



Research article

Analysis of co-operative irrigation farming and household food security in Africa: A PRISMA model approach

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ABSTRACT

This study provides a comprehensive bibliometric analysis of the relationship between co-operative irrigation farming and household food security in Africa. The research aims to identify key studies, authors, and thematic clusters, analyse the geographical distribution of research efforts, and evaluate the impact of co-operative irrigation farming on food security indicators. Utilizing the PRISMA model, data were systematically gathered from peer-reviewed publications indexed in the Dimensions database, focusing on materials published between 2019 and 2023. The study employed both bibliometric and descriptive-quantitative methodologies to analyse the data. The results reveal a significant positive impact of co-operative irrigation farming on improving household food security across various regions in Africa. The findings highlight the need for targeted policy interventions and sustainable agricultural practices that support co-operative irrigation efforts. A growing scholarly attention toward co-operative irrigation farming and household food security in recent years reveals a potentiality in finding a sustainable solution to food insecurity challenge. These insights are essential for shaping future research and informing policies aimed at enhancing food security through co-operative farming models in the African context.

1. Introduction

Food security is one of the most persistent and critical global challenges affecting millions daily [1]. The situation is particularly acute in Africa, where most of the population faces challenges in accessing adequate, safe, and nutritious food [2]. According to the Food and Agriculture Organization [3], approximately 820 million people worldwide suffer from chronic hunger, with about 256 million in Africa accounting for roughly 19 % of the continent's population. This underscores the urgent need for comprehensive strategies to address food insecurity in Africa [4].

The complexities of food security in Africa extend beyond mere food access, encompassing aspects such as food quality, nutritional diversity, affordability, and the resilience of food systems to shocks and stresses [5]. Factors like climate change, land degradation, water scarcity, political instability, and economic disparities further compound these challenges [6]. Against this backdrop, the

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literature suggests that irrigation plays a critical role in enhancing food security by improving agricultural productivity, stabilizing the food supply, and reducing vulnerability to climate variability [7]. While irrigated agriculture accounts for only 20 % of the total cultivated land in Africa [8], it contributes to over 40 % of total food production [9,10]. Thus, efficient and sustainable irrigation systems are essential for increasing agricultural productivity and improving crop yields in water-stressed regions [7,9,11,12].

Irrigation, moreover contributes to stable and predictable agricultural production, reducing the risk of crop failures and food shortages [13]. In countries like Ethiopia and Kenya, investments in small-scale irrigation schemes have resulted in increased crop diversification, improved nutrition outcomes, and enhanced resilience to climate-related shocks among smallholder farmers [14]. However, despite the potential benefits of irrigation, access to and management of irrigation infrastructure remain a key challenge in many African countries [3]. Limited access to irrigation technologies, inadequate irrigation system maintenance, and water resource conflicts hinder the full realization of irrigation's potential to enhance food security [15]. To address these challenges requires promoting sustainable irrigation practices, improving water governance, investing in infrastructure, and enhancing the capacity of smallholder farmers in irrigation management [13,15]. Efforts to promote sustainable irrigation practices, improve water governance, invest in irrigation infrastructure, and enhance the capacity of smallholder farmers in irrigation management are essential components of a comprehensive strategy. These efforts are crucial for addressing food security challenges in Africa. By integrating irrigation development within broader food security initiatives, policymakers, researchers, and practitioners contribute to building resilient and sustainable food systems that meet African populations' nutritional needs and promote inclusive economic development [16,17]. Within this integrated approach, co-operative irrigation farming emerges as a key pillar, offering a collaborative approach to irrigation management that fosters efficiency, equity, and community resilience.

