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SUSTAINABLE AGRICULTURAL FINANCE IN DEVELOPING COUNTRIES: TRENDS, COLLABORATIONS, AND FUTURE PATHWAYS

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ABSTRACT

Sustainable Agricultural Finance (SAF) is an increasingly important area of research, especially in developing countries where agriculture is the backbone of food security, poverty alleviation and environmental sustainability. Lack of previous studies has resulted in a failure to provide sufficient guidelines on how SAF research has developed in developing countries and the thematic gaps that remain unfilled. Bibliometric techniques provided the framework for the study to explore the key questions. Data was collected from the Scopus database from 1983 to 2025. The results indicate an increase in scholarly interest in SAF through an increase in publications, citations and international collaboration as well as the integration of finance, sustainability and policy frameworks in the agricultural sectors of developing countries. Moreover, 'sustainability' emergence most important source, and South Africa has been revealed as the main contributor and collaborator. The results also reveal six types of themes: rural finance, smallholder inclusion, agroecology, patterns of environmental change, and linkages to global policies. Several pathways can be explored in future research including gender-inclusive finance, tools to gauge climate risk, and new funding transport mechanisms. The study broadens insights into overlooked areas and indicates possible future research paths, which serve as a guide to aid policymakers, researchers, and practitioners, aiming to strengthen sustainable agricultural financing throughout the Global South.

Keywords: Sustainable Agricultural Finance, Developing Countries, Rural Finance, Environmental Change, Gender-inclusive Finance, Economic development.

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INTRODUCTION

Agriculture is crucial to the economies of developing nations and ensures food security, jobs, and livelihoods of rural people (Goli *et al*., 2024). However, in agriculture, there are severe challenges such as climate change, depletion of resources, fluctuations in the market, and limited access to finances (Shehzad and Khan, 2024a). All over the globe, by means of green practices, the concept of sustainable agriculture has emerged significantly (Muhie, 2022). Sustainable agriculture contributes to economic development, poverty eradication and environmental sustainability in developing countries. Many regions of the globe can use agricultural productivity, productivity growth, and capital investments to bring forth sustainable development (Anik *et al*., 2017; Liu *et al.*, 2020). Also, in developing countries, sustainable agricultural practices can be enhanced tremendously by means of eco-enterprises and conservation agriculture (Kesavan and Swaminathan, 2007; Shahbaz *et al.*, 2023). In order to minimize hurdles in farming industry, innovative financial mechanisms, customized policies and collaborative efforts are imperative (Bhutto and Bazmi, 2007; Candemir and Karahan, 2024). The perspective emphasizes the need to adopt sustainable practices in agricultural industry (Amankwah, 2023).

Sustainable agricultural finance (SAF) can connect sustainability goals, small- and large-scale farmers, and resilient farming systems (Vlaicu *et al*., 2024). Small and medium enterprises are considered as indispensable instruments for reducing hunger and poverty in developing and under developing countries of the world (Tenaw *et al*., 2009). Sustainability commitment can reduce the negative impact of implementing sustainable agricultural practices in developing countries (Luzzini *et al*., 2015). In developing countries, rural financial development can play an important role in sustainable agricultural development through adoption of new technology (Liu *et al*., 2021).

Specifically, facilitating rural financing for sustainable agriculture developments will help reduce carbon emission by large margin (Sun *et al*., 2022). Green-based technological innovation (Zhou *et al*., 2018), green finance and institutional quality (Sethi *et al*., 2024), interest-free credit (Sher *et al*., 2024), blended finance (Havemann *et al*., 2022), sustainable finance (Zhou and Du, 2021), tailored financial solutions (Liu *et al*., 2021), and total factor productivity growth (Coomes *et al*., 2019) are some of the strategies that can lead to environmental sustainability. SAF has been defined as one of the cornerstones for economic development, poverty eradication, and environmental sustainability in developing countries (Hu *et al*., 2020). Thus, SAF has been established as a pillar of economic development, poverty elimination, and environmental sustainability in developing countries. Despite its growing significance in establishing both the theoretical and practical foundations for the SAF field, it still remains fragmented. The assessment of SAF development has been very little dealt with in the past, comprising its critical issues and institutional bases, particularly for developing countries where there is the greatest requirement for innovative financing measures (Bryan et al., 2009).

Prior literature has emphasized rural credits, subsidizations and technical innovations as necessary for agricultural development and for the solution of the problem of food scarcity (Kori *et al.*, 2023). Very few writers on the subject have emphasized the adoption of innovative financial measures for the attainment of sustainable agricultural development (Branca and Perelli, 2020). There is also a discrepancy in the research methodology, as either a meta-analysis or a systematic literature review on SAF was mainly applied (Billah *et al*., 2025; Olarewaju *et al*., 2025). Some scholars, like Tamasiga *et al*. (2023), have used a mixed methods approach to identify emerging themes and research streams in the agricultural finance literature (Tamasiga *et al*., 2023). Sellami *et al*. (2025) discuss the need for financial resources and sustainable farming practices for wheat production in emerging economies. Viera *et al*. (2025) further explains the need for SAF in addressing poverty, unemployment, and food scarcity issues, as well as fostering economic growth. Most recently, Khan *et al*. (2025) discussed the theoretical and historical evolution of SAF by employing Scopus data from 1994 to 2023. But their study is less geographically bound and misses the most recent developments in literature. Additionally, the study also overlooked the recent call for analyzing the SAF status in developing and emerging economies. That is why researchers emphasize the need for bibliometric analysis in these countries to evaluate the significance of SAF.

This study aims to address gaps by employing bibliometric analysis of SAF literature on key trends, themes, key players and collaborations in research. It seeks to answer the following questions: 1) How has the amount and focus of research in SAF in developing countries changed over time? 2) Which sources, authors, institutions and countries exert the strongest influence in the area? 3) What collaboration exists in the area of SAF research between researchers and institutions in the Global South? 4) Which areas are underexplored but may indicate potential directions for future work? These objectives will highlight the financial mechanisms and institutional dynamics which are assisting the development of SAF in the Global South. In addition, it will highlight underexplored areas that will be of assistance to researchers, policy makers and practitioners.

