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Enhancing Climate Resilience in Nigerian Agriculture

Implications for Sustainable Adaptation and Livelihood Diversification

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Key Highlights

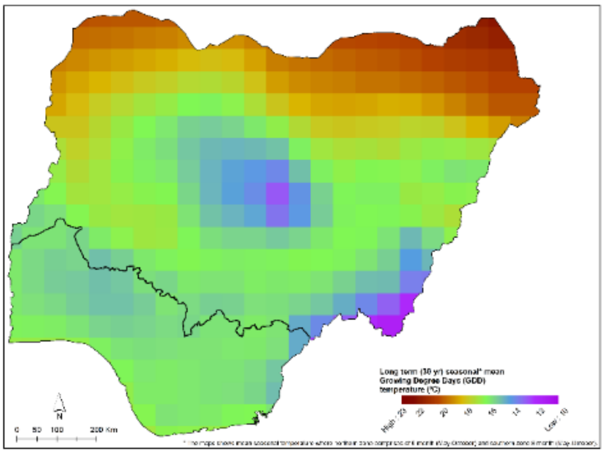
- Changes in temperature, measured in harmful degree days (HDDs), and precipitation have a significant negative impact on agricultural productivity in Nigeria, which highlights the adverse effects of extreme weather on crop yields.
- Climate changes affect income sources for farming households. We found that an increase in HDDs reduces households' income share from crops and nonfarm self-employment, implying threats to household food security for smallholders whose livelihoods depend on subsistence farming and food consumption from own sources.
- In response to the risks posed by climate change, farmers adopt changes in crop mixes (for example, reducing the share of land allocated to cereals) and input use decisions (for example, reducing fertilizer use and purchased seeds) as an adaptation strategy. Adaption strategies that lead to low use of yield-enhancing modern inputs could worsen agricultural productivity and household food insecurity. However, we found that farmers in Nigeria respond to extreme climate by switching to drought tolerant root or tuber crops. Such strategies could partially offset the adverse effects of climatic shocks on households' welfare.
- Climate changes negatively impact agricultural productivity for both poor and non-poor households, but the effects are more pronounced among poorer households, according to our heterogenous effects analysis on household's initial endowments (based on wealth indicators measured in asset and livestock holdings). This implies low adaptive capacity on the part of poor households and thus their high vulnerability to climate-related shocks.
- Suggested policy recommendations include interventions to incentivize adoption of climate-resilient agriculture, targeted pro-poor interventions such as low-cost financing options for improving smallholders' access to climate-proof agricultural inputs and technologies, and policy measures to reduce the inequality of access to livelihood capital, such as land and other productive assets.

Background and Context

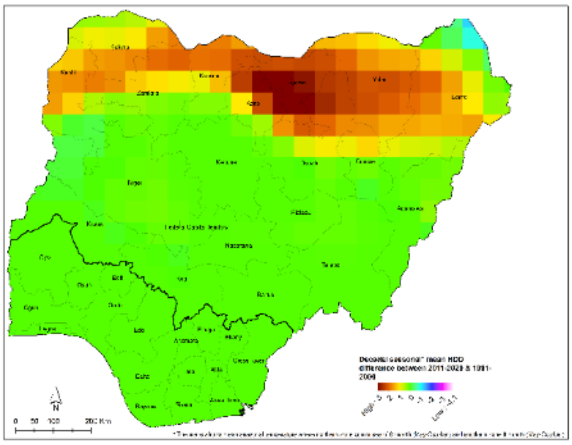
Climate variability and extreme weather events present significant challenges to the agricultural productivity, livelihoods, and food security of rural households in sub-Saharan Africa (SSA) (Di Falco and Veronesi 2013). Climate shocks are predicted to grow more frequent and severe, with escalating repercussions. Smallholder agricultural households with limited assets, coping methods, and adaptation skills are particularly vulnerable (IPCC 2012; Fankhauser and McDermott 2014). The complex interplay of climatic and non-climatic factors, such as limited access to productive assets and markets, further diminishes the resilience of impoverished households, exacerbating food insecurity. In this context, understanding the nature and effects of different adaptation strategies that smallholders adopt to cope with extreme climate events is crucial for designing interventions to mitigate the adverse impacts.

