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Assessing the Nexus between Environmental Degradation, Agro-Climate Financing, and Economic Growth in Sub-Saharan Africa

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Abstract

This study assesses the connection between environmental degradation, agro-climate financing, and economic growth in Sub-Saharan Africa (SSA) using yearly time series data from 2000 to 2022. The system generalized method of moments (GMM) was employed to tackle endogeneity issues, with robustness checks performed using DOLS and FMOLS to address cross-sectional dependence through robust standard errors. This method revealed important insights into the dynamics of economic growth. The findings show a significant positive connection between the economy's past success and its current growth. CO_2 emissions negatively impact economic growth, demonstrating the detrimental effects of environmental degradation. Agricultural finance has a positive influence on economic growth by boosting productivity and fostering economic growth. However, climate financing has a short-term negative impact on growth owing to high initial costs and inefficiencies, but it promotes long-term growth when combined with agricultural finance. The interaction between CO_2 emissions and agricultural finance shows that increasing emissions reduces the benefits of agricultural investments, underscoring the vulnerability of agriculture-dependent economies. Conversely, the interaction of agricultural finance with climate finance enhances economic growth, demonstrating the relevance of combining climate and agricultural investments. Additionally, the study finds that exchange rate stability positively affects growth, while inflation has a negative impact. Robustness checks validate these findings and underscore the need for varied analytical methods to capture economic interactions comprehensively. The study recommends comprehensive policy measures to tackle environmental, agricultural, and climate challenges, promote sustainable growth, and leverage integrated financial solutions for long-term development in Sub-Saharan Africa.

Keywords: environmental degradation; agro-finance; climate finance; economic growth

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1. Introduction

Economic growth is critical for social well-being and national development [1]; thus, governments across the world—including those in Sub-Saharan Africa—advance their growth through a range of policies, programmes, and strategies [2–4]. When economies grow, governments are better equipped to collect taxes and raise the revenues needed to provide important public goods and services to their residents. These include power, infrastructure, defence, social security, healthcare, and other critical services. Even while the production of goods and services is required for economic growth, it usually results in undesirable living and environmental conditions [5]. Environmental degradation causes habitat destruction, upsets ecosystems, depletes resources through soil, water, and air pollution, and drives certain species towards extinction [6]. This issue is especially urgent in developing nations like Sub-Saharan Africa, where weak environmental laws allow environmental deterioration to continue unchecked and obstruct green climate funding [3,7]. This has far-reaching effects that compromise both ecological equilibrium and economic expansion [4]. The effects include fluctuating air temperatures, loss of biodiversity, soil erosion, acid rain, floods, landslides, endangering species, natural disasters, global warming, public health emergencies, loss of livelihoods, famine, conflicts, disease outbreaks, declines in tourism, and overall economic instability [5]. These problems exacerbate the detrimental consequences on economic growth by causing severe challenges for the impacted communities. Natural disasters and human-caused activities like mining, unlawful dumping, deforestation, pollution, inadequate waste management, unsustainable resource extraction, overfishing, overpopulation, and landfills are some of the causes of environmental degradation [6]. Countries are facing more and more economic difficulties as environmental conditions deteriorate, increasing government spending to solve these issues, especially when property and human lives are at risk [8].

The degradation of the human environment also impedes progress in the agricultural sector. The studies [9,10] report that the agricultural industry in Sub-Saharan Africa faces significant hurdles due to rising food demand driven by population growth and changing diets, stagnating crop yields, and diminishing natural resources and biodiversity. Additional challenges include climate change, insufficient funding, reliance on untrained labour, and inadequate storage infrastructure. The adverse impacts of environmental pollution, such as climate change, exacerbate these difficulties. For instance, climate change could potentially reduce crop yields by up to 25%, and extreme weather events associated with climate change pose severe risks to farmers, their lands, and their crops [8]. To revamp the sector and enhance resilience, it is essential to significantly increase investments in climate-smart agricultural practises [10,11]. Historically, agriculture has struggled to attract financing due to perceptions of low profitability and high risk. As such, robust financial investments are crucial for sustaining the global food system, particularly in Sub-Saharan Africa. Consequently, agro-climate financing is crucial for boosting agricultural productivity in the region and driving economic growth and development.

Climate change is an increasingly prominent topic in academic research and policy debates. Numerous studies have explored the relationship between environmental variability and economic growth, as evidenced by works such as [11–16]. Nevertheless, there is a notable gap in research focusing on the specific link between climate mitigation practises—such as climate financing—and economic growth. The empirical evidence on how climate variability influences economic growth remains ambiguous due to the varied ways it can affect economic outcomes. For instance, ref. [17] reports that regular climate disasters cause economic disruptions by destroying infrastructure, displacing populations, and draining resources. These factors impede long-term economic planning and growth, which in turn affects productivity, especially in industries like energy, industry, and agricul-

ture. Moreover, they discourage investment, which slows down economic development. Refs. [13,18] further notes that regulations aimed at reducing environmental pollution might inadvertently raise manufacturing costs, potentially obstructing economic growth.

Climate change presents a significant challenge in Sub-Saharan Africa, bringing forth both distinct issues and untapped opportunities [19]. Agro-climate financing has the potential to greatly advance eco-friendly practises, promote sustainable development, and drive regional economic growth. This financing supports a range of initiatives, such as the development of renewable energy, agricultural adaptation efforts, and emission reduction programmes [20,21]. For instance, in Sub-Saharan Africa, focused investments in enhancing agricultural resilience can lead to increased productivity and improved food security, thereby supporting both rural economic stability and national prosperity [18,22]. Additionally, climate financing can also facilitate the region's shift towards low-carbon economies by funding clean energy infrastructure, decreasing dependence on fossil fuels, fostering industrial diversification, and creating employment opportunities in green technologies and renewable energy sectors [18,21]. Similarly, using the ARDLbounds testing techniques, [23] examines how agricultural finance affected Nigeria's agricultural growth between 1985 and 2021. Foreign finance has a long-term negative influence on agricultural GDP, owing to resource rivalry, but domestic finance, including interest rates and bank loans, and agricultural supports schemes increases it [24,25]. Policymakers and stakeholders stand to gain from these insights.

Despite the potential benefits, several obstacles hinder climate financing from making a substantial impact on regional economic growth. Regulatory challenges and an insufficient financial infrastructure can diminish the effectiveness of these investments [26]. Additionally, environmental pollution continues to be a major issue, increasing the costs for businesses that must comply with environmental regulations [27]. To ensure that growth is not stifled by pollution control measures, it is crucial to align environmental regulations with economic policies. To this effect, ref. [7] argued that stringent regulations may divert resources away from productive activities and towards compliance efforts, resulting in increased operating expenses. However, effective environmental regulations serve to safeguard the environment by reducing pollutants and avoiding ecological harm. They promote sustainability, preserve biodiversity, improve public health, and lower environmental costs. Additionally, ref. [28] highlights that environmental pollution may obstruct economic advancement by negatively impacting human health, underscoring the critical role of health in fostering economic growth. Numerous studies have also linked environmental pollution to adverse health outcomes [12].

Previous studies have shed light on the complex relationship between environmental degradation and economic growth [4,5,9,29–31]. Our research builds on this knowledge by examining the interactions among environmental degradation, agro-climate finance, and economic growth specifically within Sub-Saharan Africa. Building on this foundation, the objectives of our study are to (a) assess how environmental degradation affects economic growth in the region; (b) explore the connection between agricultural finance and economic growth; (c) investigate the impact of climate finance on economic growth; (d) analyse the combined effects of environmental degradation and climate finance on economic growth; and (e) evaluate how the combined effects of agro-finance and climate finance contributes to economic expansion in Sub-Saharan Africa.

To achieve these objectives, we tested the following hypotheses: (a) environmental degradation has no significant effect on economic growth in Sub-Saharan Africa; (b) agricultural finance does not significantly influence economic growth in Sub-Saharan Africa; (c) climate finance has no significant impact on economic growth in Sub-Saharan Africa; (d) the interaction between environmental degradation and agro-climate finance does not

significantly affect economic growth in Sub-Saharan Africa; and (e) the interaction between agro-finance and climate finance does not significantly contribute to economic expansion in Sub-Saharan Africa utilising advanced econometric methods, including the panel dynamic system generalized method of moments (GMM), which effectively addresses endogeneity issues. Additionally, we employed panel dynamic ordinary least squares (DOLS) and panel fully modified ordinary least squares (FMOLS) to ensure robust results by accounting for cross-sectional dependency, heterogeneity, and country-specific effects across Sub-Saharan Africa.

This study distinguishes itself from existing research in several ways. First, while prior studies have focused on individual elements of environmental and financial dynamics and their role on economic growth [4,5,32–34], our research provides a holistic analysis of how environmental degradation, agro-climate finance, and economic growth interact in Sub-Saharan Africa. For instance, whereas [4,5] have documented the impacts of environmental degradation on economic stability, our study incorporates agro-climate finance, offering new insights into how financial strategies can alleviate these challenges. Second, despite previous research by [35] identifying various issues related to agricultural finance and climate change, there has been limited exploration of their combined effects on economic growth. Our study addresses this gap by investigating the role of agro-climate finance in influencing economic growth, thereby providing a clearer picture of how targeted financial interventions can enhance resilience and productivity. Third, while earlier studies have generally addressed environmental impacts, our research specifically examines how different forms of environmental degradation—such as soil erosion, deforestation, and water pollution—affect economic growth. This analysis expands on the work of [6] by linking these environmental issues directly to economic growth and financial factors. Finally, by employing sophisticated econometric techniques like dynamic GMM, dynamic OLS, and fully modified OLS, our study addresses the limitations of previous research methods that may have overlooked endogeneity, cross-sectional dependency, heterogeneity, and country-specific effects. This approach provides a more comprehensive and nuanced understanding of how addressing environmental and climate finance issues can promote sustainable economic development in Sub-Saharan Africa.

