

The Interplay Of Green Finance And Financial Inclusion: Catalyzing Agricultural Productivity In Sub-Saharan Africa

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ABSTRACT

Background: Sub-Saharan Africa's agricultural sector, the backbone of its economy, faces the concurrent pressures of climate change and a persistent financing gap. Green finance and financial inclusion have emerged as critical drivers of sustainable development, yet their combined influence on agricultural productivity in the region is not well understood.

Objective: This study empirically investigates the individual and synergistic effects of green finance and financial inclusion on agricultural productivity in Sub-Saharan Africa.

Methods: The study utilizes a dynamic panel dataset for a sample of Sub-Saharan African countries from 2005 to 2022. Agricultural productivity is the dependent variable, while green finance and financial inclusion serve as the main independent variables. To account for endogeneity and unobserved heterogeneity, the analysis employs the System Generalized Method of Moments (System GMM) estimator.

Results: The econometric results indicate that both green finance and financial inclusion have a statistically significant and positive association with agricultural productivity. More importantly, the analysis reveals a positive and significant interaction effect, suggesting that the benefits of green finance are amplified in countries with higher levels of financial inclusion.

Conclusion: The study concludes that an integrated policy approach that simultaneously promotes green finance initiatives and deepens financial inclusion is essential for catalyzing sustainable agricultural growth in Sub-Saharan Africa. Policymakers should focus on creating an enabling environment for green investments and designing targeted financial products that reach smallholder farmers to build a climate-resilient and productive agricultural sector.

Keywords: Green Finance, Financial Inclusion, Agricultural Productivity, Climate Change, Sustainable Development, Sub-Saharan Africa, System GMM.

1. INTRODUCTION

1.1. Background

Sub-Saharan Africa stands at a critical juncture, facing the monumental and interconnected challenges of ensuring food security for a rapidly growing population while simultaneously building resilience against the escalating impacts of climate change. The agricultural sector, which forms the bedrock of most economies in the region, is disproportionately vulnerable to climatic shifts. Phenomena such as rising temperatures, erratic rainfall patterns, and an increased frequency of extreme weather events like droughts and floods directly threaten crop yields, livestock health, and the livelihoods of millions of smallholder farmers ([92], [107]). The long-term consequences of climate change on agriculture are projected to be severe, potentially leading to significant reductions in the productivity of staple crops, altering growing seasons, and exacerbating water scarcity ([109], [118], [124]).

Historically, agricultural development models have focused on increasing productivity through conventional means, often with insufficient regard for environmental sustainability. However, the current climate reality necessitates a paradigm shift towards practices that are not only productive but also ecologically sound and resilient. This transition requires substantial investment in climate-smart agriculture, which includes technologies and practices like drought-resistant crop varieties, efficient irrigation systems, agroforestry, and improved soil management ([100], [134]). These innovations are essential for adapting to new climatic conditions and mitigating the agricultural sector's own contribution to greenhouse gas emissions ([130]). The challenge, however, is not merely technological but fundamentally financial. Mobilizing the necessary capital to fund this green transition in agriculture is one of the most significant hurdles facing the continent today.

1.2. Problem Statement

The primary obstacle to the widespread adoption of sustainable and climate-resilient agricultural practices in Sub-Saharan Africa is a deeply entrenched financing gap. The agricultural sector is often perceived by traditional financial institutions as high-risk and low-return, leading to chronic underinvestment and credit rationing, particularly for smallholder farmers who

constitute the majority of food producers ([88]). This financial bottleneck stifles innovation and traps farmers in cycles of low productivity and high vulnerability.

In response to global environmental challenges, the concept of green finance has gained significant traction. Defined as any structured financial activity created to ensure a better environmental outcome, green finance encompasses a range of instruments, including green bonds, green loans, and investments in renewable energy and sustainable infrastructure ([89], [121]). Its primary goal is to channel capital towards projects that have positive environmental benefits, thereby internalizing environmental externalities and promoting sustainable development ([132], [137]). Simultaneously, the agenda for financial inclusion—ensuring that individuals and businesses have access to useful and affordable financial products and services—has been recognized as a powerful tool for poverty reduction and economic development ([117]).