Co-operative irrigation farming has emerged as a key pillar within this broader food security framework. By allowing smallholder farmers to pool resources, share knowledge, and collectively manage irrigation systems, co-operative farming fosters efficiency, equity, and community resilience [18]. Scholars like [19,20] argue that co-operative irrigation schemes lead to increased crop yields, diversify production, improve livelihoods, and strengthen social cohesion in rural communities. Co-operatives further empower marginalized groups, such as women and youth [21], in agricultural decision-making processes, ensuring equitable access to irrigation benefits [22]. Moreover, co-operative irrigation farming complements broader food security initiatives by enhancing the resilience of farming communities to climate variability and market shocks [21,23]. Through collective action, farmers in co-operatives cope better with droughts, floods, and other environmental challenges, thereby reducing the risk of crop failures and food shortages. Additionally, co-operatives strengthen farmers' bargaining power in the market, thereby leading to better prices for their produce and improved market access.

However, the success of co-operative irrigation farming depends on effective institutional support, capacity building, access to credit and inputs, and enabling policy environments [24]. Governments, development agencies, and NGOs play crucial roles in facilitating the establishment and sustainability of co-operative irrigation schemes through policy reforms, infrastructure development, and extension services [23]. Leveraging the potential of co-operative irrigation farming within a broader food security framework can help create resilient and sustainable agricultural systems in Africa, promoting inclusive economic development, poverty reduction, and environmental sustainability [25].

While much of the literature highlights the benefits of irrigation in enhancing food security, there is a need for more nuanced research on the sustainability of these systems and addressing the challenges in their implementation. Research has extensively documented the impacts of irrigation on food security and agricultural productivity [13,26]. However, there are gaps in understanding the long-term sustainability of co-operative irrigation systems, particularly concerning institutional support, access to credit, and the socio-political factors that influence their success in ensuring food security. Additionally, more research is needed to explore the specific challenges faced by smallholder farmers in accessing and maintaining irrigation infrastructure in different African contexts.

This paper aims to fill the existing gaps in the literature about co-operative irrigation farming and its impact on household food security by conducting a bibliometric analysis of the African global research landscape. Using the PRISMA model, the study systematically reviews and analyzes scholarly publications to identify the most influential studies and authors in the field, the geographical distribution of research efforts, thematic clusters, and emerging topics such as sustainable irrigation practices, climate resilience, and smallholder farmer participation. The analysis covers publications from various regions, including Africa, Asia, Europe, and the Americas, to provide a comprehensive African perspective.

2. Methodology

The data collection process for this study was meticulously structured, and grounded in the PRISMA model. This model is esteemed for its rigorous approach to conducting literature searches, screening articles, and synthesizing findings; thus enhancing the reliability and reproducibility of systematic reviews [26]. The PRISMA framework was particularly well-suited for this study, as it facilitated the methodological identification, screening, and inclusion of relevant studies while minimizing potential biases [27].

The initial phase of the data collection involved a systematic search of scholarly materials within the Dimensions database, chosen for its extensive coverage of high-quality, peer-reviewed journals. This database was particularly relevant to the study due to its comprehensive inclusion of literature on co-operative irrigation farming and household food security in Africa. A broad set of keywords was employed to ensure the identification of a wide array of pertinent studies [28]. Following the initial search, which yielded a substantial volume of articles, a rigorous screening process was applied. This screening was based on predefined inclusion and exclusion criteria, focusing on studies published within the last five years to ensure the analysis was grounded in the most current research. Non-empirical publications, such as book chapters, edited volumes, monographs, pre-prints, and conference proceedings, were systematically excluded.

The study then concentrated on field research within the disciplines of development studies, agriculture, veterinary, and food sciences, narrowing the focus to articles that directly contributed empirical evidence to the topic at hand. The final dataset, which consisted of open-access journals, was subjected to a detailed coding and extraction process [29]. Key information, including publication year, authorship, geographical focus, and thematic emphasis, was systematically extracted. This thorough approach ensured that the subsequent bibliometric analysis was both comprehensive and robust, providing critical insights into the interconnectedness of research within the domain of co-operative irrigation farming and household food security.