2. Empirical Literature

This section provides a thematic overview of the empirical studies reviewed. This review is organised thematically, focusing on critical areas such as the connections between environmental degradation and economic growth, agricultural finance and economic growth, and climate finance and economic growth. Understanding current research, concepts, and methodologies in these areas will offer a solid foundation for the study.

2.1. Environmental Degradation and Economic Growth

The dispute over the consequences of environmental deterioration and the need to regulate its impacts to maintain long-term resource sustainability, agricultural output, and economic stability remains unresolved. Consequently, many researchers from across the globe have contributed significantly to this issue. Some studies found a negative association between environmental damage and economic growth, while others found a positive connection, particularly in SSA nations. The authors of [34] explore how environmental degradation affects economic growth. Their study finds that emissions and economic growth have an inverse relationship, while measures of the ecological footprint display a U-shaped association with economic growth. They identify three key factors—health, foreign direct investment (FDI), and technological innovation—that could exacerbate challenges to economic progress in the face of environmental decline. The study also highlights the

policy implications of these findings and suggests areas for further research. The authors of [36] evaluated the environmental consequences of industrialisation and foreign direct investment in 36 African countries from 1980 to 2014. It was observed that industrialisation had minimal effect on the environment; however, foreign direct investment had a significant impact.

In a few African nations, [10] examines the connections between economic growth, CO_2 emissions, and agricultural value added between 1997 and 2020. The study demonstrates that there is a considerable rise in environmental pollution with economic expansion, using the two-step difference generalised method of moments (GMM). While agricultural productivity and labour tend to minimise pollution, other factors such as capital, foreign direct investment (FDI), and food prices also contribute to greater levels of pollution. The findings demonstrate that labour, food prices, and foreign direct investment all have different effects on agricultural output and provide credence to the growth-led pollution theory. Using panel data from 1980 to 2014, ref. [37] investigates the nexus of environmental sustainability and agro-economic performance in Sub-Saharan Africa. Using the Kao test and the pooled mean autoregressive distributed lag (PMG-ARDL) model, the research reveals that CO_2 emissions, GDP, natural resource rents, agriculture, and urbanisation are all cointegrated in the long run. The analysis shows that while agricultural value added is linked to decreased emissions, GDP and CO_2 emissions have a positive long-term association. Conversely, higher CO_2 emissions are associated with urbanisation and the rental of natural resources. Furthermore, addressing rural–urban mobility is critical for effective emission management, as shown by a bidirectional causal relationship between agricultural value added and CO_2 emissions.

Additionally, ref. [33] discovered a link between pollution and natural resource rents in their investigation on the impact of energy use on environmental quality across G7 countries. When renewable energy is utilised, pollution is considerably decreased; yet, when fossil fuels are used, carbon dioxide emissions rise and environmental deterioration accelerates. The research also found that the usage of fossil fuels and income levels had a significant influence on environmental degradation. The authors recommend that the G7 countries invest in renewable energy rather on natural resource revenues to align economic interests with environmental sustainability and create a more sustainable world. The study by [38] examines the effects of economic growth, urbanisation, energy use, fossil fuel use, and natural resource rents on environmental sustainability in Africa between 1980 and 2014. According to the research, there is a positive significant association between pollution emissions and non-renewable energy sources, urbanisation, and electricity use. Granger causality tests show that there is a reciprocal relationship between economic progress, electricity use, and emissions. To lessen the consequences of climate change and ensure long-term environmental and financial sustainability, the research suggests converting to renewable energy sources and putting carbon capture and storage plans into place. Thus, ref. [39] explores the Granger causality between economic growth and energy consumption in six Asian economies: India, Indonesia, Pakistan, the Philippines, Malaysia, and Singapore. The findings show that in Indonesia, India, and Pakistan, there is cointegration between energy and income. Specifically, Pakistan exhibits mutual causality, while India and Indonesia display unidirectional causality, where energy consumption drives economic growth. These results highlight energy's critical role in economic development in certain countriesThe study [40] examined the climate change effect on cereal output in lower–middle-income nations from 1971 to 2016. The study uses average yearly temperatures, rainfall, CO_2 emissions, cultivated land, and rural population as control variables. The findings show that rising temperatures reduce cereal yield, but rainfall and CO_2 emissions have a positive effect. The article suggests that authorities should work

on creating heat-resistant cereal crops to offset the adverse impacts on food security and ensure food supply. Using data from 1991 to 2018, Ref. [11] investigates the connection between India's rice output and climate change. The findings indicate that while good rainfall and carbon emission shocks have a major influence, the mean temperature has a long-term detrimental impact on rice output. The study also indicates that producing climate-resilient crops and upgrading the irrigation system while offering farmers suitable skills are essential for the sustained cultivation of rice in India. On the other hand, Ref. [41] found that environmental contamination had a positive impact on Vietnam's agricultural output. The authors of [42] emphasised that Pakistan's agricultural productivity is negatively impacted by climate change. While [43] observed an unfavourable association between agricultural output and economic growth in the Gambia from 1960 to 2017, in [44] explores the influence of real sector output on the link between information technology and economic growth in 26 sub-Saharan African nations from 2000 to 2019. The research employs three variables: industrial value-added, agricultural value-added, and total factor productivity. The findings suggest that information technology has a mixed influence on economic growth in these nations. The relationship between agricultural value-added and information technology has a positive impact, whereas industrial value-added and total factor productivity have an adverse effect. The report recommends improving the real sector is crucial for exploiting information technology's development potential.

Diverse conclusions have been drawn from research on the relationship between environmental pollution and economic growth. The studies [45,46], for example, show that rising economic growth is accompanied by rising CO_2 emissions. On the other hand, Refs. [47,48] discover that in nations such as Saudi Arabia and Pakistan, economic expansion may have an adverse impact on emissions. These inconsistent results imply that geographical variables and study techniques have a significant influence on the link between economic growth and environmental damage. Mixed findings are also seen in studies on how CO_2 emissions affect agricultural productivity. While rising temperatures and greater CO_2 levels have a negative effect on grain yield, Ref. [49] shows that CO_2 emissions have a favourable effect. In [19], it was investigated if climate change raises the likelihood of a disastrous economic downturn using quantile regression. The hazards associated with economic growth are significantly and continuously influenced by temperature in every aspect.

2.2. Agricultural Finance and Economic Growth

Agriculture is an important industry in many African nations; hence, agricultural finance is critical for encouraging economic growth [50]. Financial assistance, such as financing, grants, and subsidies, allows farmers to invest in better technologies, seeds, equipment, and infrastructure. This leads to higher production, improved food security, and the creation of new job possibilities. Furthermore, access to funding enables smallholder farmers to overcome market access restrictions while also strengthening their resilience to environmental and economic shocks. Agricultural financing promotes the adoption of sustainable practises and the creation of value chains, both of which are critical for driving future prosperity. Many researchers have emphasised the importance of agriculture in enhancing economic growth in Sub-Saharan Africa (SSA), providing insights into policies that should be implemented to progress the regional economy through agricultural development. Using information from the Central Bank of Nigeria, [51] investigates the impact of guaranteed agricultural funding on Nigeria's real GDP over a 37-year period. The findings show that the financing had no discernible effect on GDP, underscoring the need for further funding and a detailed analysis of which agricultural expenses had the most effects on economic expansion.

The study [52] focuses on the roles and constraints of both public and private investors, as well as the restricted availability of concessionary finance for sustainable agriculture. It draws attention to the financial gap and talks about several finance options to overcome obstacles. The results underscore the necessity of utilising a variety of funding options and investigating hybrid financing arrangements in order to enhance agricultural investments that are in line with the Sustainable Development Goals (SDGs). The study [53] examines how FinTech assists Sub-Saharan Africa to promote sustainable agriculture. The results show how FinTech may play a significant role in facilitating environmentally friendly agriculture by assisting small-scale farmers in overcoming obstacles related to sales and production. However, in order to attain sustainability, governments should concentrate on closing the infrastructural gap between rural and urban regions, and farmers must receive training on the use of digital platforms.

The study [54] investigates how China's smallholder farmers are adopting sustainable agriculture practises (SAPs) in relation to digital financing. It was discovered that via reducing credit constraints, enhancing information availability, and promoting social connections, digital finance greatly increases SAP adoption. SAP use is greater among farmers with more education, smaller farms, and extension services. According to the report, training programmes and network infrastructure improvements for rural areas are needed by the government in order to offer safe and affordable digital financial services. Evidence from [55] shows the impact of agro-financing on Nigerian food production in relation to two SDGs for 2030. The study concludes that agro-financing has a positive effect on food production by using Johansen and canonical cointegration approaches. This effect backs initiatives in Nigeria to end hunger, guarantee food security, enhance nutrition, and advance sustainable farming methods.