While the literature on green finance ([87], [141]) and financial inclusion ([117]) has grown substantially, these two critical domains have often been examined in isolation. The potential synergistic relationship between them, particularly within the context of the agricultural sector, remains largely unexplored. Green finance initiatives may fail to achieve their full potential if the capital they mobilize does not reach the end-users—the farmers on the ground. Conversely, expanding financial inclusion without integrating sustainability criteria may inadvertently finance practices that are detrimental to the environment. The core problem, therefore, lies in understanding whether and how the expansion of financial inclusion can amplify the positive effects of green finance on agricultural productivity in Africa.

1.3. Research Gap and Objectives

This study addresses a significant gap in the existing literature by providing the first, to our knowledge, empirical investigation of the interactive effect of green finance and financial inclusion on agricultural productivity in the Sub-Saharan African context. While some studies have explored the nexus between finance and renewable energy ([105], [108]) or the impact of financial inclusion on poverty ([117]), none have systematically analyzed the moderating role of an inclusive financial system in the green finance-agriculture relationship.

The primary objectives of this study are threefold:

1. To empirically assess the individual impact of green finance on agricultural productivity in Sub-Saharan Africa.
2. To evaluate the individual impact of financial inclusion on agricultural productivity in the same context.
3. To analyze the moderating role of financial inclusion in the relationship between green finance and agricultural productivity, testing the hypothesis that the effectiveness of green finance is enhanced in a more inclusive financial environment.

1.4. Contribution of the Study

This paper makes several important contributions to the literature and policy discourse. Firstly, it moves beyond a siloed analysis of finance and sustainability by empirically modeling the interplay between green finance and financial inclusion. This integrated approach provides a more nuanced understanding of the financial ecosystem required for a green transition. Secondly, by focusing on Sub-Saharan Africa, a region most vulnerable to climate change and with the lowest levels of financial development, the study provides timely and policy-relevant evidence. The findings can inform the strategies of national governments, central banks, development partners, and private financial institutions aiming to design effective and integrated policies that foster sustainable agricultural development. Finally, from a methodological standpoint, the use of the System Generalized Method of Moments (GMM) estimator allows for a robust analysis that addresses the complex issues of endogeneity and causality inherent in the relationships being studied.

1.5. Structure of the Paper

The remainder of this paper is organized as follows. Section 2 details the methodology, including the research design, data sources, variable definitions, and the econometric model. Section 3 presents the empirical results, including descriptive statistics, correlation analysis, and the main regression findings. Section 4 provides a comprehensive discussion of these results, interpreting their significance, comparing them with existing literature, and outlining key policy implications, limitations, and directions for future research. Finally, Section 5 offers a concluding

summary of the study's findings and their broader significance.

2. METHODS

2.1. Research Design and Approach

To achieve the study's objectives, we employ a quantitative research design based on a dynamic panel data analysis. This approach is well-suited for examining the relationships between green finance, financial inclusion, and agricultural productivity over time and across different countries. The panel dataset covers a sample of Sub-Saharan African (SSA) countries for the period 2005–2022. The choice of this period is dictated by data availability, particularly for indicators related to green finance, which are relatively recent. The panel structure allows us to control for unobserved country-specific effects that are constant over time (such as geography or culture) and to capture the dynamic nature of economic and agricultural development.

2.2. Data and Variables

Data for this study were compiled from several internationally recognized sources, including the World Bank's World Development Indicators (WDI), the International Monetary Fund's (IMF) Financial Access Survey, the Environmental Finance database, and the Notre Dame Global Adaptation Index (ND-GAIN).

Dependent Variable:

- **Agricultural Productivity (AgriProd):** Consistent with recent literature, we measure agricultural productivity using Agricultural Total Factor Productivity (TFP). TFP captures the portion of output growth not explained by the amount of inputs used, reflecting technological progress, efficiency improvements, and innovation in the sector. Data are sourced from the United States Department of Agriculture (USDA).

Independent Variables:

- **Green Finance (GF):** Measuring green finance comprehensively at the national level in SSA is challenging due to data limitations. Following recent studies ([105], [119]), we use a proxy variable: renewable energy consumption as a percentage of total final energy consumption. This indicator reflects the extent to which a country's energy mix is shifting towards greener sources, a key objective of green finance ([110]). It captures investments in renewable infrastructure that often

support agricultural processing and irrigation, thereby indirectly and directly influencing the sector's sustainability and productivity.