MATERIALS AND METHODS

Data and Methodology: The research discusses the historical evolution of SAF in developing countries, highlighting core themes, funding mechanisms and gaps that tender opportunities for subsequent study and policy making. A comprehensive search strategy was used to obtain data from the Scopus database from 1 January 1983 to 17 August 2025. The search strategy was constructed in three phases according to the strategy presented by (Farooq *et al.*, 2023). First the researchers incorporated the terminology supporting SAF. The second phase the researchers included keywords favoring developing countries. In the last phase inclusion criteria were specified and limited strictly to the research question. After this stage the niche researchers included all literature related to SAF from 1983 to 2025 of which there were 1386 documents. After this, the selection is restricted by subject area (1275), document type (1053), source type (1039), stage (1021) and language (1012). The method of query for the search is defined in detail in Table 1.

The bibliometric analysis was performed with the help of VOSviewer and Biblioshiny for R. Figure 1 shows important information about the SAF research works. The final dataset consists of a total of 1012 documents, articles (931) and review papers (81) published in 476 papers (journals). The annual growth rate and the average citation show that SAF literature follows a regular tendency revealing that it is not a "passing trend" but it has become a legitimate area of research. The acceptance among scholars exhibits that the field grows stronger in time and the fundamentals of knowledge are repeatedly quoted and developed. Moreover, involving more authors and increasing worldwide collaborations show the interest of scholars in the new area of SAF in developing countries. This shows not only the cross-disciplinary significance of the discipline, but also its growing relevance for the tackling of global development challenges, especially in the global south.

Table 1: SAF Query Development Process

Stages	Queries	Results
1	TITLE-ABS-KEY(("sustainable agriculture" OR "sustainable farming" OR "climate-smart agriculture" OR "regenerative agriculture" OR agroecology OR "low-carbon agriculture") AND ("green finance" OR "sustainable finance" OR "impact investment*" OR "agricultural credit" OR "agricultural loan*" OR "agricultural microfinance" OR "rural finance" OR "development finance" OR "financial inclusion"))	60468
2	TITLE-ABS-KEY(("sustainable agriculture" OR "sustainable farming" OR "climate-smart agriculture" OR "regenerative agriculture" OR agroecology OR "low-carbon agriculture") AND ("green finance" OR "sustainable finance" OR "impact investment*" OR "agricultural credit" OR "agricultural loan*" OR "agricultural microfinance" OR "rural finance" OR "development finance" OR "financial inclusion") AND ("developing countr*" OR "emerging econom*" OR "low-income countr*" OR "Global South" OR Africa OR Asia OR "Latin America" OR "Middle East" OR "South Asia" OR "Sub-Saharan Africa" OR "Southeast Asia" OR "Pacific Island*" OR Afghanistan OR Bangladesh OR Bhutan OR India OR Maldives OR Nepal OR Pakistan OR Sri Lanka OR Angola OR Ethiopia OR Ghana OR Kenya OR Nigeria OR Rwanda OR South Africa OR Tanzania OR Uganda OR Argentina OR Bolivia OR Brazil OR Chile OR Colombia OR Ecuador OR Paraguay OR Peru OR Uruguay OR Venezuela))	1386
3	(TITLE-ABS-KEY((("sustainable agriculture" OR "sustainable farming" OR "climate-smart agriculture" OR "regenerative agriculture" OR agroecology OR "low-carbon agriculture") OR ("green finance" OR "sustainable finance" OR "impact investment*" OR "agricultural credit" OR "agricultural loan*" OR "agricultural microfinance" OR "rural finance" OR "development finance" OR "financial inclusion") AND ("developing countr*" OR "emerging econom*" OR "low-income countr*" OR "Global South" OR Africa OR Asia OR "Latin America" OR "Middle East" OR "South Asia" OR "Sub-Saharan Africa" OR "Southeast Asia" OR "Pacific Island*" OR Afghanistan OR Bangladesh OR Bhutan OR India OR Maldives OR Nepal OR Pakistan OR Sri Lanka OR Angola OR Ethiopia OR Ghana OR Kenya OR Nigeria OR Rwanda OR South Africa OR Tanzania OR Uganda OR Argentina OR Bolivia OR Brazil OR Chile OR Colombia OR Ecuador OR Paraguay OR Peru OR Uruguay OR Venezuela))) AND (LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"AGRI") OR LIMIT-TO (SUBJAREA,"ECON") OR LIMIT-TO (SUBJAREA,"BUSI") OR LIMIT-TO (SUBJAREA,"MULT")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (PUBSTAGE,"final")) AND (LIMIT-TO (LANGUAGE,"English")))	1012