The bibliometric analysis was conducted using VOS viewer version 1.6.20, a sophisticated software tool renowned for its ability to construct and visualize bibliometric networks, thereby offering deep insights into scientific landscapes [29]. This tool was instrumental in clustering related publications and mapping the intricate web of collaboration networks within the research domain. The data, meticulously exported from the Dimensions database, underwent a series of analyses through VOS viewer. Direct citation analysis was employed to explore the citation relationships between articles, pinpointing the most influential studies within the dataset [30]. Co-citation analysis further delved into the frequency with which pairs of articles were cited together, revealing thematic clusters and key research trends. Additionally, bibliographic coupling helped identify studies that shared common references, thereby illuminating emerging areas of research [31].

The visualizations generated by VOS viewer included network, overlay, and density maps, which collectively provided a nuanced understanding of the structure and dynamics of research within the field. To ensure that the analysis was focused and meaningful, terms included in the mapping visualizations were carefully filtered for relevance, highlighting only the most significant patterns. The final dataset, comprising 1,947 articles, was thoroughly analyzed to discern trends, gaps, and emerging themes in the literature on co-operative irrigation farming and household food security summarized in Table 1 and Fig. 1. This comprehensive analysis not only sheds light on the current state of research in this area but also identifies critical areas where further studies are warranted.

3. Results

This section presents a bibliometric investigation focusing on 1947 selected publications related to the global perspective on co-operative irrigation farming and household food security. The analysis delves into the year of publication, country of origin, authors, source of journals, institutions, sponsors, and keywords associated with these publications.

3.1. Yearly distribution of publication output

Analyzing the number of published articles year-on-year provided valuable insights into the trends within the research domain of co-operative irrigation farming and household food security. The trend analysis offers indications of potential future directions in research. Notably, there has been a significant increase in scholarly attention towards understanding the drivers of co-operative irrigation farming and household food security globally.

From 2019 to the end of 2021, the volume of available publications has steadily risen. In 2019 there were 241 publications, which increased to 328 in 2020, marking a growth of approximately 36.10%. This upward trend continued into 2021, with the number of publications increasing to 446, representing a growth of approximately 35.98% compared to 2020. This upward trajectory continued into 2022, with 458 publications recorded, which raised to 480, in 2023 (see Fig. 2). These findings reflect a consistent and substantial upward growth in the number of publications focused on co-operative irrigation farming and household food security over the years.

The analysis of these findings indicates a growing interest and focus on co-operative irrigation farming and household food security among researchers and scholars. The significant increase in publications suggests a heightened awareness of the importance of sustainable agricultural practices and food security measures, particularly in regions where smallholder farming plays a crucial role. The cumulative impact and accumulation of knowledge in this research domain are evident in the increasing number of publications each year. This growing body of evidence and insights informs policy interventions, sustainable agricultural practices, and strategies to enhance household food security, especially in regions like Africa where these issues are particularly pertinent.

3.2. Visualization of the relationship between co-authorship and organization

The visualization of the relationship between co-authorship and organizations using VOS viewer revealed interesting insights. Typically, in VOS viewer, the minimum number of relationships is set at 2 terms. However, in this study, we set the minimum number

Table 1

Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Focus on agriculture, food science articles	Articles not focusing on agriculture or food sciences
Focus on current articles published between 2019 and 2023	Articles published in 2018 or before
Peer-reviewed articles with full content available	Conference proceedings, reports, student dissertations
Articles published in the English language	Book chapters, editorials, government, and company publications
Articles that include original results of primary data	Articles that lack original empirical data and finding
Articles that are found in all open access (OA)	Articles on source title and journal list