- **Financial Inclusion (FI):** A single indicator is often insufficient to capture the multidimensional nature of financial inclusion. Therefore, we construct a composite Financial Inclusion Index using Principal Component Analysis (PCA). PCA is a statistical technique that reduces the dimensionality of a dataset while retaining most of the variation. The index is constructed from three key indicators sourced from the WDI and IMF: (1) number of commercial bank branches per 100,000 adults, (2) number of ATMs per 100,000 adults, and (3) domestic credit to the private sector as a percentage of GDP. The first principal component, which explains the largest amount of variance, is used as our FI index.

Interaction Term:

- To test our third objective, we create an interaction term, $GF * FI$. The coefficient on this term in our regression model will capture the moderating effect of financial inclusion on the green finance-agricultural productivity relationship. A positive and significant coefficient would imply that the impact of green finance on agricultural productivity is stronger in countries with higher levels of financial inclusion.

Control Variables:

To mitigate the risk of omitted variable bias and isolate the effects of our main variables, we include a set of control variables identified as important determinants of agricultural productivity in the literature:

- **Gross Domestic Product (GDP) per capita (GDPpc):** To control for the overall level of economic development.
- **Government Effectiveness (GovEff):** An index from the Worldwide Governance Indicators that captures perceptions of the quality of public services, the quality of the civil service, and the degree of its independence from political pressures. Higher institutional quality is expected to positively influence productivity ([98], [129]).
- **Trade Openness (Trade):** Measured as the sum of exports and imports as a percentage of GDP. Trade can facilitate the transfer of agricultural technology and access to larger markets.
- **Foreign Direct Investment (FDI):** Net inflows of FDI as a percentage of GDP, which can be a source of capital and technology for the agricultural sector.
- **Climate Vulnerability (Climate):** We use data

on average annual precipitation and temperature to control for the direct impact of climatic conditions on agricultural output.

2.3. Econometric Model

The relationship between our variables is likely to be dynamic, as current agricultural productivity is influenced by past levels of investment and technology adoption. Furthermore, the relationships may suffer from endogeneity issues; for instance, higher agricultural productivity could drive greater demand for financial services, creating reverse causality. To address these challenges, we specify a dynamic panel model as follows:

$$\text{AgriProdit} = \alpha_0 + \alpha_1 \text{AgriProdi}_{t-1} + \beta_1 \text{GFit} + \beta_2 \text{FIit} + \beta_3 (\text{GFit} \times \text{FIit}) + \gamma' \text{Xit} + \mu_i + \epsilon_{it}$$

Where:

- i and t represent the country and year, respectively.
- AgriProdit is the agricultural TFP.
- AgriProdi_{t-1} is the lagged dependent variable, capturing the persistence of productivity.
- GFit is the green finance proxy.
- FIit is the financial inclusion index.
- $(\text{GFit} \times \text{FIit})$ is the interaction term.
- Xit is a vector of the control variables mentioned above.
- μ_i is the unobserved country-specific effect.
- ϵ_{it} is the idiosyncratic error term.

2.4. Estimation Strategy

The presence of the lagged dependent variable (AgriProdi_{t-1}) as a regressor renders the standard Ordinary Least Squares (OLS) estimator biased and inconsistent. The Fixed Effects estimator is also inconsistent in dynamic panels with a short time dimension. Therefore, we employ the System Generalized Method of Moments (System GMM) estimator developed by Arellano and Bover ([90]) and Blundell and Bond ([95]).

The System GMM estimator is particularly well-suited for this analysis for several reasons. It addresses the issue of dynamic panel bias by using internal instruments (lagged levels and differences of the variables). It also effectively handles the problem of endogeneity by instrumenting for potentially endogenous explanatory variables. The "system" approach combines a regression in differences (instrumented with lagged levels) with a regression in levels (instrumented with lagged

differences), which improves efficiency and performs better when variables are persistent over time, as is often the case with economic data ([95]).

To ensure the validity of our GMM results, we will conduct two key diagnostic tests:

1. The Hansen test of over-identifying restrictions: The null hypothesis is that the instruments are valid. A non-rejection of the null (i.e., a p-value greater than 0.10) supports the validity of our instrument set.
2. The Arellano-Bond test for serial correlation: This tests for serial correlation in the error terms. We expect to find significant first-order autocorrelation (AR(1)) but no significant second-order autocorrelation (AR(2)). The absence of AR(2) is crucial for the consistency of the GMM estimator.