Using information from the CBN and a range of analytical methods, Ref. [56] investigated the effect of agricultural finance on Nigeria's economic growth from 1986 to 2022. The findings demonstrated a significant connection between GDP and bank loans for agriculture. The analysis showed a significant link between government spending on agricultural and economic development. Furthermore, it was discovered that bank loans, public investments in agriculture, and the Agricultural Credit Guarantee Scheme Fund had all made a substantial contribution to Nigeria's economic growth. The study [56] points out that although severe credit requirements sometimes restrict the influence of agriculture, particularly for small-scale farmers who have difficulty acquiring financing, agriculture plays a significant role in Nigeria's economic growth. The study [57] further underscores the difficulties faced by small-scale farmers as a result of limited access to financing and their incapacity to provide collateral—factors that heighten output uncertainty in agriculture. However, Ref. [58] contends that reducing the cash–reserve ratio may increase bank credit availability, loosening strict borrowing standards. The study [59] found that smallholder producers were prospective investors; [60] found that Kenyan farmers cannot obtain credit because they cannot provide collateral for a loan. In his analysis of Nigeria's agricultural policy, Ref. [61] noted that credit is essential to agricultural growth and that credit shortages may affect a farmer's ability to make investments. In order to increase farmers' trust and lower the risk of credit default, the research suggests a number of actions, such as boosting loan diversification and appointing experts to train local farmers.

The study [62] emphasised the risk associated with uncertainty in the agriculture industry. They made the point that lenders that only set up short-term loans and imposing exorbitant interest rates deters farmers from taking out loans. Similarly, if farmers are unable to pay back their loans, Ref. [63] warns that their credit rating may suffer and future access to financing may be limited. Based on empirical evidence indicating the relationship between the two, Refs. [64,65] examine if there is a causal association between

agro-financing and economic growth. By using the Granger test for causal analysis, they ascertain the existence of a bi-directional causal link. Stated differently, the agricultural sector gains from substantial and adequate support, which promotes economic expansion. The study [24] asserts that having access to enough funding is essential to the agricultural sector's ability to foster growth, as it allows farmers to invest in cutting-edge machinery, such as the purchase of premium seedlings. In [11,20,22,27,66,67], the autoregressive distributed lag (ARDL) and error correction mechanism (ECM) are used to find the uneven link between state expenditure, private investment, and the growth of the agriculture sector. Despite government public expenditure improving agricultural output, private investment has very little impact on it. This conclusion is not totally surprising, as private investors often feel that the agriculture industry is unpredictable and yields low returns.

The study [68] also employs the autoregressive distributed lag (ARDL) model and error correction mechanism (ECM) to show that agricultural loans and economic growth have both short- and long-term relationships. The real exchange rate and private domestic investment have a positive correlation, whereas the inflation rate has a negative correlation, according to the investigation's other control variables [50,69]. These studies [50] show that public spending has a beneficial impact on the increase of agricultural production, while foreign investment has insignificant impact. The study study also show that real exchange rates, real interest rates, inflation rates, and private domestic investment are only a few of the dynamic variables that affect economic development. Therefore, in order to sustain agricultural output, combination of public and private investment is pertinent and other macroeconomic indicators such as real exchange rates, real interest rates and inflation rates should be properly managed.

Findings from the formal agricultural credit allocation factors into the farm sector study by [70] using the ordinary least squares (OLS) procedure to show how important it is to critically evaluate the dynamics influencing the rate at which government credit scheme beneficiaries allocate credit. Based on their interpretation of the data, [71], study on the connection between Nigerian families' loan availability and agricultural output revealed that agricultural yields were greater in families with access to agricultural finance facilities than in those without it, while those without credit often have to deal with difficulties like cutting down on spending and selling possessions, which may make their poverty worse. Also, [72] conclude that families with access to agricultural financing produced three times as much as those without such credit. This study goes beyond the existing corpus of empirical research by analysing the impact of shocks from other endogenous regressors in the model on economic development in addition to examining the link between agro-finance and growth. Furthermore, with the aid of the propensity score matching (PSM) model on cross-sectional data from Wave 2 of the Living Standard Measurement Study—Integrated Survey on Agriculture (LSMS-ISA), [71,72] findings on agricultural credit and agricultural productivity in Nigeria lend additional credence to the previously mentioned claim. Research like [65,73] criticise the conditions and application process for loans. They contended that farmers, particularly female farmers, are denied financing as a result of bureaucratic procedures.

2.3. Climate Finance and Economic Growth

In order to evaluate the impact of climate change on Nigeria's overall economic development, Ref. [13] used data from 1981 to 2014 using the ordinary least squares (OLS) prediction technique. The authors' findings indicate that carbon emissions have an adverse effect on growth over the long run as well as the short term. The study [74] examined the long-term consequences of climate change on economic activity in 174 countries. In their study, the authors used a stochastic growth model using a panel data set that included

precipitation and temperature. As a consequence, the authors discovered that prolonged temperature variations above or below historical norms have a detrimental influence on real output growth per capita, whereas precipitation has no statistically significant effect. According to [14], the study was based on an assessment of how long-term temperature and precipitation changes caused by climate change influence industrial and economic outputs. According to [16], the consequences of climate change on the economy as a whole are generally unfavourable but bearable. The study [15] looked into the relationship between climate change and Lebanon's economic growth. Based on the OLS approach, the author has used a time series analysis for the years 1990–2013. He has explained climate change using factors related to precipitation, forest area, and carbon emissions.

Research has been performed on how a country's weather affects its GDP and its main sources of production inputs, which are employment, capital stock, and total factor productivity [75]. They included the examination of 101 national services from 1961 to 2010 in the panel data set. They proved that the main weather-related element driving GDP growth is temperature. They also found that developing countries are less resilient to increasing temperatures than industrialised ones. The study [35] has researched the connection between temperature and growth in the US and the EU. They found that the development of the US and EU economies was significantly harmed by forecasted temperature increases over the optimal temperature. Their assessment comprised the impact of climate change on gross regional product (GRP) in at least 1500 areas across 77 countries.

According to [74], rising temperatures dramatically impede economic development in developing countries, perhaps leading to slower growth rates over time. These temperatures also reduce industrial and agricultural productivity, which threatens political stability and has an impact on both. These results highlight the grave harm that rising temperatures do to poor nations' economy. There are regional variations in temperature and the effects of climate change, according to [76]. The research voiced worry about the fact that many studies preferred country-level weather averages over significant country differences. Dynamic spatial econometric approaches were used in studies to explore the possibility for geographical reliance through spillovers and diverse effects across different spatial regimes. According to the study, economic development responds nonlinearly to rising temperatures across places, which is consistent with earlier research [25]. The study's surprising discovery is that the effects vary depending on the beginning temperature. Increased temperatures have a detrimental influence in warmer areas while promoting development in colder climes.

A research by [17] investigates how temperature and pollution affect income from 1960 to 2014 using panel and time series techniques. The findings indicate that whereas income is stimulated by 0.22% by a 1% rise in emission levels, it is decreased by 0.39% by a 1% increase in temperature. According to the research, wealth creation is supported by environmental pollution and vice versa, and income and emissions are associated. Economic growth is hampered by the shift from ideal temperatures ranges to extreme patterns, underscoring the need of changing the structure of the economy and moving from brown to green development. With a data from 21,576 Kenyan dairy farmers, the [31] examined how borrowers' production capability affected their ability to get loans from commercial banks. The findings indicated a significant association between farmers' access to funding and output capacity. The report suggests encouraging the use of production resources when approving loans. Further investigation shows that credit facilities in Nigeria have a significant impact on agricultural productivity and food security. The implementation of various adaptation and mitigation techniques is the aim of climate finance, according to [77]; sustainable finance is used to provide the required funding for ecologically good projects that benefit society as a whole. Moreover, the phrase "green

finance" encompasses several other concepts, such as "sustainable finance", "climate finance", "carbon finance", and "environmental finance". This kind of financial service seeks to protect the environment, increase resource efficiency, and lower greenhouse gas emissions. According to [18], climate finance is a subset of sustainable finance, which is a subset of green finance. They claim that the goal of sustainable finance is to accomplish more general goals of sustainable development, such social and environmental goals. For example, the 2030 Agenda for Sustainable Development has 17 SDGs. Definitions of climate finance and green money are not widely accepted. According to study findings [30], China plans to switch to more energy-efficient sources by 2050 and will finance this transition through the green bond market. Furthermore, China expanded its funding channels and introduced cutting-edge climate finance products by launching a pilot programme for the carbon trading market that links financial institutions to carbon emissions. Both terms refer to funding systems aimed at addressing environmental issues, but [15] distinguishes green finance from climate finance by defining it as a financial investment that can create environmental benefits.

2.4. Literature Gap

Despite substantial study into environmental degradation, agricultural financing, and climate finance, there are significant gaps in the understanding of their combined effects on economic growth, particularly in Sub-Saharan Africa. While previous research provides insights into each factor independently, there is lack of comprehensive analysis of how they interact within this specific regional context. Research shows a generally negative association between environmental degradation and economic growth, as indicated by [34,48]. However, this relationship is complex and is contingent upon the circumstances in each region, with some studies indicating a U-shaped curve. Thus, a targeted study is required to understand how these dynamics specifically affect Sub-Saharan Africa, where environmental and economic problems are particularly pressing. Also, it is commonly known that access to credit is crucial for enhancing productivity and growth. Studies like [55] focus on individual countries, frequently ignoring the broader regional context. The unique agricultural and financial landscape of Sub-Saharan Africa, characterised by tight credit restrictions and a disparate financial infrastructure, has not been well studied. Furthermore, the relationship between agricultural financing and climatic or environmental finance has not received much attention.