Source: VOS viewer, May 2024

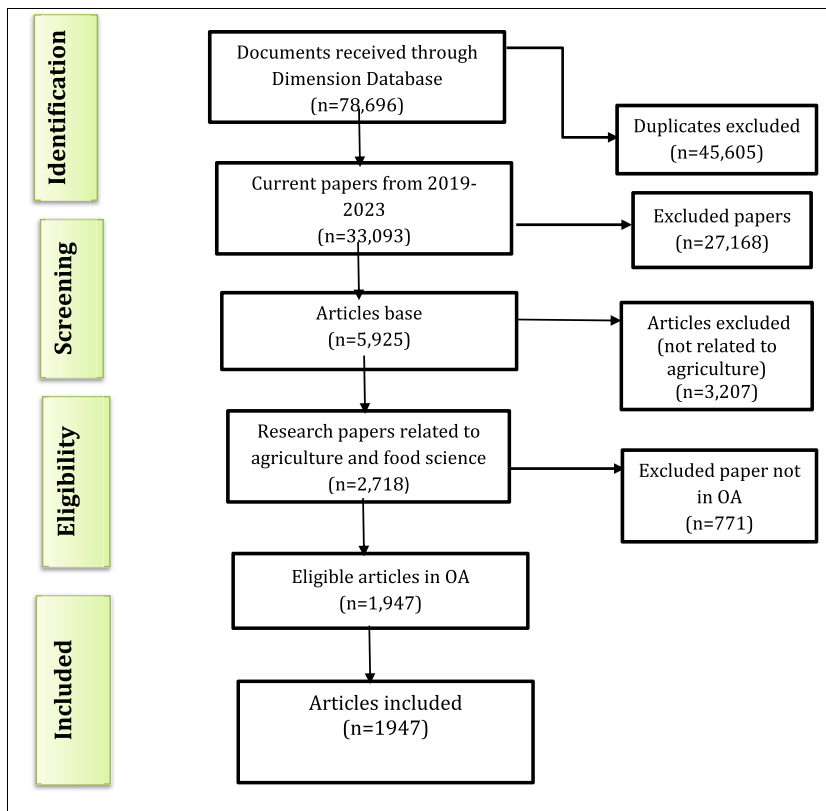


Fig. 1. PRISMA model for article inclusion [27].

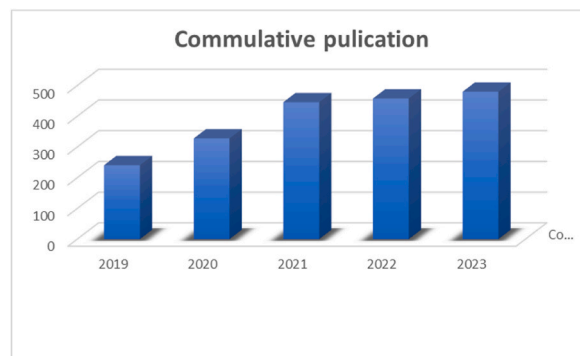


Fig. 2. Publication volume from 2019 to 2023.

of relationships between terms to 3. Consequently, the analysis yielded 20 items grouped into 3 distinct clusters.

Cluster 1 comprises 10 items and includes significant organizations such as Cornell University, Humboldt-University zu Bellin, the International Food Policy Research Institute, the International Institute of Tropical Agriculture, the International Livestock Research Institute, the International Maize and Wheat Improvement Centre, the International Water Management Institute, Michigan State University, the Swedish University of Agricultural Science, and Wageningen University & Research. These organizations are visualized in red in Fig. 3.

Cluster 2 encompasses 6 items and features institutions like Addis Ababa University, Bahir Dar University, Ethiopian Institute of Agricultural Research, International Rice Research Institute, Kansas State University, and Mekelle University. These organizations are depicted in green in Fig. 3. Cluster 3 comprises 4 items and includes Obafemi Awolowo University, the University for Development Studies, the University of KwaZulu-Natal, and the University of the Free State. These organizations are represented in blue in Fig. 3.

