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Review

The Inter-Relationship between Climate Change, Inequality, Poverty and Food Security in Africa: A Bibliometric Review and Content Analysis Approach

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Abstract: Despite the persistent income inequality and climate change shocks in Africa, there is limited research on their effects on food security. Hence, this study adopted a mixed-methods approach including a bibliometric analysis and content analysis to examine emerging themes in the literature on climate change, inequality and poverty, and food insecurity in Africa. The bibliometric data used were retrieved from the Scopus database for the period 2000–2022. The exercise revealed an increasing trend in the number of publications in the field, as well as strong collaboration between African countries. Specifically, most of the leading research was published by Kenyan, USA, and UK institutes. From the analysis, seven themes emerged; namely; (1) the impact of governance and policy on poverty alleviation, nutrition status, and food security; (2) the role of innovation and sustainable agriculture in mitigating climate change in developing countries; (3) integrating gender in evaluations of the impact of climate change on food security and livelihoods in Africa; (4) climate change adaptation among smallholders in building resilience for nutrition; (5) the role of institutions in assisting smallholders mitigate and adapt to climate shocks; (6) inequality, food unavailability, and agricultural production; and (7) gendered impacts of climate-smart agriculture in climate adaptation and mitigation. We also found out that there was a dearth of longitudinal studies on these seven themes. Another key element revealed by the study was the lack of policies that address the gender-differentiated impacts of climate change; hence, there is limited research on the agricultural gender productivity gap. Policies based on the tenants of socio-economic inclusion need to guide the distribution of wealth and economic participation in order to reduce inequality and improve food security and nutrition outcomes.

Keywords: climate change; food security; inequality; Sustainable Development Goals (SDGs); bibliometric analysis; content analysis; VOSviewer

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1. Introduction

Over the last two decades, the global climate has changed in a way that has affected life in an uncertain way. Climate change has a far-reaching impact on the prospects of achieving all seventeen of the Sustainable Development Goals (SDG), either directly or indirectly. A direct link exists between food security and SDGs 1 (no poverty), 2 (zero hunger), and 12 (responsible consumption and production).

In Africa, food security and agricultural productivity are influenced by both demand and supply factors. Changing employment patterns, rising income, increased globalization, vacillating consumer behavioral patterns, and increasing population growth represent the demand-side factors influencing Africa's food security and agricultural productivity growth. On the supply side, changes in natural resources, technological advancements, and resource utilization efficiency will impact potential agricultural yield in Africa [1,2]. The issue of climate change in Africa compounds the already herculean task of achieving food security in Africa.

Climate change is having a devastating impact on food security in Africa. Changing precipitation patterns, rising temperatures, and more extreme weather have a wide range of effects, such as increased weather volatility and extreme events, rising sea levels, changed glacial meltwater flows (first increasing and then, eventually, declining), altered occurrences of agricultural pests and diseases, and an immediate impact on crop yields. These factors contributed to mounting food insecurity, poverty, and displacement in Africa in 2020, compounding the socio-economic and health crisis triggered by the COVID-19 pandemic, according to a new multi-agency report coordinated by the World Meteorological Organization (WMO). Climate change also contributes to the displacement of rural populations, as farmers are forced to abandon their land due to increasingly unpredictable weather patterns and soil degradation. Increasing atmospheric CO2 levels, extreme temperature and rainfall fluctuations, heat waves, and sea level fluctuations have all contributed to disasters with substantial economic losses for global economies [3,4]. Furthermore, the increasing frequencies of extremely dry and wet years instigated by changing climatic conditions are expected to impact food supply and productivity [5]. This has led to increased competition for resources, further exacerbating the problem of food insecurity.

Currently, 20% of Africa's population is malnourished, with nearly 690 million hungry individuals in 2019 alone [6]. The number of people facing hunger in Africa is expected to double by 2050 due to climate change, with an estimated 300 million people in Sub-Saharan Africa at risk of food insecurity by 2030 [6]. In addition, authors have pointed out ways that climate change can affect food security [5,7], including through low crop yields and livestock productivity: climate variability and loss of arable land due to climate change are expected to increasingly limit food production growth in sub-Saharan Africa. For example, the growth rate for grain yields is likely to fall from 1.96 to around 1.14 by 2050.

Furthermore, due to climate change, rainfall is decreasing and prolonged droughts are becoming more common on the continent, resulting in the loss of about two thirds of its arable land [4,8]. As more arable land becomes inundated by floods and uncultivated due to droughts, it is becoming more challenging to produce enough food. Shrinking food stocks, unstable markets, and high energy costs contribute to rising food prices in developing countries. This increase in food prices will likely continue as climate change hits and puts immense pressure on scarce land and water resources. World market prices are key indicators of the impact of climate change on agriculture and food security. As local food production decreases due to the adverse effects of climate change, food prices will increase, affecting food availability, especially for those who obtain their daily groceries from the markets.

When the production yields and patterns for various food products that contribute to people's nutritional needs are affected by climate change impacts and policies, the overall nutritional needs of the population also change. Affordability becomes a difficult issue when food prices increase. In Africa, many rural dwellers depend on farming as their source of livelihood. If not properly managed, the devastating effects of climate variability, floods, and droughts can put farmers out of business and, ultimately, cause loss of income. Furthermore, everyone along the food production chain will be affected due to the loss of jobs in agro-based and allied industries. The effects of climate change are disproportionately affecting the poorest communities, who lack access to resources that could help them cope with the impact of climate change on their livelihoods. According to the IPCC Report [8], Africa will be the most susceptible to the negative effects of climate change in the coming years, although its total contribution to global greenhouse emissions is less than 4% [7,9]. This is due to its low capacity to adapt the effects of climate change, extensive dependence on rain-fed agriculture, growing population, and high poverty levels, amongst many other reasons [10]. Forecasts of the impact of climate change vary significantly across different regions based on the models used for projections and the scenarios under consideration [7,11]. However, using technology to share data in agri-food systems can help address challenges related to climate change by developing practices that make agriculture more resilient to extreme weather, reduce greenhouse gas emissions, and conserve natural resources [12]. Increasing inequality, as stated by the author of [13], is a major challenge in developing countries. It exists in three dimensions—gender-based, economic and social—and leads to imbalances in power and unequal distribution of and access to resources. Moreover, the author of [14] argued that inequality has increased in many developing counties, including African counties. Another study [15] showed that, even though inequality persists in Africa, it has not led to an increase in deaths resulting from malnutrition or food insecurity. However, the link between inequality, climate change, and food security still remains unclear and unexplored. Against the above background, the aim of this study was to investigate the inter-connection between climate change, inequality, and food security. The study attempts to provide an understanding of the evolution of publications on the topic in order to identify the key themes that emerge and the policy prescriptions. For this reason, this study adopted a mixed-methods approach including a bibliometric review and a content analysis regarding the inter-connection between climate change, inequality, and food security in African countries. The following research questions (RQs) guided the present study:

RQ1: Is it possible to identify publication trends for the papers in the field from 2000 to 2022? (a) What are the field's most prestigious articles and topics? (b) In which journals were these paper published? (c) What are the leading research institutes and countries and the collaborations between them?

RQ2: What are the key interests (keyword analysis) of these studies?

RQ3: What are the emerging themes in the literature on the interconnections between climate change, inequality, and food security?

RQ4: What are the main literature gaps and future research directions based on the emerging themes identified in RQ3?

The contributions of this article are threefold: Firstly, we identify the publication trends for the literature in the field, providing an indication of the most prolific authors, the most productive journals, and the institutions and countries that are most influential in the field. Second, the content analysis carried out reveals the emerging topics in the field and their contributions to the literature, as well as the gaps that continue to persist. Thirdly, we posit future research directions based on the emerging themes, as well as policy prescriptions.

2. Materials and Methods

This study adopted a mixed-methods approach including a bibliometric review and content analysis [16,17]. In principle, a bibliometric analysis is used to evaluate the development of the literature on a particular topic over years [9]. On the other hand, content analysis allows scholars to unearth the main results of particular studies [18]. In general, content analysis is a commonly used method [19,20] that establishes clusters of data based on published studies. Figure 1 depicts the flowchart for the methodology employed in this study, including the procedures followed in selecting the articles used in the study, as well as the analysis and findings.

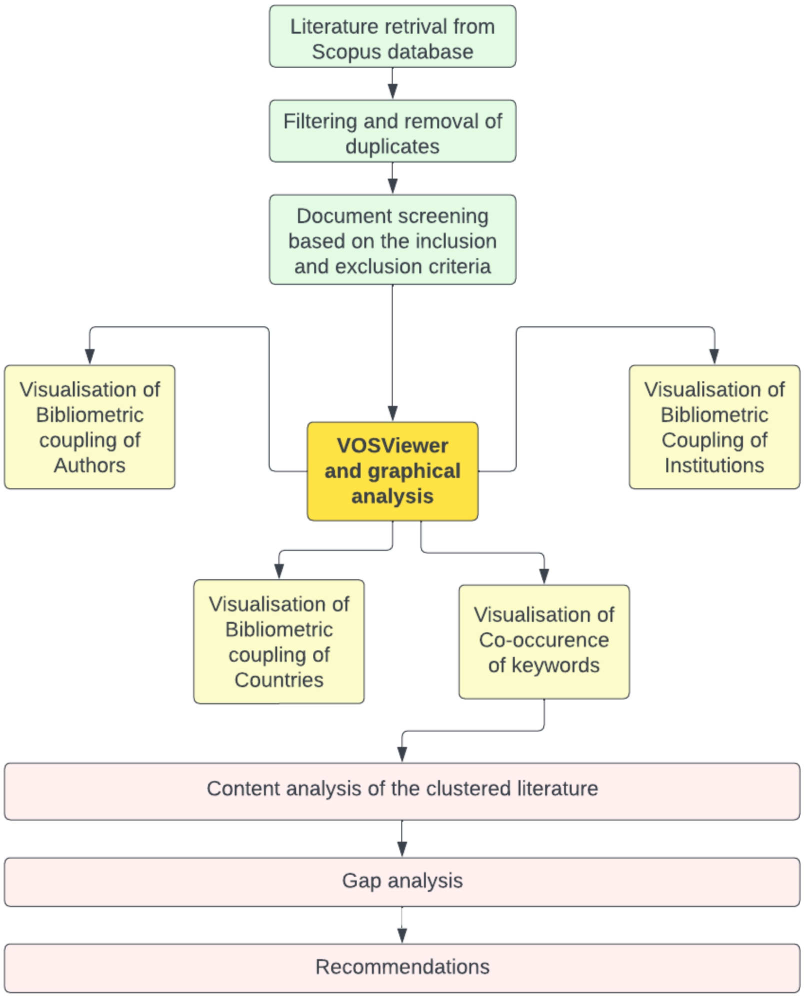

Figure 1. Flowchart of the bibliometric review process.