The effects of climate finance on economic growth have been extensively researched, revealing both positive and negative outcomes depending on the regional and sectoral context. While studies such as [13,18,26] highlight the role of climate finance in addressing climate change, there is a limited understanding of its impact within Sub-Saharan Africa's distinct economic environment. Many existing studies focus on broader or non-African regions, neglecting the specific needs of Sub-Saharan Africa. In general, while there is ample research on environmental degradation, agricultural finance, and climate finance individually, there is a notable gap in integrated studies that examine how these factors interact and influence economic growth in Sub-Saharan Africa. The relationship between agro-climate finance, environmental degradation, and economic growth is still not well understood, particularly in terms of its effects on regional development and resilience. To fill these gaps, there is a need for more thorough and region-specific research employing consistent methodologies. This approach will improve the understanding of how these factors interrelate and aid in crafting targeted policy recommendations for Sub-Saharan Africa.

3. Materials and Methods

This study examines the relationship between environmental degradation, agro-climate financing, and economic growth in Sub-Saharan Africa between 2000 and 2022. Ex-post research designs are frequently used in time series data analysis, particularly when assessing the effects of interventions, policies, or events. This study design was used in this instance. With the use of data collected across time at various times, this approach allows the research to investigate the relationships among the variables over a range of time periods. As a result, data for the research, which covers the years 2000 to 2022, were generated for each of the 54 Sub-Saharan African nations that were sampled. After carefully reviewing the available literature, the variables listed in Table 1 below were selected. As such, the data were obtained from the IMF Climate Finance Database (2023) and the World Bank Indicator (2023), as Table 1 below illustrates.

Table 1. Definition of the variables.

Acronym	Definition	Source	Apriori
Dependent Variable			
RGDP	Real gross domestic product	World Bank's Development Indicators (WDI, 2023)	To be determined
Explanatory Variables			
CO_2	Carbon dioxide emissions—measure of environmental degradation	World Bank's Development Indicators (WDI, 2023)	Negative
AGF	Agricultural finance measured by total financial assistance and flow for agriculture by recipients	World Bank's Development Indicators (WDI, 2023)	Positive
CLF	Climate finance proxied with green bond issuance	IMF (2023) Climate Fund Database	Positive
Control Variables			
EXR	Exchange rate	World Bank World Development Indicators (WDI, 2023)	Positive
INFL	Inflation rate	World Bank Development Indicators (WDI, 2023)	Negative

Source: authors' concept. Countries elected are Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Republic of Congo, Rwanda, Sao Tome and Principe Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe.

3.1. Model Specifications—Baseline Model (GMM)

In this paper, the relationship between environmental degradation, agro-climate financing, and economic growth in Sub-Saharan Africa from 2000 to 2022 was examined using the panel generalised method of moments (GMM) technique, in accordance with the methodology from [78]. When the number of cross-sectional units (N) is greater than the number of time periods (T), this econometric approach is very efficient. It solves the problem of weak instruments that the difference GMM technique has in common and solves issues with endogeneity bias, reverse causality, and omitted variables. Because of the system GMM's (SGMM) ability to withstand several estimation problems, including simultaneity bias, endogeneity, and overidentification of instruments, as well as its ability to handle long-term connections, it was chosen as the model of choice.

The following is the expression of the panel model used to evaluate the link between environmental degradation, agro-climate financing, and economic growth:

$$RGDP_{i,t} = \alpha + \pi RGDP_{i,t-1} + \vartheta X_{i,t} + \varnothing Cont_{i,t} + \theta_i + \delta_I + \varepsilon_{i,t} \quad (1)$$

where $RGDP_{i,t}$ denotes real gross domestic product in constant US dollars, $RGDP_{i,t-1}$ is the first-year lag of $RGDP$, $X_{i,t}$ represents the the vector of explanatory variables (including environmental degradation, agricultural finance, and climate finance) and control variables ($Cont_{i,t}$) such as the exchange rate and inflation rate. Environmental degradation is measured by carbon dioxide (CO_2) emissions per capita, while agricultural finance (AGF) is represented by total financial aid for agriculture, including government budgets, international aid, and private investments. Climate finance (CLF) is proxied by green bond issuance, assessing the financial flows towards climate-related projects and their effect on economic growth. Hence, θ_i represents the time specific effect, while δ_I denotes the country specific effect. $\varepsilon_{i,t}$ represents the error term, while i indicates the cross-sectional index. Thus, t is the time index.

The rationale behind selecting the control variables ($Cont_{i,t}$) stemming from inflation and exchange rates are essential for Sub-Saharan Africa's (SSA) economic growth. Price stability, which is essential for countries dependent on agriculture and minerals, is maintained by a stable exchange rate, which increases export competitiveness. However, fluctuating exchange rates according to [79,80] have the potential to impede commerce and discourage investment and growth. Therefore, it is possible that currency depreciation may impact the effective value of foreign aid and investments in agro-climate finance, thus influencing the execution and outcomes of climate finance initiatives. Additionally, purchase power and investment are impacted by inflation, and excessive inflation reduces earnings and deters long-term investment, as well as boosts borrowing costs and hinders growth [81]. However, agro-climate project funding may become less valuable in real terms during periods of high inflation, which would lessen the projects' ability to combat environmental deterioration and advance sustainable farming methods [71]. Consequently, knowing how changes in exchange rates affect agricultural financing and environmental consequences aids in the creation of efficient policies that stabilise the industry and guarantee the effective use of foreign investments and finances.

Panel dynamic system GMM is favoured when the number of time periods (T) is smaller than the number of cross-sectional units (N), a requirement met in this study with T = 22 and N = 55. This method is particularly well-suited for dynamic panel data models that confront issues such as endogeneity, autocorrelation, and unobserved heterogeneity. Compared to fixed effects (FEs), random effects (REs), 2SLS, and difference GMM, system GMM often delivers more reliable estimates, particularly when managing dynamic relationships and addressing endogeneity. Its advantage lies in its ability to use internal instruments and correct for the limitations of difference GMM, such as weak instruments. By using lagged values of the independent variables as instruments, system GMM effectively tackles endogeneity resulting from the presence of initial values of RGDP and other endogenous variables. Additionally, it accounts for cross-country heterogeneity, which is expected in Sub-Saharan Africa due to the dynamic nature of RGDP over time.

Moreover, system GMM resolves the misspecification issues frequently encountered in static models by including a lagged dependent variable that is often excluded in such models. This variable is essential because of its substantial impact on predicting the current behaviour of the dependent variable. System GMM is also more efficient than difference GMM, as it addresses the problem of weakened instruments after first-difference estimation. Furthermore, the method accounts for autocorrelation and heteroskedasticity by utilising robust standard errors, making it a powerful tool for panel data analysis in dynamic settings. However, careful attention must be given to instrument selection and model specification to ensure reliable results.

The GMM model addresses endogeneity by using lagged values of the independent variables as instruments, effectively handling the influence of initial RGDP and other endogenous factors. It also tackles country-specific variability, which is especially relevant in Sub-Saharan Africa, where economic growth patterns fluctuate over time. Furthermore, GMM mitigates the common misspecification issues in static models by incorporating the effects of lagged variables. Despite these strengths, system GMM has some drawbacks, such as the risk of overidentification, excessive instrument generation, sensitivity to model specifications, and potential bias in small samples. To ensure reliable estimates, the careful selection of instruments and precise modelling of dynamic relationships are essential [82].

To address these concerns, the study applied Hansen's J test following [83] for overidentification to validate the instruments and conducted Arellano–Bond tests for autocorrelation. The model's moment conditions are defined as follows:

$$RDGP_{i,t} - RGDP_{i,t-1} = \pi(RGDP_{i,t-1} - RGDP_{i,t-2}) + \vartheta(X_{i,t} - X_{i,t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \quad (2)$$

First differencing removes both the country-specific effects (η) and the intercept in Equation (2). Equation (1)'s estimation, however, will be skewed and inconsistent since the error term and the lagged dependent variable are likely correlated, making the explanatory factors endogenous [84]. Consequently, the following moment criteria must be met by the model, according to [22]:

$$E[RGDP_{i,t-n}\ (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \text{ for } n \geq 2,\ t = 3,\ \ldots\ldots\ldots\ T$$
$$E[X_{i,t-n}\ (\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \text{ for } n \geq 2,\ t = 3,\ \ldots\ldots\ldots\ T$$

Therefore, it is important to clarify how the model will address certain estimate concerns like identification, simultaneity, and limitations in order to ensure that they are addressed. The Hansen J test of identifications is used as the statistical test to validate the variables that were chosen, and according to [85], the null hypothesis of the underlying Sargan overidentifying restrictions test should not be rejected in order for the strictly exogenous variables to explain the dependent variable solely through the channel of known or suspected endogenous variables. In order to make sure that AR2 is absent from the estimated results, we also estimated the Arellona–Bond serial correlations, which contain both AR1 and AR2 [22].

