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Discover Sustainability

Review

Mapping research frontiers in gender and sustainability in agricultural development: a bibliometric review

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Abstract
Gender and sustainability are crucial in agriculture, which remains a significant source of global employment. However, urbanization, industrialization, and technological advancements have reshaped the sector, impacting labor dynamics and gender roles. Traditional agricultural labor faces challenges due to low wages, physically demanding tasks, and unfavorable working conditions. Addressing gender disparities and promoting inclusive work environments is essential for achieving sustainability. According to the ILO (International Labour Office) decent work encompasses productivity and equal employment opportunities for both genders. This study aims to review the literature on gender, sustainability and agricultural development using a bibliometric analysis of Scopus-indexed articles. The findings identify five main research domains: gender dynamics and roles, agriculture and climate change, sustainability and development, human and labor dynamics, and environmental and technological aspects. Additionally, four key scientific communities led the research: Gender studies, agricultural economics, environmental management, and rural sociology. Emerging research trends focus on gender roles in sustainable farming, environmental innovation, and labor governance in agriculture. Spain, the United Kingdom, United States, and Canada lead in knowledge production, contributing significantly to these research domains. This review highlights the importance of interdisciplinary approaches to address the complex issues of gender and sustainability in agriculture. It also specifies a target for expectations research, highlighting that the ILO's definition of appropriate employment can guide efforts to improve gender equity and labor conditions, ultimately supporting sustainable development in the agricultural sector.

Keywords Gender empowerment · Sustainability & development · Agriculture

1 Introduction

Rural areas comprise more than 43% of the world population and 27% of employment worldwide in agriculture. Through urbanization, industrialization and service sector growth, the agricultural workforce has shrunk over the last few decades largely because national structural change pulled many rural workers out of farming. Technological progress has enabled capital to replace labor, decreasing the demand for traditional labor [53]. Consequently, the desirability of agricultural jobs has been drastically reduced by decreased earnings, more laborious work, and longer working hours, making it difficult to maintain and replenish the ranks of agricultural employees.

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Gender inclusivity and sustainability have become critical pillars in the discourse on agricultural development [23]. Historically, the contributions of women in agricultural systems have been underestimated, even though they constitute a significant portion of the workforce in numerous areas. Sustainable farming methods are crucial for mitigating environmental challenges and securing long-term productivity [13, 57]. Addressing gender disparities and promoting sustainability are crucial to achieving equitable and resilient agricultural systems.

In this context, ensuring gender equality and promoting inclusive practices are vital for achieving sustainability in agricultural development. Gender equality in agriculture, as defined by global development frameworks, involves equitable access for women and men to resources, opportunities, and decision-making practices [1, 3]. It emphasizes equal participation in the agricultural workforce, ensuring fair wages, secure working conditions, and access to education and training that fosters personal and professional growth. Moreover, Croppenstedt et al. [11] state that social integration and coherence exist because male and female persons can implement themselves and participate in activities that culminate in actualizing their goals and dreams. It thus provides leadership, innovation and resilience that makes agricultural development sustainable for every person who is non-disabled, male or female. Therefore, this paper urges gendered interventions to transform agriculture systems towards sustainable and equitable development of the rural population.

The diverse and interconnected nature of gender and sustainability in agricultural development necessitates interdisciplinary approaches to address a wide range of related topics effectively. In sync with this view, a rising cluster of papers and special issues in the current years speaks about the complexities and possibilities in this field. For instance, equity in utilization of fertilizers and employment of farm and agri-business ventures and outlets, women and men in soil management regarding sustainable farming and change, effects of change resilience agriculture on social economy and access to land and decision making [51, 63]. Some contributions have been discipline-specific, while others demonstrate a growing interest in combining perspectives to enhance our understanding of the intersections between gender, environmental sustainability, and agricultural development [22, 39].

An inclusive analysis of the scientific literature is essential to map the existing knowledge and identify current research trends. This approach not only serves to benchmark future research but also reveals critical gaps and emerging topics within the field. Recent investigations based on scientific indexed articles show that scientific knowledge related to gender and sustainability in agricultural development is organized into crucial research domains, reflecting a complex network of contributions from diverse disciplines. These domains underscore the global significance of integrating gender equality into sustainable agricultural practices to advance social equity and environmental resilience [42, 71]. Despite the growing recognition of gender's importance in sustainable agricultural practices, the scientific landscape remains fragmented. A review of existing literature is needed to map out the research frontiers in this domain. However, some database discrepancies may cause certain biases in the highlighted research as the share of the enclosed areas and the journals indexed differs. In comparing the two major bibliographic databases, the Web of Science indexes natural and engineering sciences, especially the agricultural sciences, while the Scopus of social sciences [46]. Consequently, we assert that an inquiry utilising the Scopus file could significantly enhance the findings. This study also emphasizes the critical role of integrating gender equity into sustainable agricultural development to align with the United Nations Sustainable Development Goals (SDGs). Specifically, it underscores the relevance of SDG 5 (gender equality) and SDG 2 (zero hunger) in addressing systemic disparities and fostering inclusive policies for sustainable growth in agriculture. For instance, research has shown that gender equality in access to resources and decision-making roles enhances food security and agricultural productivity [2, 48]. By highlighting these connections, the research aims to provide actionable insights for policymakers and stakeholders to align agricultural development with global sustainability targets.

This paper includes the following aims: To assess and analyze the current state of literature available in the field of Gender Diversity in Agricultural Development using scientific articles from the Scopus bibliographical base based on Country, Author, Journals, and Keywords. Based on this literature review and to address the stated objectives, this study will discuss the following research questions:

RQ1: What are the dominant research domains at the intersection of gender and sustainability in agricultural development?

RQ2: Which key scientific communities contribute to this interdisciplinary field, and what are their major focus areas?

RQ3: What emerging research trends can be identified within the literature on gender and sustainability in agricultural development?

RQ4: How can the integration of gender equity contribute to achieving sustainable agricultural practices and aligning with the United Nations Sustainable Development Goals (SDGs)?

The methodology of the bibliometric analysis is described in detail in the next section. Subsequently, we show the appearances and map of the most representative scientific communities worldwide that have conducted the research most significant to the work in agriculture according to the record in Scopus during the last decade.

2 Data selection and review methodology

The bibliometric analysis was done following four steps: The PRISMA directive by [47] explains the methodology of systematically searching papers from bibliographic databases, and the papers were screened out from the database Fig. 1. The first procedure was to find articles in the Scopus bibliographic database to create our base. From this context, the Agrovoc Wordlist was used to identify the key terms even though the scientific standard language was used for the terms 'gender', 'sustainable', and 'agriculture', which were our two central ideas in this study.