The visualization mapping analysis showcases the collaborative networks and partnerships among various organizations involved in co-operative irrigation farming and household food security research. The clustering of organizations provides a clear overview of

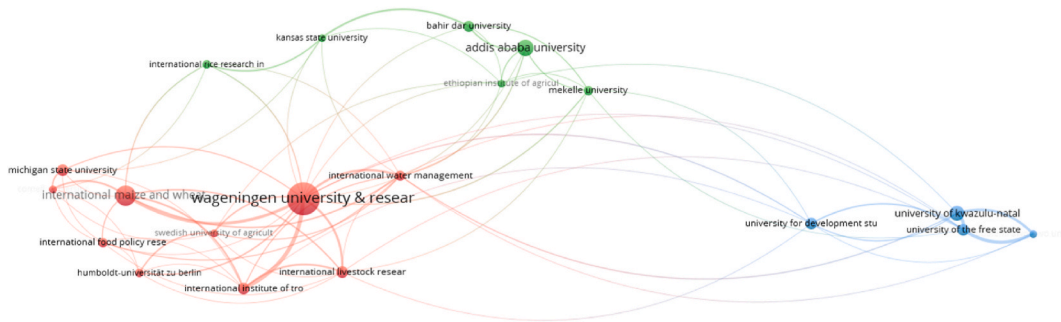


Fig. 3. Network visualization between the co-authorship vs organization.

the key players and their contributions to advancing knowledge and innovation in this critical domain.

The analysis of the organizations involved in co-operative irrigation farming and household food security research reveals notable differences between those in developed countries and those in developing countries. In developed countries, organizations such as Cornell University, Humboldt-University zu Bellin, Michigan State University, and Wageningen University & Research are prominent contributors. These institutions are renowned for their advanced research capabilities, access to funding, and established networks with industry partners [32,33]. Their contributions often involve cutting-edge technologies, innovative practices, and comprehensive studies that shape global agricultural policies and practices.

Organizations in developing countries, such as Addis Ababa University, Bahir Dar University, Ethiopian Institute of Agricultural Research, and Mekelle University, are actively engaged in research related to co-operative irrigation farming and household food security. However, they face challenges such as limited funding, infrastructure constraints, and fewer opportunities for collaboration with international partners [34,35]. This can result in a gap in resources, expertise, and access to advanced technologies compared to their counterparts in developed countries [33]. To bridge the gap between organizations in developed and developing countries in co-operative irrigation farming and household food security, measures such as capacity building, collaborative partnerships, funding opportunities, technology transfer, and policy support are essential for enhancing research capabilities, knowledge exchange, and sustainable agricultural practices worldwide.

3.3. Co-authorship vs countries

The visualization analysis of co-authorship relationships in co-operative irrigation farming and household food security research reveals distinct patterns between developed and developing countries. Developed nations like the United States, the United Kingdom,

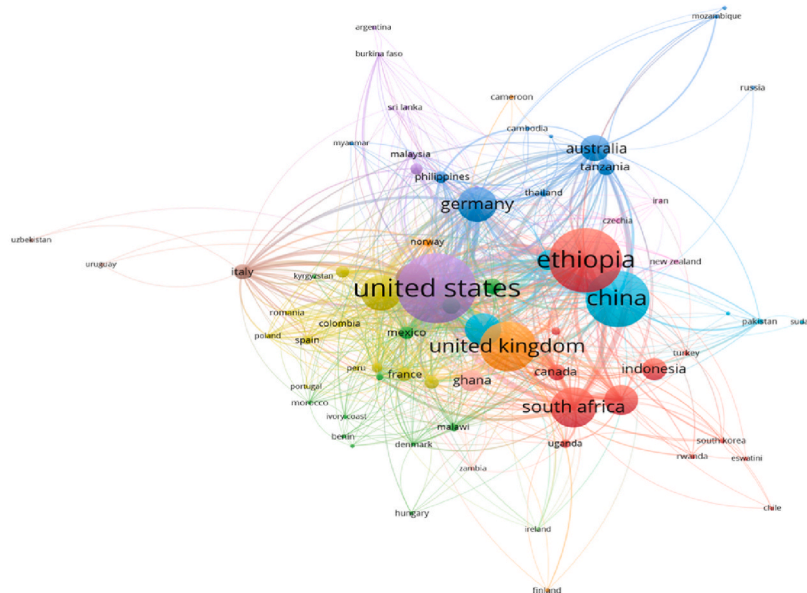


Fig. 4. Network visualization between co-authorship and countries.