3.2. Model for Robustness Check

In addition, we used panel dynamic ordinary least square (DOLS) and panel completely modified ordinary least squares (FMOLS) to further reliably check the GMM model results [2,74,86]. In addition to handling country-specific and heterogeneity difficulties, the FMOLS and DOLS models are also capable of handling cross-sectional dependency. Endogeneity, serial correlation, bias from missing variables, measurement errors, and other issues are all resolved by the FMOLS technique, which also yields optimal estimates of cointegration compatible with the parameters, even with small sample sizes. It permits long-run parameter heterogeneity as well. developments of stochastic regressors, and the cointegrating equation over an extended period of time. Asymptotically unbiased and with a completely efficient mixture of normal asymptotes, the resulting completely modified OLS (FMOLS) estimator permits standard Wald tests through asymptotic Chi-square statistical inference. The residuals' long-run covariance matrices are used by the FMOLS estimation. Direct estimation from the difference regressions is possible. However, the cointegrating equation error term that results from the dynamic OLS approach augments the cointegrating regression with lags and leads, making it orthogonal to the full history of the stochastic regressor innovations. Based on the assumption that all long-run correlation between the error components is handled by the differenced regressors' lags and leads, the

DOLS model has the same asymptotic distribution as those derived from FMOLS [87]. According to [88], DOLS does not put extra restrictions on the cointegration of the regressors and the integration of all variables of the same order [I(1)]. This approach has the benefit of the DOLS model compensating for any errors in stationarity determination. The following are the details of the FMOLS and DOLS:

$$\beta^* NT - \beta FMOLS = \left[\sum_{i=1}^{N} L_{22t}^{-1} \sum_{t=1}^{T} (x_{it} - x_{it})^2\right] \sum_{t=1}^{N} L_{11t}^{-1} L_{22t}^{-1} \left[\left(\sum_{t=1}^{T} (x_{it} - x_t)\mu_{it}^* - T_{\gamma 1}\right)\right] \quad (3)$$

It should be noted that [86] panel FMOLS estimation and the dynamic OLS estimator shared the same asymptotic distribution. To verify the consistency of the result, the estimations for both DOLS and FMOLS were carried out as demonstrated. Nonetheless, we have provided the DOLS model below in accordance with [89].

$$Y_t = \alpha + bX_t + \sum_{i=-k}^{i=k} \varphi_i \Delta X_{t+i} + \varepsilon_t \quad (4)$$

This model implies that all of the long-run correlation covariance matrices of the residuals are absorbed by adding the lags and leads of the differenced regressors, and that the asymptotic distribution of the least squares estimates is the same as that of the estimates derived from FMOLS and CCR.

4. Results

Firstly, given the relevance of descriptive statistics features—such as mean, median, variance, standard deviation, skewness, and kurtosis—we present the summary to facilitate the understanding of the central tendency, dispersion, and overall distribution of the time series data. The findings of the descriptive statistics are shown in Table 2 below. The variables display considerable variation in their mean values, with RGDP having the highest average at 22.71 and AGF having the lowest at 1.135. This suggests that RGDP is associated with higher economic activity, whereas AGF indicates lower levels of agricultural finance. The median values are close to the means, implying that the distributions are generally symmetrical. However, CO_2 has a right-skewed distribution, as its median (4.399) exceeds its mean (3.689). Additionally, CO_2 has a broader range of values, spanning from −5.829 to 5.906 compared to the narrower range for RGDP, which is from 18.64 to 28.93.

Table 2. Results of descriptive statistics.

Var	RGDP	CO_2	AGF	CLF	EXR	INFL
Mean	22.71	3.689	1.135	1.803	2.821	2.735
Median	22.64	4.399	0.863	1.943	3.258	2.616
Maximum	28.93	5.906	5.058	4.901	5.529	6.879
Minimum	18.64	−5.829	−7.002	−3.808	−4.383	−0.134
Std. Dev.	2.052	1.819	2.161	1.334	1.948	1.221
Skewness	0.627	−2.254	0.250	−0.653	−1.704	0.284
Kurtosis	3.236	7.878	2.616	3.804	5.301	2.561
Jarque–Bera	85.99	2263.	14.34	53.22	891.7	27.03
Probability	0.000	0.000	0.000	0.000	0.000	0.000
Obs	1265	1231	867	542	1265	1260

Source: authors' concept.

Standard deviations show that CO_2 (1.819) and AGF (2.161) have greater variability than INFL, which has a lower standard deviation of 1.221. The skewness values reveal that CO_2 has a notable left skew (−2.254), while RGDP shows a slight right skew (0.627). The

kurtosis indicates that CO_2 has a leptokurtic distribution with pronounced tails (7.878), while AGF has a more moderate kurtosis (2.616). The Jarque–Bera test confirms that all variables significantly deviate from a normal distribution, with *p*-values of 0.000.

Furthermore, we used additional pre-estimation tests, such as Spearman's correlation and unit root tests, to see if variations in one variable are related to changes in another and if the variable exhibits a random walk (where past values do not accurately predict future values). While descriptive statistics summarise the data, a correlation analysis reveals the relationships between variables, and unit root tests assess the time series characteristics required for advanced modelling and estimation. These tests provide a deeper understanding of the data's behaviour and consequences.

Based on the test criteria, where a rank between 0 and ±0.20 indicates no correlation, ±0.21 to ±0.40 denotes a weak correlation, ±0.41 to ±0.60 represents a moderate correlation, ±0.61 to ±0.80 signifies a strong correlation, and ±0.81 to ±1.00 denotes a very strong correlation, the results shown in Table 3 were evaluated accordingly. Spearman's correlation test identifies several relationships between the variables. In contrast to its negative relationship with climate financing (CLF) and agricultural financing (AGF), the real GDP (RGDP) has a strong association with inflation and CO_2 emissions. The significant relationships between CO_2 emissions and RGDP, agricultural financing, and climate finance demonstrate a complex interaction between economic activity and environmental consequences. The correlations between the other variables show varied degrees of connection, emphasising the necessity for more research into these relationships in the context of environmental and economic policies.

Table 3. Results of Spearman's correlation test.

Var	RGDP	CO_2	AGF	CLF	EXR	INFL
RGDP	1					
CO_2	0.812	1				
AGF	−0.787	−0.618	1			
CLF	−0.532	−0.385	0.546	1		
EXR	0.400	0.283	−0.378	−0.211	1	
INFL	0.677	0.154	−0.188	−0.129	0.534	1

Source: authors' concept.

In summary, the economic growth of Sub-Saharan Africa is positively correlated with both agricultural finance (AGF) and climate finance (CLF), with strong and moderate relationships, respectively, as well as the exchange rate (EXR) and inflation rate (INFL), with moderate and strong positive relationships, respectively.

4.1. Testing for Stationarity

To determine if the model variables are integrated at I(0) or I(1) and to check for unit root issues, this study employed unit root tests based on established econometric procedures [29]. Table 4 summarises and present the results of unit root testing for various variables, indicating the integration ordering. The tests used were LLC [90], IPS [91], Fisher-ADF, and Fisher-PP [92], with *p*-values in parentheses and significance levels indicated by asterisks. The decision criterion in this test is to reject the null hypothesis if the probability value is less than 0.05 and accept the alternative, with the null hypothesis being "unit root" and the alternative being "no unit root". Consequently, the results displayed in Table 4 show that RGDP, CO_2, EXR, and INFL have an integration of order one (I(1)), which means they are non-stationary in their initial values but become stationary after taking the first differences. AGF and CLF, on the other hand, have an integrated order of zero

(I(0)), suggesting that they remain stationary at their original values. Understanding these integration orders is critical for accurate econometric modelling and analysis, especially when working with cointegration and dynamic modelling.

Table 4. Results of unit root tests.

Var	LLC	IPS	Fisher-ADF	Fisher-PP	Order of Integration	
					Level	First Diff.
RGDP	−5.529 *** (0.000)	−6.370 *** (0.000)	218.2 *** (0.000)	421.4 *** (0.000)	–	I(1)
CO_2	7.063 *** (0.000)	−4.574 *** (0.000)	276.0 *** (0.000)	518.9 *** (0.000)	–	I(1)
AGF	−5.050 *** (0.000)	−8.267 *** (0.000)	294.8 *** (0.000)	294.3 *** (0.000)	I(0)	–
CLF	−4.368 *** (0.000)	−3.875 *** (0.000)	178.2 *** (0.000)	177.3 *** (0.000)	I(0)	–
EXR	−25.44 *** (0.000)	−23.57 *** (0.000)	673.7 *** (0.000)	877.0 *** (0.000)	–	I(1)
INFL	5.914 *** (0.000)	−2.859 *** (0.002)	218.0 *** (0.000)	216.2 *** (0.000)	–	I(1)

Source: authors' concept. ***, represent the 1% levels of significance, respectively. (.) represents the probability value.

4.2. Testing for Cointegration

Subsequently, we conducted cointegration tests on the model to determine whether environmental degradation, agro-climate finance, and economic growth in Sub-Saharan Africa cointegrate or not. For this investigation, Ref. [86]'s cointegration test was employed, and as a robustness check, Ref. [74]'s cointegration test was added. The panel v-statistic, panel rho-statistic, panel pp-statistic, and panel ADF-statistic under "within dimension" and the group rho-statistic, group pp-statistic, and group ADF-statistic under "between dimension" are among the seven (7) cointegration tests that [86] proposed. The test includes cointegration as the alternative hypothesis and no cointegration as the null hypothesis. It also includes a decision rule that states that the null hypothesis should be rejected if the probability value is less than 0.05. However, we present the results of the cointegration tests in Table 5 below. Based on the statistical significance of five out of seven Pedroni cointegration tests, the null hypothesis "no cointegration" should be rejected. This led us to the conclusion that in Sub-Saharan Africa, environmental degradation, agro-climate funding, and economic expansion are cointegrated. Nonetheless, Ref. [74] was used as a robustness check, and the outcome verified that environmental degradation, agro-climate funding, and economic growth in Sub-Saharan Africa are cointegrated.

Table 5. Summary of the cointegration results.

	Within Dimension				Between Dimension			Kao Test (Robustness Check)
	Panel V-Statistic	Panel Rho-Statistic	Panel PP-Statistic	Panel PP-Statistic	Group Rho-Statistic	Group PP-Statistic	Group ADF-Statistic	ADF-Statistic
Model 1	−4.606 *** (0.000)	5.012 *** (0.000)	2.476 (0.993)	6.764 *** (0.000)	8.112 *** (0.000)	3.284 (0.999)	8.879 *** (0.000)	2.466 *** (0.006)
Model 2	−3.037 *** (0.000)	2.862 ** (0.033)	−1.819 ** (0.023)	4.255 *** (0.001)	5.822 *** (0.000)	2.084 *** (0.002)	2.791 *** (0.000)	3.661 (0.000)

Source: computed. ***, and **, represent the 1%, and 5%, levels of significance. (.) represents the probability value.