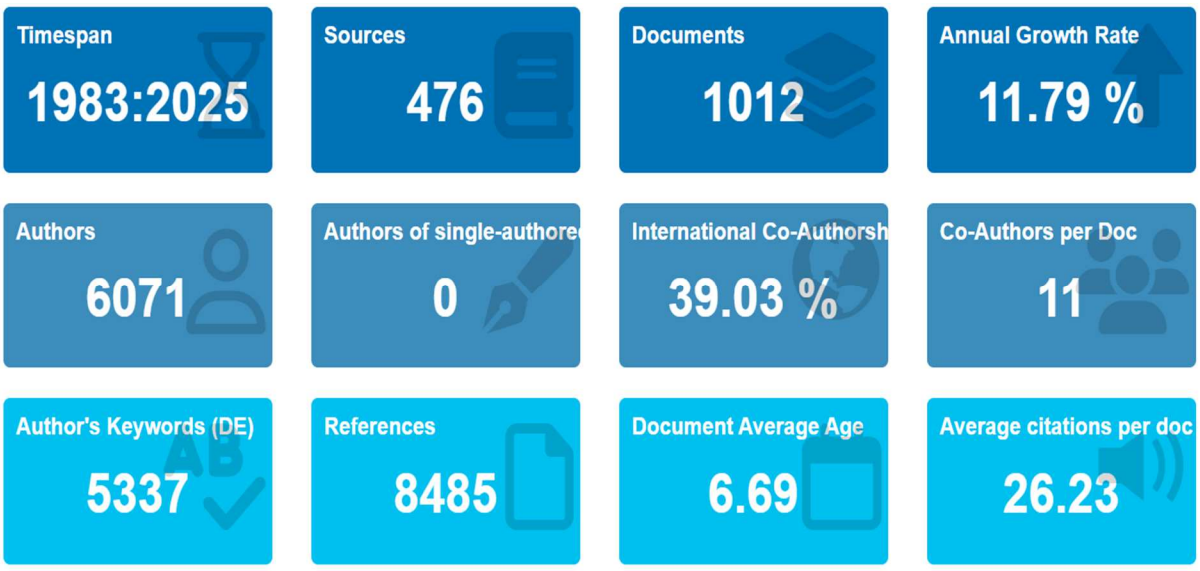

Figure 1. Key Information of SAF Research Studies

Data Analysis and Results

Evolution of Research Volume and Focus: Figure 2 illustrates the past and growing importance of sustainable agricultural finance as a research field, demonstrating that research activity was relatively static from 1983 to 2000, during the early development of sustainability ideas in agriculture and finance. Both were co-evolutionary processes of sustainability reported at the time, including the foundational principles of sustainable development and the evolving process outlined in the 1987 Brundtland Report (Ayaz and Zahid, 2024; Mavlutova *et al*., 2023). A slight increase in publications during the 2000s reflected the intensification of policy discussions on climate change and food security, catalyzed by international agreements that underpinned a multidisciplinary and interconnected concept of sustainability as it related to countries, regions, sectors, and fields such as agricultural finance. Since 2015, there has been a dramatic increase in research outputs because of the United Nations Sustainable Development Goals (SDGs), particularly: (1) zero hunger (SDG 2), and (2) climate action (SDG 13).

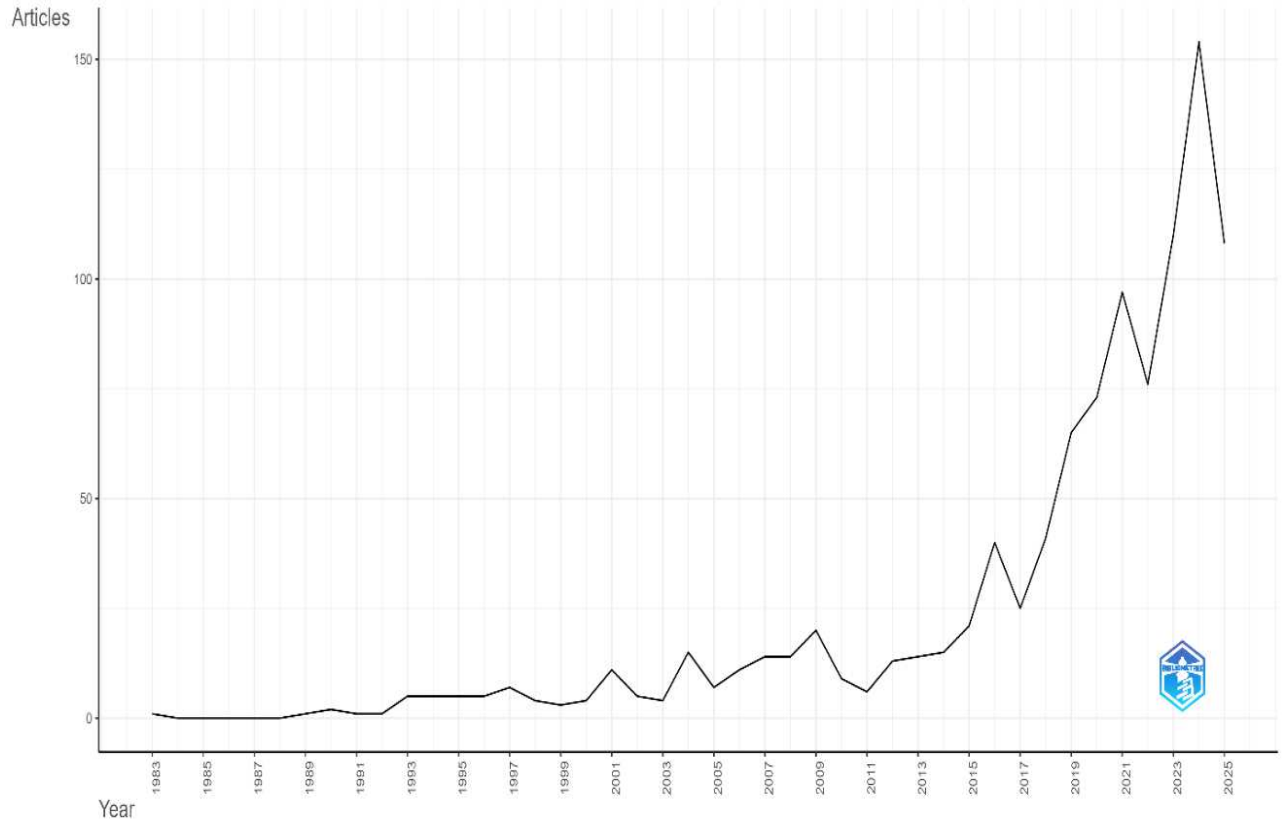

Figure 2. SAF Annual Scientific Production

The goals facilitated and provided a basis for transdisciplinary ecosystem, environmental science, and policy analysis as a framework to explore the policy discourse of financing sustainable farming practices (Grecu *et al*., 2025; Mujiani, 2023; Nasim, 2023; Pitaloka *et al*., 2024). The significant jump from 2022 to 2023 emphasizes the relevance of the field in the current era. It recognizes a number of things, such as recovering from COVID and its accompanying recovery programs, that there is an increasing emphasis on environmental, social, and governance (ESG) criteria in investment strategy, and the recent breakdown in supply chains in agriculture (163). The shift from being a niche area to an area of active research compares the financial mechanisms that support sustainable agricultural practices with farming and the environmental agenda. Bibliometric analysis was used to reveal the changing trends in research as well as articles that require further study on new challenges therein (Swarupa *et al.*, 2024). Creating data driven and data informed financial frameworks to manage agricultural needs has established sustainable agricultural finance as a dynamic and urgent research field.

Figure 3 outlines the intellectual heritage of sustainable agricultural financing by examining its references. The apparent absence of any written scholarship before the year 1980 refers to relatively recent initial texts in the field and reflects a necessity to depend on interdisciplinary concepts more than extensive

historical contexts of such disciplines as economics, agriculture or environmental sciences. A large rise in the volume of research since after 1990 can be attributed to international campaigns for environmental sustainability (the 1992 Rio Summit) and to the resulting academic debate about green finance techniques. The increased academic activity recorded after 2000 corresponds with the raising concern with climate change and is consequent on: i) the funding paradigm's 2008 financial crisis exposure for agriculture, and ii) the Paris Agreement and UN Sustainable Development Goals (SDGs) 2015. The convergence of all these factors seems to engender a self-perpetuating cycle of knowledge creation, stimulating further research, and engendering a living growing body of knowledge on sustainable agricultural finance. The variations of the figure uncovered important points in literature. The peaks of the positive were seminal papers, which played an important key role in contributing to the debate within the topic. The dips may denote transitional states with little high-impact products, therefore showing changes in the momentum of the research subject. The general trend is that sustainable agricultural finance is a relatively young research area, yet one growing rapidly with a "citation horizon" which is leaned towards recent literature, thereby indicating a rapid evolution of sustainable agricultural finance.

