultural sector's upstream and downstream linkages to the rest of the economy.

Country SAMs are the primary data sources for CGE models. SAMs are "a comprehensive, flexible, and disaggregated framework that elaborates and articulates income generation by activities of production and the distribution and redistribution of income between social and institutional groups" (Round 2003). Nigeria's 2018 SAM has 42 industries (including 18 agricultural activities), five production factors (including agricultural land), three labor categories, and ten representative household groups. The SAM' Account for Activities-Tobacco' has a zero value, while the 'Account for Commodities-Tobacco' has a positive value of 22. To avoid this potential source of computational difficulty for the model, the tobacco accounts were aggregated with those of beverages and tobacco, thereby reducing the activities and commodities for agriculture to 17 industries. Thurlow (2021) provides more detailed information on Nigeria's 2018 SAM.

Modeling the Micro-Economic Effects of Climate Change

Micro-economic models deal with the economic decisions and actions of economic agents in reaction to policy shocks. They integrate the heterogeneous behavior of individuals and firms while accounting for the aggregate costs and benefits of interventions or shocks (Bourguignon and Spadaro 2006). There is a growing interest in combining CGE and Micro-Simulation (MS) models to assess the effectiveness of macroeconomic policies and shocks. CGE models address macroeconomic and sectoral issues such as growth, employment, and earnings. However, they do not capture issues related to income distribution, inequality, and poverty like MS models do. The latter focus on individual and firm-level distributive effects, but they fail to capture general equilibrium effects, as well as macro- and sectoral issues, policies, and shocks. Integrated CGE-MS analysis can be conducted in many ways. The choice of approach depends on data availability, the research question, and time constraints (Cockburn, Savard, and Tiberti 2014).

The proposed MS model builds on the flexibility of the reweighting technique. The latter consists of altering the sample weights in the MS model to reproduce changes in employment and earnings from the CGE model and other population variables. New weights are generated so that the novel aggregate values of the population for selected variables are reproduced with minimal adjustments to the original weights. In other words, the approach minimizes the distance between new and old weights subject to a set of constraints on aggregate values. Thus, shocks are generated by the CGE model and transmitted to the MS model. Consistency between the two models is created by adjusting the household weights. In a comparison of the behavioral and the reweighting microsimulation approaches, Herault (2010) concludes that the two approaches delivered similar results when applied to the issue of trade liberalization in South Africa.

The CGE and MS models are linked through the productive factors, i.e., the three categories of labor, agricultural land, and other capital. One of the advantages of the reweighting approach is the ability to project population dynamics for various demographic categories, e.g., by region, gender, or age. This feature is important in the context of climate change analyses, which provide long-term impact assessments of people's livelihoods.

The MS model is implemented using the latest available survey data. The 2018/19 Nigeria Living Standards Survey (NLSS) is used to calibrate the MS models and to conduct the micro-economic analysis.

Simulation Scenarios

The economic impacts of climate change and adaptation pathways are assessed by comparing two scenarios: the Business-as-Usual (BaU) scenario and the climate change (CC) scenario. The first scenario, or BaU, is built on the agricultural yield trends for the past 21 years, i.e., 2000-2020 (Table 5). The low bounds are the average values of negative changes to agricultural yields. The high bounds are the average values of positive changes in agricultural yields. The BaU scenario does not incorporate climate change impacts but projects the continuation of historical trends in the agricultural sector and economy in general. The BaU scenario is the reference against which outcomes from the other scenarios are compared.

Table 5: Changes in Agricultural Yields in Nigeria, 2000-2020 (BaU scenario)

Agricultural Activities	Yield Variation (%)		
	Mean	Low bound	High bound
Maize	0.5	-6.8	5.7
Rice	2.1	-10.7	8.7
Other cereals	4.7	-22.0	21.2
Pulses	2.8	-14.6	12.1
Oilseeds	-0.1	-1.4	2.9
Roots	-0.5	-7.0	7.3
Vegetables	-0.2	-14.2	14.0
Sugarcane	-1.6	-8.6	5.1
Cotton and fibers	2.8	-17.2	13.8
Fruits and nuts	0.6	-0.7	1.5
Coffee, tea, and cocoa	0.2	-4.7	7.2
Other crops	1.2	-2.1	2.8
Cattle and raw milk	-1.1	-5.7	11.6
Poultry and eggs	1.1	-3.5	5.8
Other livestock	-1.0	-3.8	5.3
Forestry[1]	-0.7	-0.7	0.0
Fisheries[2]	2.9	-3.7	7.7

Source: FAOSTAT online database. [1] Data for Fisheries were sourced from the FAO Statistical Yearbook (2022 and earlier issues) - (measured by annual capture); [2] Data for Forestry were sourced from the World Bank WDI online database (Forest area is measured annually by % of land area).

The second scenario is the climate change (CC) scenario. This scenario is based on the existing empirical evidence on the impacts of climate change on agricultural yields and production. The results of this review for Nigeria are presented in Table 2, with further details available in annexed Tables A.3 to A.8. The latter displays variations in agricultural yields at different levels of global warming (i.e., increase from 0.5 °C to 5.5 °C) and precipitation.[1] The analysis considers the extreme values (low and high bounds) predicted by these studies.

1 The limitation in the literature studies focused on Nigeria or West Africa did not allow us to assess the impacts at different levels of warming.

Table 6: Climate Change Impacts on Agricultural Yields in Nigeria (CC scenario)

Agricultural Activities	Yield Variation (%)	
	Low bound	High bound
Maize	-25.0	-11.0
Rice	-42.0	8.0
Other cereals	-40.0	28.2
Pulses	-14.2	-4.9
Oilseeds	-38.7	-24.0
Roots	-21.7	-3.9
Vegetables	-10.7	18.7
Sugarcane	-56.1	-8.1
Cotton and fibers	-19.5	6.1
Fruits and nuts	-26.0	10.0
Coffee, tea, and cocoa	-14.1	9.5
Other crops	-	-
Cattle and raw milk	-36.0	-5.0
Poultry and eggs	-36.0	-5.0
Other livestock	-36.0	-5.0
Forestry	-57.0	-49.0
Fisheries	-42.0	-3.0

Source: Authors' compilation from a review of the literature.

The BaU and climate change scenarios are introduced based on a stochastic approach to consider the historical variability of agricultural yields and uncertainties in the evolution of climate change and its effects on agricultural yields. Shocks to agricultural yields are implemented using the Monte Carlo Technique, i.e., random selections of yield variations. The shocks are distributed uniformly using uniform probability with minimum and maximum variations (Tables 5 and 6). One thousand scenarios or iterations are implemented, and mean changes and standard deviations (SD) for output variables are computed. These are discussed in the next section.