The bibliometric analysis was conducted using the SCOPUS/Web of Science database, which provides extensive coverage of interdisciplinary research, particularly in the social sciences, gender studies, and agricultural development.

The keywords of the query were: According to the following search terms, the relevant articles were found: gender AND diversity OR gender and role OR agriculture OR firm AND sustainable OR farming. For this study, the articles included in the search had to have included at least two terms in the article title. However, realizing that the current research on Gender in the dairy sector is vast, the research period was limited to investigations conducted within the last ten years (2012–2023) and in English alone. The article searches produced 2159 hits. As the article's topic indicates, it was in the second step only that these papers so selected were reviewed to delete and exclude the article from our database, which consisted of about 1180 papers, mainly encompassing social issues in rural areas. Finally, 979 articles were selected to build the data, which was comprised of meta-data from the articles: Any author, any journal, any country, any times cited and any keywords as arrow marked in Fig. 1. This was conducted in stage 3, as depicted in Fig. 1 above**.** The bibliometric analysis utilised the criteria established in the Scopus "tool analysis," focussing on the frequency of publications based on the following variables: It will consequently encompass the characteristics of Countries, Journals, Authors, Keywords, and the Most Cited documents. Additionally, a network analysis and a comparison analysis were incorporated into the proposal framework to examine the primary research domains of the journal and the trending issues among the correspondents. The network exploration was conducted via CorTexT, a software incorporating Cortext and VOSeviwer

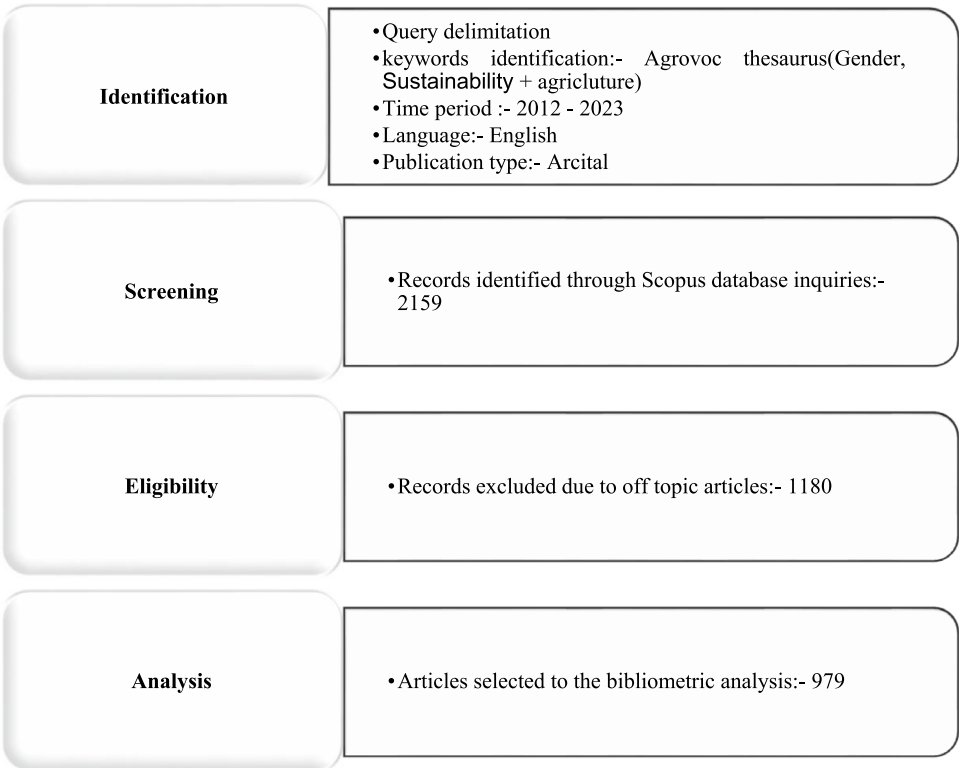

Fig. 1 Flow diagram of the review process

technology. The corresponding relationships between the articles' keywords used during the identification process were as follows. It enabled us to define the main scientifically researched topics concerning gender in the framework of the dairy sector in the Scopus database. Communications were determined based on the frequency of the keywords, and the Louvain algorithm was used to compute the linkages [41]. Data was presented in a network form in which the nodes were the specific keywords and the connections between them. In this representation, nodes are triangles, meaning the higher the keyword frequency, the larger the triangle. Lines join nodes, and citations of the keywords are depicted by the lines where the intensity of the linkage is represented by shade of grey, Liquid. The extent to which two nodes are connected defines the level of the frequency at which nodes are linked; closeness means nodes are linked very often. Those nodes with a high level of connectivity among nodes have coloured circles around them. After that, a cross-over analysis was done to compare the research domains that came out from the Network investigation with the core topics, which were derived from papers that were highly cited and by the authors of the primary papers. It enabled us to identify what is topical in the present international research without it becoming an established trend. Ultimately, the scientific communities were defined by connecting the major publications, references, authors, and relevant affiliation documents pertinent to each research domain.

3 Scientific publication situation: countries, journals, most-cited documents and authors

3.1 Countries

This section may be subdivided into heads. The description must be succinct and accurate, encompassing the experimental data, their interpretation, and the conclusions that can be derived from the experiments. In the 86 recognised countries, industrialised and developing nations have disseminated research about Gender and Sustainability in Agricultural Development over the previous decade. Nevertheless, industrialised nations constituted the majority within the top 15 countries, accounting for 72% of the published publications. The United States is the largest publisher, accounting for 26% of published publications, followed by the United Kingdom at 12%, South Africa at 7.5%, Australia at 7%, China at 6.2%, and India at 6% (Table 1). Subsequently, Kenya, Germany, and Spain were identified as upper-middle publishing nations.