4.3. Estimation of the Baseline Model—System GMM Analysis

This study investigates the connection between environmental degradation, agro-climate funding, and economic growth in Sub-Saharan Africa. To test the proposed hypotheses, the system generalized method of moments (GMM) was employed as the primary analytical method, with dynamic OLS (DOLS) and fully modified OLS (FMOLS) used as robustness checks. The choice of system GMM, DOLS, and FMOLS over alternatives such as the two-stage least squares (2SLS) and fixed effects models was based on their ability to solve endogeneity problems and cross-sectional dependence issues. Specifically, including lags in the DOLS model helps mitigate endogeneity issues across time. To ensure the reliability of the GMM results and to achieve consistent and efficient estimates, suitable instrumental variables were employed. Both GMM and FMOLS were estimated with robust standard errors to address cross-sectional dependence, enhancing the robustness and accuracy of the results for policy forecasting.

Additional pre- and post-estimation tests were conducted, including serial correlation tests for first-order (AR1) and second-order (AR2) effects, the Ramsey RESET test for specification errors, the White heteroscedasticity test for detecting non-constant variance in the error terms, and the Breusch–Godfrey serial correlation LM test to identify serial correlation in the residuals of the DOLS and FMOLS models. The results indicated that the errors are homoscedastic, serially uncorrelated, and normally distributed, as detailed in Table 7, confirming that the models are well specified.

Table 6 presents the dynamic system GMM findings on the relationship between environmental degradation, agro-climate financing, and economic growth in Sub-Saharan Africa. The positive and significant coefficients for lagged RGDP in both models, with values of 22.04 and 22.26 in Model 1 and Model 2, respectively, indicate a strong connection between previous economic growth and current economic performance. In Model 1, CO_2 emissions have a significant negative coefficient of −3.165 (p-value < 0.001), indicating a link between increasing emissions and decreased economic growth. This observation leads to the rejection of the null hypothesis (H_{Oa}), implying that environmental deterioration has a considerable influence on economic growth in Sub-Saharan Africa. The region's reliance on natural resources, such as mining, agriculture, and fossil fuels, is demonstrated in an adverse relationship between CO_2 emissions and growth, which has serious consequences. The study [93] underscores the intricate connections between economics and the environment in places with varying climates, such as SSA.

Table 6. Estimated GMM results.

Variable	Model 1	Model 2
	Sys. GMM	**Sys. GMM**
RGDP (−1)	22.04 *** (0.000)	22.26 *** (0.000)
CO_2	−3.165 *** (0.000)	-
AGF	0.074 *** (0.000)	-
CLF	−0.601 *** (0.000)	-
EXR	0.093 *** (0.000)	0.054 *** (0.000)
INFL	−0.058 *** (0.000)	−0.078 *** (0.000)

Table 6. *Cont.*

Variable	Model 1	Model 2
	Sys. GMM	**Sys. GMM**
CO_2*AGF	-	−0.106 *** (0.000)
AGF*CLF		0.031 *** (0.000)
No. of Obs.	1085	1085
AR1	−1.448 (0.086)	−1.854 (0.158)
AR2	1.525 (0.227)	1.669 (0.195)
Hansen	28.13 (0.464)	68.25 (0.338)

Source: authors' concept. ***, represent 1% levels of significance. (.) indicates probability values.

The assessment of H_{Ob} indicates that agricultural financing (AGF) holds a significant positive coefficient of 0.074 in Model 1, illustrating a clear link between increased AGF and economic growth in Sub-Saharan Africa. This finding underscores the vital role agricultural financing plays in advancing economic development across the region, particularly given its reliance on the agricultural sector. AGF supports greater agricultural productivity, which in turn stimulates overall economic growth. Improved access to agricultural finance enables investments in modern equipment, technology, and sustainable agricultural methods, resulting in higher crop yields, enhanced food security, and reduced poverty levels. Research conducted by [70], along with [71], revealed that agricultural funding contributes significantly to both short- and long-term economic growth. Consequently, agricultural financing is recognised as a pivotal factor for promoting sustainable development in Sub-Saharan Africa. Therefore, agricultural financing significantly impacts economic growth in Sub-Saharan Africa and as such, the null hypothesis is rejected.

Similarly, the evaluation of H_{Oc} demonstrates that climate finance (CLF) has a significant negative coefficient, suggesting that an increase in CLF is linked to a decrease in economic growth in Sub-Saharan Africa (SSA). This negative association is significant for SSA's growth, particularly given its vulnerability to climate change, and may be due to the region's socioeconomic conditions and inefficiencies in how resources are allocated. While CLF plays an important role in reducing carbon emissions, enhancing climate resilience, and supporting sustainability, the current levels of financing may not provide immediate economic benefits. This could be because of initial costs related to climate adaptation and mitigation efforts, especially in SSA, with weak infrastructure and limited institutional capacity. The shift in resources towards long-term environmental objectives might cause a temporary economic slowdown instead of stimulating short-term growth. Previous studies such as [13,14] have shown that climate finance can negatively impact economic growth in the short term due to these upfront expenses, particularly in regions like SSA that lack adequate infrastructure and institutional support. Thus, given the above, we reject the null hypothesis, which assumes that climate finance has no significant impact on the economic growth of SSA.

The study investigates the interaction among CO_2 emissions and AGF on the economic growth in SSA. Model 2 reveals a statistically significant interaction between CO_2 emissions and AGF (coefficient = −0.106, p-value < 0.001). This illustrates the connection in which growing CO_2 emissions reduces the positive effects of AGF on economic growth, resulting in the rejection of H_{Od} for the SSA region [see Table 6]. The negative coefficient indicates

that rising carbon emissions lower AGF's beneficial influence on economic growth. This is consistent with the idea that agriculture, a critical industry in many SSA economies, is extremely vulnerable to environmental changes, particularly those driven by emissions and climatic variability. In areas where agriculture relies on climate-sensitive methods, such as rain-fed farming, increased emissions worsen climate-related challenges such as droughts, floods, and altering weather patterns, lowering agricultural production. A previous study has shown that environmental deterioration, worsened by CO_2 emissions, might reduce the efficacy of agricultural investments. Furthermore, the problems provided by rising emissions make it more difficult for AGF to foster long-term agricultural expansion, as seen by the negative interaction observed in SSA. This finding is consistent with [36], which demonstrates how environmental deterioration, aggravated by carbon emissions, might impair the efficacy of investments fostering agricultural development. Similarly, Ref. [93] believes that environmental issues, such as growing CO_2 emissions, exacerbate the vulnerability of agriculture-dependent economies, making agricultural finance less effective in driving long-term economic growth.

The analysis identifies a significant and positive interaction between agricultural financing (AGF) and climate finance (CLF), with a coefficient of 0.031 in Model 2, demonstrating that their combined effect boosts economic growth in Sub-Saharan Africa (SSA). This finding suggests that when climate finance is effectively integrated with agricultural funding, it amplifies the growth potential of the agriculture sector, a critical driver of economic progress in SSA. Climate finance, aimed at supporting climate adaptation and reducing emissions, enhances the efficiency and productivity of agricultural investments. Given the region's vulnerability to climate-related issues such as droughts, floods, and unpredictable weather, climate finance mitigates these challenges, safeguarding agricultural output. By investing in infrastructure, technology, and sustainable practises to strengthen climate resilience, climate finance complements agricultural funding, leading to enhanced economic performance. Studies [7,93] corroborate this, showing that investments in climate resilience and green technologies can counteract the harmful effects of climate change on agriculture and boost sectoral growth. Thus, the evidence affirms that the interaction between AGF and CLF plays a crucial role in driving economic growth in SSA, resulting in the rejection of H_{Oe}.

The significant and positive exchange rate coefficients (0.093 in Model 1 and 0.054 in Model 2, both with p-values < 0.001) show that an appreciating exchange rate leads to economic growth in Sub-Saharan Africa (SSA). A stronger currency boosts buying power, decreases import prices, and helps keep inflation under check. In SSA, where economies rely largely on imports for consumer products and industrial inputs, a stronger exchange rate lowers import costs, hence promoting industrial growth and development. Furthermore, an appreciating exchange rate might indicate economic stability, attracting international investment and boosting growth. However, for export-driven industries like agriculture and industry, a higher exchange rate may diminish global competitiveness. This might pose difficulties by raising export prices in foreign markets. The study [92] argues that stable and appreciating exchange rates can boost GDP, particularly in economies that rely on capital imports. Similarly, Ref. [94]'s research on inflation in Pakistan's economy suggests that stability boosts investor confidence, encourages foreign direct investment (FDI), and contributes to overall economic growth.

The negative coefficients of inflation (−0.058 in Model 1 and −0.078 in Model 2, both with p-values < 0.001) indicate that rising inflation has a detrimental impact on economic growth in Sub-Saharan Africa (SSA). Inflation reduces buying power, creates uncertainty, and discourages investment. In SSA, where poverty is prevalent and economic uncertainty is rampant, inflation disproportionately affects vulnerable populations by

lowering real earnings and limiting access to critical goods and services. Furthermore, excessive inflation raises borrowing rates, restricts credit availability, and discourages investment in productive areas, eventually slowing economic development. Studies [95,96] argue that inflation stifles economic progress by distorting pricing signals, lowering savings, and impeding effective resource allocation. In SSA, where inflation is usually caused by supply-side shocks and currency rate volatility, managing inflation is critical to establishing a stable macroeconomic environment conducive to long-term growth.