3.2. The Economic Impacts of Climate Change

Effects on Agriculture

A comparison of the CC and the BaU scenarios indicates that climate change shocks substantially reduce agricultural productivity (Table 3). Under the BaU scenario, agricultural productivity increases slightly at an annual rate of 0.03 percent compared to 2019 (between -0.97 percent and 1.03 percent at a 95 percent confidence level). Agricultural productivity is severely affected by climate change shocks, with a decline of 9.7 percent in annual average productivity compared to the 2019 level (between -11.7 percent and -7.7 percent at a 95 percent confidence level). Average annual agricultural productivity falls by 10.7 percentage points and up to 11.7 percentage points in the CC scenario compared to BaU.

The results also indicate that productivity falls across all agricultural activities (with the exception of vegetables and other crops) under the CC scenario compared to BaU (Table 7). **Forestry, sugarcane, oilseeds, fisheries, cattle and raw milk, poultry and eggs, other livestock, maize,** and **rice** are by far the most affected activities by climate change shocks. Some of the least severely affected activities by climate change shocks are **coffee, tea, cocoa, other cereals, and pulses**.

Table 7: Changes in Nigeria's Agricultural Productivity

	Business-as-Usual		Climate change	
	Mean	SD	Mean	SD
Agriculture	0.0	0.5	-9.7	1.0
Maize	-0.5	0.4	-18.2	0.4
Rice	-1.1	0.6	-17.1	1.4
Other cereals	0.3	1.2	-4.6	2.0
Pulses	-1.5	0.8	-9.5	0.3
Oilseeds	0.6	0.1	-31.4	0.4
Roots	-0.1	0.4	-13.1	0.5
Vegetables	-0.3	0.8	4.0	0.9
Sugarcane	-1.7	0.4	-31.9	1.4
Cotton and fibers	-1.4	0.9	-6.6	0.7
Fruits and nuts	0.4	0.1	-8.1	1.0
Coffee, tea, and cocoa	1.2	0.3	-2.4	0.7
Other crops	0.4	0.1	0.3	0.1
Cattle and raw milk	3.0	0.5	-20.1	0.9
Poultry and eggs	1.1	0.3	-20.0	0.9
Other livestock	0.7	0.3	-19.9	0.9
Forestry	-0.4	0.0	-52.9	0.2
Fisheries	2.1	0.3	-22.3	1.1

Source: Compilation of simulation results (2023).

Agricultural productivity and value-added follows a similar pattern (Table 8). As can be seen, **oilseeds, forestry, coffee, tea and cocoa, sugarcane, maize,** etc., are some of the most severely affected crops in terms of decline in value-added due to climate change shocks.

Table 8: Changes in Agricultural Value-added in Nigeria

	Business-as-Usual		Climate change	
	Mean	SD	Mean	SD
Agriculture	0.0	0.6	-9.6	0.8
Maize	-0.4	0.2	-14.3	0.3
Rice	-0.7	0.3	-12.1	0.8
Other cereals	0.0	1.0	-8.7	1.7
Pulses	-1.0	0.5	-9.2	0.2
Oilseeds	0.4	0.1	-27.2	0.3
Roots	-0.1	0.3	-11.6	0.4
Vegetables	-0.2	0.6	-0.6	0.6
Sugarcane	-0.6	0.1	-15.2	0.6
Cotton and fibers	-1.7	1.0	-10.4	0.8
Fruits and nuts	0.2	0.1	-8.2	0.7
Coffee, tea and cocoa	5.0	1.5	-20.7	2.2
Other crops	0.7	0.5	-2.7	0.5
Cattle and raw milk	1.7	0.3	-13.6	0.5
Poultry and eggs	0.6	0.1	-12.3	0.5
Other livestock	0.4	0.2	-13.0	0.6
Forestry	-0.1	0.0	-23.7	0.1
Fisheries	1.2	0.2	-13.8	0.7

Source: Compilation of simulation results (2023).

Effects on Non-agricultural Sectors

Agricultural value-added decline affects the rest of the economy through the backward and forward linkages connecting the agricultural and non-agricultural sectors. In Nigeria, the industrial sector shows strong linkages with the agricultural sector. The input intensity (i.e., the ratio of an industry's intermediate consumption of agricultural products to the industry's value-added) of the industrial and service sectors relative to the agricultural sector was 9.4 percent and 1.0 percent, respectively, in 2018, representing backward linkages. Forward linkages, measured by the share of total demand for agricultural products by the industrial and service sectors, were 7.2 percent and 1.5 percent, respectively, in 2018. The service sector value-added declines less than industry value-added under the CC scenario (-0.9 percent against -2.5 percent respectively), indicating the relative dominance and resilience of the service sector in the Nigerian economy compared to the industrial sector. The exposure to external trade (i.e., the ratio of exports to production) for the industrial and service sectors was estimated at 24.3 percent and 2.0 percent, respectively, in 2018. Notably, the share of the services and industrial sectors for 2018 was 53.6 percent and 20.2 percent, respectively (Nigeria National Bureau of Statistics 2019).

Several non-agricultural industries are severely affected by the effects of climate change shocks on agricultural yields (Figure 1):