3.2 Journals

This study analyzed 979 articles published in 389 journals, with 29% published in the 15 journals with the highest volume over the past decade (Table 2). These journals were categorized into two main groups: (1) multidisciplinary journals focusing on sustainability and rural development and (2) specialized journals focusing on corporate social responsibility (CSR), environmental management, and land use policy. Sustainability (Switzerland) led 109

Table 1 Top 15 published documents in countries during the previous ten decades

Sl No	Name of Country	Publications
1	United States	196
2	United Kingdom	96
3	South Africa	72
4	Australia	70
5	China	67
6	India	63
7	Kenya	55
8	Germany	54
9	Spain	52
10	Nigeria	44
11	Italy	40
12	Canada	36
13	Ghana	36
14	Netherlands	35
15	Ethiopia	27

Table 2 Top 15 most productive journals with articles published during the last ten years

Sl No	Name of Journal	Number of publications
1	Sustainability Switzerland	109
2	Journal Of Rural Studies	28
3	Corporate Social Responsibility and Environmental Management	26
4	Journal Of Cleaner Production	26
5	Frontiers In Sustainable Food Systems	22
6	Development In Practice	21
7	Land Use Policy	17
8	Business Strategy and The Environment	15
9	International Journal of Environmental Research and Public Health	13
10	African Journal of Food Agriculture Nutrition and Development	12
11	Science of the Total Environment	12
12	World Development	12
13	Food Security	11
14	Journal Of Ethnobiology and Ethnomedicine	11
15	Climate And Development	10

publications, while the Journal of Rural Studies had 28 articles. Other prominent journals include CSR, Environmental Management, and the Journal of Cleaner Production, with 26 publications. Frontiers in Sustainable Food Systems and Development in Practice contributed significantly to sustainable food practices and development policies. Land Use Policy published 17 publications, while Business Strategy and the Environment published 15 papers. The International Journal of Environmental Research and Public Health released 13 papers emphasizing the convergence of environmental research and public health.

3.3 Most cited documents

Four main topics were acknowledged in the 15 highly cited documents connected to gender diversity and sustainability in commercial governance and agriculture over the past ten years: (1) Board Gender Diversity and Corporate Sustainability was the most prominent topic, with two sub-themes: (a) the role of women directors in shaping environmental and sustainability policies, as discussed in Elmagrhi et al. [12] and Fernandez-Feijoo et al. [14], (b) Evaluating the impact of gender diversity on boards on corporate sustainability reporting, explored by Jizi [25] and Setó-Pamies [63]. (2) Gender Dimensions in Agricultural Practices focused on the role of women in sustainable agriculture, with studies like Jost et al. [27] addressing climate change adaptation by women farmers and Ndiritu et al. [53] Examining gender differences in adopting sustainable agricultural practices in Kenya. (3) Corporate Social Responsibility (CSR) and Board Composition highlighted the influence of female board members on CSR practices, with significant contributions from Seto-Pamies [63] and Frias-Aceituno et al. [16]. On the impact of women on CSR strategies in Europe and beyond. (4) Farm Production and Food Security assessed by Jones et al. [26]. Found that the study shows the relationship between Agricultural diversity and household dietary outcomes in Malawi.

Spain has been notably highlighted in the highly cited documents of the last ten years, with several articles authored by scholars from Spanish institutions such as Universidad de Granada and Universidad de Vigo. The high representation of Spanish scholars shows the country's significant contribution to research on gender diversity in corporate governance and sustainability. Three of the 15 articles involved Spanish first authors or co-authors, emphasizing the country's active role in sustainability research (Table 3).

Most highly cited papers were empirical studies employing large datasets and robust statistical methods. These articles were published in multidisciplinary journals covering various topics, from sustainability and environmental management to gender diversity in corporate settings. Journals such as *Corporate Social Responsibility and Environmental Management* and the *Journal of Cleaner Production* played a central role in disseminating this knowledge. Disciplinary journals were primarily focused on business, governance, and environmental studies, providing a broad platform for research at the intersection of gender, sustainability, and corporate performance.

Table 3 Top 15 Cited Articles over the past ten years

Order	Times cited	Authors	Title	Year	Source title	First authors' affiliation	First authors' country	TC per year	Normalized TC	Methodological Approach
										Quantitative (Content Analysis)
1	458	[16]	The role of the board in the dissemination of integrated corporate social reporting	2013	Corporate Social Responsibility and Environmental Management	Universidad De Granada, Granada, Campus de Cartuja	Spain	38.17	9.42	Empirical (Survey Analysis)
2	398	[26]	Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data	2014	Food Policy	University of Michigan, School of Public Health, Ann Arbor, MI	United States	36.18	8.80	Quantitative (Structural Equation Modeling—SEM)
3	354	[10]	Examining green consumerism motivational drivers: Does premium price and demographics matter to green purchasing?	2016	Journal of Cleaner Production	Faculty of Business, Economics and Accountancy, Universiti Malaysia Sabah	Malaysia	39.33	6.05	Mixed-Methods (Panel Data & Qualitative Analysis)
4	349	[12]	A study of environmental policies and regulations, governance structures, and environmental performance: the role of female directors	2019	Business Strategy and the Environment	University of Huddersfield, Huddersfield	United Kingdom	58.17	10.19	Quantitative (Regression Analysis)
5	308	[25]	The Influence of Board Composition on Sustainable Development Disclosure	2017	Business Strategy and the Environment	Lebanese American University, A. Kassar School of Business, Beirut	Lebanon	38.50	7.54	Quantitative (Statistical Analysis)
6	249	[63]	The Relationship between Women Directors and Corporate Social Responsibility	2015	Corporate Social Responsibility and Environmental Management	Department of Business Management, Universitat Rovira i Virgili	Spain	24.90	5.35	Qualitative (Case Study)

Table 3 (continued)

Order	Times cited	Authors	Title	Year	Source title	First authors' affiliation	First authors' country	TC per year	Normalized TC	Methodological Approach Quantitative (Content Analysis)
7	237	[27]	Understanding gender dimensions of agriculture and climate change in smallholder farming communities	2016	Climate and Development	Climate Change, Agriculture and Food Security (CCAFS) of the CGIAR	Denmark	26.33	4.05	Empirical (Panel Data Analysis)
8	226	[20]	The impact of CEO characteristics on corporate sustainable development	2013	Corporate Social Responsibility and Environmental Management	National Chiao Tung University, Hsinchu City	Taiwan	18.83	4.65	Quantitative (Logistic Regression)
9	224	[14]	Women on boards: Do they affect sustainability reporting?	2014	Corporate Social Responsibility and Environmental Management	Department of Finance and Accounting, Universidad de Vigo, Lagoas Marcosende	Spain	20.36	4.95	Empirical (Survey & Field Data)
10	204	[53]	Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya	2014	Food Policy	Strathmore Business School, Madaraka, Nairobi	Kenya	18.55	4.51	Conceptual (Model Development)
11	200	[37]	The Land Administration Domain Model	2015	Land Use Policy	Dutch Cadastre, Land Registry and Mapping Agency, Apeldoorn	Netherlands	20.00	4.30	Quantitative (Panel Data)
12	195	[18]	Do board characteristics affect environmental performance? A study of EU firms	2020	Corporate Social Responsibility and Environmental Management	Faculty of Economics, University of Valencia	Spain	39.00	6.88	Empirical (Regression Analysis)
13	194	[49]	Boardroom gender diversity and corporate sustainability practices: Evidence from Australian Securities Exchange listed firms	2017	Journal of Cleaner Production	Auckland University of Technology, Auckland	New Zealand	24.25	4.75	Qualitative (Ethnographic Study)
14	186	[4]	Rural male suicide in Australia	2012	Social Science and Medicine	Monash University, Melbourne	Australia	14.31	5.27	Quantitative (Panel Data & Regression)