Table 2 provides an analysis of keywords within four headings, namely: i) Keyword Plus. ii) Author Keywords, iii) Title and iv) Abstract, indicating the use of specific wording in those studies. In the Keyword Plus, "South Africa" has the highest usage with 179 occurrences and this indicates a regional trend. This is followed by "Agroecology" (153) and "Climate Change" (140). Here, the inter-connection between ecological processes and environmental practices are emphasized. In the Author Keywords "Sub-Saharan Africa" has the largest usage (123), followed by "Sustainable Agriculture" and "Food Security" (142). This reflects a trend towards regionalization, sustainability and nutritional stability. "Small=Holder" and "Alternative Agriculture" reflect the importance of small farming operations in delivering ecological activities. In the title and abstract category there are high frequencies of "Farmers" (1115), "Africa" (1067) and "Sustainable" (130) focusing on the roles of practitioners and the geographical focus as well as "Financial" (1055) to indicate economic factors, "Climate" (107) referring to environmental connections, and "Development" (90) together with "Practices" (90) to indicate activities, with a view towards their practical outputs. Overall, these keywords show that the essential integration of financial mechanisms with agricultural and sustainable aims in this field includes ecological, economic and social factors that can help in the development of policies and practices to deal with the global issues in agricultural resilience and resource management.

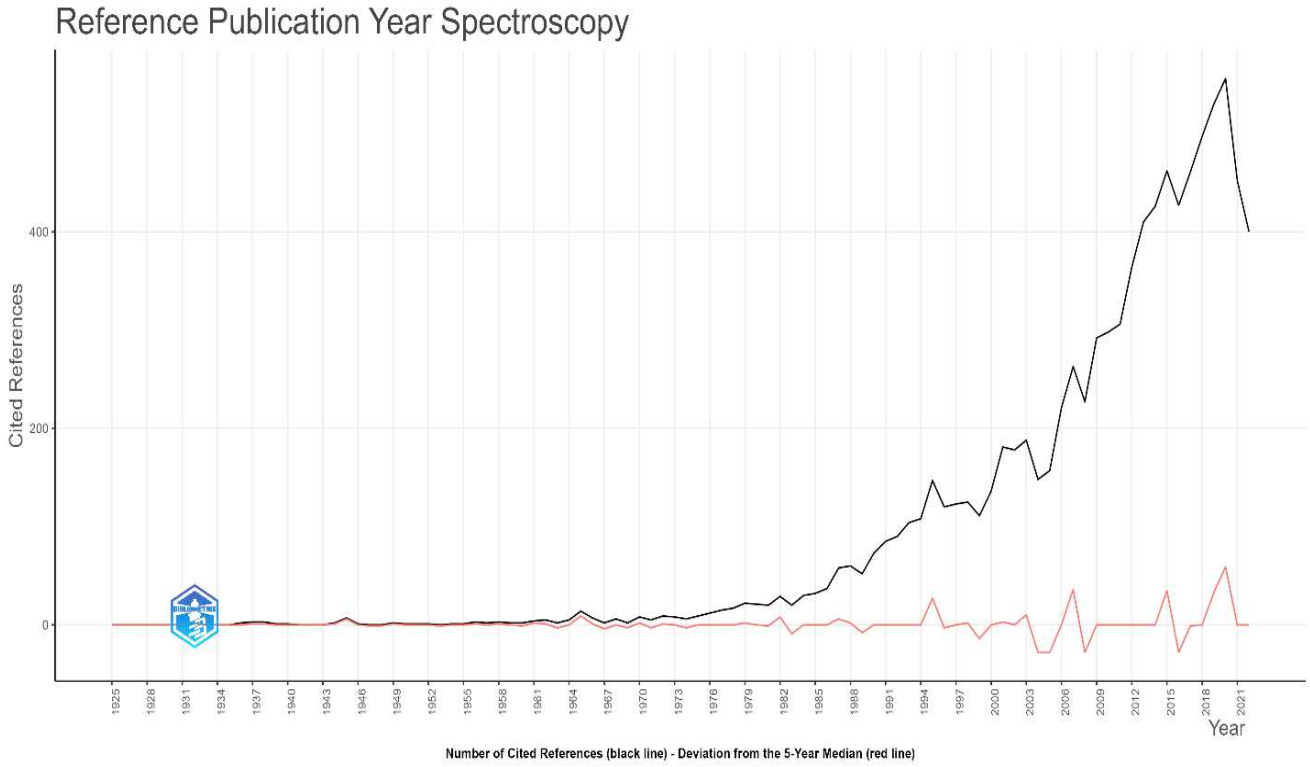

Figure 3. SAF Reference Publication Year Spectroscopy

Table 2: Keywords Analysis

Keyword Plus		Author Keyword	
Words	**Occurrences**	**Words**	**Occurrences**
South Africa	179	South Africa	229
Agroecology	153	Climate Change	216
Climate Change	140	Agroecology	208
Sub-Saharan Africa	123	Sub-Saharan Africa	188
Africa	115	Sustainable Agriculture	184
Agriculture	102	Africa	181
Alternative Agriculture	90	Food Security	142
Sustainable Development	89	Agriculture	139
Smallholder	86	Sustainable Development	117
Kenya	83	Ghana	116
Title		**Abstract**	
Words	**Occurrences**	**Words**	**Occurrences**
Africa	352	Farmers	1115
South	238	Africa	1067
Agriculture	146	Financial	1055
Financial	134	Rights	1051
Sustainable	130	Reserved	1035
Agricultural	118	Food	797
Climate	107	Agricultural	783
Farmers	94	Agriculture	758
Development	90	Practices	750
Ghana	83	Climate	749

Influential Sources, Authors, Countries, and Institutions: Table 3 investigates the changing trends in agricultural sustainability finance by assessing the output of the major journals while looking at citation frequencies, theme emphasis and important articles that have been published since the early 1990s. Research based on some 1500 citations from a variety of sources suggests a growing convergence of financial mechanisms with the objectives of ecological and social sustainability in agriculture. A major journal, namely the Sustainability Journal (Switzerland), with high citation frequency since 2010, was concerned with new models of finance which combined ecological protection with economic sustainability for farmers. Policies and financial instruments have been developed in World Development which could lead to greater food security, poverty alleviation, economic growth, and environmental conservation (Reardon and Vosti, 1995; Zemba *et al*., 2025). Frontiers in Sustainable Food Systems, on the other hand, provided comprehensive frameworks that can be used to tackle food system inequalities and result in resilience (Even *et al*., 2024).