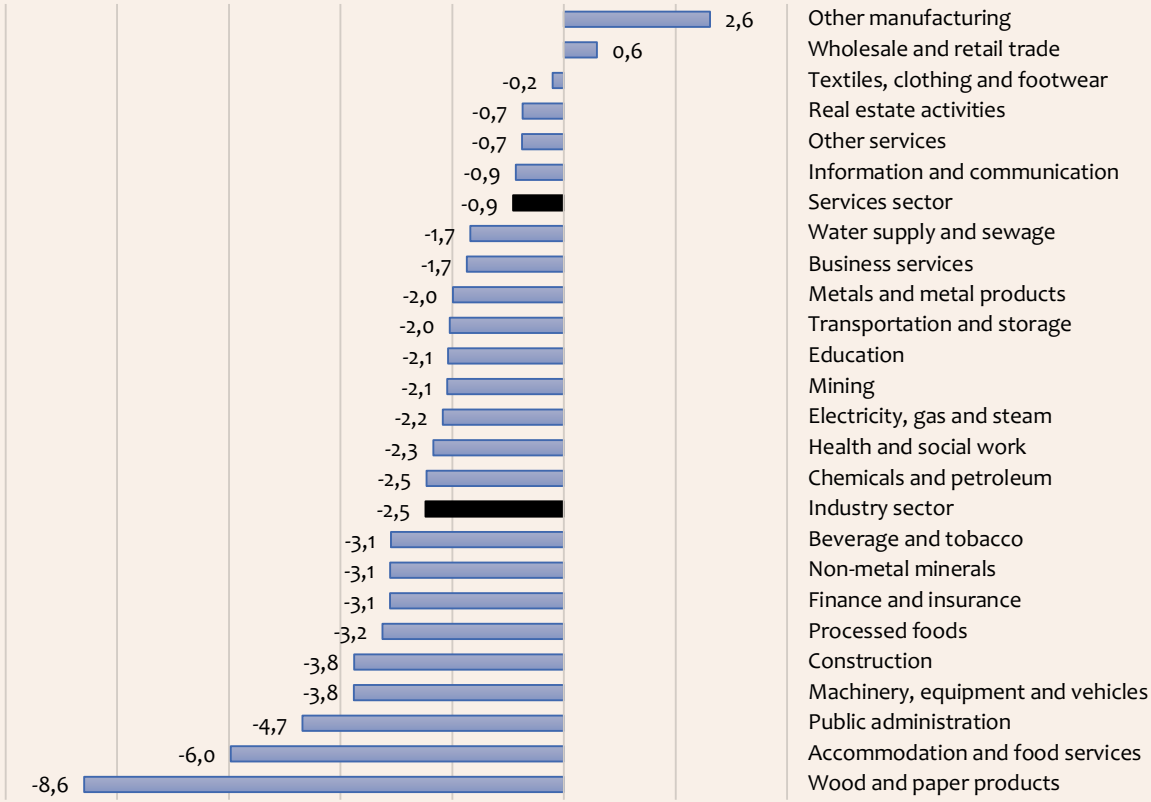
- Wood and paper products, accommodation and food services, and public administration are the sub-sectors most negatively affected by climate change shocks compared to the BaU scenario.
- The negative effects of climate change shocks on wood and paper products are attributable to the substantial linkages of this sector with forestry activities (forestry products represent 15 percent of the total input costs of wood and paper products).
- Accommodation and food services also have strong linkages with the agricultural sector, explaining the industries' poor performance in the face of climate change shocks. Agricultural products represent 16 percent and 29 percent of the total input costs of the accommodation and food services industries.
- Public administration will naturally contract due to the fiscal policy effects that emerge with the economy's underperformance.

Some non-agricultural industries stand to benefit from climate change shocks on agricultural yields through their non-linkages to agricultural industries. Other manufacturing industries increase their value-added under the CC scenario compared to the BaU scenario due to the complete absence of agricultural inputs in their industry products. The wholesale and retail trade industry does not consume any of the agricultural industries' output, and it, therefore, follows a similar pattern to other manufacturing industries.

Effects on the National Economy

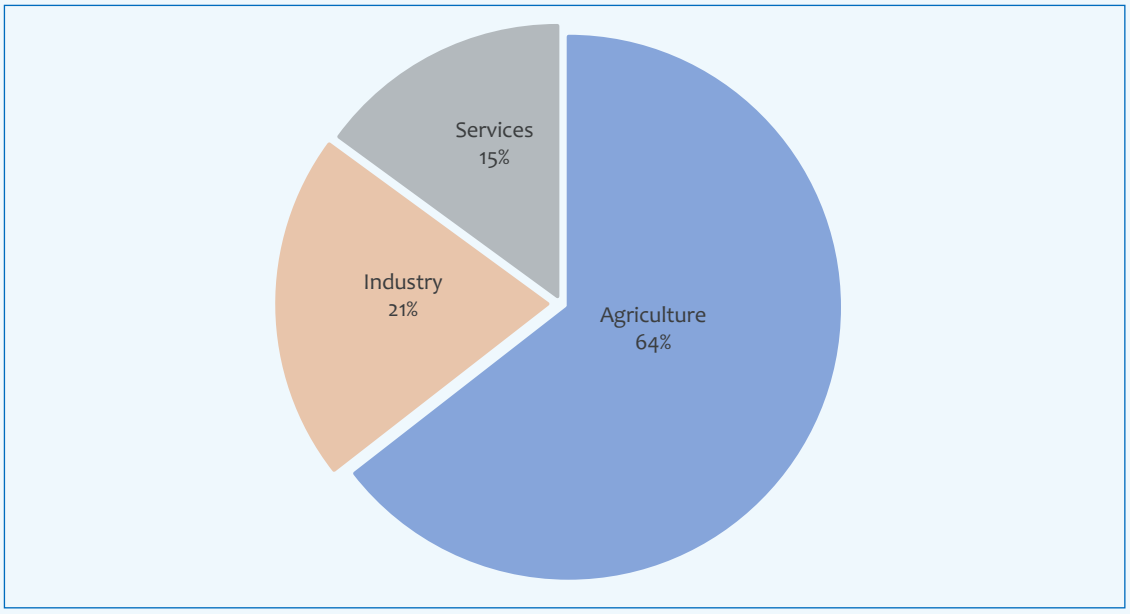
The impacts of climate change on agricultural yields reduce Nigeria's economic output (measured in terms of GDP) by 4.2 percent compared to the BaU scenario. The shrinking agricultural sector is primarily responsible for the GDP reduction, contributing 64 percent to the decline (Figure 3). The industrial sector also makes a modest contribution of 21 percent to GDP decline under the climate change scenario, while the service sector contributes the least at 15 percent. These effects are consistent with the country's economic structure, with the share of agriculture, industry, and services in Nigeria's economy estimated at 26.2 percent, 20.2 percent, and 53.6 percent, respectively, in 2018.

Figure 2: Changes in Value-added for the Industrial and Service Sectors in Nigeria, CC against BaU Scenarios



Source: Compilation of simulation results (2023).

Figure 3: Sectoral Contributions to GDP Decline, under CC Scenario
Change in GDP Growth: -4.2 percent (under climate change scenario)

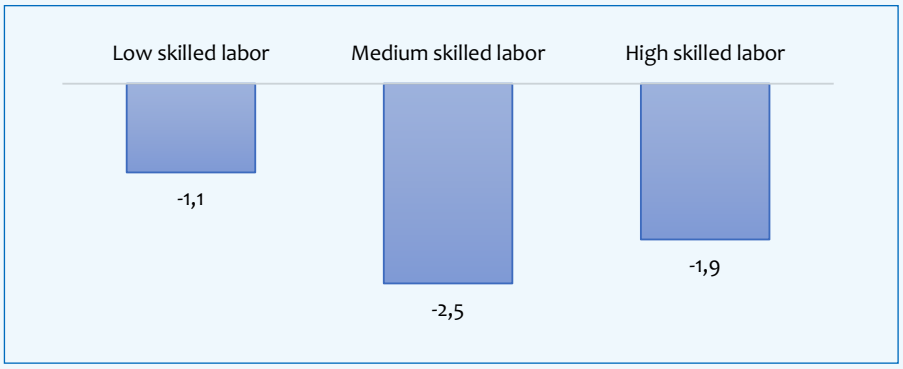


Source: Simulation results.