Table 3 (continued)

Order	Times cited	Authors	Title	Year	Source title	First authors' affiliation	First authors' country	TC per year	Normalized TC	Methodological Approach Quantitative (Content Analysis)
15	185	[56]	Corporate social responsibility strategy and corporate environmental and social performance: The moderating role of board gender diversity	2020	Corporate Social Responsibility and Environmental Management	Bang College of Business, KIMEP University, Almaty	Kazakhstan	37.00	6.53	Quantitative (Panel Data & Regression)

3.4 Authors

In this section, 15 most productive authors published about four main topics related to gender and sustainability in agricultural development in the past decade: (1) Food security and climate change—this was the primary topic among American authors, with Nyantakyi-Frimpong H. from the University of Denver being the most productive author, focusing on the intersection of food security, climate change, and farming practices. (2) Health geography and environmental issues in Africa—this was the main topic in Canada, where Luginaah I. from the University of Western Ontario led research in health geography and environmental concerns, particularly in African contexts. (3) Agroecology and sustainable development—this theme was dominant among researchers in the United States and Africa. Key contributors included Bezner Kerr R. from Cornell University, who focused on agroecology and nutrition, and Nchanji Eb. from Cameroon's International Maize and Wheat Improvement Center, whose work emphasized agricultural development and maize farming. (4) Climate-smart agriculture and sustainable agriculture—this was a central topic in Africa, particularly in Zimbabwe and Kenya, with Makate C. from the Africa Center of Excellence for Climate Smart Agriculture and Mugwe Jn. from the Association for Strengthening Agricultural Research in Kenya leading efforts in promoting sustainable farming practices and soil management (Table 4).

These researchers represent a broad range of expertise from institutions in the United States, Canada, Africa, and Europe. Universities such as Cornell University and the University of Texas played a key role in advancing agroecology and social development research. At the same time, institutions like the University of Leeds in the United Kingdom contributed to climate change and environmental science studies. Most highly cited work involved empirical research and interdisciplinary collaboration, addressing critical issues at the nexus of agriculture, sustainability, and gender. The topics covered by these authors reflect the global nature of agricultural challenges and the importance of diverse approaches to solving them.

4 An insight into the international research findings on gender and sustainability in agricultural development

Based on the article analysis, 2881 plus keywords were distinguished in the 979 articles. The most frequent keywords shed light on (1) The themes studied over the past decade, including agriculture, climate change, sustainable development, gender, and food security, among others; (2) Types of agricultural systems and practices, such as farming systems, smallholder agriculture, and alternative agriculture, indicating a strong focus on sustainable and diverse farming practices; (3) Workforce and gender dynamics, with frequent mentions of terms like a female, male, gender relations, and agricultural workers, emphasizing research on gender roles, decision-making, and gender disparity in the agricultural sector; (4) Empirical context, with countries like China, Nigeria, and the United States frequently studied, showcasing the global nature of research in agriculture, particularly in rural and developing regions. Keywords like livelihood and sustainable development goals further emphasise rural development and global sustainability efforts (Table 5).

4.1 The main research domains

Five primary study domains were found while examining the connections among the keywords: gender dynamics and roles, agriculture and climate change, sustainability and development, human and labor dynamics, and environmental and technological aspects Fig. 2. The first research domain, gender dynamics and roles, is characterized by topics related to social structures and inequalities, particularly in rural agricultural communities in developing regions like Sub-Saharan Africa and India. Themes such as gender relations, women's status, and intersectionality highlight the challenges faced by women in agriculture, where gender inequality is prevalent [36, 62]. The network explains how these gender issues cut across other, more general areas, such as poverty and food security, among other labour markets. The situation for women has been aggravated by their restricted opportunities and, in particular, a lack of resources and education [40]. This concern affects their productivity and contributions to AO farming systems [6] (Fig. 2).

The second research domain, agriculture and climate change, focuses on associating climate variability with farming practices. It explores how smallholder farmers adapt to climate change and what strategies are employed

Table 4 The authors having written most articles in the last ten years are listed below alphabetically

S.I No	Authors	No. of articles	Articles fractionalized	Keywords	Country	Affiliation
1	Nyantakyi-Frimpong H	10	4.47	Food security, Climate change, Farming	United States	University of Denver, Dept. of Geography & Environment
2	Luginaah I	7	1.3	Health geography, Environment, Africa	Canada	University of Western Ontario, Dept. of Geography
3	Jr	6	1.26	Social work, Family studies	United States	University of Texas, Austin, School of Social Work
4	Nchanji Eb	6	1.3	Agriculture, Development, Maize	Cameroon	International Maize and Wheat Improvement Center (CIMMYT)
5	Bezner Kerr R	5	1.35	Agroecology, Nutrition, Development	United States	Cornell University, Dept. of Nutritional Sciences
6	Brown B	4	0.74	Public health, Social work	United States	San Diego State University, School of Social Work
7	Dakishoni L	4	0.6	Agriculture, Food security, Malawi	Malawi	Cornell University, Dept. of Development Sociology
8	Kerr Rb	4	1.11	Agroecology, Sustainable development	United States	Cornell University, Dept. of Development Sociology
9	Lupafya E	4	0.55	Development, Agroecology, Malawi	Malawi	Cornell University, Dept. of Development Sociology
10	Makate C	4	1.37	Climate-smart agriculture, Development	Zimbabwe	Africa Center of Excellence, Climate Smart Agriculture
11	Mugwe Jn	4	0.68	Sustainable agriculture, Kenya	Kenya	Association for Strengthening Agricultural Research
12	Ngetich Fk	4	0.63	Agriculture, Soil management, Kenya	Kenya	University of Nairobi, Dept. of Land Resource Management
13	Ojo To	4	1.17	Education, Social development, Nigeria	Nigeria	University of Ibadan, Dept. of Adult Education
14	Antwi-Agyei P	3	1.33	Climate change, Environmental science	United Kingdom	University of Leeds, Dept. of Environmental Science
15	Bickle P	3	1.53	Archaeology, Environmental history	United Kingdom	University of York, King's Manor