2.1. Data Collection and Analysis Steps

The data collection and analysis in this research consisted of seven steps (see Figure 1).

i. Retrieval of studies from the Scopus database: The first step was to gather bibliometric data from a database of scientific papers. Documents used in this study were retrieved from the Scopus database. The Scopus database is one of the largest sources of bibliometric data and it indexes nearly 20,000 peer-reviewed journals from many scientific publishers. Search criteria were used when selecting the papers to be used in this study. We specified the time period of the study as 2000 to 2022. Furthermore, we used the following keywords in the search strategy: “poverty” OR “inequality” AND “climate change “ AND “food security” AND “Africa”. This ensured that the extracted articles were restricted to the domain of the chosen keywords;
ii. Filtering and removal of duplicates: In the second step, we assessed the extracted papers. We checked for duplicate records and deleted one copy of the duplicates and kept the other;
iii. Document screening based on inclusion and exclusion criteria: We proceeded by reviewing the document titles, keywords, and abstracts of the selected articles to remove articles that were not relevant to the subject area of our study. After screening and removing irrelevant journal articles, we obtained a dataset of 120 articles. Table 1 illustrates the inclusion and exclusion criteria;
iv. Descriptive analysis: We carried out a descriptive analysis of the remaining set of documents to establish the publication trends. We specifically investigated the

most cited articles, most cited authors, most cited journals, influential countries and institutions, and the time series of publication;

v. VOSviewer and graphical illustration: We produced a network graphical illustration of the bibliometric coupling of authors, bibliometric coupling of institutions, bibliometric coupling of countries, and the co-occurrence of keywords, which led to a cluster analysis. VOSviewer software was used for this task. VOSviewer is a software package that facilitates the generation, analysis, and visualization of bibliometric networks. The networks can use authors, journals, countries, keywords, and countries as nodes. The nodes are then connected by lines indicating either co-occurrence, in the case of keywords, or collaborations, in the case of authors, institutions, and countries [21];

vi. Content analysis of the clustered literature: Based on the clusters identified, we analyzed the main themes and content of the literature;

vii. Policy recommendations: The content analysis of the literature guided the policy recommendations drawn from the literature and highlighted key theoretical and practical contributions of interest for researchers and policymakers. The steps followed in the bibliometric cum systematic review are illustrated in Figure 1.

Table 1. Criteria used in selecting articles from Scopus database.

Criteria	Dimension
Logical Statement	TITLE-ABS-KEY (“poverty” OR “inequality” AND “climate change “ AND “food security” AND Africa AND (LIMIT-TO (PUBSTAGE, “final”)) AND (LIMIT-TO (SUBJAREA, “ENVI”) OR LIMIT-TO (SUBJAREA, “SOCI”) OR LIMIT-TO (SUBJAREA, “AGRI”) OR LIMIT-TO (SUBJAREA, “ECON”) OR LIMIT-TO (SUBJAREA, “ENER”)) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010) OR LIMIT-TO (PUBYEAR, 2009) OR LIMIT-TO (PUBYEAR, 2008) OR LIMIT-TO (PUBYEAR, 2007) OR LIMIT-TO (PUBYEAR, 2006) OR LIMIT-TO (PUBYEAR, 2005) OR LIMIT-TO (PUBYEAR, 2003) OR LIMIT-TO (PUBYEAR, 2000)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (DOCTYPE, “ar”))
Inclusion	Document is located in Scopus database Document is an article Document is in its final state Published from 2000 to 2022 Document is written in the English language Document has the keywords “poverty”, “inequality”, “food security”, “africa”, and “climate change”
Exclusion	Non-peer-reviewed journals Lack of references, authorship, or full text Document is not written in English Document is not a journal article Document does not relate to climate change, food security, or poverty and inequality

2.2. Selection Criteria

The selection criteria for the documents used are illustrated in Table 1. It shows the logical statement, the inclusion criteria, and the exclusion criteria used to retrieve the 120 documents.

3. Results Analysis

The results analysis consisted of two parts:

(1) Bibliometric analysis: In the bibliometric analysis, trends for publications and citations over the years, influential aspects of the literature, the co-occurrence of keywords, and bibliographic coupling were studied. We employed diverse tools for the statistical and visual processing. We constructed tables using Microsoft Excel and undertook network analysis with VOSviewer [21];

(2) Content analysis: We carried out content analysis in the second part of the analysis, which was based on the co-occurrence of keywords and resulted in key clusters/themes. Finally, we identified research recommendations and both theoretical and practical future research areas.

3.1. Bibliometric Analysis

3.1.1. Trends for Publications per Journal

The search keywords and filtering resulted in a total of 120 articles being obtained from the Scopus database. As illustrated in Figure 2 the highest numbers of publications were produced in 2017 and 2022, and the lowest numbers of publications were from 2001 to 2004, when no publications were produced. There was a nonlinear increase characterized by fluctuations from 2011 to 2017. This increase could be attributed to the Paris Agreement on climate change, as countries began to include climate change in their policies, especially in African countries where large populations are employed in the agricultural sectors, making them more vulnerable to climate change shocks, which, consequently, affect food security. However, there was a sharp decline in publications from 15 in 2017 to 7 in 2018. The increase in publications could be an indication that the domain of food security has attracted more and more attention from researchers in recent years.

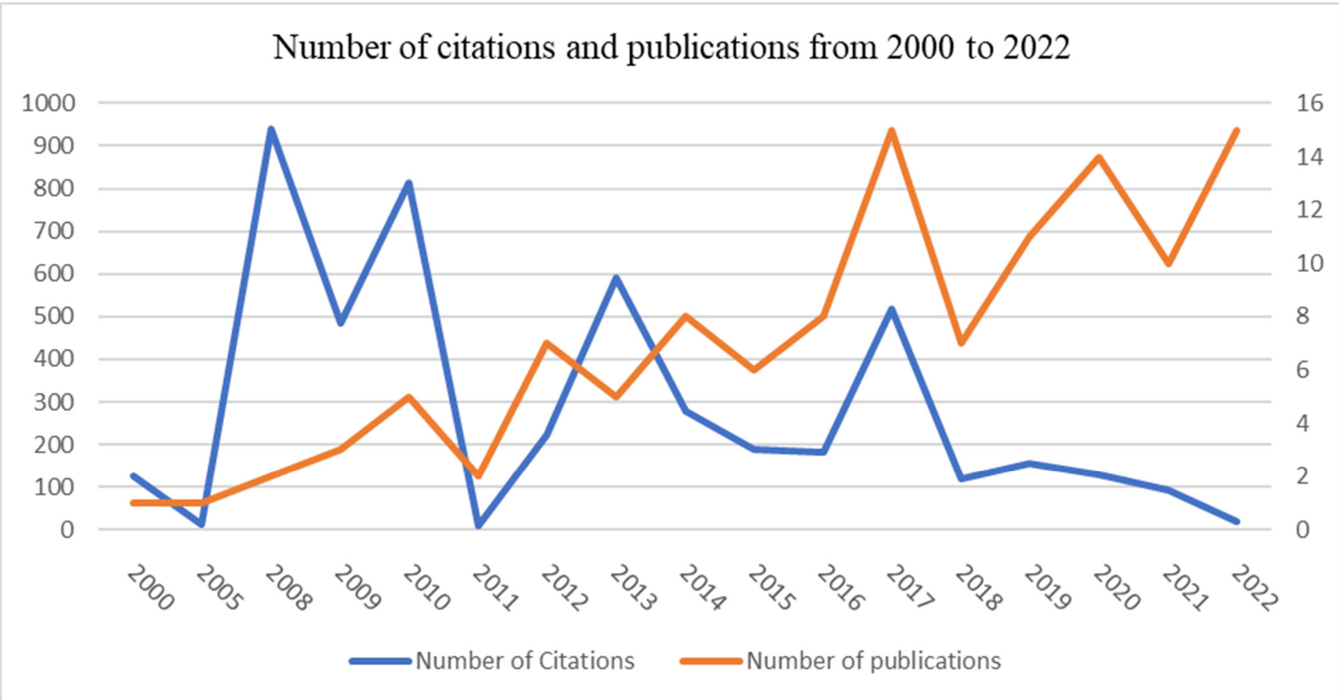

Figure 2. Citation and publication trends from 2000 to 2022.

As illustrated in Table 2, about 15% (n = 18) of the published papers were the work of single authors, whereas 37% (n = 39) of the papers were the work of two or three authors. The number of papers produced by four or five authors was 19 (about 28%), six or seven authors produced about 10% of the papers (n = 10), and eight or nine authors produced 4 papers (about 4%). Table A1 in Appendix A shows the complete list of the articles used in this bibliometric analysis.

3.1.2. Top Ten Journals with Greatest Impact (Citations per Journal)

Table 3 indicates that *Comprehensive Reviews in Food Science and Food Safety* had the lowest number of publications and the highest number of citations per paper of about 403. This was congruent with its impact factor of 15.91. In contrast, *Food Security*, which had the highest number of publications (five), recorded the second lowest number of citations per paper. *Agriculture, Ecosystems and Environment* recorded the highest number of citations but had the second highest number of citations per paper of about 305.67. *PLoS ONE* was at the bottom of the list with 72 citations per paper, and this corresponded with its having the lowest impact factor of 3.38.

Table 2. Summary descriptions.

CHARACTERISTIC	CATEGORY	NUMBER	PERCENT
TOTAL NUMBER OF PUBLICATIONS		120	100.00
YEAR OF PUBLICATION	2000–2004	1	0.83
	2005–2009	6	5.00
	2010–2014	27	22.50
	2015–2019	47	39.17
	2020–2022	39	32.50
NUMBER OF AUTHORS	1	18	15.0
	2–3	39	35.8
	4–5	19	27.5
	6–7	10	10.0
	8–9	4	6.67
	>10		5.00
COUNTRY OF FIRST AUTHOR (TOP 10)	South Africa	19	15.83
	Kenya	16	13.33
	USA	15	12.50
	UK	12	10.00
	Germany	10	8.33
	Uganda	5	4.17
	Italy	4	3.33
	Netherlands	4	3.33
	China	3	2.50
	Finland	3	2.50
	Ghana	3	2.50

Table 3. Most productive journals for the period 2000–2022.

Rank	Year of Publication	Article Title	Number of Citations	Citations per Paper	Journal Impact Factor *
1	*Comprehensive Reviews in Food Science and Food Safety*	1	403	403.00	15.91
2	*Agriculture, Ecosystems and Environment*	3	917	305.67	6.26
3	*Geoforum*	1	240	240.00	3.95
4	*Global Environmental Change*	3	559	186.33	10.63
5	*Energy Policy*	1	95	95.00	7.32
6	*Environmental Science and Policy*	3	283	94.33	6.53
7	*Agricultural Systems*	4	320	80.00	6.74
8	*Agricultural and Forest Meteorology*	1	76	76.00	6.42
9	*Food Security*	5	371	74.20	6.93
10	*PLoS ONE*	1	72	72.00	3.58

* Impact Factor of Journal Found Online through Impact Factor Search Engine Resurchify.