the Netherlands, Germany, Italy, Australia, and Canada exhibit extensive co-authorship networks, reflecting their advanced research infrastructure, funding capabilities, and established partnerships with other developed nations. These collaborations contribute to cutting-edge innovations, comprehensive studies, and impactful policy recommendations. On the other hand, developing countries such as Kenya, India, Ethiopia, South Africa, Nigeria, Ghana, and Mexico also engage in co-authorship, often forming regional networks and collaborating with both developed and developing nations (see Fig. 4).

However, developing nations face challenges such as limited research funding, infrastructure constraints, and fewer opportunities for international collaboration. Despite these challenges, partnerships with developed countries enable knowledge exchange, capacity building, and technology transfer, enhancing research capabilities and promoting sustainable agricultural practices in developing regions. Overall, the visualization underscores the importance of collaborative efforts between developed and developing countries in advancing research agendas, bridging knowledge gaps, and addressing global food security challenges.

The visualization’s implications are significant, indicating a notable disparity in research collaboration between developed and developing countries in co-operative irrigation farming and household food security. Among the top ten countries with the highest co-authorship networks, a majority are developed nations, underscoring their dominance in global research partnerships and knowledge creation. This disparity suggests limited participation and representation of developing countries in shaping research agendas and influencing policy decisions related to agricultural practices and food security. Consequently, there is a risk of perpetuating existing inequalities in access to resources, technology, and innovative solutions, potentially exacerbating food insecurity challenges in developing regions. To address this imbalance, concerted efforts are needed to enhance research capacities, foster inclusive collaborations, and promote equitable knowledge exchange. Initiatives that prioritize funding, training, and partnership-building in developing countries can empower researchers and institutions to contribute meaningfully to global research endeavours and drive impactful solutions for sustainable agricultural development.

3.4. Citation vs sources of data/journals

The network visualization generated by VOS viewer reveals the complex connections and citation patterns among different publications, with a specific emphasis on subjects about food security, sustainability, and agricultural practices. The journal “Sustainability” holds a central and prominent position within the green cluster, highlighting its crucial role in sharing research across several interdisciplinary subjects such as environmental studies, sustainable development, and integrated food systems. This journal, characterized by its significant node size and extensive connections, functions as a crucial hub for academic communication and the sharing of knowledge. See Fig. 5.

The blue cluster, consisting of periodicals such as “Agronomy,” “Agricultural Systems,” and “Food Security,” emphasizes the focused research endeavors on agricultural methods, food production, and food security concerns. The interconnection of these periodicals demonstrates the symbiotic relationship between agronomic research and practical implementations in tackling global food security issues. The red cluster includes periodicals such as “World Development” and “Development Studies Research,” which extensively explore the economic and policy aspects of food security. These periodicals make a substantial contribution to the comprehension of the socioeconomic issues and development policies that impact the availability, accessibility, and stability of food in various places.

The purple cluster, comprising journals like “Heliyon” and “Journal of Agriculture and Food,” focuses on the significance of scientific progress and agricultural engineering in improving food security. The emphasis on applied research and innovation in this