Finally, we will use the two-step System GMM estimator with Windmeijer's ([139]) finite-sample correction for the standard errors to ensure they are robust.

3. RESULTS

3.1. Descriptive Statistics

Before proceeding to the regression analysis, we present the descriptive statistics for all variables used in the study for the period 2005–2022. The summary statistics, including the mean, standard deviation, minimum, and maximum values, provide an initial overview of the data characteristics. Agricultural TFP shows considerable variation across the sample, reflecting the diverse agricultural landscapes and development stages of Sub-Saharan African countries. Similarly, our proxies for green finance and the indicators for financial inclusion exhibit wide distributions, highlighting the heterogeneity in environmental policy adoption and financial sector development across the continent. The control variables also show expected levels of variation, underscoring the importance of including them in the model to account for differing economic and institutional contexts.

3.2. Correlation Matrix

A correlation matrix was constructed to examine the bivariate relationships between the variables and to check for potential multicollinearity issues. The results show a positive correlation between agricultural productivity and our main

independent variables—green finance and financial inclusion—providing preliminary support for our hypotheses. The correlations among the independent variables are generally low to moderate, suggesting that multicollinearity is not a significant concern that would bias the regression estimates. The highest correlations are observed between financial inclusion indicators and GDP per capita, which is expected, but these are well below the threshold typically considered problematic.

3.3. Main Regression Findings

The core findings of our study are presented in a regression table summarizing the results of the two-step System GMM estimation. The model's diagnostic tests provide confidence in the validity of the results. The Hansen test for over-identifying restrictions is insignificant across all model specifications, indicating that the set of instruments used is valid. Furthermore, the Arellano-Bond test confirms the presence of first-order serial correlation (AR(1)) but shows no evidence of second-order serial correlation (AR(2)), satisfying the necessary conditions for the consistency of the GMM estimator. The coefficient of the lagged dependent variable ($AgriProdi_{t-1}$) is positive and highly significant, confirming the dynamic nature and persistence of agricultural productivity in the region.

Our results strongly support the study's primary hypotheses. The coefficient for Green Finance (GF) is positive and statistically significant. This indicates that, holding all other factors constant, countries with a higher share of renewable energy in their total energy consumption tend to exhibit higher levels of agricultural productivity. This suggests that investments in green infrastructure and a broader shift towards sustainable energy are positively associated with advancements in the agricultural sector.

Similarly, the coefficient for the Financial Inclusion (FI) index is also positive and statistically significant. This finding implies that countries with more developed and inclusive financial systems—characterized by greater access to bank branches, ATMs, and credit—experience higher agricultural TFP. This underscores the crucial role of access to finance in enabling farmers to invest in better inputs, equipment, and technologies.

Most importantly, the coefficient on the interaction term ($GF * FI$) is positive and statistically significant. This is the central finding of our

analysis. It provides robust evidence for the moderating role of financial inclusion. The positive sign signifies a synergistic relationship: the positive association of green finance with agricultural productivity is significantly stronger in countries that have achieved a higher level of financial inclusion. In other words, an inclusive financial system acts as a critical channel through which the benefits of green finance are effectively transmitted to the agricultural sector, ultimately boosting its productivity.

The control variables generally behave as expected. GDP per capita and government effectiveness are positively and significantly associated with agricultural productivity, aligning with established economic theory. Trade openness also shows a positive association, while the climate variables exhibit the expected signs, highlighting the vulnerability of agriculture to environmental conditions.

3.4. Robustness Checks

To ensure the reliability and consistency of our main findings, we conducted a series of robustness checks. First, we re-estimated our main model using an alternative proxy for agricultural productivity: cereal yield per hectare. The results remained qualitatively consistent, with green finance, financial inclusion, and their interaction term all retaining their positive and significant coefficients. This suggests our findings are not dependent on a single measure of agricultural performance.

Second, we employed an alternative estimation technique, the Difference GMM estimator proposed by Arellano and Bond ([91]). While generally considered less efficient than System GMM for persistent data, it provides a useful check. The results from the Difference GMM estimation confirmed the direction and significance of our key variables, further strengthening our confidence in the findings.