Effects on Employment and Factor Rewards

A comparison of the CC and BaU scenarios shows that climate change shocks on agricultural yields would hit medium-skilled laborers more severely than low-skilled and high-skilled laborers in terms of change in employment numbers (Figure 4). The model results indicate medium-skilled employment losses of up to 2.5 percent due to climate change shocks. At the same time, high-skilled employment losses are expected to stand at 1.9 percent, while low-skilled employment losses will be 1.1 percent.

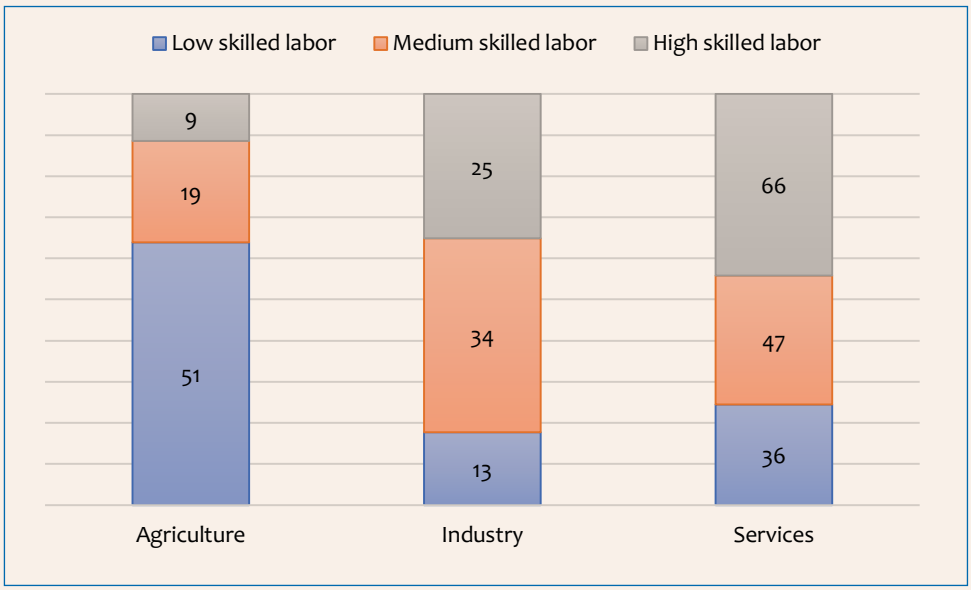
Figure 4: Changes in Employment Volume by Category in Nigeria, CC compared to BaU scenarios



Source: Compilation of simulation results (2023).

Similarly, the returns to the production factors are expected to be significantly affected by climate change shocks. As low-skilled employment earnings are primarily generated in the agricultural sector (Figure 5), this sector will account for 51 percent of all earnings by low-skilled laborers in the long run. The service sector will account for 36 percent of earnings by low-skilled laborers, while the industrial sector will be responsible for only 13 percent of earnings by this category of laborers. The service sector will have the highest share of earnings for both high-skilled and medium-skilled workers in Nigeria, accounting for 66 percent and 47 percent, respectively, of all earnings by this category of laborers. The industrial sector will remain stable as the sector is expected to retain 34 percent of earnings by medium-skilled workers and 25 percent by high-skilled workers. Only 9 percent and 19 percent of earnings by high-skilled and medium-skilled workers, respectively, are in the agricultural sector, suggesting that employment of these categories of workers in the sector continues to shrink due to climate change shocks. Overall, high-skilled and medium-skilled laborers are less negatively affected by climate change shocks because of the higher involvement of these categories of workers in Nigeria's industrial and service sectors compared to low-skilled laborers (Figure 5).

Figure 5: Share of Employment Earnings by Labor Category and Economic Sector in Nigeria

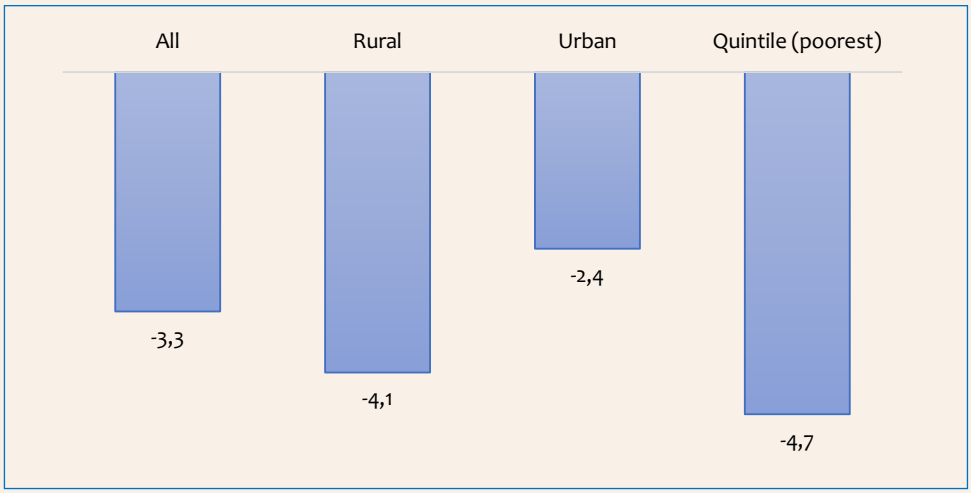


Source: Compilation of simulation results (2023).

Effects on Poverty and Inequality

Increased employment of high- and medium-skilled workers in the service and industrial sectors will compensate for the large productivity declines in agricultural activities severely hit by climate shocks, such as forestry, sugarcane, oilseeds, and fisheries. Since agricultural activities are undertaken mainly by households in rural areas and those in the lowest income quintile, climate change shocks are expected to severely affect the real consumption expenditures of households in these two groups the most. Figure 5 shows that real consumption expenditures among households in Nigeria's lowest quintile will decrease by 4.7 percent due to climate change shocks, while those of rural households will decline by 4.1 percent. Urban households are expected to experience much better outcomes in terms of change in real consumption expenditures as they will only suffer a decline of 2.4 percent. Overall, the decrease in real consumption expenditures for the entire country will be 3.3 percent.