The journals, such as Science of the Total Environment, and Agricultural Systems have initiated discussion of mitigating agriculture's environmental impacts through adaptive systems and innovative tools (Coderoni and Esposti, 2018). Whereas Field Crops Research and Agriculture and Ecosystems and Environment have encouraged the development of customized, place-specific models for specific crops in certain regions, while promoting resource conservation (Even *et al*., 2024). Local or regionally oriented journals, such as the South African Journal of Agricultural Extension and Development in Southern Africa, provided local insights, emphasizing extension services and locally based financing for resource-poor farmers (Hlatshwayo and Worth, 2019; Qwabe *et al*., 2022). In sum, this research reveals an emerging overlap in terms of disciplinary participation in literature, requiring intersecting approaches between policy makers, financial institutions, and society as a whole in order to address the global requirement for sustainable agriculture.

Table 4 reveals the contributions of prominent authors in building the landscape of sustainable agricultural finance. Bernard Vanlauwe (with an h-index of 8 and 441 citations from 2001) investigated sustainable methods for soil fertility and health. Likewise, Giller Ken (having an h-index of 7 and 380 citations, since 2007) advocates for sustainable intensification that promotes agricultural production without destroying the earth, and his idea of merging productivity and resource management gained significant scholarly attention. In addition, Philip Antwi-Agyei and Robert Zougmore (both h-index 6) have written on the social and economic determinants of climate adaptation as well as more recently on the role of financing in protecting agriculture from the threats of climate. Together, they argued for an inclusive system that protects vulnerable groups against

the impact of the environment. John Annandale, Andrew John Dougill, and Mark A.G. Darroch gave another take on policies and procedures. To this end, they proposed how finance models can appropriately intersect with sustainable outcomes, putting forth a strong collaboration between the government and private sector being the way to properly channel funding.

Table 3: Most Cited and Relevant Publication Sources

Sources	h Index	g Index	m Index	TC	NP	PY Start
Sustainability (Switzerland)	20	38	1.25	1509	53	2010
World Development	15	15	0.429	1196	15	1991
Frontiers in Sustainable Food Systems	10	22	1.429	486	27	2019
Science of the Total Environment	10	11	0.5	380	11	2006
Agricultural Systems	9	12	0.36	616	12	2001
Field Crops Research	9	12	0.474	546	12	2007
South African Journal of Agricultural Extension	9	10	0.36	114	17	2001
Agriculture, Ecosystems, and Environment	7	7	0.778	290	7	2017
Development Southern Africa	7	12	0.241	152	16	1997
Environmental Monitoring and Assessment	7	10	0.318	145	10	2004

Note: N= publication output; TC=Total Citations; NP=Net Production; PY=Publication

Table 4: Major Academic Contributors

Contributors	h_index	g_index	m_index	TC	NP	PY_start
Bernard Vanlauwe	8	9	0.32	441	9	2001
Giller E. Ken	7	7	0.368	380	7	2007
Philip Antwi-Agyei	6	8	0.75	209	8	2018
Robert B. Zougmoré	6	6	0.6	499	6	2016
John George Annandale	5	5	0.357	68	5	2012
Mark A.G. Darroch	5	5	0.172	76	5	1997
Andrew John Dougill	5	6	0.625	181	6	2018
Christiaan Cornelius C. Du Preez	5	5	0.152	281	5	1993
Zeyaur Rahman Khan	5	5	0.625	378	5	2018

Note: TC=Total Citations; NP=Net Production; PY=Publication

Zeyaur Rahman Khan's work has helped to bring sustainable agriculture to the fore and demonstrate that productivity can be increased while being ethical and sustainable. These research papers indicate how the models could open up various avenues for different farming cohorts in emerging markets through inclusive and innovative financial products. The cumulative work of these authors subtly describes sustainable agro-finance as a combination of practical farming, innovative financial management, and planetary care. In these studies, they provide instruments in a pluralistic framework that has the potential to change the normal thought processes relating to productivity, climate change, and food security. Based on our analysis, development on these corners will be important to overcome perennial issues in agriculture, and points towards more synergetic and forward-looking research in the future.

Table 5: Top Institutional Affiliations and their Countries

Institutions	Countries	Articles
University of KwaZulu-Natal	South Africa	123
University of Pretoria	South Africa	91
Wageningen University and Research	Netherlands	79
University of the Free State	South Africa	77
Stellenbosch University	South Africa	68
International Centre of Insect Physiology and Ecology, Nairobi	Kenya	64
North-West University	South Africa	57
Kwame Nkrumah University of Science and Technology	Ghana	56
University of Ghana	Ghana	48
International Institute of Tropical Agriculture	Nigeria	42

Table 5 lists the most common institutional affiliations with the most published research on sustainable agribusiness finance, with a clear South African focus along with meaningful representation from West and East Africa, which suggests a focus on the region in seeking solutions to sustainability issues in agriculture. Leading the way is the University of KwaZulu-Natal in South Africa, which has generated 123 articles through cross-disciplinary partnerships that bridge socio-economic and environmental dimensions to develop knowledge on sound agronomic practice. In second place is the University of Pretoria, with 91 articles, which focus on managing and improving farm productivity, strategies for sustainability, and promoting improved financial access for farmers in the face of economic and environmental stressors. Outside Africa, Wageningen University and Research in the Netherlands leads the way with 79 articles, following its global reputation for innovative agronomy and policy research supporting the economic and environmental aspects of planetary farming systems. South Africa's neighbors have expanded the scope of their work by exploring agrarian sciences and environmental economics in relation to local community practices in order to tackle real-world realities with the better financial and technological resources available. The University of the Free State, with 77 papers, and Stellenbosch University (68 papers), explore these fields. In Nairobi, the International Centre of Insect Physiology and Ecology published 64 papers on the management of pests and on environmentally friendly practices, which provide an adequate basis for good investment by way of food production in Eastern Africa. West African institutions, including the Kwame Nkrumah University of Science and Technology (56 papers) and the University of Ghana (48 papers), contribute to this discourse with important reflections on food security, policy formulation on a contextual basis and financial models for local farmers.