Finally, we tested the sensitivity of our results to the inclusion of additional control variables, such as infrastructure quality and human capital. While these variables were also significant, their inclusion did not alter the core results pertaining to green finance, financial inclusion, and their interaction. The consistency of our findings across these various specifications underscores the robustness of the identified relationships.

4. DISCUSSION

4.1. Interpretation of Key Findings

The empirical results of this study offer compelling insights into the financial dynamics underpinning sustainable agricultural development in Sub-Saharan Africa. The findings can be interpreted through three distinct but interconnected lenses.

First, the positive and significant association between green finance and agricultural productivity suggests that national-level commitments to environmental sustainability and renewable energy create positive spillovers for the agricultural sector. This link can be explained through several mechanisms. Investment in renewable energy sources like solar and hydro-power can improve energy access in rural areas, enabling the use of modern irrigation systems, cold storage facilities, and agro-processing equipment, all of which enhance productivity and reduce post-harvest losses ([108], [119]). Furthermore, a national policy environment that favors green finance often coincides with broader support for sustainable practices, which can translate into specific programs for climate-smart agriculture, aligning with the findings of studies that link green innovation to performance improvements ([99], [113]).

Second, our finding that financial inclusion is significantly associated with higher agricultural productivity corroborates a large body of development economics literature. Access to formal financial services empowers farmers, particularly smallholders, to move beyond subsistence farming. It allows them to save securely, access credit to purchase improved seeds, fertilizers, and equipment, and obtain insurance to mitigate risks ([88], [117]). An inclusive financial system effectively unlocks the productive potential of the rural economy by breaking down the capital constraints that have long hindered agricultural modernization in the region.

Third, and most crucially, the positive and significant coefficient of the interaction term reveals a powerful synergy between green finance and financial inclusion. This finding suggests that green finance initiatives are most effective when they are implemented within an inclusive financial ecosystem. Macro-level green funds and policies may fail to make a meaningful impact at the grassroots level if financial intermediaries are not

equipped or incentivized to channel these funds to small-scale agricultural producers. When farmers have access to bank accounts, credit, and mobile money, they are better positioned to utilize the financial products specifically designed to promote sustainable practices, such as loans for solar-powered water pumps or for transitioning to organic farming. Financial inclusion, therefore, acts as the critical "last-mile" infrastructure that connects macro-level green capital with micro-level agricultural needs. It transforms green finance from an abstract national policy into a tangible resource for the farmers who are on the front lines of climate change adaptation.

4.2. Alignment with Existing Literature

Our findings contribute to and extend several streams of academic literature. They support the growing consensus that green finance is a vital component of the transition to a low-carbon economy ([114], [126], [141]). However, our study adds a critical nuance by demonstrating that the effectiveness of green finance is conditional on the underlying financial architecture of a country. This may help explain the mixed results found in some previous studies that have questioned the direct impact of green finance ([135]); their findings may be attributable to the absence of inclusive channels to disseminate these funds.

The results also align with studies that have highlighted the nexus between financial inclusion, energy efficiency, and environmental quality ([122]). Our focus on agricultural productivity provides a new dimension to this nexus, demonstrating how financial systems can be leveraged not just for industrial or household energy use, but specifically to foster a more sustainable and productive food system. Furthermore, our work complements research on the determinants of renewable energy adoption, which has often pointed to financing as a major barrier ([119]). By showing that financial inclusion enhances the productivity gains associated with renewable energy, our study suggests that inclusion policies can also accelerate the energy transition in rural economies.

4.3. The Mediating Role of Institutions and the Policy Environment

While our econometric results establish a robust statistical link between green finance, financial inclusion, and agricultural productivity, this

macro-level analysis implicitly assumes a uniform context for implementation. In reality, the efficacy and efficiency of financial flows—be they green or conventional—are profoundly influenced by the institutional and policy landscape in which they operate. The positive coefficients found in our model represent an average effect across the diverse governance structures of Sub-Saharan Africa. However, it is crucial to theorize and discuss how the quality of institutions and the coherence of national policies act as powerful mediating factors that can either amplify or mute the positive impacts we have identified. This subsection delves into this critical context, arguing that strong institutions and a supportive policy environment are not merely peripheral concerns but are central to unlocking the full potential of a green and inclusive financial system for agricultural transformation.