Table 5 The top 30 most frequent keywords over the past ten years

Keyword	Frequency	Keyword	Frequency
Agriculture	177	Perception	66
Climate change	138	Food security	59
Sustainable development	133	Farming system	57
Female	126	Gender relations	56
Gender	118	Decision making	55
Male	103	China	50
Sustainability	96	Alternative agriculture	46
Human	90	Middle-aged	45
Agricultural worker	89	Livelihood	42
Womens status	82	Rural area	42
Smallholder	74	Sustainable development goal	41
Adult	73	Gender disparity	40
Gender role	72	Agricultural production	38
Humans	72	Nigeria	38
Article	68	United states	38

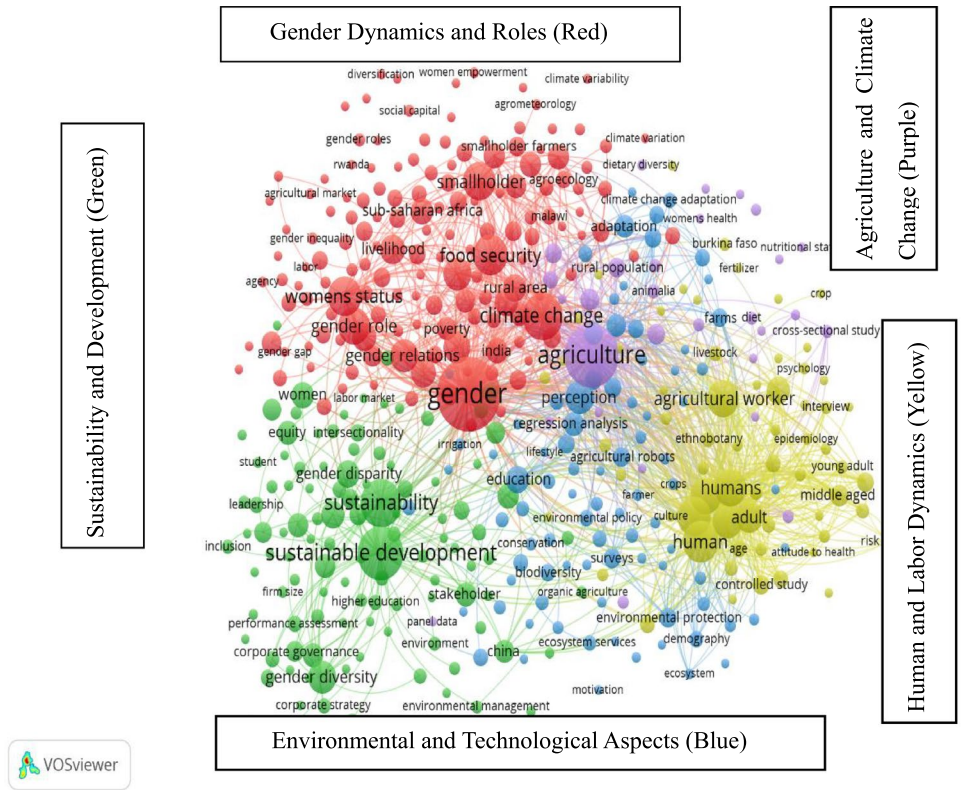

Fig. 2 The main research domains: (1) Gender Dynamics and Roles, (2) Agriculture and Climate Change, (3) Sustainability and Development, (4) Human and Labor Dynamics, and (5) Environmental and Technological Aspects

to mitigate the effects of climate variability. This domain covers climate adaptation, agroecology, and food security, particularly in regions vulnerable to climate stress, as discussed by Molotoks et al. [45]. These links illustrate how climatic changes directly impact agricultural production, influencing food security and rural life (Fig. 2).

The third research domain is Sustainability and development. The key themes include the principles of sustainable development and environmental management, with specific governance and policy considerations. This domain covers how organizations and their actors deal with environmental concerns, utilizing elements of sustainability evaluation and management strategies. Corporate diversity and environmental management with specific reference to policy implementation show increasing concern in environmental responsibility with the corporate decision-making processes,

particularly within the sectors related to environmental sectors, including agriculture and natural resource management, as indicated in Fig. 2.

The fourth research domain, human and labor dynamics, addresses issues related to human labor in agriculture, focusing on agricultural workers and labor markets. It highlights the socio-economic conditions of workers in rural areas, where employment in agriculture is often precarious and influenced by external factors such as climate and market shifts [64]. Keywords like human health, labor dynamics, and gender disparities suggest that the research within this domain explores physical and socio-economic conditions affecting workers. Labor market dynamics and the mobility of agricultural workers are crucial to understanding how employment shifts influence agrarian production and worker well-being [9, 70] (Fig. 2). The fifth research domain, focusing on environmental and technological aspects, highlights the use of agricultural robots and machines, irrigation systems, and the adoption of conservation practices such as biodiversity protection and ecosystem services. This domain also addresses the role of public policies in shaping technological adoption, particularly in relation to mitigating environmental impacts and enhancing farm-level efficiency (Fig. 2).

Figure 3 The network map depicts the connections between various research topics, concepts, and publications from 2012 to 2023. The themes of sustainability and sustainable development goals are central hubs connecting various research areas. The map is organized into colour-coded clusters, each representing a distinct thematic area. The green cluster focuses on sustainability goals and environmental studies. In contrast, the red cluster focuses on agricultural issues, agroecology, and smallholder farmers, particularly emphasising gendered aspects of development. The blue cluster represents corporate social responsibility, environmental management, and sustainable business practices. The purple cluster revolves around adaptive management strategies, gender relations, and resilience, particularly in climate change adaptation. The dense interconnections among nodes highlight the strong relationships between central themes, particularly sustainability and other research areas like climate change, gender, and food security. The inclusion of country-specific nodes like Ethiopia and Pakistan indicates the integration of regional studies into the broader research network. The strong interconnections suggest an interdisciplinary approach that links gender equity with sustainability and agricultural performance. Prominent journals, including *Sustainability (Switzerland)* and *Gender, Place & Culture*, emerge as key contributors to the discourse

Overall, this network map visually represents the research landscape on sustainability and related topics from 2012 to 2023, emphasizing the complex and interconnected nature of contemporary research in this field. The map highlights sustainability as a nexus for various interdisciplinary research areas, reflecting the growing importance of addressing global challenges through collaborative and integrated approaches.

4.2 Emerging topics

It is necessary to note that the five main research domains presented here can be regarded as the mainstream investigated in the international research field. Gender Dynamics and Roles, Agriculture and Climate Change, Sustainability and Development, Human and Labor Dynamics and Environmental and Technological Aspects. This indicates that issues of gender, sustainability, and agricultural growth are well-established in the scientific community. Our analysis revealed that most of the themes covered in the highly referenced publications and those addressed by the leading writers were in line with the mainstream subjects on Gender and Sustainability in Agricultural Development. Table 6 shows that new focus areas are Gender diversity moderates environmental and social performance, social work, family, and agriculture are crucial, Climate-smart agriculture, corporate governance, and archaeology intersect.