At the other extreme, the International Institute of Tropical Agriculture in Nigeria is at the forefront of 42 articles on tropical agriculture research including crop improvement and smallholder support to farmers. These institutions exemplify a committed effort under way throughout Southern and Western Africa to seek innovation in sustainable agricultural finance, pushing local solutions by doing research which provides for ecological integrity and economic resiliency. This work continues to unfold, and it is likely that it will serve to formulate policies that will lead to long-term improvements in the attainment of agricultural sustainable development goals.

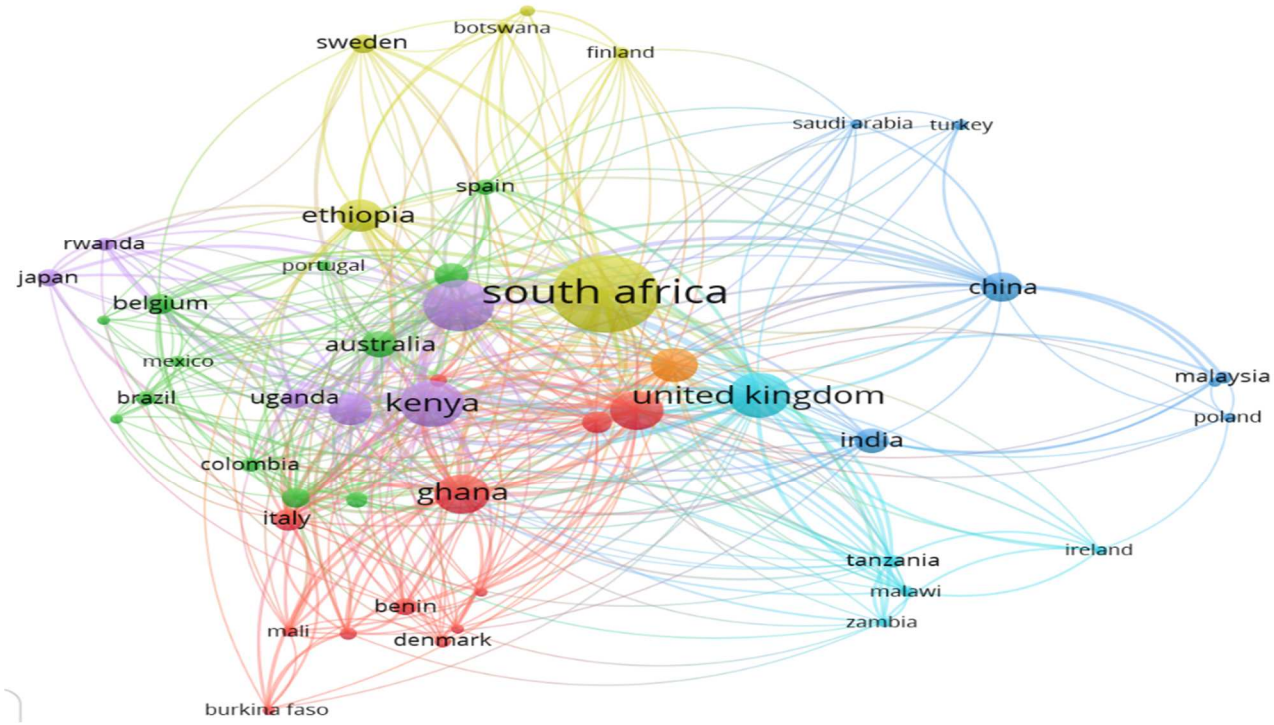

Figure 4. Co-Authorship Countries

According to figure 4, a network of co-authorship connections is produced, which demonstrates the international cooperation dynamics, where South Africa is a major connection point and the biggest node, frequently due to the developed knowledge economy in the field of academic sustainable agricultural finance.

South Africa is not the only leading country, as the UK, Kenya and Ghana, Ethiopia and China play an important role and hold strategic positions in the field of developing various contributions for agricultural sustainability developments and linked studies. In the case of this network, distinctly identifiable clusters occur, one of which forms a link or connects South Africa and Ethiopia with Europe, which focuses its partners on such countries as Spain, Sweden and Finland, in transcontinental co-operation and the promoting of agricultural sustainability. Other evident clusters are around Ghana and Italy, and on a more detailed examination of West African countries, e.g., Benin, Mali and Burkina Faso, there is evidence of regional cooperation commonly encouraged by European players, to exchange knowledge, expertise and resources. There is the Asian cluster which includes China, India, Malaysia, Saudi Arabia and Turkey, interested in regionalization aimed at sustainable agricultural financing, as there is a common interest in the promotion of systems of practice and funding.

Additionally, a more generalized cluster, which includes Kenya, Uganda, Australia, Belgium, Brazil, and Colombia, points to the African part, in relation to the interaction between both developing and developed world economies, to enable access to knowledge and capital to deal with sustainable issues. The cluster represents North-South cooperation between individual African countries and developed world nations (i.e. the UK, Australia and several European countries), so that technology, know-how and funds may be transferred to meet agricultural challenges. New participants like Mexico, Colombia, Rwanda, and Malaysia reveal the potential for greater participation and publication in the field, perhaps leading to more impact in the global debate about sustainable agricultural finance. The co-authorship networks place South Africa and other important African countries at the center of research in the area, in which international networks and partnerships show the importance of cross-border knowledge generation and exchange in the face of sustainability issues.

Conceptual Analysis

Citations Analysis: In Table 6 the seminal global publications are given, which highlights the intersection of agricultural, sustainability and climatic issues, including titles and DOIs, total number of citations, average citations per year and number of normalized global scores. Deressa *et al.*, (2009) in Global Environmental Change, "The determinants of farmers' choice on adaptation methods to climate change (in the Nile Basin of Ethiopia)" has received as high as 1.313 citations, giving an analysis of what are the reasons which lead Ethiopian farmers to adopt certain attitudes in protection of climate change, showing that education leads to greater diffusion of technology and that those in the male sex lead classes of information and supplies, while those in the female sex still have the antiquated reasons that prevent their entering into attempts at sustainability; and in the end there is a call for improvements which are intelligent and class conscious, with respect to sexual distinctions (Deressa *et al.*, 2009). Another study by Teklewold *et al.* (2013) published in the Journal of Agricultural Economics, "Adoption of Multiple Sustainable Agricultural Practices by Rural Households in Ethiopia", which has 538 citations, in which the authors use a multivariate probit model to analyze socio-economic determinants, showing that being close to extension services makes a difference when adopting environmentally friendly practices, even though actual difficulties such as lack of support slow the process (Teklewold *et al.*, 2013).