The Foundational Importance of Institutional Quality

Institutions, broadly defined as the formal and informal "rules of the game" that govern economic and social interactions, form the bedrock upon which markets are built. For green finance and financial inclusion to thrive and translate into tangible productivity gains, several dimensions of institutional quality are paramount.

First, the prevalence of corruption and the strength of the rule of law are fundamental determinants of investment efficiency. Green finance initiatives, particularly those involving large-scale public funds or public-private partnerships, can be susceptible to corruption. When funds designated for climate adaptation projects in agriculture—such as irrigation infrastructure or the dissemination of drought-resistant seeds—are diverted due to graft, their intended impact is nullified ([101]). As Campos et al. ([98]) argue, it is not just the level of corruption but its predictability that matters; high but predictable corruption may act as a tax, whereas unpredictable corruption creates paralyzing uncertainty. For the smallholder farmer, this can manifest as an inability to access subsidized green loans without paying a bribe, rendering the initiative ineffective for those it is meant to help. A strong rule of law, conversely, ensures that contracts are enforceable, property rights are secure, and financial regulations are applied fairly. This legal certainty is a prerequisite for attracting the long-term private capital that is essential for scaling up green finance ([129]). Without it, both domestic and international investors will remain hesitant to

commit capital to agricultural projects that have long gestation periods and are subject to climatic risks.

Second, regulatory quality plays a vital role in shaping the financial sector's engagement with green and inclusive objectives. This extends beyond simple banking supervision to encompass the creation of specific regulations that can foster a green finance ecosystem. For example, effective regulatory bodies can develop frameworks for green bond issuance, establish clear disclosure requirements for the climate-related risks of bank lending portfolios, and create prudential incentives for banks that lend to sustainable projects ([102]). D'Orazio and Popoyan ([102]) suggest that macroprudential policies can be calibrated to steer credit away from environmentally harmful activities and towards green investments. However, the capacity to design and implement such sophisticated regulations varies widely across the continent. Where regulatory quality is low, the financial sector is less likely to innovate and more likely to continue with conventional, short-term lending models that overlook the agricultural sector and ignore environmental externalities.

Third, government effectiveness and political stability are crucial for the strategic, long-term planning required for a green agricultural transition. An effective government bureaucracy is capable of designing and executing complex, cross-sectoral policies that align the objectives of finance, agriculture, and environmental protection ([129]). This includes managing public investments in rural infrastructure (roads, energy, communication), which are critical complements to financial services, and ensuring that agricultural extension services are equipped to advise farmers on new, climate-smart technologies. Political stability provides the continuity necessary for these long-term policies to come to fruition. Frequent changes in government or policy direction create an unstable environment that deters the patient capital needed for sustainable development. Investors in projects like large-scale solar irrigation or agroforestry require assurance that the policy and tax environment will remain stable over the life of their investment.

Creating a Coherent and Supportive National Policy Environment

Beyond the foundational quality of institutions, the specific content and coherence of the national policy environment are critical. Strong institutions

provide the capacity to act, but a clear and aligned policy framework provides the direction. The synergy between green finance and financial inclusion is maximized when it is supported by a deliberate and multi-pronged policy agenda.

A crucial starting point is the existence of a clear national climate change strategy, often articulated through documents like Nationally Determined Contributions (NDCs) submitted under the Paris Agreement and National Adaptation Plans (NAPs). When these high-level documents explicitly identify sustainable agriculture as a priority for both mitigation and adaptation and outline specific financing mechanisms, they send a powerful signal to both public and private sector actors ([112]). This creates a predictable roadmap for investment and helps to align the activities of different government ministries. For instance, if a country's NDC prioritizes the restoration of degraded agricultural lands ([123]), this can guide the Ministry of Finance to work with the central bank on creating preferential financing schemes for farmers engaging in agroforestry and soil conservation, directly linking national climate goals to financial sector action.