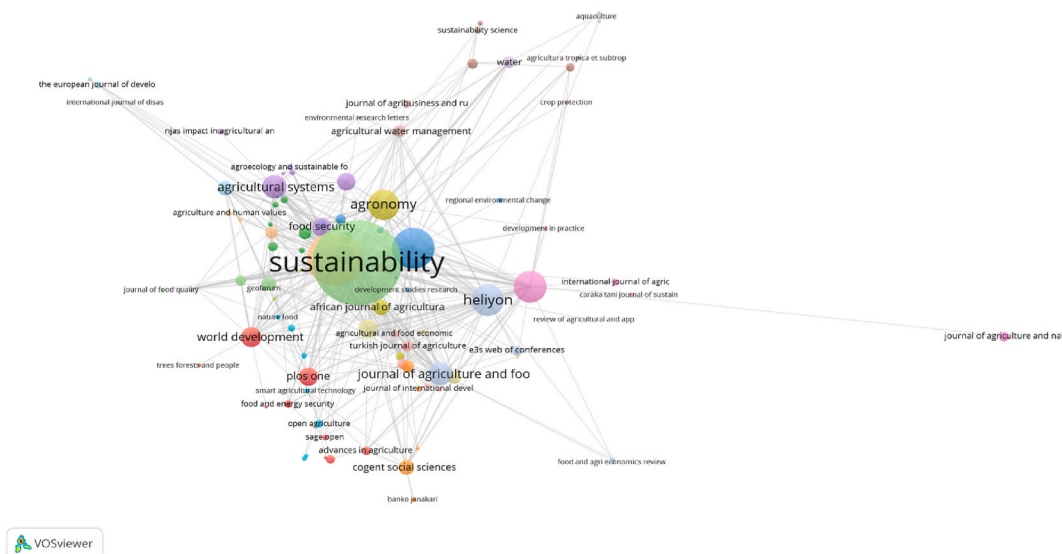


Fig. 5. Showing the relationships between different journals and how frequently they are cited in the context of certain topics.

cluster demonstrates a clear connection between technical innovations and their practical use in agricultural activities.

In general, the visualization illustrates an intricate network of references, demonstrating the interdisciplinary character of research in the fields of food security and sustainability. The presence of specific journals within clusters indicates their significant influence and pivotal position in establishing research agendas and directing future investigations. This bibliometric analysis offers significant insights for researchers, academics, and policymakers by identifying key journals and developing trends in the extensive field of food security and sustainability research.

3.5. Citation based on key terms co-occurrence

The network visualization produced using VOS viewer offers a detailed bibliometric analysis of key terms co-occurring in the literature on food security, agricultural systems, and sustainability. The visualization in Fig. 6 reveals three significant clusters, each representing distinct thematic areas. The red cluster, with central terms such as “system,” “development,” “approach,” and “resource,” underscores the holistic and integrative methods essential for addressing complex food security issues. This cluster emphasizes systemic development approaches that integrate economic, environmental, and social dimensions, highlighting the multifaceted nature of food security challenges and solutions.

The blue cluster focuses on agricultural practices and inputs, with key terms like “crop,” “yield,” “input,” “cost,” and “fertilizer,” reflecting the critical role of technical and economic factors in optimizing food production and enhancing agricultural efficiency. This cluster’s prominence indicates a strong research emphasis on improving agronomic practices to increase productivity and sustainability. The green cluster centers on household-level dynamics and the adoption of agricultural innovations, featuring terms such as “household,” “access,” “adoption,” and “climate change.” This cluster highlights the importance of socio-economic factors, technological adoption, and environmental influences in shaping food security at the household level.

The interconnectedness of “climate change” across multiple clusters signifies its pervasive impact on all aspects of food security and agricultural systems. The visualization also points to the critical roles of technological advancements, institutional support, and gender equity in driving sustainable development. This comprehensive bibliometric analysis not only maps the current research landscape but also identifies key areas for future investigation, providing valuable insights for researchers, policymakers, and practitioners dedicated to addressing global food security challenges through interdisciplinary and systemic approaches.