5 Scientific communities leading research on gender and sustainability in agricultural development

Four central scientific communities were identified in the research on gender and sustainability in agricultural development: Gender Studies and Empowerment**,** Agricultural Economics**,** Environmental Management, and Rural Sociology**.** Gender Studies and Empowerment was the pioneering IAR scientific community that addressed the opportunities for women in agricultural systems. This community discussed two main topics: feminism and gender roles in agriculture and female enhancement in rural areas. The empowerment theme is characterized by studies on how women's inclusion in decision-making and leadership positions influences farm productivity and sustainability. The reference author was Nchanji et al. [52] From the International Maize and Wheat Improvement Center (Cameroon). Key papers in this field include "Empowering Rural Women through Sustainable Agriculture" by Fertő and Bojnec [15]

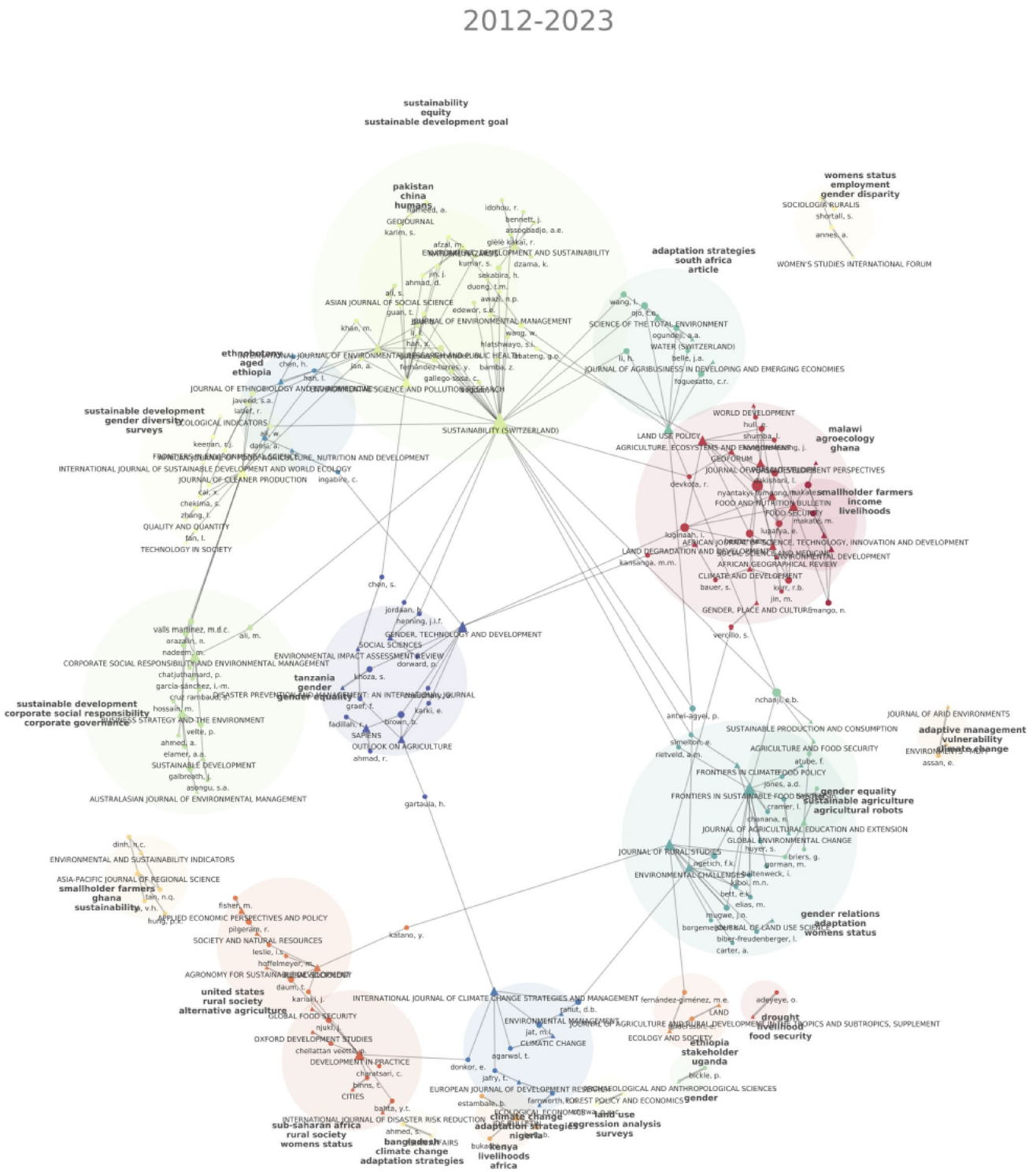

Fig. 3 Network mapping (Authors, Keywords, and Journal)

Published in Scientific Reports and "Empowering women through targeting information or role models: Evidence from an experiment in agricultural extension in Uganda" by Lecoutere et al. [35] Published in World Development and "Gender, women and agriculture in Agriculture and Human Values" by Sachs [62] Published in Agriculture and Human Values. The main journals include Scientific Reports, World Development and Agriculture and Human Values.

Table 6 Presents recent topics within mainstream and emerging studies of the last ten years

Title classification	Five main research	Main topics of the top 15 most cited articles	Main topics of the top 15 authors
Mainstream topic	Gender Dynamics and Roles	Gender dynamics in agriculture and climate change	Health Geography and Agroecology & Nutrition
	Agriculture and Climate Change	Food security and agricultural production	Food Security & Climate Change
	Sustainability and Development	Corporate social responsibility and board diversity	Sustainable Agriculture & Soil
Emerging topic	Environmental and Technological Aspects	Environmental and Social Performance Moderated by Gender Diversity	Social Work & Family
	Human and Labor Dynamics	Household Labor Allocation and Land Administration in Agriculture	Climate-Smart Agriculture
		Corporate Governance's Influence on Environmental Policies	Archaeology and Environment

Agricultural Economics was the second scientific community centered on economic analyses related to gendered access to resources such as land, credit, and markets. This field addressed two key topics: resource allocation and market participation. Studies like "Gender Disparities in Agricultural Productivity" by Makate **C.** from the Africa Center of Excellence (Zimbabwe) and "The economics of gender in sustainable farming" by Bezner Kerr R**.** from Cornell University, highlighted the challenges and opportunities for women in agricultural economies. Key journals in this community include *American Journal of Agricultural Economics* and *World Development*.