Table 6: Most Cited Global Publications

Paper	DOI	TC	ACY	NGC
Deressa *et al*. (2009)	10.1016/j.gloenvcha.2009.01.002	1313	77.24	9.21
Bryan *et al.* (2009)	10.1016/j.envsci.2008.11.002	860	50.59	6.04
Bryan *et al*. (2013)	10.1016/j.jenvman.2012.10.036	623	47.92	5.63
Teklewold *et al*. (2013)	10.1111/1477-9552.12011	538	41.38	4.87
Chivenge *et al.* (2015)	10.3390/ijerph120605685	355	32.27	7.07
Midega, *et al.* (2018)	10.1016/j.cropro.2017.11.003	303	37.88	6.40
Lyon (2000)	10.1016/S0305-750X(99)00146-1	292	11.23	3.49
Jost *et al*. (2016)	10.1080/17565529.2015.1050978	280	28.00	6.58
Harrison *et al*. (2019)	10.1016/j.jenvman.2019.05.011	277	39.57	10.05
Kassam *et al*. (2012)	10.1016/j.fcr.2012.02.023	227	16.21	4.10

Note: TC=Total Citations; ACY=Average Citations Per Year; NGC=Normalized Global Citations.

The paper "Understanding gender dimensions of agriculture and climate change in smallholder farming communities," by Jost *et al.* (2016) published in Climate and Development, has been cited a enormous 280 times, discussing gender roles in climate change adaptation, portraying them as victims of climate change instead of change agents (Jost *et al.,* 2016). Further, Chivenge *et al.* (2015) have contributed substantially with their paper

"The potential role of neglected and underutilized crop species as future crops under water scarce conditions in Sub-Saharan Africa," published in the International Journal of Environmental Research and Public Health, which has received 355 citations. The significance of agricultural biodiversity in reducing the negative consequences of water availability constraints on food production was emphasized in this study. In summary, the papers listed in Table 6 provide important elements on various aspects of sustainable agricultural finance in terms of adaptation methods, as well as socio-economic concerns, and the significance of gender and biodiversity in agricultural resilience enhancement.

Co-occurrence Analysis: The co-occurrence analysis groups associated keywords in clusters according to how frequently they appear together in the literature (Shehzad and Khan, 2024b). Each cluster represents an area of interest in SAF, and through the allocation of labels that represent themes and the display of their representative words, the table can give readers insights into how this area has been divided into related but distinct areas of concern (Khan *et al.*, 2024). This approach simplifies the interpretation of the visualization (network map), while at the same time providing transparency into how clusters of words are converted into meaningful themes for research (Khan and Shehzad, 2025). The present study had the data produced six clusters (See figure 6) and six thematic areas: (1) agricultural policy, financial assistance and strategies of adaptation to climate change, (2) climate-smart agriculture and resilient farming systems, (3), Global Sustainability, New Economies, and New Global Financial Assumptions, (4), agricultural production, food security and problems of climate in the developing countries, (5) Agroecological systems of agriculture, biodiversity, ecosystems of development, and (6) environmental sustainability, conservation of resources and impacts.

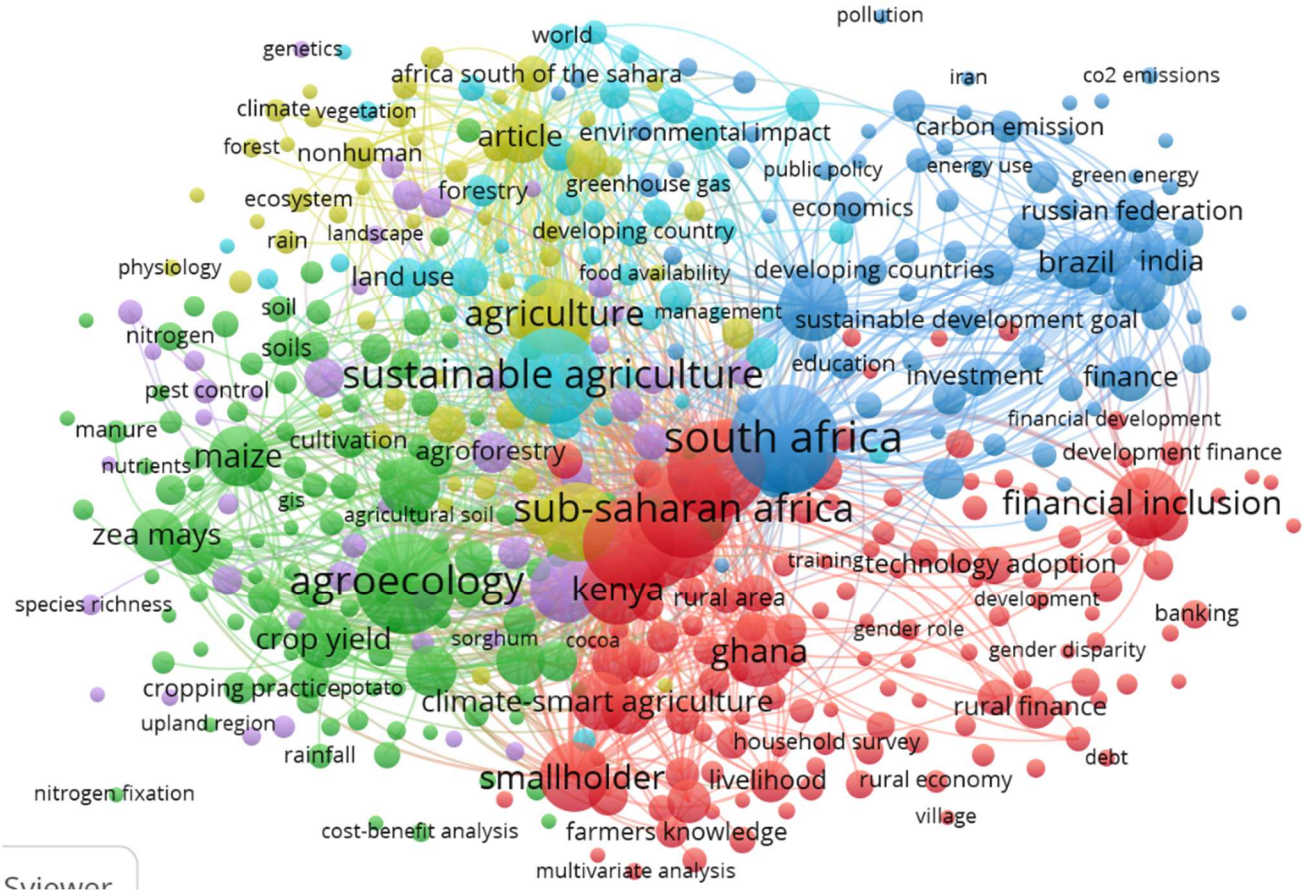

Figure 5. Co-occurrence Analysis

Table 7 outlines the key themes identified in each of the clusters according to the significant keywords. Cluster 1 deals with rural finance and inclusion concerning the impacts on the livelihoods of smallholder farmers and the need to address equity and access issues. Cluster 2 looks specifically at crop systems, ecological farming systems, and biodiversity in terms of farm-level sustainability. Cluster 3 deals with