Figure 6: Changes in Real Consumption Expenditures by Household Category in Nigeria, CC against BaU Scenarios



Source: Compilation of simulation results (2023).

Climate change shocks are also expected to worsen the poverty situation in Nigeria. Using the 2019 national poverty line of 137,430 Naira per person per year and the 2019 food poverty line of 81,767 Naira per person per year, the results in Table 8 indicate that climate change shocks will worsen rural and urban poverty rates. Simulations based on the national poverty line indicate that the poverty rate will increase by 2.1 percent overall, 2.9 percent for rural households, and 0.7 percent for urban households due to climate change shocks. Overall, 4,358,851 households will be affected, 3,821,611 of whom are rural, while the remaining 537,239 are urban.

Simulations based on the food poverty line also indicate that climate change shocks will increase the poverty rate by 0.9 percent overall and 1.6 percent among rural households, representing 1,861,045 individuals and 2,142,321 individuals, respectively. Interestingly, the food poverty rate for urban households will be reduced by 0.4 percent due to climate change shocks. This outcome can be explained by our earlier results, which showed that high-skilled and medium-skilled workers are less negatively affected by climate change shocks due to the high involvement of these employment categories in Nigeria's industrial and service sectors. These employment categories are mostly found in urban areas.

Table 9: Change in Poverty Levels, CC against BaU Scenarios

		All Areas	Rural	Urban
Poverty Headcount, National poverty line	*Percentage*	*2.1*	*2.9*	*0.7*
	Number of Individuals	4,358,851	3,821,611	537,239
Poverty Headcount, Food poverty line	*Percentage*	*0.9*	*1.6*	*-0.4*
	Number of Individuals	1,861,046	2,142,321	-281,275

Source: Computation of simulation results (2023)

3.3. Contributions of Different Climate Change Adaptation Strategies

This section presents results from the testing of four adaptation options. These are (i) Soil and water conservation (reduced tillage, terracing, ridging, bunds, and mulching), (ii) Use of improved varieties, (iii) Irrigation, and (iv) Use of organic and inorganic fertilizers. Empirical evidence on the impacts of these adaptation strategies on crop yields was sourced from existing research results (peer-reviewed) and is presented here:

Adaptation Scenarios

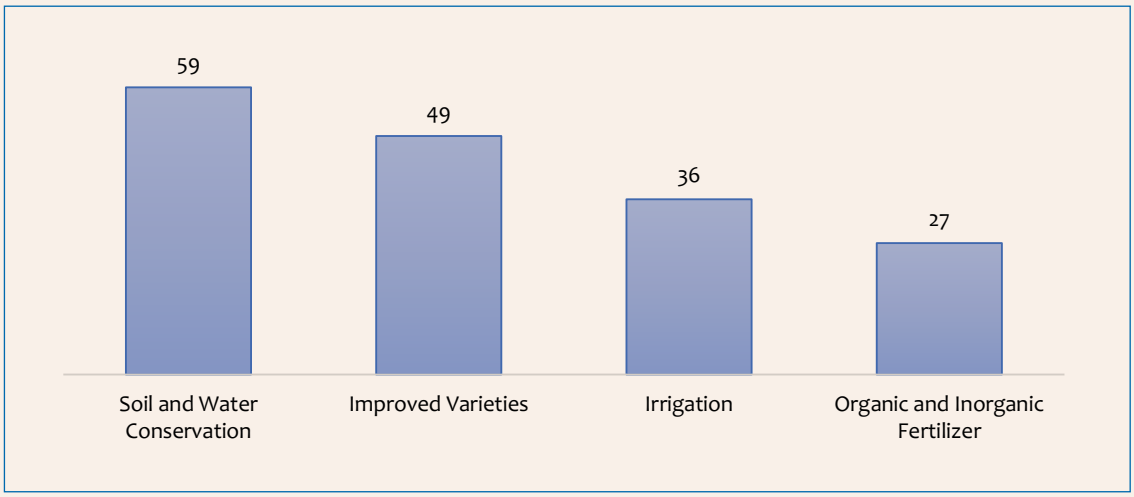
- *Soil and water conservation*
  - Reduced tillage increases crop yields by 8 percent for Côte d'Ivoire (World Bank 2019).
  - Terracing, ridging, and bunds increase crop yields by 44 percent for Côte d'Ivoire (World Bank 2019).
  - Mulching increases crop yields by 46 percent for Côte d'Ivoire (World Bank 2019).
  - Soil and water conservation increases maize yields by between 14 percent and 50 percent in Africa (Lebel et al. 2015).
- *Improved varieties*
  - Crop yields increase by at least 25 percent in Africa south of the Sahara (Waha et al. 2013).
  - In Cote d'Ivoire, crop yields increased by 36 percent (World Bank 2019).
  - Maize yields increased by between 20 percent and 50 percent in Western Africa (CGIAR 2010).
  - In Cameroon, maize yields rose from 32.1 percent to 62.3 percent, sorghum yields from 38.3 percent to 155.7 percent in 2020, while the Bambara groundnut yields rose from 11 percent to 100 percent (Tingem and Rivington 2008)
- *Irrigation*
  - Increased agricultural production by 38 percent for Africa south of the Sahara (Mabhaudhi 2018).
  - Has the potential to boost agricultural productivity by ~50 percent (Shukri 2013).
  - Increased rice yields by 23 percent in Ghana (Koide et al. 2021).

- *Organic and inorganic fertilizers [Crops 42-73 percent]*
    - In Côte d'Ivoire, inorganic fertilizers increased crop yields by 68 percent (World Bank 2019).
    - Also, in Côte d'Ivoire, organic fertilizers increased crop yields by 73 percent (World Bank 2019).
    - Use of green manure increased crop yields by 42 percent in Cote d'Ivoire (World Bank 2019).

Simulation Results

The key question driving the climate adaptation simulation scenarios was, "What is the share of the cultivated area that Nigeria must cover under each adaptation strategy to wipe out the economic (GDP) losses caused by climate change shocks on agricultural yields?" Figure 7 shows the answers to this based on simulation results.

Figure 7: Additional Cultivated Area to Cover under Various Adaptation Options (%)



Source: Compilation of simulation results (2023).

Soil and water conservation (reduced tillage, terracing, ridging, bunds, and mulching) in Nigeria needs to cover an additional 59 percent of the total crop area to recover the GDP losses arising from climate change shocks. The country must also cultivate an additional 49 percent of the total crop area using improved varieties to recover the GDP losses due to climate change shocks. Irrigation may be a contentious adaptation measure – however, our simulation results show that Nigeria can recover the GDP losses associated with climate change shocks by irrigating an additional 36 percent of the total crop cultivation area. Finally, the application of organic and inorganic fertilizers on an additional 27 percent of Nigeria's total crop area will also help to recover the GDP losses arising from climate change shocks in the country.