Environmental Management emerged as the third significant scientific community. It focused on how gender diversity in environmental leadership can improve sustainable practices and corporate social responsibility (CSR) in agricultural sectors [5]. This community tackled two major themes: sustainable development and environmental governance. Researchers like Setó-Pamies [63]. From the University of Leeds have published extensively on the topic, with reference articles such as "Gender diversity in environmental decision-making" in *Sustainable Agriculture* and "The impact of CSR on gender equality in farming communities" in *Environmental Science & Policy*. Major journals include *Environmental Science & Policy* and *Journal of Environmental Management*.

Rural Sociology was the fourth scientific community dealing with social structures, migration, and poverty within rural agricultural systems. It focused on the interplay between gender, migration, and food security. Notable studies like "Migration and rural women's work in sub-Saharan Africa" by Luginaah [38] from the University of Western Ontario and "Poverty alleviation and gender roles in farming households" by Ojo [54] from the University of Ibadan have contributed to understanding gendered social dynamics in agriculture. Major publications in this area include *Rural Sociology* and *Journal of Peasant Studies*. These four scientific communities reflect the multi-dimensional approach needed to address gender and sustainability in agricultural development, highlighting economic, social, and environmental factors.

6 Discussion

6.1 Major international issues on research on gender and sustainability in agricultural development over the older ten years

Our findings indicate that research on gender and sustainability in agricultural development has been dominated by four main scientific communities: Gender Studies and Empowerment, Agricultural Economics, Environmental Management, and Rural Sociology. Over the past decade, significant progress has been made in five primary domains within these communities, shaping the global discourse on gender and sustainability in agriculture.

Gender Studies and Empowerment is a significant scientific community focused on gender and sustainability in agricultural development. The field focuses on women's roles in agricultural activities and the broader societal implications of gender inequality. Gender dynamics, particularly the division of labor between men and women, significantly impact productivity, sustainability, and development in agriculture [30, 43, 67]. However, underrepresentation of women in decision-making roles is a major concern due to historical, social, and cultural barriers. Empowering women in agriculture leads to improvements in household welfare, food security, and environmental management [24]. Education and capacity building are closely tied to women's empowerment, enabling them to engage more effectively in agricultural practices, adopt new technologies, and improve farm-level productivity [58]. Studies also explore the intersection between women's efforts in agronomy and off-farm activities, such as income diversification strategies and the social and economic value of unpaid domestic and caregiving work [33, 68].

One such populated area is Agricultural Economics, especially in the discussion part of the analyzed papers. It is related to institutions, bargaining power in the labour market and resource allocation mechanisms. The economic examination of labor mobility primarily focuses on agricultural labor, particularly the migratory movement of workers from agriculture to other sectors or non-agricultural activities [44]. In order to find the impact of gender inequality on the overall economic growth and development [32]. Both Scopus and Web of Science recognize agricultural economics as one of the largest scientifically significant groups, with the main discussion on the gendered nature of access to agricultural markets and financial resources. "Women's economic opportunities in sustainable agriculture" from years [7, 34] the experiences and prospects of women in delivering to the economic elements of sustainable farming. Such topics as labor deficit, how women are incorporated into the world of work, and the effects on the economy of women. Access for participation in agricultural value chains.

Environmental Management has emerged as a leading domain in the past decade, reflecting the increasing role of women in environmental decision-making and their contributions to sustainable farming practices. Research has

highlighted how women are more likely to adopt environmentally friendly agricultural practices and promote sustainability at both local and global levels. The role of gender diversity in shaping environmental governance and influencing corporate social responsibility (CSR) in agriculture has been a major theme [21, 60, 69]. Studies such as Gender diversity in environmental decision-making [17, 61, 66]. Reflect the growing consensus that diverse perspectives improve environmental outcomes, making this an important issue for future research.

Rural Sociology has focused on the social implications of gender roles in agricultural systems, particularly in relation to migration, poverty, and food security. Research over the past decade has consistently explored the intersection of gender, rural development, and agricultural sustainability [31]. This field has highlighted how gendered labor divisions within households, particularly in developing regions, contribute to or hinder sustainable development [59]. The role of women in ensuring household food security and the impact of migration on gender roles in farming communities have been central themes. Studies such as Migration and rural women's work in sub-Saharan Africa by [29, 50]. Emphasize how women's contributions to rural agriculture affect both social and economic development.

Across these four scientific communities, a common theme has emerged: the critical importance of integrating gender considerations into agricultural development to achieve sustainability. The diversification of labor strategies, gender equality in resource access, and women's leadership in environmental management have all been identified as critical areas for advancing sustainable agricultural practices globally. The insights gathered from the Scopus database reflect a broader international trend towards recognizing and addressing gender disparities of farm systems, ensuring that women's contributions are fully integrated into the future of sustainable farming.

6.2 Trends for further research

Three major research trends emerged from the bibliometric analysis: gender dynamics in sustainable agricultural practices, environmental technological innovation, and the role of labor governance in agricultural sectors. These trends reflect the ongoing transformations in the field of agricultural development, especially as they intersect with gender and sustainability. Identifying emerging trends alongside the five main research domains is important for highlighting future research directions, providing significant insights for global agricultural sustainability and gender equality.

Gender Dynamics in Sustainable Agricultural Practices is one of the most important trends identified in the reviewed research on agriculture over the years. Some of the current research emphasize the adoption of gender mainstreaming into agricultural policy formulation, in the world in which women play crucial roles in farming particularly in the developing countries of Sub-Saharan Africa and Asia. Specifically, scholarship has examined Women's labour participation in climate-smart Agriculture to fill the gender gap in agricultural productivity [22]. Thus, it comes as no surprise that the following barriers are significant concerns within households and communities: Availability of resources, information and decision-making powers. It is increasingly appreciated that women's empowerment in agriculture has multiple impacts on the tenets of food security, poverty, and climate innovative solutions [55]. Future research should, therefore, be devoted to policies that include ways to increase the share of women in ownership of land and other inputs necessary for agriculture and policies that promote women's access to digital solutions in agriculture for gender-equal outcomes.

Technological innovation and environmental sustainability are also emerging areas of research. Technological advancement, which includes precision farming, AI and robotics applications in agriculture, and water management, has been noted as an essential factors influencing environmental performance in agricultural production [19]. The studies emphasize the need for the participation of women with no choking culture in the adoption of new ways of doing things, stating the need for good business practices towards the environment [8]. Research on gender-inclusive approaches to adding green technologies can lead to more wide-ranging and sustainable agricultural practices. Additionally, understanding the gender-specific impacts of technological adoption is necessary to ensure that women farmers are not left behind in the digital revolution in agriculture.