Complementing this is the importance of a dedicated National Financial Inclusion Strategy (NFIS). Many African nations have adopted an NFIS with specific targets for increasing access to and usage of financial services. These strategies are instrumental in creating the infrastructure needed for green finance to reach rural populations. An effective NFIS typically focuses on promoting digital financial services, enhancing financial literacy, and strengthening consumer protection frameworks. Digital finance platforms, especially mobile money, can dramatically lower the transaction costs of delivering credit and insurance to remote farmers. Financial literacy programs are essential to ensure that farmers not only have access to new green financial products but also understand how to use them effectively to improve their operations. Without such a foundational strategy, efforts to launch green credit lines may fail due to a lack of uptake channels and insufficient demand-side capacity.

Finally, agricultural and trade policies must be in alignment with green objectives. Governments must scrutinize their existing policies to eliminate "brown" subsidies that may counteract the goals of green finance. For example, providing heavy subsidies for synthetic nitrogen fertilizers, which are energy-intensive to produce and contribute to

greenhouse gas emissions, works at cross-purposes with an agenda to promote organic and low-carbon farming ([116]). Instead, agricultural support could be repurposed to incentivize the adoption of climate-smart practices. Similarly, trade policies can be designed to support sustainability. Brandi et al. ([97]) find that environmental provisions in trade agreements can encourage greener exports from developing countries. By aligning trade policy with environmental standards, governments can create market-based incentives for producers to adopt the very practices that green finance is intended to support.

In synthesis, the relationship is not linear but deeply interactive. Strong institutions are necessary to design and implement coherent policies. A government with low effectiveness and high levels of corruption will struggle to execute a complex, multi-sectoral strategy, regardless of how well-written it is. Conversely, even a country with relatively strong institutions may fail to achieve its goals if its policies are fragmented and contradictory—for example, if the central bank promotes green finance while the ministry of agriculture simultaneously subsidizes unsustainable practices. The greatest potential for transformation lies at the nexus of institutional strength and policy coherence, where a capable state directs a well-aligned set of incentives towards the shared goal of a productive, resilient, and sustainable agricultural sector. For Sub-Saharan Africa, this means that the journey towards leveraging green and inclusive finance must be intrinsically linked to the broader agenda of strengthening governance and building state capacity.

4.4. Policy Implications

The findings of this study, enriched by the discussion of the institutional context, yield several important and actionable policy implications for governments, financial regulators, and development partners in Sub-Saharan Africa.

1. **Adopt an Integrated Policy Framework:** The most significant implication is the need to move beyond siloed policy-making. Ministries of finance, environment, and agriculture must collaborate to create integrated frameworks that simultaneously promote green finance and financial inclusion. Policies should not treat these as separate objectives but as mutually reinforcing components of a single strategy for sustainable agricultural

development ([142]).

2. **Develop Targeted Green Financial Products:** Financial institutions, with support from central banks and governments, should be encouraged to design and scale up financial products tailored to the needs of smallholder farmers. This could include "green micro-loans" with preferential interest rates for adopting certified sustainable practices, weather-indexed insurance tied to climate-resilient crops, and asset financing for small-scale renewable energy equipment ([137]).

3. **Leverage Digital Finance for Scale:** Digital financial services, particularly mobile money, offer a powerful and cost-effective way to rapidly expand financial inclusion in rural areas. Policymakers and financial service providers should leverage these platforms to deliver green financial products, disseminate climate information, and facilitate payments for environmental services.

4. **De-risk Private Sector Investment:** Governments and international partners can play a crucial role in de-risking private investment in sustainable agriculture. This can be achieved through mechanisms such as blended finance, first-loss guarantees, and technical assistance programs that help local banks build their capacity in green lending and agricultural risk assessment ([106], [140]).

5. **Strengthen Governance and Institutional Capacity:** Efforts to channel green and inclusive finance to agriculture must be paired with a commitment to strengthening governance. This includes anti-corruption measures to ensure funds reach their intended recipients, improving regulatory quality to foster financial innovation, and building the capacity of public institutions to design and implement coherent, long-term policies.

4.5. Limitations and Avenues for Future Research

While this study provides valuable insights, it is subject to certain limitations that open avenues for future research. The primary limitation is the use of a proxy variable for green finance due to the scarcity of comprehensive, country-level data on green investment flows in Africa. While our proxy is grounded in the literature, future research would benefit immensely from more granular data on green bonds, green loans, and public and private expenditures on environmental projects. Second, our macro-level analysis does not capture the heterogeneity of impacts at the sub-national or

household level. Future research using micro-level or survey data could provide deeper insights into how different types of farmers (e.g., smallholder vs. commercial, male- vs. female-headed households) are affected by and engage with green and inclusive financial services.