3.1.3. Most Cited Journal Articles

Table 4 illustrates the most cited articles and their citation impacts (calculated as citations/number of years since publication). Between 2000 and 2022, there were a total of 4881 citations of all the articles used in this study. The highest number of citations occurred in 2008 (n = 940) and the lowest number of citations was in 2011 (n = 9). The two papers that had the highest citations of 940 in 2008 were the article titled "Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation” and the article titled “Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique”.

Table 4. Top ten articles by citation impact from 2000 to 2022.

Rank	Year of Publication	Article Title	Total Citations	Citations per Year
1	2008	Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation	700	50
2	2013	Millet grains: Nutritional quality, processing, and potential health benefits	403	45
3	2010	Evergreen agriculture: A robust approach to sustainable food security in Africa	321	27
4	2010	The poverty implications of climate-induced crop yield changes by 2030	278	23
5	2009	Spatial variation of crop yield response to climate change in East Africa	268	21
6	2008	Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique	240	17
7	2009	Croppers to livestock keepers: Livelihood transitions to 2050 in Africa due to climate change	201	15
8	2010	Adapting to climate change: Agricultural system and household impacts in East Africa	153	13
9	2000	Linking climate change research with food security and poverty reduction in the tropics	126	6
10	2014	Integrated landscape initiatives for African agriculture, development, and conservation: A region-wide assessment	112	14

3.1.4. Top Authors by Documents Published

Table 5 indicates that the most productive authors were Zomer R.J., Trabucco A., Bossio D.A., and Verchot L.V, who published their article entitled “Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation” in 2008. Their paper received the most citations, as well as the most citations per year. The five most prolific authors included authors from Kenyan institutions—the World Agroforestry Centre (ICRAF) and the International Livestock Research Institute (ILRI)—in positions one, three, and five, respectively, and authors from Chinese and USA institutions in position two and four, respectively. Five Kenyan institutions appeared in the top ten most prolific institutions on the field, showing that studies on climate change and food security with a focus on Africa are dominated by scholars from Kenyan institutions and China.

Table 5. Top ten most productive authors in the period 2000–2022.

Country	Authors	Number of Articles	Citations	Citations per Year	Leading Author Affiliation
Kenya	Zomer R.J., Trabucco A., Bossio D.A., Verchot L.V.	1	700	50	World Agroforestry Centre (ICRAF)
China	Saleh A.S.M., Zhang Q., Chen J., Shen Q.	1	403	45	College of Food Science and Nutritional Engineering, China Agricultural University
Kenya	Garrity D.P., Akinnifesi F.K., Ajayi O.C., Weldesemayat S.G., Mowo J.G., Kalinganire A., Larwanou M., Bayala J.	1	321	27	World Agroforestry Centre
USA	Hertel T.W., Burke M.B., Lobell D.B.	1	278	23	Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University
Kenya	Thornton P.K., Jones P.G., Alagarswamy G., Andresen J.	1	268	21	International Livestock Research Institute (ILRI)
UK	Osbahr H., Twyman C., Neil Adger W., Thomas D.S.G.	1	240	17	School of Agriculture, Policy and Development, Walker Institute for Climate Systems Research, University of Reading
UK	Jones P.G., Thornton P.K.	1	201	15	Waen Associates
Kenya	Thornton P.K., Jones P.G., Alagarswamy G., Andresen J., Herrero M.	1	153	13	International Livestock Research Institute (ILRI)
Kenya	Sanchez P.A.	1	126	6	International Centre for Research In Agroforestry
USA	Milder J.C., Hart A.K., Dobie P., Minai J., Zaleski C.	1	112	14	EcoAgriculture Partners

3.1.5. Top Countries for Publishing

Table 6 illustrates the publication productivity ranking for the top ten countries covered by the articles used in this study. There were two African countries in the top five (Kenya in the first position and South Africa in the fifth position), the USA was in the second position, the UK in the third position, and China in the fourth position. This implies that Kenya is the knowledge center for climate change, food security, and poverty in Africa. Although Kenya did not have the leading number of publications, it had the highest number of citations (1904) and the highest number of citations per paper (199). In contrast, South Africa, which had the highest number of publications (19) in the field, did not have the highest citation impact; it recorded 270 citations and about 14.21 citations per paper.

Table 6. Top ten countries in terms of publication productivity.

Rank	Country	Number of Publications	Number of Citations	Citations per Paper
1	Kenya	16	1904	119.00
2	USA	15	665	44.33
3	UK	12	646	53.83
4	China	3	467	155.67
5	South Africa	19	270	14.21
6	Germany	10	204	20.40
7	Uganda	5	148	29.60
8	Turkey	1	95	95.00
9	France	2	76	38.00
10	Netherlands	4	62	15.50

3.2. Bibliometric Coupling

In this study, we used VOSviewer software, which is a publicly available bibliometric mapping tool. It is used to generate graphical network visualizations in which the positions of objects (nodes) and the distances between these nodes give an indication of the degree of similarity between the objects [21].

3.2.1. Bibliometric Coupling of Documents

Figure 3 indicates that the author of [22] was the most influential author in the field because the size of the brown node was the largest, indicating that reference [22] had the highest number of citations. This deduction is in agreement with the descriptive statistics shown in Table 2. The second most influential author was the author of [23], which had the second highest number of citations. Other influential authors included the authors of [24,25], as shown by the blue nodes.

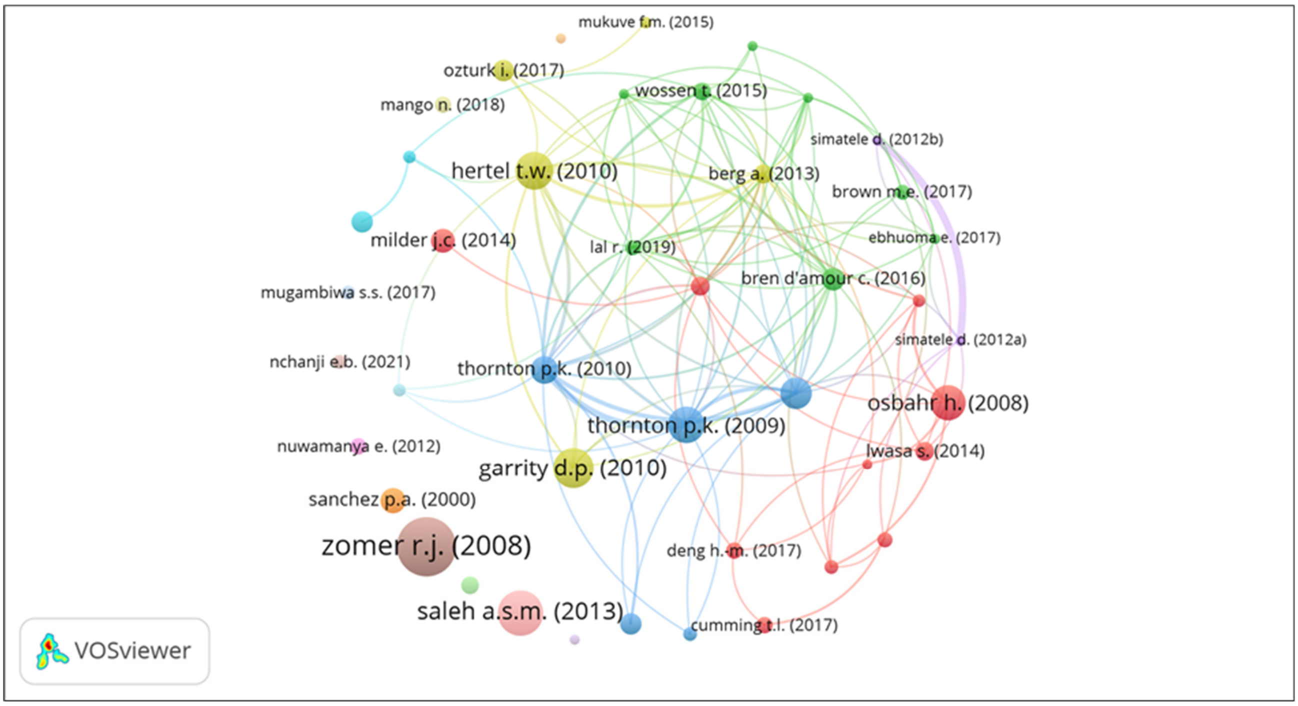

Figure 3. Bibliometric coupling by document indicating the relational strength between articles published by authors in the period 2002–2022. The circles are nodes of documents and they give an indication of the impact or influence of the document. Documents with the same colored nodes belong to the same cluster. A large node indicates that the document has the greatest impact in the research field considered in this study and small node indicates a small impact of the document.

3.2.2. Bibliometric Coupling of Journals

The graphical display in Figure 4 shows that *Global Environmental Change*, *Food Security*, *Agricultural Food Systems*, and *Agriculture, Ecosystems and Environment* were some of the influential journals in the field. Taking into account the number of citations as a measure of influence, *Agriculture, Ecosystems and Environment* had the highest number of citations, as illustrated in Table 3.