linking global policy agendas and sustainability objectives as well as funding mechanisms, with emerging economies involved. Cluster 4 exemplifies the links between agriculture, land use, and environmental sustainability. Here, the connections between food production and land use practices are emphasized and clarified. Cluster 5 addresses agricultural inputs and ecological processes such as nutrient management and agricultural impacts on ecosystems. Finally, cluster 6 treats major environmental problems, including pollution and greenhouse gas emissions, in relation to agriculture and global environmental changes and issues of policy.

These clusters collectively illustrate the multidimensional aspects of SAF in developing countries, covering micro-level farm practices, rural finance, international sustainability policies, and environmental concerns. This thematic framework maps the existing knowledge, highlighting connections and gaps, and establishes a foundation for future research and policy initiatives that aim to advance sustainable agriculture in the Global South.

Table 7: Conceptual Clusters from Co-occurrence Analysis

Clusters	Themes	Representative Keywords
1	Agricultural Policy, Finance, and Climate Adaptation Strategies	Financial Inclusion, Rural Finance, Accessibility, Adaptation Strategies, Adaptive Management, Africa, Agricultural Development, Smallholder, Technology Adoption, Rural Economy
2	Climate-Smart Agriculture and Resilient Farming Systems	Agroecology, Agricultural Management, Agricultural Modeling, Agricultural Practice, Agricultural Research, Agricultural Robots, Agricultural Soil, Agro-Ecological Zones, Soil, Crop Yield, Biodiversity
3	Global Sustainability, Emerging Economies, and Innovative Financing Models	Agricultural Practices, Alternative Energy, Argentina, Brazil, Carbon Dioxide, Carbon Emission, Finance, Investment, Sustainable Development Goal, India
4	Agricultural Production, Food Security, and Climate Challenges in Developing Regions	Agriculture, Sustainable Agriculture, Forestry, Land Use, Food Availability, Environmental Impact, Africa, Agricultural Land, Agricultural Procedures, Agronomy
5	Agroecological Systems, Biodiversity, and Ecosystem-Based Agriculture	Agricultural Ecosystem, Agricultural Intensification, Agroforestry, Alternative Agriculture, Animals, Nutrients, Cropping Practice, Physiology, Species Richness
6	Environmental Sustainability, Resource Conservation, and Socio-Economic Impacts	Agricultural Sustainability, Agricultural Worker, Carbon Footprint, Conservation of Natural Resources, Desertification, Developing Country, Greenhouse Gas, Pollution, Environmental Impact

DISCUSSION

The role of Sustainable Agricultural Finance (SAF) in developing countries is vital because agriculture is a critical element for food security, poverty alleviation and environmental sustainability. The outcomes of the present study uncovered a variety of interconnections which are simultaneously similar to or different from prior academic literature. Drawing on a brief overview of bibliometric literature published between 1983 and 2025, the discussion below summarizes these emerging patterns, demonstrating similarities and dissimilarities among academic research. A fundamental area to note that re-emerged in the literature was the ramifications of access to finance within agricultural development processes in developing countries. An example of this is presented by Onyiriuba *et al.* (2020), where the authors note that government agricultural finance policies ultimately favour smallholder farmers who suffer the greatest impact of lacking access to finance. This coincides with the current study's suggestions that the inclusion of smallholders is an important topic within SAF research. In support of this, Sun *et al.* (2022) also illuminated the need to break financial barriers to increase agricultural production noting that farmers without access to credit tend to have lower productivity. This underscores the importance of financial access for agricultural progress for the farmers specifically, who are often marginalized in the rural economy.

Nonetheless, even though agreement is shown about the need for financial inclusion specifically for smallholder farmers, there is variation about the impacts of broader financial instruments and strategies. The present piece focuses on blended finance mechanisms as a way to generate new capital for agricultural sustainability, while Barua (2020) examines obstacles to implementing the Sustainable Development Goals (SDGs) in developing contexts, revealing a more complicated relationship between financial strategies and their results. Furthermore, O'Toole *et al.* (2014) explain how financial crises hinder agricultural investments - challenging the optimism around the new financing formats discussed in the analysis.

Moreover, the emergence of agroecology and environmental change in the findings offer a thematic pathway that overlaps with previous literature that has yet been underexplored. Studies like Velten *et al.* (2015) demonstrate that definitions of sustainable agriculture are often vague, consistent with the current paper's discussion of the need for more holistic approaches that incorporate various dimensions of sustainability. In the realm of urban agricultural practices, Thebo *et al.* (2014) argue that urban households are increasingly involved in agricultural activities that imply an alternate theme in perspectives of sustainability in agriculture across urban and rural sectors. An innovative focus of the current study is the focus on gender inclusive finance and climate risk appraisal tools. This aspect is related to others recent publications that call for frameworks that consider gender when designing finance strategies (Chuahan and Chavda, 2024; Alamsyah *et al.*, 2024). This domain is still relatively emerging and shows there is a disparity in the literature regarding frameworks developed to consider equitable finance practice in the agricultural sector.

Conclusions: This paper is a comprehensive bibliometric analysis of SAF in developing countries, investigating its themes, key contributors, publication patterns and collaboration networks, focusing on developing countries. The results indicated the need for collaboration of governments, financial institutions and the agricultural industry to meet the challenges of food security, poverty alleviation and environmental sustainability. Gender sensitive funding, climate risk analysis and innovative funding models are needed to gain resilience in the global south. Limitations of the study include single source data from Scopus database. Future studies may use several data sources and mixed methods to investigate challenging future avenues like as: development of climate-smart finance mechanisms, gender and climate-smart finance frameworks, mainstreaming of policies with the SDGs and the use of fintech and blended finance to enhance access to smallholders.

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