Agriculture is a major contributor to both employment and economic development in Nigeria, constituting approximately 23 percent of GDP and engaging 70 percent of the labor force. Yet nearly 40 percent of Nigeria's population grapples with poverty and food insecurity. Existing challenges, including low agricultural productivity and inadequate technology adoption, are exacerbated by adverse climate changes. Reduced rainfall, a shorter growing season, and rising temperatures threaten agricultural output, with some crops facing potential yield reductions of up to 25 percent by 2050 (Hassan et al. 2013). Spatial analysis indicates that northern Nigeria experiences greater temperature fluctuations and more extreme heat, while the southern region has a more stable growing season.

Figure 1. Distribution of Historical Average Growing Degree Days and Harmful Degree Days, 1985–2016



(a) Growing Degree Days



(b) Harmful Degree Days

Figure 1 illustrates these spatial variations, demonstrating the disparities in growing degree days (GDDs) and harmful degree days (HDDs) between the northern and southern regions, with northern states experiencing greater climatic unpredictability, including extreme heat events, while the southern region enjoys a more stable growing season due to its humid coastal climate. Over the period of three decades (1985–2016), northern Nigeria had generally experienced significant climatic fluctuations (from temperatures as low as 11°C in states such as Taraba and Adamawa to extremely high, reaching 26 °C in states including Borno, Yobe, Sokoto, and Katsina).

Livelihood diversification emerges as an effective adaptation strategy for smallholders to mitigate the impacts of climate variability and climate change. Such diversification strategies include diversifying crop portfolios, expanding livestock holdings, diversifying income sources, adjusting agricultural input usage, and diversifying labor activities. By combining nationally representative household-level panel data with long-term satellite-based spatial data on temperature and precipitation, we examined smallholder farm households' adaptation strategies to climate changes and the pathways through which these impacts affect the welfare of households. Specifically, we quantified the impacts of climate change on agricultural productivity, income diversification, crop selection, and input usage decisions. We found that changes in temperature, measured in HDDs, and precipitation have significant negative impacts on agricultural productivity and reduce the income share of households from crops and nonfarm self-employment. In addition to examining the overall influence of climate change on agricultural productivity and income sources, we identified the transmission channels to these effects, for instance through farmers decisions to change their crop mix and reduce use of yield enhancing agricultural inputs such as fertilizer use in response to increases in extreme heat.

Data

We use panel datasets from the Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) in Nigeria. These datasets provide comprehensive information on household demographics, assets, agricultural and nonfarm income, labor allocation, and service access. The agriculture module includes details on crop and livestock production, technology use, and crop productivity. Our analysis focuses on farm households that planted crops and for which temperature and rainfall data were available, resulting in a balanced panel of 2,129 households across three waves. Daily average temperatures from NASA MERRA-2 and monthly precipitation data from Climate Hazards Group InfraRed Precipitation Station (CHIRPS) archives are used. The spatial datasets cover a 30-year period from 1986 to 2015. Geo-referenced data enables us to link satellite-based climate data to households.

Variables

Climate variables: We use the growing season to define the relevant period for temperature and precipitation variables. GDDs and HDDs are calculated from daily average temperatures. Change in precipitation is calculated as the deviation of a year's growing season precipitation from historical averages for the same location.

Outcomes variables of interest: (1) *Agricultural Productivity:* Measured as real net crop income per hectare, adjusted to 2010 purchasing power parity (PPP); (2) *Crop Mix*: Represented as the share of area planted in major crops relative to total land area cultivated, including categories for cereals, pulses and legumes, roots and tubers, tree crops, and other uses; (3) *Income Share:* Income is categorized into crop income, livestock income, nonfarm self-employment, wages, and other sources, and income share is calculated by dividing each income component by total real income, adjusted to 2010 PPP; (4) *Input Use:* Indicator variables are created for fertilizer use, purchased seeds, and pesticide use, with values of 1 indicating usage and 0 denoting non-usage.

We use panel data and instrumental variables econometric specifications to estimate the effects of climate variables on our outcome variables (Amare and Balana 2023).