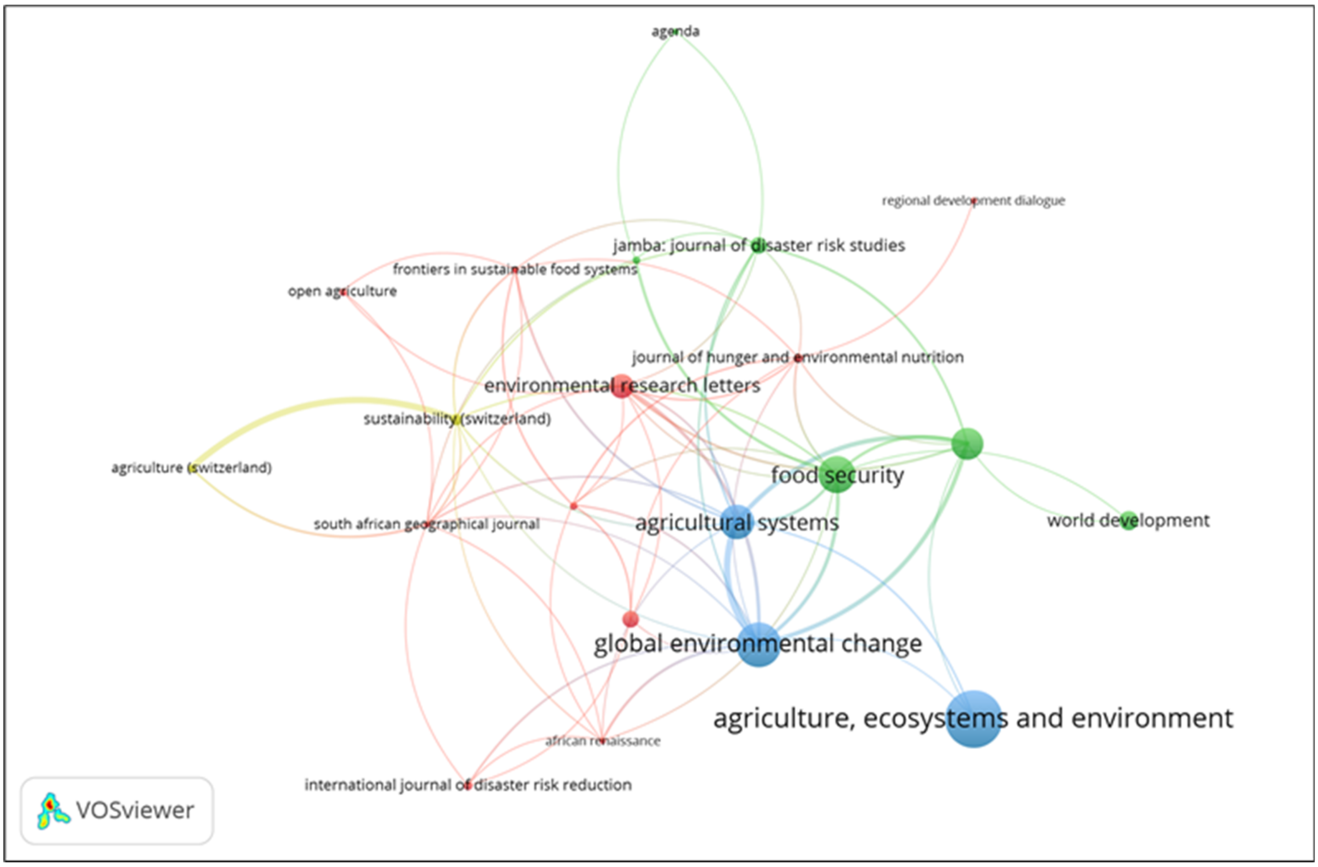

Figure 4. Bibliometric coupling of journals indicating the most prolific journals in the field and the degree of collaboration. The circles are nodes of journals and the size of the nodes indicate the degree of impact of the journal. A large node indicates that the journal has the greatest impact in the research field considered in this study and small node indicates a small impact of the journal. Journals with the same colored node belong to the same cluster.

3.2.3. Bibliometric Coupling of Institutions

As illustrated in Figure 5, Michigan State University and the International Livestock Research Institute had the largest node sizes, indicating that they were the most influential research institutes in the field of study, as measured by total citations. The Department of Sociology and Anthropology in Limpopo had the smallest node size, indicating that it was among the least influential research institutes in the field. There was a thick line connecting Michigan State University and the International Livestock Research Institute, indicating that they had the most frequent and strong academic collaborations on the topic.

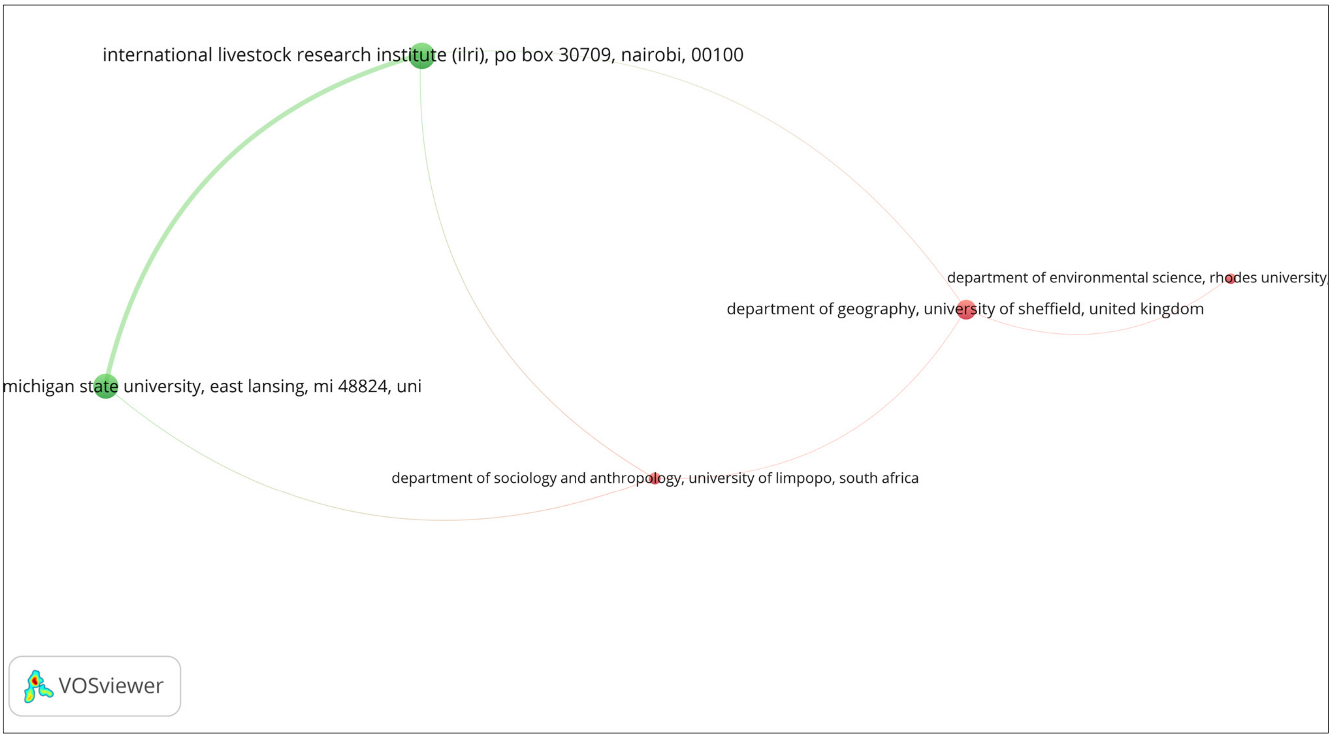

Figure 5. VOSviewer results for prolific research institutions on climate change impacts on food security and inequality in Africa for the period 2000 to 2022. The circles are nodes of institutions and the lines between them are an indication of research collaborations that took place between the institutions. Institutions with the same colored nodes belong to the same cluster. A large node indicates that the institution has the greatest impact in the research field considered in this study and small node indicates a small impact of the institution.

3.2.4. Bibliometric Coupling of Countries

A graphical network visualization of the most prolific countries and the collaborations between countries is illustrated in Figure 6. The size and font of the node indicates the weight of the influence of the publishing country, as measured by the number of citations. The thickness of the line connecting the nodes indicates the strength of the collaboration between the countries. Hence, Figure 6 shows varying degrees of cross-country collaboration between the USA, the UK, China, Germany, Kenya, Uganda, etc. As shown in the figure, there was a thick line between the UK and Kenya, between Ghana and Kenya, and between Kenya and South Africa, indicating that there were frequent academic collaborations between these countries. On the other hand, there were fewer collaborations between China and South Africa, China and Uganda, and Ghana and Uganda.

The most influential non-African countries were the UK, the USA, and Germany. The most influential countries by citation in Africa were Kenya, South Africa, Ghana, and Uganda. This bibliometric mapping corresponded with the results in Table 6 for the top ten countries in terms of publication productivity.

3.2.5. Bibliometric Coupling of Keywords

Keyword co-occurrence clustering was generated using VOSviewer and resulted in seven main clusters, as depicted by Figure 7. The font and size of each node depend on the weight of the particular keyword. The larger the node is, the more frequently the keyword appears. Moreover, the thickness of the lines connecting the nodes also indicates the frequency with which the two keywords appear together. The most frequently occurring keywords were climate change, followed by food security and agriculture.

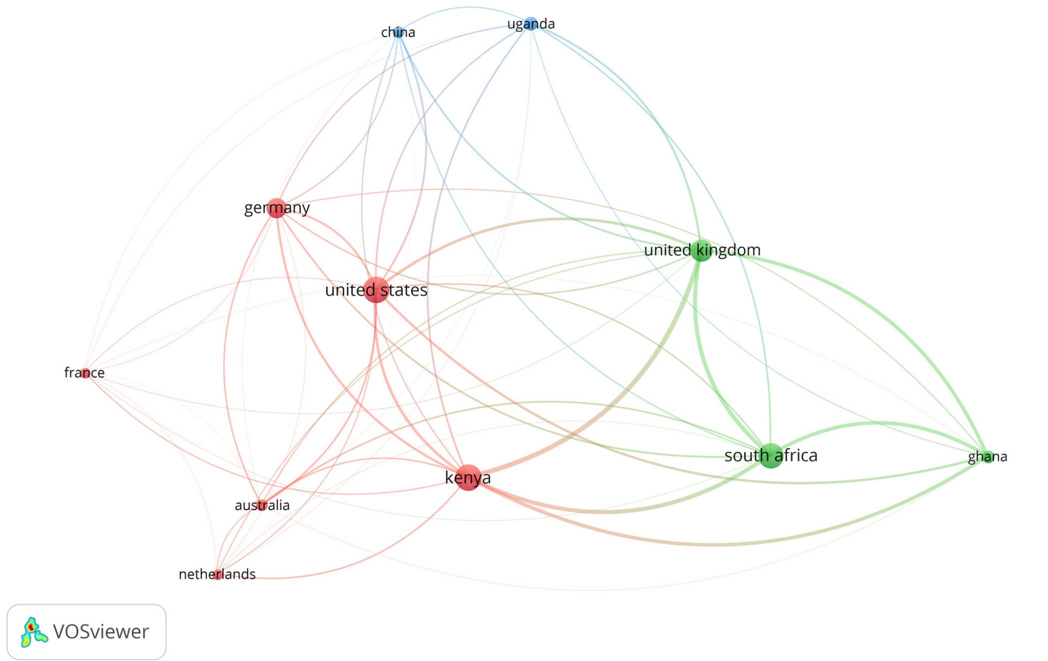

Figure 6. Bibliometric coupling of countries with the most research influence measured by citations. The circles are nodes of countries and the lines between them are an indication of research collaborations that took place between the countries. Countries with the same colored nodes belong to the same cluster. A large node indicates that the country has the greatest impact in the research field considered in this study and small node indicates a small impact of the country.