4. Summary and Conclusion

The following key conclusions are drawn from the analyses and results presented above.
First, guided by the National Adaptation Strategy and Plan of Action for Climate Change in Nigeria, NASPA-CCN (2011), the NAP Framework (2020), and the Nigeria Climate Change Policy Response and Strategy (NCCPRS) 2021, the country has developed several climate change adaptation and mitigation strategies, and action plans. In May 2021, Nigeria submitted its final updated NDC to the UNFCCC to serve as an update to the document submitted earlier in 2016. The updated NDC covers both mitigation and adaptation plans. The adaptation plan consists of key interventions across all the sectors. In addition to the NDC, Nigeria recently enacted the Climate Change Act (2021) to provide a legal framework to facilitate coordination and alignment of its climate change response goals with other relevant development priorities, making it the first country to pass this type of law in West Africa. Although Nigeria has yet to submit a NAP to the UNFCCC, reviews of implementation progress based on existing reports and evidence indicate that the country is making good progress toward implementing proposed actions. In all of the proposed strategic areas, several encouraging actions have been implemented that can be further scaled up and streamlined to combat the adverse impacts of climate change.

Second, the assessment of the economic impacts of climate change has clearly shown the urgent necessity of implementing adaptation strategies. If the country continues on the 'business-as-usual' track without embracing significant adaptation measures, climate change will reduce Nigeria's economic output (measured in terms of GDP) by 4.2 percent in the long run (this is in view of the long-run closure adopted in the model). The agricultural sector is primarily responsible for the GDP decline with a contribution of 64 percent. Relatedly, the number of impoverished people will increase by 0.9 percent due to climate change impacts. This represents an additional 1,861,045 individuals who are unable to afford the cost of the minimum food basket. However, the extensive promotion and implementation of soil and water conservation measures, irrigation, improved crop varieties, and organic and inorganic fertilizers will help combat climate change's damaging effects. To better insulate the country from these adverse impacts of climate change, cultivated areas under soil and water conservation will have to increase by 59 percent, irrigation by 49 percent, improved crop varieties by 36 percent, and fertilizers by 27 percent, respectively.

Based on these findings, the study recommends the following:

- Scale-up of best practices related to the institutionalization of climate change actions and funding of mobilization efforts. Nigeria has done well in turning the spotlight on climate change actions from National to State levels through multiple policy documents. However, every official policy document on climate adaptation strategies, actions, and targets in the country is replete with numerous actions and strategies, and little or no consideration is given to harmonizing adaptation actions and strategies. It is vitally important to synchronize these climate policy documents.
- A significant number of countries have developed institutional frameworks and capacities for mobilizing climate funds and implementing climate change projects. The country needs to develop a comprehensive costing system for adaptation measures in the proposed NAP sectoral action plans to mainstream these climate change actions into the various development priorities.
- Mainstreaming adaptation practices in the agricultural sector will require improved prediction capabilities and a better knowledge of climate suitability for crops. The predictions will help to determine – with a level of certainty – how the climate will change in the short-term and enable planning for cropping activities. Based on the predictions above, crop climate suitability data will indicate suitable places to grow specific crops based on the prevailing climate. These input data would help the country adapt to a changing climate instead of relying only on traditional knowledge of the crop calendar.
- The study advocates for the promotion of climate-smart practices such as soil and water conservation practices, irrigation, and improved agricultural technologies to protect the productivity declines in the agricultural sector and shield the economy from climate-induced crises.

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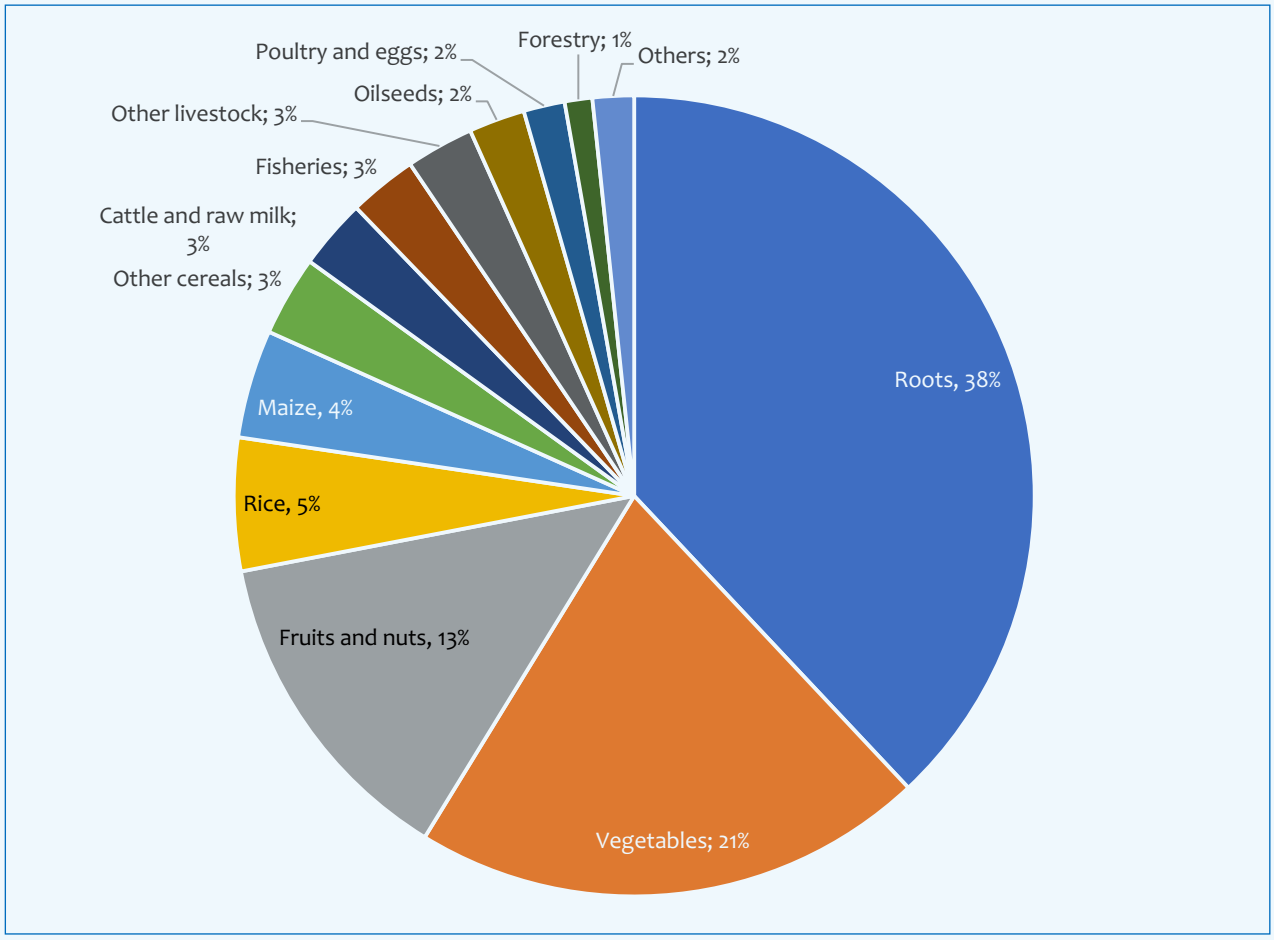
Poultry and eggs; 2%
Forestry; 1%
Others; 2%
Oilseeds; 2%
Other livestock; 3%
Fisheries; 3%
Cattle and raw milk; 3%
Other cereals; 3%
Maize, 4%
Rice, 5%
Fruits and nuts, 13%
Vegetables; 21%
Roots, 38%