Hypotheses

The following three hypotheses underpin our empirical analyses:

- *Hypothesis 1*: In the context of imperfect or missing credit, insurance, and labor markets, food security will be the primary objective of farm households. Farmers may mitigate the risks of food insecurity caused by climate change by changing crop mixes, that is, allocating farmland to crops that are less susceptible to climate shocks.

- *Hypothesis 2:* Adverse climate change pushes vulnerable farm households to diversify off-farm activities and thus to decrease their income share from crop and livestock but increase their income share from off-farm sources.
- *Hypothesis 3*: Climatic factors lead farmers to shift from purchasing productivity-enhancing inputs such as fertilizer to loss-reducing inputs such as pesticides to protect their crops from pests, crop diseases, and weeds.

Key Findings[1]

Impacts on Agricultural Productivity: Our results reveal that the effect of climate change remains significant even after controlling the confounding factors. Specifically, increases changes in HDDs are negatively associated with agricultural productivity. Notably, increases changes in HDDs exert a more pronounced effect on agricultural productivity than precipitation changes, suggesting that temperature variability plays a more significant role in influencing agricultural outcomes.

Impacts on Income Sources: The findings indicate that the effect of climate change remains significant even after controlling for household-level fixed effects. We observe nonlinearity in the relationship between climate change and income shares. Increases in HDDs reduce income shares from crops and nonfarm self-employment while increasing those from livestock and non-agricultural wage income. Likewise, precipitation changes reduce the income share from crops while increasing livestock and wage income shares.

Impacts on Crop Mixes: The effect of climate change on crop-mix decisions is substantial and significant. This is the case even after controlling for household characteristics. Farmers adjust their crop mix in response to climate change, with increases in HDDs reducing the land allocated to cereals and tree crops but increasing the allocation to legumes and tubers.

Impacts on Input Use: Increases in HDDs positively impact planted area but negatively affect fertilizer use. For instance, increases in HDDs decreases the likelihood of purchased seed use by 18 percent, and reduces fertilizer use by approximately 3 percent However, extreme heat increases pesticide use which likely to counteract pest infestation induced by the climate anomalies.

Heterogeneous Effects by Wealth: Poorer households, facing liquidity constraints and greater risk aversion, may respond differently to climate-induced changes. We find that the impact of climate change on agricultural productivity and input use is stronger for poorer households than for their relatively wealthy counterparts. Specifically, changes in HDDs and precipitation have a more pronounced negative effect on productivity for poor households. Similarly, changes in input use are more significant for poor households, indicating that they may face greater constraints in adapting to climate change.

Policy Implications

Promoting Climate-Resilient Agriculture: Given the negative impacts of climate factors on agricultural productivity, targeted interventions that promote climate-resilient agricultural practices are essential. Investments in water-storage infrastructure and small-scale irrigation systems, for instance, can help mitigate the effects of climate change, particularly for poorer smallholder farmers.

[1] Due to the nature of the data used in the study (observational/survey data), while some of the relationships we discuss may imply causation, we avoid making definitive claims of causality.

Enhancing Access to Inputs: Crop diversification and adaptive input use are potential coping strategies for climate anomalies. Policies should focus on improving smallholders' access to climate-resilient crop varieties and yield-enhancing agricultural inputs to make these strategies more viable.

Developing the Livestock Sector: As income shares from livestock and nonfarm activities increase with climate shocks, there is an opportunity to develop the livestock sector and micro/small enterprises. Supporting these sectors can provide alternative income sources for farming communities during climate-related challenges.

Pro-Poor Interventions: Recognizing the more severe effects of climate change on poor than nonpoor households, pro-poor interventions are recommended. These interventions should include low-cost financing options for climate-proof agricultural technologies and measures to reduce inequality in access to productive assets like land.

Addressing the challenges posed by climate change requires a multifaceted approach that considers both short-term adaptations, such as changes in crop mix and input use, and long-term investments in climate-resilient agriculture and income diversification. Tailoring interventions to the specific needs and vulnerabilities of different households, particularly those with limited resources, is crucial for building climate resilience in the agriculture sector.

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