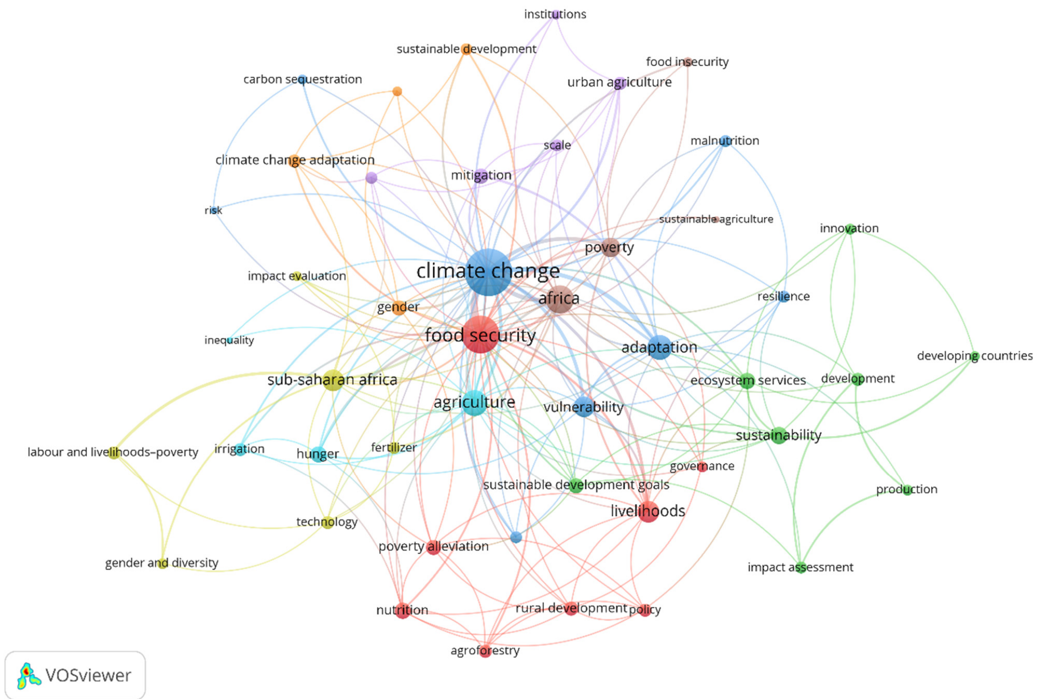

Figure 7. Co-occurrence of keywords. The size of the circle/nodes indicates the frequency of the keyword's occurrence, whereas the lines between the nodes indicate relationships among keywords. A lager node would imply that that the keyword is the most frequently occurring while a small node would mean that the keyword is less frequently occurring. Keywords occurring in the same colored nodes are in the same cluster. The closer the nodes are to each other, the more frequently the keywords occur together, the further apart the nodes are, the less frequent the keywords occur together.

The main keywords were grouped into seven clusters (see Table 7) and they are further discussed in the content analysis section.

Table 7. Keywords for research topics and clusters.

Cluster	Keywords	Emerging Theme
1 (n = 8)	Agroforestry, food security, governance, livelihoods, nutrition, policy, poverty alleviation, rural development	The impact of governance and policy on poverty alleviation, nutrition status, and food security
2 (n = 8)	Developing countries, development, ecosystem services, impact assessment, innovation, production, sustainability, sustainable development	The role of innovation and sustainable agriculture in mitigating climate change in developing countries
3 (n = 6)	Fertilizer, gender and diversity, impact evaluation, labor and livelihoods, Sub-Saharan Africa, technology	Integrating gender in evaluations of the impact of climate change on food security and livelihoods in Africa
4 (n = 6)	Adaptation, climate change, malnutrition, resilience, smallholders, vulnerability	Climate change adaptation among smallholders in building resilience for nutrition
5 (n = 5)	Institutions, mitigation, scale, smallholder farmers, urban agriculture	The role of institutions in assisting smallholders mitigate and adapt to climate shocks
6 (n = 4)	Agriculture, hunger, inequality, irrigation	Inequality as a driver of food unavailability and hunger
7 (n = 4)	Climate change adaptation, climate smart-agriculture, gender, sustainable development	Gendered impacts of climate-smart agriculture in climate adaptation and mitigation

4. Content Analysis

In this study, we focused on analyzing bibliometric data on poverty, inequality, food security, and climate change in Africa during the period 2000–2022. Based on the descriptive analysis and bibliometric coupling, as well as the co-occurrence of keywords, the study identified the following seven themes.

Theme one: the impact of governance and policy on poverty alleviation, nutrition status, and food security

The dimensions of food security, such as availability, accessibility, and affordability, as well as nutritional outcomes, are influenced by the food and governance policies drawn up and implemented in a country [26]. The strength of governance influences the levels of food prices and food utilization and, hence, affects the extent of inclusion [27].

Food insecurity is one of the main challenges faced by developing countries and it impedes the attainment of the Sustainable Development Goals that aim to attain zero hunger. It requires holistic, multi-sector participation from the government, the private sector, policy institutes, and academia. Governance is not the sole mandate of the government and all sectors need to contribute to develop tools for the assessment and evaluation of the quality of governance and institutions [28]. These tools include trade regulations, storage reserves, and statutory set transfers of cash to the marginalized.

Theme two: the role of innovation and sustainable agriculture in mitigating climate change in developing countries

The studies under this theme sought to establish whether there is a relationship between sustainable agricultural practices, innovation efficiency, and the levels of greenhouse emissions produced. Technological innovation can be used to improve efficiencies for agriculture, thus reducing environmental externalities [29]. An example of an innovation in agriculture is incubators, which can play a significant role in the development of mitigation and adaptation capabilities within the agricultural sector. Development of new incubators needs to be expedited and existing incubation activities must be revived and located within agricultural clusters in African countries [30]. Innovation activities, such as improving seed diversity, could assist farmers in coping with the effects of climate change, reduce yield losses, and improve income and food security [31]. The introduction of technology to smallholders requires a participatory process, as the authors of [32] stated that active participation from and inclusion of farmers can ensure that innovation is relevant to the local context. Another study [1] highlighted that soil nutrient depletion jeopardizes food security for smallholder farmers and their families, leading to poverty. The authors investigated how nutrient flows can be optimized to improve yields for smallholder banana–coffee-based farming systems. Their study revealed that nutrient balances can be achieved alongside the implementation of sustainable land management practices.

Theme three: integrating gender in evaluations of the impact of climate change on food security and livelihoods in Africa

Differences in socio-economic status between men and women imply that there are differences in adaptive capacities [33–35]. This implies the need for a closer look into the gender dimensions of climate shock management. The question is whether the losses and damages due to climate impacts affect women and men in the same way. Is there a differential in gender vulnerabilities to climate? What are the appropriate gender-responsive measures and tools to reduce the burden of vulnerability on women? The research paper [36] investigated the extent of gender integration in agricultural policies in Uganda and Tanzania and whether budgets were allocated for the inclusion of gender at lower levels of governance. The authors concluded that there were signs of gender responsiveness in both countries, as well as at different levels of governance. Another study [37] investigated the extent to which gender-sensitive index insurance had been scaled out amongst smallholders in South Africa. The authors concluded that there is a lack of data on agricultural insurance with a gender dimension; hence, it is difficult to address the challenges and barriers of scaling out index insurance for risk management in agriculture. The authors of [38] explained that gender differences imply that there are gender-specific adaptation responses to climate change. A highlight of their study was the finding that, whilst males adapt to climate change through migration and seeking employment in other parts of the country, females, on the other hand, adapt by engaging in off-farm jobs, such as basketry. The authors also pointed out that access to credit facilities, extension services, and perceived losses affect the different adaptation strategies chosen by males and females.

Theme four: climate change adaptation among smallholders in building resilience for nutrition

The extent of the inter-connection between climate change, nutrition, and agriculture was demonstrated in several studies [39–41]. Authors asserted that there are three pathways through which climate change affects nutritional outcomes: the food security levels of the household, practices of feeding and caring for children, and access to health services and environmental health. The authors asserted that climate change exacerbates the existing challenges of food insecurity and nutritional deficiencies. Furthermore, the authors of [42,43] stated that climate resilience and strategies aimed at improving nutritional outcomes are negatively affected by malnutrition. Another study [44] investigated the impact of climate change on oil palm production. Their study revealed that oil palm smallholder farmers make significant contributions to food security and that rising temperatures lead to yield losses. Another pertinent question that needs to be addressed is how climate change affects the food supply chains that ensure that nutrition moves from the farm to the end consumer. Different elements of the food supply chain are negatively affected by climate change, hence affecting nutritional outcomes [45].

Theme five: the role of institutions in assisting smallholders mitigate and adapt to climate shocks

Smallholders constitute a large component of farm producers in developing countries and they face the effects of climate shocks and, consequently, increased levels of vulnerability to poverty. The question is whether they receive optimal institutional support in mitigating and adapting to climate change [14]. National policies do not always include climate change adaptation measures and their interrelation with food security. In the same vein, the authors of [46] argued that part of the challenge is the incoherency that exists in both the legislature and main policies that attempt to inculcate climate change adaptation, food security, and disaster risk reduction measures. Furthermore, the author of [47] attempted to investigate whether national policy in the Southern African Development Community (SADC) is shaped and influenced by risk containment strategies for food security. The author concluded that, although the SADC has strategic mechanisms for climate change mitigation and adaptation, the most crucial part that remains to be addressed is the implementation of such measures.

Theme six: inequality, food unavailability, and agricultural production

Population growth and income inequality continue to be the main challenges at the forefront of the economic policies of many African countries. These two phenomena aggravate food insecurity, malnutrition, and undernutrition. The puzzling fact is that there remains a dearth of research on the linkages between inequality, food security, and climate change. Without consideration of climate change impacts, the authors of [48,49] showed that inequality and population growth lead to increased levels of hunger. As such, policies that are aimed at reducing inequality and improving food security and nutritional outcomes are a social and economic imperative. A report [50] highlighted that differences in socio-economic power affect nutritional outcomes; that is, people with lower socio-economic status, especially rural dwellers, are likely to be affected the most by food insecurity and malnutrition. Ethnic minorities, women, and girls are some of the victims of social inequality, which reduces their access to and capacity to afford basic social services and nutrition. As a result, these marginalized groups experience the largest burden of hunger and malnutrition. Women and girls constitute 60% of those disproportionately affected by hunger.