Annex A1: Contribution of agricultural activities to agricultural value-added in 2018 for Nigeria

NIGERIA

Annex A2: Evidence of climate change impacts on **livestock** in West Africa/ Africa south of the Sahara (ASS)

Country	Productivity Change ()		Journal/Publisher	Authors	Climate Change Scenario (Var. Temperature and Precipitation)
ASS	-10	-20	Environmental science & policy / Wiley Online Library	Jones, P. G., & Thornton, P. K. (2009)	Greenhouse gases integrations
ASS	20	-17	Book chapter/FAO	Havlik, P. , Leclère, D., Valin, H. , Herrero, M., Schmid, E., Soussana, J.F., Mueller, C., & Obersteiner, M. (2015)	RCPs scenario
Mali	-14	-16	Climatic Change/Springer Nature	Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005)	Greenhouse gases integrations
Mali	-5	-36	Climate Policy/Taylor & Francis	Butt, T. A., McCarl, B. A., & Kergna, A. O. (2006)	1°–2.75°C
Burkina Faso	-3	-10	Report/Postdam Institute for Climate Impact Research (PIK)	Röhrig, F., Gloy, N., von Loeben, S., Arumugam, P., Aschenbrenner, P., Baek, H., Bado, I., Chemura, A., Habtemariam, L., Kaufmann, J., Koch, H., Laudien, R., Liersch, S., Lüttringhaus, S., Murken, L., Neya, O., Noleppa, S., Ostberg, S., Santo, S., Schauberger, B., Shukla, R., Tomalka, J., Wesch, S., Wortmann, M. & Gornott, C. (2021)	RCPs Scenarios

Annex A3: Evidence of climate change impacts on **maize** yields in **Nigeria**

Region/ Country	Yield Variation ()		Publisher	Author	Climate Change Scenario (Var. Temperature and Precipitation)
Nigeria	**0**	-20	Springer Nature.	Mereu, V., Carboni, G., Gallo, A., Cervigni, R., & Spano, D. (2015)	IPCC A1B emission scenario
Nigeria	-5	-25	IFPRI Research Monograph.	Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013)	1°C to 3°C and 0 to 4.7%
Nigeria	-11.0	**-20.2**	Springer Nature	Ahmed, K. F., Wang, G., Yu, M., Koo, J., & You, L. (2015)	RCP 8.5 Scenario
Nigeria	-4.8	-12.5	Book+ World Bank.	Cervigni R, Valentini R, Santini M. (2013)	A1B emission scenario

Annex A4: Evidence of climate change impacts on rice yields in Nigeria/West Africa

Region/Country	Yield Variation		Publisher	Authors	Climate Change Scenario (Var. Temperature and Precipitation)
Nigeria	-25.0	8.0	Springer Nature	Mereu, V., Carboni, G., Gallo, A., Cervigni, R., & Spano, D. (2015)	IPCC A1B emission scenario
Nigeria	-25.0	-11.0	Book+ World Bank	Cervigni R, Valentini R, Santini M. (2013)	A1B emission scenario
Nigeria (rainfed)	-28.0	-26.0	Global Change Biology	Van Oort, P. A. J., & Zwart, S. J. (2017)	Base temperature 14°C and optimum temperature 31°C (RCP 8.5 scenario)
Nigeria (irrigated)	-30.0	-42.0	Global Change Biology	Van Oort, P. A. J., & Zwart, S. J. (2017)	Base temperature 14°C and optimum temperature 31°C (RCP 8.5 scenario)
West Africa	-1.8	0.4	IFPRI report	Nelson, G. C., M.W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee (2009)	0.5°C to 4°C and 2% to 10%
West Africa	-6.0	1.0	Science	Lobell D. B., Burke M. B., Tebaldi C., Mastrandrea M. D., Falcon W. P., and Naylor R. L., (2008)	0.5°C to 2°C and -10% to +5%
West Africa	-4.4	0.5	Book + FAO	Thomas, T. & Rosegrant, M. (2015)	1.5°C to 2.3°C and -23mm to +30mm
West Africa (irrigated)	-20.0	-12.4	IFPRI Research Monograph	Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013)	1°C to 3°C and 0 to 4.7%
West Africa (rainfed)	0.5	**4.4**	IFPRI Research Monograph	Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013)	1°C to 3°C and 0 to 4.7%
West Africa (irrigated)	-20.0	-20.0	Global Change Biology	Van Oort, P. A. J., & Zwart, S. J. (2017)	Base temperature 14°C and optimum temperature 31°C (RCP 8.5 scenario)
West Africa (rainfed)	**-25.0**	-19.0	Global Change Biology	Van Oort, P. A. J., & Zwart, S. J. (2017)	Base temperature 14°C and optimum temperature 31°C (RCP 8.5 scenario)

Annex A5: Evidence of climate change impacts on **other cereals** (**millet** and **sorghum**) yields in **Nigeria**/ **West Africa**