The *p*-values for AR1 in Model 1 and Model 2 are 0.186 and 0.258, respectively, demonstrating no significant first-order autocorrelation in residuals. Similarly, AR2 *p*-values of 0.227 in Model 1 and 0.195 in Model 2 indicate that second-order autocorrelation is not a concern in either model. Also, in Model 1, we observed that the Hansen J statistic, 28.13 with a *p*-value of 0.464, is significantly higher than the standard significance level of 0.05, demonstrating that the instruments utilised are valid and do not present any issues; in Model 2, the Hansen J statistic is 68.25 and the *p*-value is 0.338, showing that the model's instruments are valid. According to the R-squared values, the explanatory variables account for between 84% and 67% of the variation in economic growth in Sub-Saharan Africa.

4.4. Estimation of the Robustness Check Model—FMOLS and DOL Analysis

In this section, results from dynamic GMM were cross validated with robust methods like DOLS and FMOL, since they significantly improve the credibility of the findings. Dynamic system GMM is most useful for examining short-term dynamics in panel data, handling issues like endogeneity with lagged variables. In contrast, DOLS and FMOLS are more suitable for analysing long-term relationships, particularly when variables are cointegrated. Therefore, comparing the long-term coefficients from DOLS and FMOLS with those from dynamic GMM, we can evaluate the consistency of results over various time frames, offering a clearer view of both short- and long-term effects on economic growth. Thus, consistent findings across these methods enhance the reliability of the results, validating the identified relationships and boosting the credibility of policy recommendations.

The results of the robustness check on the impact of past economic growth revealed that the significant positive coefficient of 22.26 (*p*-value = 0.000) from the FMOLS model aligns with the dynamic GMM result of 22.04 (*p*-value = 0.000), emphasising the strong influence of past economic growth on current performance (see Table 7). This is confirmed by empirical research that shows the persistence of economic growth, implying that previous economic success has a major impact on present growth patterns [10,34]. These results corroborate the notion that while FMOLS offers insightful long-term information, dynamic models such as GMM are good at capturing the immediate consequences of past growth. The results of the FMOLS indicate that there is no association between economic growth (RGDP) and CO_2 emissions. The system GMM demonstrates a significant negative coefficient of −3.165 (*p*-value = 0.000), whereas DOLS displays a positive coefficient of 0.0006 (*p*-value = 0.000). Thus, this illustrates the intricate connection between economic expansion and environmental degradation. Due to their detrimental impacts on productivity and environmental quality, excessive CO_2 emissions are often shown to inhibit economic growth; these findings are corroborated by studies conducted in [7,10]. This underscores how important it is to have robust environmental policies in order to address these issues and support sustained economic growth.

Furthermore, the FMOLS evidence indicates a significant association of 0.0058 (*p*-value = 0.000) between agricultural finance and economic growth, indicating a positive long-term impact of agricultural financing on growth. On the other hand, DOLS shows variability over time with a non-significant coefficient of 0.0009 (*p*-value = 0.331). The FMOLS results are supported by the system GMM's significant positive coefficient of

0.074 (p-value = 0.000), which indicates that agricultural financing has a positive impact on economic growth. This finding is in line with research in [24,68,71,72]. These results emphasise how crucial it is to fund agricultural development in order to boost sub-Saharan Africa's economic expansion. A substantial positive coefficient of 0.0086 (p-value = 0.000) is reported by DOLS; however, an insignificant coefficient of 0.0007 (p-value = 0.202) is found in the FMOLS evidence regarding climate finance (CLF) and economic growth (RGDP). The short-term negative effect is reflected by the system GMM's negative coefficient of −0.601 (p-value = 0.000). Research findings from studies like [18,71,72,93] indicate that although climate financing may have positive long-term effects, initial implementation difficulties may have a negative short-term impact. This contradictory evidence suggests that tactics that optimise potential benefits while minimising short-term drawbacks are necessary.

Table 7. Estimated FMOLS and DOLS results.

Variable	Model 1		Model 2	
	FMOLS	**DOLS**	**FMOLS**	**DOLS**
RGDP (−1)	−0.015 *** (0.000)	−0.067 *** (0.000)	0.469 *** (0.000)	0.243 *** (0.000)
CO_2	−0.0003 ** (0.024)	0.0006 *** (0.000)	-	-
AGF	0.0058 *** (0.000)	0.0009 (0.331)	-	-
CLF	0.0007 (0.202)	0.0086 *** (0.000)	-	-
EXR	−0.0002 (0.629)	0.3 (0.534)	0.0004 *** (0.000)	0.0006 *** (0.000)
INFL	−2.429 *** (0.000)	−0.266 *** (0.002)	4.426 (0.600)	4.976 (0.578)
CO_2*AGF			1.979 *** (0.001)	−1.301 *** (0.000)
AGF*CLF			0.036 *** (0.000)	0.177 ** (0.016)
No. of Obs.	1195	1200	1085	1145
R^2	0.786	0.615	0.648	0.843
χ^2 Normal	36.82 (0.201)	25.61 (0.224)	70.86 (2.113)	14.85 (0.198)
χ^2 Serial	7.052 (0.948)	30.23 (0.000)	36.82 (0.237)	19.31 (0.347)
Reset	−3.030 (0.000)	10.05 (0.948)	9.052 (0.948)	−3.812 (0.202)
χ^2 *ARCH*	2.534 (0.673)	−6.435 (0.188)	−0.030 (0.261)	4.777 (0.389)

Source: Authors' Concept. (.) = probability values, ***, and **, represent the 1%, and 5%, levels of significance.

A negative coefficient of −0.106 (p-value = 0.000) is seen in the FMOLS results of the interaction between CO_2 and agricultural finance, indicating that CO_2 emissions lessen the positive effect of agricultural financing on growth. In contrast, DOLS reveals different dynamics with a positive coefficient of 1.979 (p-value = 0.001). The disparity emphasises how crucial it is to take contextual elements into account since, as previously indicated in [42,47], environmental and agricultural policies may interact in complicated ways. If sub-Saharan African policymakers are to effectively handle these interconnections, they should do so with a comprehensive strategy. Additional analysis of the combined impacts

of climate and agricultural financing from an FMOLS perspective reveals a coefficient of 0.031 (p-value = 0.000), whilst a DOLS coefficient of 0.177 (p-value = 0.016) indicates that the two variables work together to boost economic growth. This validates the efficacy of integrated finance solutions as previously mentioned in [46,59,67] and is consistent with the system GMM results. These results demonstrate the potential benefits of combining climate and agriculture funding to support sub-Saharan economic growth in SSA. Exchange rates, on the other hand, show a significant association with growth, as indicated by the FMOLS coefficient of 0.054 (p-value = 0.000) and the DOLS result of 0.0006 (p-value = 0.000). Similar to the GMM results showing that high inflation has an adverse impact on growth, the FMOLS result for inflation rates reveals a coefficient of −0.078 (p-value = 0.000). These findings underscore how crucial stable exchange rates and reined-in inflation are to fostering economic expansion, as earlier emphasised by the study in [52].

The comparison shows that the FMOLS and DOLS models provide insightful information on long-term relationships, whereas the system GMM model captures short-term impacts. Reliability in these results is increased when variables like RGDP, EXR, and AGF are consistent across models. Nevertheless, different outcomes for CO_2, CLF, and interaction terms underline the need to use a variety of approaches in order to fully understand the breadth of economic interactions. Strong policy suggestions are reinforced by robustness assessments, which confirm the findings, especially in areas that need extensive long-term planning.

This study therefore underlines how crucial it is to apply a variety of approaches in order to fully represent the range of economic processes present in SSA. Credibility in these conclusions is increased by the substantial findings for RGDP, EXR, and AGF, but it is made clear that context-specific and sophisticated policy interventions are required by the inconsistent results for CO_2, CLF, and interaction terms. Long-term thorough planning is necessary to handle the many problems that SSA faces and to promote sustained economic growth.

5. Discussion of Findings

The evidence revealed a significant negative association between CO_2 emissions and economic growth, suggesting that increased carbon emissions are associated with decreased economic growth. The negative impact of CO_2 emissions on growth suggests that extreme weather events, droughts, and floods—as well as other climate-related problems—pose serious threats to economic growth and stability. These environmental problems can reduce the region's agricultural output, harm its infrastructure, and increase expenses and losses across a number of industries. In order to reduce emissions and improve resilience against the consequences of climate change, broad policy changes are needed, such as prioritising investments in sustainable practises and green technology. Consequently, a number of studies including [21,45,97] shows the intricate link between economic growth and CO_2 emissions in Sub-Saharan Africa. The study also showed that industrial activities exacerbate environmental degradation, which hinders long term economic growth. The study further argued that while industrialisation offers immediate benefits, it also harms the environment and eventually halts long-term growth. To address this problem, numerous studies have called for governments in both advanced and emerging economies to invest in green technology, enforce stricter environmental regulations, and adopt sustainable economic practises [7,32,34,86]. According to empirical research, effectively managing the environmental consequences of economic expansion is critical to avoiding further stagnation and promoting sustainable development [20,23,98].