Theme seven: gendered impacts of climate-smart agriculture in climate adaptation and mitigation

Climate-smart agriculture is defined as agricultural practices and methods that increase the productivity and income of farmers, build the resilience of farmers in adapting to climate changes, and reduce greenhouse gases [51]. The report highlighted that, whilst farming produces greenhouse gases that lead to climate change, it also suffers from the climate change shocks. Therefore, climate-smart agriculture offers a promising solution by cushioning farmers against the shocks of climate change while reducing the environmental externalities of farming activities by improving techniques and practices used by farmers. Amongst the many challenges of implementing climate-smart agriculture is the lack of understanding of the gender dimension in climate mitigation and adaptation. One study [52] highlighted the importance of not avoiding the gender and social differences in climate change. With the same frame of mind, the authors of [53] argued that implementations and information relays regarding climate change should be cognizant of gender and social differences. It is thus important to use the gender lens to address the differences in access to land, the access and affordability of agricultural technology, access to agricultural education, and the roles of men and women in societal structures. These points may affect the productivity gap between genders in the agricultural sector, especially in developing countries. With the same frame of mind, the authors of [38] stated that women are the most susceptible group to climate change shocks. Consequently, gender mainstreaming in development plans and policies is required in order to deal with climate change impacts [36].

Gap Analysis and Future Research

This bibliometric cum systematic review has shown that, although there has been increasing research output in the field of climate change, food security, and inequality in African countries, some research gaps still remain as illustrated by Table 8. We investigated the main themes (themes one to seven) discussed in the content analysis section and suggest the following research directions.

Table 8. Themes, gap analysis and future research directions.

Theme	Gap Analysis and Future Research
Theme one: the impact of governance and policy on poverty alleviation, nutrition status, and food security	Government institutions should spearhead policy frameworks that create a "climate for food and nutrition security". Such policies need to be inclusive of other key stakeholders, such as the private sector, academia, policymakers, and traditional leadership structuresThe political will of governments and leaders in African countries is necessary to implement climate-resilient initiatives that are sensitive to food security and nutrition outcomes
Theme two: the role of innovation and sustainable agriculture in mitigating climate change in developing countries	The agriculture development agenda in Sub-Saharan Africa is increasingly influenced by advances in technology; e.g., adoption of genetically modified crops. Regrettably, technology is limited for smallholders. Smallholders make up approximately 80% of all farms and produce most of what the region needs [54].Studies should focus on technological uptake by smallholders
Theme three: integrating gender in evaluations of the impact of climate change on food security and livelihoods in Africa	Recent research has revealed that climate change has notable gendered effects, but research fails to incorporate gender mainstreaming. This implies that the susceptible groups, including women, are left out. Research in this area should make a concerted effort to incorporate gender mainstreaming in climate policy, as well as effects of policy focused specifically on women's empowerment
Theme four: climate change adaptation among smallholders in building resilience for nutrition	Emerging research has revealed that smallholders bear the brunt of climate change, especially in terms of keeping up with food supply chain demands. As the main suppliers for food and nutritional needs in Africa, climate change effects should be explicitly considered when developing policies that build the resilience of smallholders
Theme five: the role of institutions in assisting smallholders mitigate and adapt to climate shocks	There is an eminent need for collaboration between climate experts, economists, and health care workers in drafting climate change adaptation and mitigation initiatives that are cognizant of food security
Theme six: inequality, food unavailability, and agricultural production	Climate change has significant differentiated effects on vulnerable groups, but studies in this area do not implicitly make a distinction. Implicitly modeling the differential effects would close this gap and guide policies to address inequality and the most affected members of the community. For example, rural and urban dwellers are affected differently, and the degree to which smallholders and large-scale producers face the brunt of climate change varies
Theme seven: gendered impacts of climate-smart agriculture in climate adaptation and mitigation	It has been documented that women have limited access to finance, technological training, and land, which affects their participation in climate-smart agriculture. Future research must endeavor to explore the gender productivity gap in agriculture. Research needs to aim at understanding the effects of the gender productivity gap on food security and nutritional outcomes

5. Conclusions and Recommendations

The main aim of this study was to explore the literature on the interconnections between climate change, inequality, poverty, and food security in African countries. The study investigated the trends for publications in the field, the key research interests based on frequently co-occurring keywords, the emerging themes in the literature, and, finally, the gaps and policy recommendations. To accomplish this aim, the study adopted a combination of bibliometric analysis and content analysis. In the first step the bibliometric analysis identified the prolific scholars, the top journals by citation number, the most influential institutions and countries, and the trends for publications for each year. The second step involved a content analysis, which resulted in the emergence of key themes and gaps.

This study revealed an increase in publications on the interconnections between climate change, inequality, poverty, and food security. Moreover, the study results indicated that Kenya was the knowledge center of the field, and African countries were well-represented among the top ten most productive countries. Furthermore, the most cited articles and authors were found to be primarily focused on climate change mitigation and adaptation. The data also revealed that *Comprehensive Reviews in Food Science* and *Food Safety* had the highest impact factors and citations per paper, while *PLoS ONE* had the lowest impact factors and citations per paper. The findings of this study provide insights into the current state of research on the impacts of climate change on food security, poverty, and inequality in Africa and suggest areas for future research to address the challenges in this field. Seven keyword clusters were determined and seven themes emerged from the keyword clusters: (1) the impact of governance and policy on poverty alleviation, nutrition status, and food security; (2) the role of innovation and sustainable agriculture in mitigating climate change in developing countries; (3) integrating gender in evaluations of the impact of climate change on food security and livelihoods in Africa; (4) climate change adaptation among smallholders in building resilience for nutrition; (5) the role of institutions in assisting smallholders mitigate and adapt to climate shocks; (6) inequality, food unavailability, and agricultural production; (7) gendered impacts of climate-smart agriculture in climate adaptation and mitigation.

Based on the findings of the study, the following recommendations can be made to address the impacts of climate change on food security, poverty, and inequality in Africa:

1. Increase research funding: Governments and funding organizations should prioritize research on the impacts of climate change on food security, poverty, and inequality in Africa. A significant amount of funding should be allocated to these efforts;
2. Encourage interdisciplinary collaboration: Collaboration between researchers from different disciplines can help address climate change's complex challenges for food security, poverty, and inequality in Africa. Collaboration between economists, health experts, climate experts, and policy analysts needs to be coordinated in order to deliver national and local policies that are sensitive to climate change, food security, and nutrition outcomes;
3. Focus on African institutions: Research efforts should be centered on African institutions to guarantee they are culturally relevant and contextually appropriate;
4. Foster knowledge sharing: Increased knowledge sharing among researchers, policymakers, and practitioners is pivotal to make sure that the latest research findings are put into practice to mitigate the impacts of climate change on food security, poverty, and inequality in Africa;
5. Promote innovative solutions: Research should focus on developing innovative solutions to address the impacts of climate change on food security, poverty, and inequality in Africa and explore new technologies, policies, and practices. For example, there is a need for policies that support and promote the use of novel agricultural practices that are locally relevant and technological improvements aimed at both efficiency gains and sustainable resource use. The administration of agricultural innovation hubs for sustainable land management and plowing practices needs to be expedited. Another example is the development of seeds and nutrient flows, which would improve productivity and yields;
6. Raise public awareness: The general public needs to be aware of climate change's impacts on food security, poverty, and inequality in Africa. This will help mobilize support for efforts to tackle these challenges;
7. Longitudinal studies: There is a dearth of research at the intersection of climate change, food security, and inequality in African countries and on all the seven themes

discussed. There is rising interest in the roles of institutions, climate-smart agriculture, and gender integration in improving food security and nutritional outcomes. Therefore, longitudinal studies would help explore the seven themes;

8. Reduction in income inequality: The formulation of policies aimed at reducing socio-economic inequalities and fostering the inclusion of women and marginalized groups needs to be expedited; for example, cash transfers, labor market participation, land ownership, and access to finance.

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Appendix A

Table A1. Complete list of the articles used in the bibliometric analysis.

Article No.	Authors	Title	Journal	Year
[1]	Zomer R.J., Trabucco A., Bossio D.A., Verchot L.V.	Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation	Agriculture, Ecosystems and Environment	2008
[2]	Zembe A., Nemakonde L.D., Chipangura P.	Policy coherence between food security, disaster risk reduction and climate change adaptation in South Africa: A summative content analysis approach	Jamba: Journal of Disaster Risk Studies	2022
[15]	Wouterse F., Andrijevic M., Schaeffer M.	The microeconomics of adaptation: Evidence from smallholders in Ethiopia and Niger	World Development	2022
[22]	Wossen T., Berger T.	Climate variability, food security and poverty: Agent-based assessment of policy options for farm households in Northern Ghana	Environmental Science and Policy	2015
[23]	Wanyama J., Banadda N., Kiyimba F., Okurut S., Zziwa A., Kabenge I., Mutumba C., Tumutegyereize P., Komakech A.J., Kiggundu N.	Profiling agricultural engineering technologies for mechanizing smallholder agriculture in Uganda	Agricultural Engineering International: CIGR Journal	2016
[24]	Venter S.L., Fouché H.J., De Wit M., Mavengahama S., Coetzer G.M., Swart W.J., Amonsou E.O.	The effect of fostering partnerships on broadening the food base: The role of cactus pear, an under-utilised crop with unlimited potential—the South African perspective	Acta Horticulturae	2019

Table A1. *Cont.*

Article No.	Authors	Title	Journal	Year
[25]	Varis O., Abu-Zeid K.	Socio-Economic and environmental aspects of water management in the 21st century: Trends, challenges and prospects for the MENA region	International Journal of Water Resources Development	2009
[30]	van Wesenbeeck C.F.A., Sonneveld B.G.J.S., Voortman R.L.	Localization and characterization of populations vulnerable to climate change: Two case studies in Sub-Saharan Africa	Applied Geography	2016
[31]	Van Maanen N., Andrijevic M., Lejeune Q., Rosa L., Lissner T., Schleussner C.-F.	Accounting for socioeconomic constraints in sustainable irrigation expansion assessments	Environmental Research Letters	2022
[32]	Valente de Macedo L.S., Barda Picavet M.E., Puppim de Oliveira J.A., Shih W.-Y.	Urban green and blue infrastructure: A critical analysis of research on developing countries	Journal of Cleaner Production	2021
[33]	Tshishonga N.	Women growing livelihoods through food security: Inanda's Inqolobane Yobumbano Secondary Co-operative	Agenda	2016
[34]	Tirivangasi H.M.	Regional disaster risk management strategies for food security: Probing Southern African Development Community channels for influencing national policy	Jamba: Journal of Disaster Risk Studies	2018
[35]	Tirado M.C., Hunnes D., Cohen M.J., Lartey A.	Climate Change and Nutrition in Africa	Journal of Hunger and Environmental Nutrition	2015
[37]	Thornton P.K., Jones P.G., Alagarswamy G., Andresen J., Herrero M.	Adapting to climate change: Agricultural system and household impacts in East Africa	Agricultural Systems	2010
[38]	Thornton P.K., Jones P.G., Alagarswamy G., Andresen J.	Spatial variation of crop yield response to climate change in East Africa	Global Environmental Change	2009
[43]	Thiele G., Khan A., Heider B., Kroschel J., Harahagazwe D., Andrade M., Bonierbale M., Friedmann M., Gemenet D., Cherinet M., Quiroz R., Faye E., Dangles O.	Roots, Tubers and Bananas: Planning and research for climate resilience	Open Agriculture	2017
[44]	Singh P.	India's Evergreen Revolution	Future of Food: Journal on Food, Agriculture and Society	2017
[46]	Simatele D., Binns T., Simatele M.	Sustaining livelihoods under a changing climate: The case of urban agriculture in Lusaka, Zambia	Journal of Environmental Planning and Management	2012