Country	Yield Variation		Journal/Publisher		Authors	Climate Change Scenario (Var. Temperature and Precipitation)
Nigeria (Millet)	-40.0	20.0	Climatic Change	Springer Nature	Mereu, V., Carboni, G., Gallo, A., Cervigni, R., & Spano, D. (2015)	IPCC A1B emission scenario
Nigeria (Millet)	-23.0	3.0	Book	World Bank	Cervigni R, Valentini R, Santini M. (2013)	A1B emission scenario
Nigeria (Millet)	-29.3	-32.1	Climatic Change	Springer Nature	Ahmed, K. F., Wang, G., Yu, M., Koo, J., & You, L. (2015)	RCP 8.5 Scenario
Nigeria (Sorghum)	**-20.0**	0	Climatic Change	Springer Nature.	Mereu, V., Carboni, G., Gallo, A., Cervigni, R., & Spano, D. (2015)	IPCC A1B emission scenario
Nigeria (Sorghum)	-5.0	-25.0	IFPRI Research Monograph	IFPRI	Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013)	1°C to 3°C and 0 to 4.7%
Nigeria (Sorghum)	-11.8	28.2	Climatic Change	Springer Nature	Ahmed, K. F., Wang, G., Yu, M., Koo, J., & You, L. (2015)	RCP 8.5 Scenario
West Africa (Sorghum)	-5.0	5.0	Science	American Association for the Advancement of Science	Lobell D. B., Burke M. B., Tebaldi C., Mastrandrea M. D., Falcon W. P. and Naylor R. L. (2008)	0.5°C to 2°C and -10% to +5%

Annex A6: Evidence of climate change impacts on agriculture

Crop	Country	Yield Variation ()		Journal/Publisher		Authors	Climate Change Scenario (Var. Temperature and Precipitation)
Vegetables	Nigeria		**18.7**	Climate Change Economics	World Scientific	Lokonon, B. O. K., Egbendewe, A. Y. G., Coulibaly, N. & Atewamba, C. (2019)	SPSS2 with RCP scenario
Vegetables	ASS		**-10.7**	Rural Development Report	IFAD	Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019)	1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario)
Fruits	Mali	**-7.1**	**-7.0**	Report	World Bank	World Bank Group (2019)	**1**.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5)
Potato	West Africa	**-25.4**	**10.5**	Report	IFPRI	Nelson, G. C., M.W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee. (2009)	0.5°C to 4°C and 2% to 10%
Potato	West Africa	**-15.0**		Tropical Plant Biology	Springer Nature	Jarvis, A., Ramirez-Villegas, J., Herrera Campo, B. V., & Navarro-Racines, C. (2012)	SRES-A1B emissions scenario
Banana	West Africa	**-26.0**		Tropical Plant Biology	Springer Nature	Jarvis, A., Ramirez-Villegas, J., Herrera Campo, B. V., & Navarro-Racines, C. (2012)	SRES-A1B emissions scenario
Coffee & Tea	ASS		**-7.2**	Rural Development Report	IFAD	Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019)	1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario)
Cocoa	Nigeria	9.5	**-14.1**	International Journal of Climate Change Strategies and Management	Emerald	Fonta, W.M., Kedir, A.M., Bossa, A.Y., Greenough, K.M., Sylla, B.M. and Ayuk, E.T. (2018)	+2.5°C in temperature and -5% in precipitation
Forestry	West Africa	**-57.0**	**-49.0**	Journal of Arid Environments	Elsevier Science	Gonzalez, P., Tucker, C. J., & Sy, H. (2012)	2°C and 4°C
Cotton	West Africa	-19.5	**-1.8**	IFPRI report	IFPRI.	Nelson, G. C., M.W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee. (2009)	0.5°C to 4°C and 2% to 10%
Cotton	Nigeria	**-0.6**	6.1	Working paper	AGRODEP	Ajetomobi J., Ajakaiye O., & Gbadegesin A. (2015)	Econometrics estimation
Oilseeds	Nigeria	-24.0	38.7	Climate Change Economics	World Scientific	Lokonon, B. O. K., Egbendewe, A. Y. G., Coulibaly, N., & Atewamba, C. (2019)	SPSS2 with RCP scenario
Roots	SSA		-7.1	Rural Development Report	IFAD	Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019)	1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario)
Yams	Nigeria	-14.5	-14.0	Environmental and Resource Economics	Springer Nature	Bosello, F., Campagnolo, L., Cervigni, R., & Eboli, F. (2017)	A1B IPCC SRES scenario

Cassava	Nigeria		-21.3	Environmental and Resource Economics	Springer Nature	Bosello, F., Campagnolo, L., Cervigni, R., & Eboli, F. (2017)	A1B IPCC SRES scenario
Cassava	Nigeria	-3.9	-21.7	Tropical Plant Biology	Springer Nature	Jarvis, A., Ramirez-Villegas, J., Herrera Campo, B. V., & Navarro-Racines, C. (2012)	SRES-A1B emissions scenario
Beans	West Africa		-20.0	Tropical Plant Biology	Springer Nature	Jarvis, A., Ramirez-Villegas, J., Herrera Campo, B. V., & Navarro-Racines, C. (2012)	SRES-A1B emissions scenario
Soybeans	West Africa	-14.2	-1.5	Book	IFPRI	Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013)	1°C to 3°C and 0 to 4.7%
Soybeans	West Africa	-14.2	-1.5	Book	FAO	Thomas, T. & Rosegrant, M. (2015)	A1B scenario and 4 AR4 GCMs
Pulses	SSA		-4.9	Rural Development Report	IFAD	Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019)	1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario)
Sugarcane	SSA		-8.1	Rural Development Report	IFAD	Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019)	1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario)
Sugarcane	Nigeria		-56.1	Climate Change Economics	World Scientific	Lokonon, B. O. K., Egbendewe, A. Y. G., Coulibaly, N., & Atewamba, C. (2019)	SPSS2 with RCP scenario

Note: SSA: Africa South of Sahara.

Annex A7: Evidence of climate change impacts on fisheries

Country	Yield Variation ()		Journal/Publisher		Authors	Climate Change Scenario (Var. Temperature and Precipitation)
West Africa	-25.9	-8.0	African Journal of Marine Science	Taylor & Francis	Lam, V. W. Y., Cheung, W. W. L., Swartz, W., & Sumaila, U. R. (2012)	The SRES A1B scenario assumes that the greenhouse gas concentration was stabilized at 720 ppm by the year 2100
West Africa	-26.0	-8.0	Nature Climate Change	Nature	Barange, M.; Merino, G.; Blanchard, J. L.; Scholtens, J.; Harle, J.; Allison, E. H.; Allen, J. I.; Holt, J.; Jennings, S. (2014)	IPCC scenario B2 andA1F1 scenario
West Africa	**42.0**	**-3.0**	Marine Policy	Elsevier Science	Belhabib, D; Lam, Vicky, W.Y.; Cheung, W. (2016)	SRES A1B scenario

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