The third research trend centers around Labor Governance in Agricultural Value Chains. Labour governance frameworks in agriculture are critical in promoting fair employment irrespective of social orientation, especially where it is largely women who are employed in most of agricultural development-oriented countries. The literature highlights the importance of fair labor practices, labor rights, and gender equity in improving social and economic outcomes for agricultural workers [72]. Researchers emphasize the role of global value chains and certification schemes in promoting gender-sensitive labor policies that aim to eliminate exploitative labor conditions [28]. Future research should explore how corporate governance and international trade policies can be leveraged to ensure the fair treatment of agricultural workers, with a particular focus on women's empowerment within labor-intensive sectors such as dairy farming and horticulture.

By focusing on these emerging research trends, scholars can identify critical gaps in current agricultural practices and develop new pathways for integrating gender equality and sustainability into future policy frameworks. Researchers are encouraged to advance future research in the broader area of gender dynamics and their roles, especially in agriculture and climate change, sustainable development, environmental and technological aspects, human labor dynamics, corporate influence on governance policies in agriculture, food security, and sustainable agriculture. These trends not only inform academic discourse but also provide actionable insights for practitioners, policymakers, and stakeholders invested in agricultural development and gender equity.

6.3 Mapping the scientific landscape of gender and sustainability in agricultural development research

Diagraming the scientific landscape of gender and sustainability in agricultural development over the past decade reveals a distinct pattern in expertise invention and distribution. Leading countries such as the United States, United Kingdom, South Africa, Australia, and China have emerged as significant contributors, representing the core of scientific knowledge production. These nations dominate the publication landscape, housing prominent authors, institutions, and high-impact journals. Their leadership is reflected in the volume and quality of research output, which aligns with findings from similar studies that assess the global discourse on agricultural development and gender [65]. A clear split exists between developed and developing countries concerning their contributions to this research area. Countries in Europe, North America, and Australia are the main contributors to both theoretical and empirical research, greatly influencing the scientific dialogue on gender and sustainability. Unlike other places, developing regions, notably Africa and Asia, generally function as data providers. These territories often present their field observations in the form of empirical studies but are, unfortunately, underrepresented among the ranks of leading publishers, authors, or articles receiving the most citations. In this category, Kenya, India, and Ethiopia take on significant roles, denoting their contributions to case studies and data from the agricultural sectors of developing economies. Latin American and Asian countries, such as Brazil, China, and India, are remarkable for their roles as providers of data as well as as major contributors to published findings. This points out a flourishing research capacity in these regions, where both academic institutions and researchers are more and more involved in the generation of international knowledge related to gender and sustainability in agriculture.

Analyzing the global landscape of exact output related to gender and sustainability in agricultural development requires simplifying complex metadata to provide meaningful insights. It is essential to acknowledge certain working limitations in such analyses. For instance, the use of the Scopus bibliographical database tends to favour social sciences, which may explain the predominance of economic and social issues in the dataset. In contrast, databases such as Web of Science, which emphasize natural sciences and engineering, may offer different perspectives, especially concerning technical aspects of agricultural development [46]. Nevertheless, both databases reveal overlapping themes, indicating a consensus within the scientific community regarding crucial research areas in agricultural work and sustainability.

Network analysis of the bibliographic data helps identify quantitatively dominant research topics, although it does not cover all aspects of gender and sustainability in agricultural development. The results underscore the importance of interdisciplinary approaches to fully understand the intricate relationship between gender dynamics and sustainable agricultural practices. Future research agendas must build on this cross-topic knowledge base, mainly focusing on how ongoing transformations in the farming sector can promote sustainable development through improved employment conditions. As such, the next decade of scientific inquiry will be critical for addressing the multidimensional challenges of gender, sustainability, and decent work, as outlined by the International Labour Organization (ILO), particularly in agricultural contexts.

7 Conclusions

The bibliometric review of articles indexed in scientific database has revealed four main scientific communities that have produced the most significant research related to gender and sustainability in agricultural development over the past decade: agricultural policy, sustainable development, gender equity, and climate change adaptation. Each of these communities was analyzed, identifying the key reference authors, articles, and journals contributing to this interdisciplinary field. The study demonstrated that research is structured into five main domains: gender dynamics and roles, agriculture and climate change, sustainability and development, human and labor dynamics, and environmental and technological aspects. These domains are interconnected, particularly in addressing critical global challenges in agricultural development, such as climate adaptation, gender disparities in labor markets, and

rural livelihoods**.** This review provides a comprehensive overview of the most relevant research in this interdisciplinary field, establishing a foundation for future research at the intersection of gender, sustainability, and agricultural development. The United Nations Sustainable Development Goals (SDGs) can serve as a guiding framework for deepening exploration into these topics, as many of the identified themes directly relate to the goal of promoting sustainable and equitable agricultural practices. Moreover, technological advancements, such as precision farming, artificial intelligence, and digital platforms, offer transformative potential for agricultural sustainability. Policies should encourage the equitable adoption of these technologies by addressing barriers faced by women, such as limited digital literacy and restricted access to financial resources. Incentivizing gender-sensitive technological solutions and providing capacity-building programs can help bridge existing gaps, fostering long-term sustainability and resilience in the agricultural sector. This bibliometric analysis offers valuable insights for advancing research that supports gender-inclusive policies and practices, ultimately contributing to the long-term sustainability and resilience of the agricultural sector**.**

7.1 Limitation

The study's findings may be constrained by methodological limitations. The dataset was restricted to English-language and qualitatively indexed journals, potentially excluding relevant research from non-English-speaking regions. This may limit the representation of diverse perspectives, particularly in areas where agricultural and gender studies are prominent but documented in local languages. The analysis focused solely on peer-reviewed journal articles indexed in Scopus/Web of Science, which may have introduced biases by prioritizing formal academic outputs over practical or applied research insights. The choice to use qualitative indexed journals may have overrepresented certain disciplines and underrepresented others, such as natural and engineering sciences. Additionally, the choice may have limited the time representation along with complementary literature on natural sciences and engineering topics. The exclusive reliance on bibliometric methods does not capture qualitative nuances or contextual factors that influence gender and sustainability dynamics in agricultural development. Future research could incorporate multilingual datasets, analyze diverse publication types, and employ mixed methods, including qualitative approaches, to provide a more comprehensive understanding of the research landscape.

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Declarations

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Consent to publication Not applicable.

Informed consent This article does not contain any studies with human participants performed by any of the authors.

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