Finally, future studies could explore the role of specific green finance instruments. For example, an analysis comparing the effectiveness of green bonds versus carbon finance mechanisms ([131]) in promoting sustainable agriculture could yield more targeted policy recommendations. Investigating the political and institutional factors that enable or hinder the development of green and inclusive financial systems would also be a fruitful area for further inquiry.

5. CONCLUSION

This study set out to investigate the interplay between green finance and financial inclusion in shaping agricultural productivity in Sub-Saharan Africa. Against a backdrop of increasing climate vulnerability and persistent financing gaps, understanding the mechanisms that can foster a sustainable and productive agricultural sector is of paramount importance. Our empirical analysis, based on a dynamic panel model for the period 2005-2022, yields clear and robust findings. We find that both green finance and financial inclusion are independently and positively associated with agricultural productivity. More significantly, we uncover a powerful synergistic effect, whereby the positive influence of green finance is substantially enhanced in countries with more inclusive financial systems.

These findings underscore a crucial message: for a green transition in agriculture to succeed, it must also be an inclusive one. Macro-level investments in sustainability will only translate into widespread productivity gains if they are accessible to the millions of smallholder farmers who are the primary stewards of the land. An inclusive financial system serves as the essential transmission mechanism, providing the channels for green capital to flow to where it is needed most. The journey ahead requires an integrated and context-sensitive approach. It demands that policymakers break down institutional silos and design coherent strategies that embed environmental goals within financial and agricultural policies. It calls for financial innovation to create products that meet the unique

needs of smallholder farmers and for a concerted effort to strengthen the institutions that underpin market efficiency and investor confidence. While the challenges are significant, our findings suggest a clear and promising path forward. By strategically harnessing the combined power of green finance and financial inclusion, Sub-Saharan Africa can move towards an agricultural future that is not only more productive but also more resilient and sustainable for generations to come.

REFERENCES

1. Abdullayev, V., Niu, Y., Ragimova, N., Alyar, A.V., Kamran, A.T., 2023. Harnessing renewable energy for sustainable urban development: case studies from the MENA region. *ESTIDAMAA* 2023, 9–17.
2. Akomea-Frimpong, I., Adeabah, D., Ofosu, D., Tenakwah, E.J., 2022. A review of studies on green finance of banks, research gaps and future directions. *J. Sustain. Financ. Invest.* 12 (4), 1241–1264.
3. Ali, E., Awume, A.N., 2025. The nexus between credit rationing and the adoption of climate-smart agricultural practices: implications for agricultural household revenue in Togo. *Dev. Sustain. Econ. Financ.*, 100052.
4. Andreeva, O.V., Vovchenko, N.G., Ivanova, O.B., Kostoglodova, E.D., 2018. Green finance: trends and financial regulation prospects. *Contemporary issues in business and financial management in Eastern Europe*. Emerald Publishing Limited, pp. 9–17.
5. Arellano, M., Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. *J. Econ.* 68 (1), 29–51.
6. Arellano, M.A.N.U.E.L. and Bond, S.T.E.P.H.E.N., 1991. Application to Employment Equations.
7. Aydin, C., Cresser, M.S., 2008. The effects of global climate change on agriculture. *American-Eurasian. J. Agric. Environ. Sci.* 3 (5), 672–676.
8. Berensmann, K., Volz, U., Alloisio, I., Bak, C., Bhattacharya, A., Leipold, G., Schindler, H., MacDonald, L., Huifang, T., Yang, Q., 2017. Fostering sustainable global growth through green finance—what role for the G20. *T20 Task. Force Clim. Policy Financ.* 20.
9. Bielinski, T., Mosionek-Schweda, M., 2018. Green bonds as a financial instrument for environmental projects funding. *Unia Eur.* 248 (1), 13–21.

10. Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. *J. Econ.* 87 (1), 115–143.
11. Brady, K., 2022. Your Stories: How Climate Change is Affecting Hunting and Fishing. Habitat and Clean Water, pulled from <https://www.trcp.org/2022/10/24/stories-climate-change-affecting-hunting-fishing/>.