Additionally, we found a significant connection between finance for agriculture and economic growth. This suggests that Sub-Saharan Africa experiences economic growth as

a result of increased AGF. This information suggests that the adoption of contemporary inputs, technology, and sustainable practises is supported by greater finance for agriculture. Therefore, this may result in increased productivity, better food security, and crop yields—all of which are critical for promoting economic growth in parts of the region where agriculture plays a significant role in the regional economy. By encouraging investments in the sector, agricultural financing may assist farmers in making the switch from subsistence to commercial farming, which can result in improved resource management, more sustainable farming techniques, higher earnings, and the creation of jobs. Similar to our findings, Refs. [9,19,66] maintained that agricultural financing increases production and economic growth cetris paribus. Also, Ref. [68] showed AGF is a vital component of long-term development since agricultural finance promotes both short- and long-term growth. However, despite benefits, challenges in SSA persist. As such, smallholder farmers have difficulty obtaining loans due to factors such excessive interest rates, insufficient collateral, and inefficient bureaucracy, as noted by [54,59,65,73]. To increase financing opportunities, legislative measures addressing these obstacles are important. Improving AGF is essential for realising the agricultural potential of SSA, promoting economic diversification, and bolstering general growth. This aligns with previous research [64] on the significance of agro-finance for economic growth in areas where agriculture is the primary industry.

In Sub-Saharan Africa (SSA), climate financing is found to be significantly negatively connected with economic growth. This inverse link emphasises important development implications for the SSA, especially considering how vulnerable it is to the effects of climate change. Reducing carbon emissions, boosting climate resilience, and promoting sustainability in the region critically depend on climate finance policies like the issuance of green bonds, spending on environmental protection, and the carbon footprint of bank loans. The inverse relationship, however, raises the possibility that present levels of climate funding are not instantly stimulating economic growth. This can be brought on by the socioeconomic difficulties in the region and ineffective funding distribution. However, empirical evidence suggests that the initial costs of climate adaptation and mitigation projects, particularly in places with weak institutional capacity and infrastructure, can immediately impede economic growth [21,32,97]. Prioritising long-term environmentally friendly objectives in Sub-Saharan Africa, such as climate-resilient infrastructure and energy efficiency, may ultimately take funds away from initiatives that promote economic growth. Thus, inefficient resource utilisation and poor governance can hinder economic benefits due to inadequate climate financing and its impact on the environment. Despite the fact that climate financing is essential for sustainable development, this study indicates that it could not have an immediate positive economic impact, particularly in the SSA region, especially when the financial systems in the region are weak. Therefore, a well-rounded strategy is required, in which SSA enhances its financial and governance frameworks to guarantee that climate financing successfully advances both environmental and economic goals.

A coefficient of -0.106 indicates that there is a negative relationship between CO_2 emissions and agricultural finance (AGF) with respect to the impact of AGF on economic growth in Sub-Saharan Africa (SSA). The adverse association suggests that while AGF may increase economic growth, its influence declines with rising carbon emissions. This demonstrates how vulnerable SSA's agriculture is to climate change, since growing emissions aggravate natural disasters such as floods and droughts. The benefits of AGF investments are diminished, and agricultural productivity is undermined by environmental issues. This finding is supported by research in [43,53,64], which demonstrate that agricultural investments are less effective due to environmental deterioration caused by CO_2 emissions.

On the other hand, the positive interaction between climate finance (CLF) and agricultural finance (AGF), with a coefficient of 0.031 in Model 2, suggests that combining these

two forms of funding may accelerate economic growth in SSA. Hence, SSA's economic growth is significantly impacted by the beneficial connection between climate financing (CLF) and agricultural financing (AGF). This implies that agricultural financing has the potential to improve rural development, modernise farming methods, and increase productivity. When AGF and CLF work effectively together, they can help to increase economic growth. Also, climatic finance may boost agricultural investments in the region by improving infrastructure, increasing resilience to climatic shocks, and facilitating the adoption of green technologies. Studies has shown that the interaction of climate finance with agricultural financing enhances the efficacy and efficiency of agricultural investments [93]. Climate financing also enables climate-smart farming methods that minimise environmental harm and maximise resource efficiency. This improves the climate for economic expansion, especially in an area like SSA, where the primary industry is agriculture [36]. According to these studies, there is a positive feedback loop between climate financing and agricultural investments that improves resilience to climate-related shocks and spurs on development and productivity. Therefore, via reducing the effects of climate change and advancing sustainable behaviours, climate finance supports agricultural development. Sub-Saharan Africa should, however, adopt an extensive strategy based on the reported findings, which combines climate adaptation strategies that can promote green technologies with agricultural support. Additionally, improvements to infrastructure can enhance climate-smart agriculture and stimulate sustainable economic growth.

The significant relationship between inflation (INFL), exchange rates (EXR), and economic growth in Sub-Saharan Africa emphasises the need for efficient exchange rate management and resolving the region's high inflation rates. A stronger currency increases buying power, lowers import prices, and reduces inflationary pressures, which all promote economic growth. This positive association between exchange rates and growth is particularly important for SSA nations, since many economies rely substantially on imports of consumer and industrial products. However, while a stronger currency might boost economic growth, it can also reduce export competitiveness, particularly in the industrial and agricultural sectors. On the other hand, the inverse relationship between inflation and economic expansion indicates that increased inflation impedes expansion. Inflation negatively affects disadvantaged communities and restricts economic progress by decreasing buying power, raising economic uncertainty, and discouraging investment. These findings are supported by empirical research such as [95,96], which show the benefits of stable exchange rates and the negative impacts of excessive inflation on economic performance. In order to create an atmosphere that is favourable for both economic growth and stability, policymakers in sub-Saharan Africa should concentrate on preserving exchange rate stability and containing inflation through sensible monetary and fiscal measures.

6. Conclusion and Policy Recommendations

The study identifies a number of critical variables influencing Sub-Saharan Africa's (SSA) economic growth. The significant negative relationship between CO_2 emissions and economic growth is a noteworthy discovery that underlines the detrimental effects of environmental deterioration on financial stability. Drastic climate-related events like droughts and floods are made worse by rising carbon emissions, which are mostly caused by industrial activity. These events reduce agricultural productivity, deteriorate infrastructure, and raise economic risks. Numerous scholars, such as the authors of [34,36], have pointed out that while industrialisation has short-term advantages, sustainable development is hampered by its long-term environmental consequences.

Agricultural financing, on the other hand, has a positive connection with economic growth, demonstrating its critical role in promoting agricultural output and guaranteeing

food security. However, the positive relationship implies that AGF encourages more sustainable agricultural practises, better resource management, and job creation by easing the transition from subsistence to commercial farming, as argued by [64]. However, in order to fully exploit the potential of agricultural financing, legal changes are required to address issues like bureaucratic blockages and small-scale farmers' restricted access to loans [24,68]. Climate financing (CLF) has promised to mitigate environmental risks and advance sustainable development, although CLF's immediate link with economic development appears to be negative. This is presumably due to climate adaptation and mitigation. This is probably because climate adaptation and mitigation have large upfront costs, which are made worse by an inefficient finance distribution and inadequate governance. However, by promoting climate-resilient agricultural practises and enhancing resistance to environmental shocks, climate financing, when combined with agricultural finance, may greatly boost GDP.

The analysis further demonstrates how crucial inflation management and stable currency rates are to fostering economic growth. Increased buying power and lower inflation are two factors that promote growth in exchange rates; nevertheless, unrestrained inflation deters investment and threatens economic stability. These findings suggest that in order to lower CO_2 emissions, SSA governments should prioritise green technology investments and implement sustainable economic strategies. In order to reduce carbon emissions and increase resistance to the effects of climate change, it is imperative that stronger environmental rules be enforced and that renewable energy, sustainable agriculture, and environmentally friendly infrastructure development be encouraged. Policymakers must ensure increased access to agricultural financing, particularly for smallholder farmers, in order to fully realise the region's agricultural potential.

Addressing concerns such as high borrowing rates and cumbersome administrative procedures is critical to promoting commercial farming, supporting environmentally friendly procedures, and boosting economic diversification. Strengthening the regulatory and financial infrastructure is also required to guarantee that climate financing is successfully used. Transparent money distribution, as well as transparency systems, will assist to maximise climate finance's impact on ecologically friendly practises and economic growth. Incorporating climate financing into agricultural investments may encourage climate-smart agriculture while also contributing to long-term growth. Finally, SSA authorities should implement good fiscal and monetary policies to keep exchange rates stable and inflation under control. By applying these methods, the SSA region may better manage its economic issues, encourage long-term growth, and boost economic resilience.

Although the study gives significant policy recommendations and fascinating insights into the link between the factors, it is not without limits. First, the precision of the study may have been impaired by the availability of data and quality, specifically by the inconsistencies in time series data across Sub-Saharan Africa (SSA). Particularly, data on climate funding may not have been documented uniformly in all nations, which might introduce bias. Furthermore, the results, which rely on combined data, could not be entirely applicable to specific nations because of the wide range of environmental and economic circumstances found in Sub-Saharan Africa. Finally, the lack of inclusion of other significant socioeconomic variables in the research, such as income inequality or the fight against poverty, restricts our ability to comprehend the region's overall development outcomes.

Given the above limitations mentioned, future research should focus on detailed country-level analyses within Sub-Saharan Africa (SSA) to better understand how local factors affect the interplay between CO_2 emissions, agricultural and climate finance, and economic growth. This approach would provide insights into specific national dynamics and enable more tailored policy recommendations. Additionally, investigating the long-term impacts of financing, especially in terms of investments in green technologies and

sustainable practises, will be crucial. Expanding research to include broader development outcomes such as poverty alleviation and income equality will offer a more comprehensive understanding of how environmental and financial factors influence overall development. Furthermore, assessing the role of institutional quality and governance, along with sector-specific effects of CO_2 emissions and financing, could lead to more effective and targeted policy interventions.

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