Table A1. *Cont.*

Article No.	Authors	Title	Journal	Year
[47]	Sibiko K.W., Qaim M.	Weather index insurance, agricultural input use, and crop productivity in Kenya	Food Security	2020
[55]	Shine T., Dunford B.	What value for pastoral livelihoods? An economic valuation of development alternatives for ephemeral wetlands in eastern Mauritania	Pastoralism	2016
[56]	Shikuku K.M., Valdivia R.O., Paul B.K., Mwongera C., Winowiecki L., Läderach P., Herrero M., Silvestri S.	Prioritizing climate-smart livestock technologies in rural Tanzania: A minimum data approach	Agricultural Systems	2017
[57]	Shackleton S.E., Shackleton C.M.	Linking poverty, HIV/AIDS and climate change to human and ecosystem vulnerability in southern Africa: Consequences for livelihoods and sustainable ecosystem management	International Journal of Sustainable Development and World Ecology	2012
[58]	Shackleton C.M., Scholes B.J., Vogel C., Wynberg R., Abrahamse T., Shackleton S.E., Ellery F., Gambiza J.	The next decade of environmental science in South Africa: A horizon scan	South African Geographical Journal	2011
[59]	Sell M., Vihinen H., Gabiso G., Lindström K.	Innovation platforms: a tool to enhance small-scale farmer potential through co-creation	Development in Practice	2018
[60]	Seaman J.A., Sawdon G.E., Acidri J., Petty C.	The household economy approach. managing the impact of climate change on poverty and food security in developing countries	Climate Risk Management	2014
[61]	Schuenemann F., Thurlow J., Meyer S., Robertson R., Rodrigues J.	Evaluating irrigation investments in Malawi: economy-wide impacts under uncertainty and labor constraints	Agricultural Economics (UK)	2018
[62]	Satgar V., Cherry J.	Climate and food inequality: the South African Food Sovereignty Campaign response	Globalizations	2020
[63]	Sandstrom S., Juhola S.	Continue to blame it on the rain? Conceptualization of drought and failure of food systems in the Greater Horn of Africa	Environmental Hazards	2017
[64]	Sanchez P.A.	Linking climate change research with food security and poverty reduction in the tropics	Agriculture, Ecosystems and Environment	2000
[65]	Sanchez A.C., Osborne P.E., Haq N.	Identifying the global potential for baobab tree cultivation using ecological niche modelling	Agroforestry Systems	2010

Table A1. *Cont.*

Article No.	Authors	Title	Journal	Year
[66]	Saleh A.S.M., Zhang Q., Chen J., Shen Q.	Millet grains: Nutritional quality, processing, and potential health benefits	Comprehensive Reviews in Food Science and Food Safety	2013
[67]	Rufino M.C., Thornton P.K., Ng'ang'a S.K., Mutie I., Jones P.G., van Wijk M.T., Herrero M.	Transitions in agro-pastoralist systems of East Africa: Impacts on food security and poverty	Agriculture, Ecosystems and Environment	2013
[68]	Reetsch A., Schwärzel K., Dornack C., Stephene S., Feger K.-H.	Optimising nutrient cycles to improve food security in smallholder farming families—a case study from banana-coffee-based farming in the Kagera Region, NW Tanzania	Sustainability (Switzerland)	2020
[69]	Quarshie P.T.	Exploring the concept of place in the literature on smallholder farmers and climate change adaptation in Sub-Saharan Africa	South African Geographical Journal	2022
[70]	Ozturk I.	The dynamic relationship between agricultural sustainability and food-energy-water poverty in a panel of selected Sub-Saharan African Countries	Energy Policy	2017
[71]	Ozor N.	The role of agribusiness innovation incubation for Africa's development	African Journal of Science, Technology, Innovation and Development	2013
[72]	Otieno G., Ogola R.J.O., Recha T., Mohammed J.N., Fadda C.	Climate Change and Seed System Interventions Impact on Food Security and Incomes in East Africa	Sustainability (Switzerland)	2022
[73]	Osbahr H., Twyman C., Neil Adger W., Thomas D.S.G.	Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique	Geoforum	2008
[74]	Onyutha C.	African food insecurity in a changing climate: The roles of science and policy	Food and Energy Security	2019
[75]	Ogbolumani O.A., Nwulu N.I.	Multi-objective optimisation of constrained food-energy -water-nexus systems for sustainable resource allocation	Sustainable Energy Technologies and Assessments	2021
[76]	Oduniyi O.S., Chagwiza C., Wade T.	Welfare impacts of conservation agriculture adoption on smallholder maize farmers in South Africa	Renewable Agriculture and Food Systems	2022
[77]	Nuwamanya E., Chiwona-Karltun L., Kawuki R.S., Baguma Y.	Bio-ethanol production from non-food parts of cassava (Manihot esculenta Crantz)	Ambio	2012

Table A1. *Cont.*

Article No.	Authors	Title	Journal	Year
[78]	Niles M.T., Emery B.F., Wiltshire S., Brown M.E., Fisher B., Ricketts T.H.	Climate impacts associated with reduced diet diversity in children across nineteen countries	Environmental Research Letters	2021
[79]	Nicolay G.L.	Understanding and changing farming, food and fiber systems. the organic cotton case in Mali and West Africa	Open Agriculture	2019
[80]	Ngigi P.B., Mouquet-Rivier C., Amiot M.-J., Termote C., Pallet D.	Increasing pulse agrobiodiversity to improve food security and sustainable agriculture in Sub-Saharan Africa	Frontiers in Sustainable Food Systems	2022
[81]	Newman R.J.S., Marchant R., Enns C., Capitani C.	Assessing the impacts of land use and climate interactions on beekeeping livelihoods in the Taita Hills, Kenya	Development in Practice	2021
[82]	Nchanji E.B., Lutomia C.K., Chirwa R., Templer N., Rubyogo J.C., Onyango P.	Immediate impacts of COVID-19 pandemic on bean value chain in selected countries in sub-Saharan Africa	Agricultural Systems	2021
[83]	Naughton C.C., Deubel T.F., Mihelcic J.R.	Household food security, economic empowerment, and the social capital of women's shea butter production in Mali	Food Security	2017
[84]	Mwangi B., Macharia I., Bett E.	A multi-dimensional adoption approach for improved sorghum varieties in eastern Kenya: a climate change adaptation perspective	Climate and Development	2021
[85]	Murungweni C., Andersson J.A., van Wijk M.T., Gwitira I., Giller K.E.	Zhombwe (Neorautanenia brachypus (Harms) C.A.Sm.)—A recent discovery for mitigating effects of drought on livestock in semi-arid areas of Southern Africa	Ethnobotany Research and Applications	2012
[86]	Munishi L.K., Lema A.A., Ndakidemi P.A.	Decline in maize and beans production in the face of climate change at Hai District in Kilimanjaro region, Tanzania	International Journal of Climate Change Strategies and Management	2015
[87]	Mulazzani L., Manrique R., Stancu C., Malorgio G.	Food security and migration in Africa: A validation of theoretical links using case studies from literature	New Medit	2020
[88]	Mukuve F.M., Fenner R.A.	The influence of water, land, energy and soil-nutrient resource interactions on the food system in Uganda	Food Policy	2015

Table A1. *Cont.*

Article No.	Authors	Title	Journal	Year
[89]	Mugambiwa S.S., Tirivangasi H.M.	Climate change: A threat towards achieving 'sustainable development goal number two' (end hunger, achieve food security and improved nutrition and promote sustainable agriculture) in South Africa	Jamba: Journal of Disaster Risk Studies	2017
[90]	Mthembu N.N., Zwane E.M.	The adaptive capacity of smallholder mixed-farming systems to the impact of climate change: The case of KwaZulu-Natal in South Africa	Jamba: Journal of Disaster Risk Studies	2017
[91]	Mpandeli S., Nhamo L., Hlahla S., Naidoo D., Liphadzi S., Modi A.T., Mabhaudhi T.	Migration under climate change in Southern Africa: A nexus planning perspective	Sustainability (Switzerland)	2020
[92]	Mosha A.C.	Impact of climate change on food security in Africa	Regional Development Dialogue	2012
[93]	Milder J.C., Hart A.K., Dobie P., Minai J., Zaleski C.	Integrated Landscape Initiatives for African Agriculture, Development, and Conservation: A Region-Wide Assessment	World Development	2014
[94]	Midega C.A.O., Bruce T.J.A., Pickett J.A., Pittchar J.O., Murage A., Khan Z.R.	Climate-adapted companion cropping increases agricultural productivity in East Africa	Field Crops Research	2015
[95]	Meyiwa T., Maseti T., Ngubane S., Letsekha T., Rozani C.	Women in selected rural municipalities: Resilience and agency against vulnerabilities to climate change	Agenda	2014
[96]	Mensah M., Vlek P.L.G., Fosu-Mensah B.Y.	Gender and climate change linkages in the semi-arid region of Ghana	GeoJournal	2022
[97]	McIntire J.M.	Transforming African Agriculture	Global Journal of Emerging Market Economies	2014
[98]	Mazenda A., Manzi P., Mushayanyama T., Ngarava S.	Household level determinants of food security in the City of Tshwane, South Africa	Food Research	2022
[99]	March A., Failler P.	Small-scale fisheries development in Africa: Lessons learned and best practices for enhancing food security and livelihoods	Marine Policy	2022
[100]	Mango N., Makate C., Mapemba L., Sopo M.	The role of crop diversification in improving household food security in central Malawi	Agriculture and Food Security	2018

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Article No.	Authors	Title	Journal	Year
[101]	Mabhaudhi T., Nhamo L., Chibarabada T.P., Mabaya G., Mpandeli S., Liphadzi S., Senzanje A., Naidoo D., Modi A.T., Chivenge P.P.	Assessing progress towards sustainable development goals through nexus planning	Water (Switzerland)	2021
[102]	Lwasa S., Mugagga F., Wahab B., Simon D., Connors J., Griffith C.	Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate change mitigation and adaptation	Urban Climate	2014
[103]	Lubaale G.	Improving urban planning for poverty reduction and climate change: Lessons from Mombasa, Kenya	Regional Development Dialogue	2011
[104]	Luan Y., Fischer G., Wada Y., Sun L., Shi P.	Quantifying the impact of diet quality on hunger and undernutrition	Journal of Cleaner Production	2018
[105]	Li Q., Samimi C.	Sub-Saharan Africa's international migration constrains its sustainable development under climate change	Sustainability Science	2022
[106]	Leroy G., Boettcher P., Besbes B., Peña C.R., Jaffrezic F., Baumung R.	Food securers or invasive aliens? Trends and consequences of non-native livestock introgression in developing countries	Global Food Security	2020
[107]	Legwegoh A.F., Fraser E.D.G.	Food Crisis or Chronic Poverty: Metanarratives of Food Insecurity in Sub-Saharan Africa	Journal of Hunger and Environmental Nutrition	2015
[108]	Lee J., Ingalls M., Erickson J.D., Wollenberg E.	Bridging organizations in agricultural carbon markets and poverty alleviation: An analysis of pro-Poor carbon market projects in East Africa	Global Environmental Change	2016
[109]	Leal Filho W., Taddese H., Balehegn M., Nzengya D., Debela N., Abayineh A., Mworozi E., Osei S., Ayal D.Y., Nagy G.J., Yannick N., Kimu S., Balogun A.-L., Alemu E.A., Li C., Sidsaph H., Wolf F.	Introducing experiences from African pastoralist communities to cope with climate change risks, hazards and extremes: Fostering poverty reduction	International Journal of Disaster Risk Reduction	2020
[110]	Leakey R.R.B., Tientcheu Avana M., Awazi N.P., Assogbadjo A.E., Mabhaudhi T., Hendre P.S., Degrande A., Hlahla S., Manda L.	The Future of Food: Domestication and Commercialization of Indigenous Food Crops in Africa over the Third Decade (2012–2021)	Sustainability (Switzerland)	2022

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Article No.	Authors	Title	Journal	Year
[111]	Lawlor K., Handa S., Seidenfeld D., THE ZAMBIA CASH TRANSFER EVALUATION TEAM	Cash Transfers Enable Households to Cope with Agricultural Production and Price Shocks: Evidence from Zambia	Journal of Development Studies	2019
[112]	Lana M.A., Vasconcelos A.C.F., Gornott C., Schaffert A., Bonatti M., Volk J., Graef F., Kersebaum K.C., Sieber S.	Is dry soil planting an adaptation strategy for maize cultivation in semi-arid Tanzania?	Food Security	2018
[113]	Lalou R., Sultan B., Muller B., Ndonky A.	Does climate opportunity facilitate smallholder farmers' adaptive capacity in the Sahel?	Palgrave Communications	2019
[114]	Lal R.	Promoting "4 Per Thousand" and "Adapting African Agriculture" by south-south cooperation: Conservation agriculture and sustainable intensification	Soil and Tillage Research	2019
[115]	Kovaleva M., Leal Filho W., Borgemeister C., Kalungu J.W.	Understanding Needs and Potentials for Gender-Balanced Empowerment and Leadership in Climate Change Adaptation and Mitigation in Africa	Sustainability (Switzerland)	2022
[116]	Kastl R.A., Liagre L.	Adapting forest policy framework conditions to climate change in the Middle East-North Africa region: A GIZ regional project	Unasylva	2014
[117]	Karki S., Burton P., Mackey B., Alston-Knox C.	Status and drivers of food insecurity and adaptation responses under a changing climate among smallholder farmers households in Bagmati Province, Nepal	Environment, Development and Sustainability	2021
[118]	Kadigi I.L., Mutabazi K.D., Philip D., Richardson J.W., Bizimana J.-C., Mbungu W., Mahoo H.F., Sieber S.	An economic comparison between alternative rice farming systems in Tanzania using a monte carlo simulation approach	Sustainability (Switzerland)	2020
[119]	Jones P.G., Thornton P.K.	Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change	Environmental Science and Policy	2009
[120]	Jerneck A., Olsson L.	Food first! Theorising assets and actors in agroforestry: Risk evaders, opportunity seekers and 'the food imperative' in sub-Saharan Africa	International Journal of Agricultural Sustainability	2014
[121]	Holden S., Shiferaw B., Pender J.	Policy analysis for sustainable land management and food security in Ethiopia: A bioeconomic model with market imperfections	Research Report of the International Food Policy Research Institute	2005

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Article No.	Authors	Title	Journal	Year
[122]	Hertel T.W., Burke M.B., Lobell D.B.	The poverty implications of climate-induced crop yield changes by 2030	Global Environmental Change	2010
[123]	Hartter J., Stampone M.D., Ryan S.J., Kirner K., Chapman C.A., Goldman A.	Patterns and perceptions of climate change in a biodiversity conservation hotspot	PLoS ONE	2012
[124]	Hammond J., Fraval S., van Etten J., Suchini J.G., Mercado L., Pagella T., Frelat R., Lannerstad M., Douxchamps S., Teufel N., Valbuena D., van Wijk M.T.	The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform climate smart agriculture interventions: Description and applications in East Africa and Central America	Agricultural Systems	2017
[125]	Glazebrook T., Opoku E.	Gender and sustainability: Learning from women's farming in Africa	Sustainability (Switzerland)	2020
[126]	Glazebrook T., Noll S., Opoku E.	Gender matters: Climate change, gender bias, and women's farming in the global south and north	Agriculture (Switzerland)	2020
[127]	Garrity D.P., Akinnifesi F.K., Ajayi O.C., Weldesemayat S.G., Mowo J.G., Kalinganire A., Larwanou M., Bayala J.	Evergreen Agriculture: A robust approach to sustainable food security in Africa	Food Security	2010
[128]	Galizzi G.	Demographic explosion in Sub-Saharan Africa, subsistence agriculture and the problem of migrants	Rivista Internazionale di Scienze Sociali	2017
[129]	Fisher E., Hellin J., Greatrex H., Jensen N.	Index insurance and climate risk management: Addressing social equity	Development Policy Review	2019
[130]	Exenberger A., Pondorfer A.	Genocidal risk and climate change: Africa in the twenty-first century	International Journal of Human Rights	2014
[131]	Estrada A., Garber P.A., Chaudhary A.	Current and future trends in socio-economic, demographic and governance factors affecting global primate conservation	PeerJ	2020
[132]	Eriksen S.H., Cramer L.K., Vetrhus I., Thornton P.	Can Climate Interventions Open Up Space for Transformation? Examining the Case of Climate-Smart Agriculture (CSA) in Uganda	Frontiers in Sustainable Food Systems	2019
[133]	Enwereji P.C.	Impact of Climate Change on Food Security and Water Supply in South Africa: Reports from Local Authorities	African Renaissance	2021

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Article No.	Authors	Title	Journal	Year
[134]	Ebhuoma E., Simatele D.	Defying the odds: Climate variability, asset adaptation and food security nexus in the Delta State of Nigeria	International Journal of Disaster Risk Reduction	2017
[135]	Dovie D.B.K., Lwasa S.	Correlating negotiation hotspot issues, Paris climate agreement and the international climate policy regime	Environmental Science and Policy	2017
[136]	Dossou-Aminon I., Dansi A., Ahissou H., Cissé N., Vodouhè R., Sanni A.	Climate variability and status of the production and diversity of sorghum (Sorghum bicolor (L.) Moench) in the arid zone of northwest Benin	Genetic Resources and Crop Evolution	2016
[137]	Deng H.-M., Liang Q.-M., Liu L.-J., Anadon L.D.	Co-benefits of greenhouse gas mitigation: A review and classification by type, mitigation sector, and geography	Environmental Research Letters	2017
[138]	De Pauw E., Ramasamy S.	Rapid detection of stressed agricultural environments in Africa under climatic change 2000–2050 using agricultural resource indices and a hotspot mapping approach	Weather and Climate Extremes	2020
[139]	Dar W.D., Laxmipathi Gowda C.L.	Declining Agricultural Productivity and Global Food Security	Journal of Crop Improvement	2013
[140]	Cumming T.L., Shackleton R.T., Förster J., Dini J., Khan A., Gumula M., Kubiszewski I.	Achieving the national development agenda and the Sustainable Development Goals (SDGs) through investment in ecological infrastructure: A case study of South Africa	Ecosystem Services	2017
[141]	Chilunjika A., Gumede N.	Climate Change and Human Security in Sub-Saharan Africa	African Renaissance	2021
[142]	Carmody P., Taylor D.	Globalization, Land Grabbing, and the Present-Day Colonial State in Uganda: Ecolonization and Its Impacts	Journal of Environment and Development	2016
[143]	Cammarano D., Valdivia R.O., Beletse Y.G., Durand W., Crespo O., Tesfuhuney W.A., Jones M.R., Walker S., Mpuisang T.N., Nhemachena C., Ruane A.C., Mutter C., Rosenzweig C., Antle J.	Integrated assessment of climate change impacts on crop productivity and income of commercial maize farms in northeast South Africa	Food Security	2020
[144]	Brown M.E., Carr E.R., Grace K.L., Wiebe K., Funk C.C., Attavanich W., Backlund P., Buja L.	Do markets and trade help or hurt the global food system adapt to climate change?	Food Policy	2017

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Article No.	Authors	Title	Journal	Year
[145]	Bren D'Amour C., Wenz L., Kalkuhl M., Christoph Steckel J., Creutzig F.	Teleconnected food supply shocks	Environmental Research Letters	2016
[146]	Born L., Spillane C., Murray U.	Integrating gender into index-based agricultural insurance: a focus on South Africa	Development in Practice	2019
[147]	Boon E.K., Oppong-Boateng R., Appiah-Acheampong A., Gyekye N.B.	Irrigated agriculture: A tool for green revolution in Ghana?	International Journal of Global Environmental Issues	2020
[148]	Boluwade A.	Regionalization and partitioning of soil health indicators for Nigeria using spatially contiguous clustering for economic and social-cultural developments	ISPRS International Journal of Geo-Information	2019
[149]	Bhatti M.A., Godfrey S.S., Divon S.A., Aamodt J.T., Øystese S., Wynn P.C., Eik L.O., Fjeld-Solberg Ø.	Micro-Investment by Tanzanian Smallholders' in Drip Irrigation Kits for Vegetable Production to Improve Livelihoods: Lessons Learned and a Way Forward	Agriculture (Switzerland)	2022
[150]	Berg A., De Noblet-Ducoudré N., Sultan B., Lengaigne M., Guimberteau M.	Projections of climate change impacts on potential C4 crop productivity over tropical regions	Agricultural and Forest Meteorology	2013
[151]	Adesina A.A.	Conditioning trends shaping the agricultural and rural landscape in Africa	Agricultural Economics	2010
[152]	Abubakar A., Ishak M.Y.	An Overview of the Role of Smallholders in Oil Palm Production Systems in Changing Climate	Nature Environment and Pollution Technology	2022
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