4. Discussion

The findings of this study reveal significant insights into the research domain of co-operative irrigation farming and household food security, reflecting both the advancements and the persistent challenges within the field. The bibliometric investigation highlights a growing scholarly interest in these topics, particularly from 2019 to 2023, where there has been a consistent increase in publication output. This trend aligns with a broader global emphasis on sustainable agricultural practices and food security, especially in regions heavily reliant on smallholder farming. The analysis of co-authorship networks, organizational affiliations, and citation patterns provides a detailed understanding of the collaborative efforts and knowledge dissemination within the research topic.

A comparison with previous studies underscores a continued dominance of research contributions from developed countries, where institutions like Cornell University, Wageningen University & Research, and others have established themselves as central hubs of innovation and policy influence. These institutions benefit from substantial funding, advanced research infrastructure, and extensive networks, allowing them to lead in cutting-edge research and global policy recommendations. This trend is well-documented in the

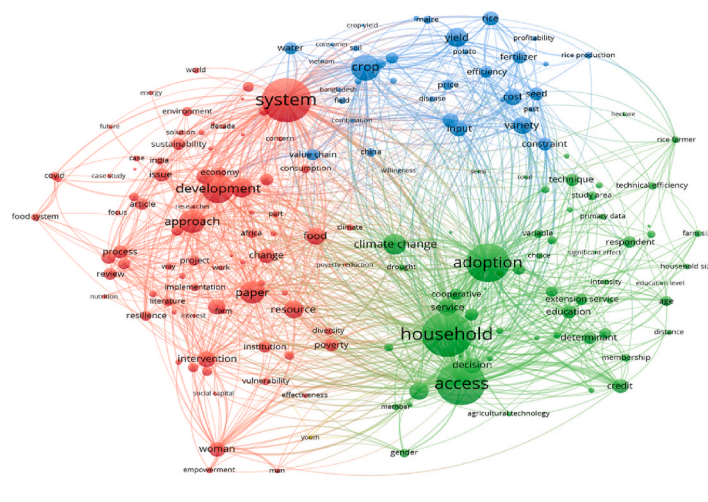


Fig. 6. Network visualization of key terms co-occurrence in household food security and co-operative irrigation farming research.

literature, with [36] highlighting how developed countries consistently drive global research agendas due to their superior resources and collaborative networks. Similarly, [37] emphasize the advanced research capabilities in developed nations, which position them at the forefront of scientific innovation and policy-making.

In contrast, while organizations in developing countries are active in the field, they face significant challenges related to funding, infrastructure, and opportunities for collaboration in the international arena [38]. detail how these challenges hinder research productivity and collaboration in developing nations, with infrastructural and financial limitations being key barriers [39]. further illustrate the disparities by showing how African institutions struggle to compete on the global stage due to these systemic issues. The recurring theme of resource and opportunity disparity between developed and developing nations is echoed in the work of [40], who discusses the peripheral position of developing countries in global scientific research. These studies collectively underscore the need for more equitable research collaborations and capacity-building initiatives to bridge the gap between developed and developing countries.

The analysis of co-authorship patterns and organizational networks consistently shows a skewed research output favoring developed countries, where their institutions dominate due to their significant resources, advanced infrastructure, and extensive global networks. Studies such as those by Ref. [41] illustrate how these advantages enable institutions to lead in cutting-edge research and global policy discussions.

Conversely, organizations in developing countries face constraints like limited funding and reduced access to international collaborations, as highlighted by [41]. These challenges contribute to a persistent knowledge gap, perpetuating global inequalities in innovation and policy influence. Despite these limitations, regional collaborations and partnerships with developed nations have been instrumental in capacity building and knowledge exchange, though they often reflect disparities in power dynamics and resource allocation, leading to dependency instead of equitable collaboration, as noted by [42].

Moreover, while collaborations between developed and developing countries offer opportunities to bridge gaps, they frequently reinforce existing inequalities [43]. argue that these partnerships often benefit developed countries more, where the majority of intellectual property and innovation gains are concentrated [44]. suggest that addressing this imbalance requires more inclusive and equitable research partnerships, with frameworks that prioritize mutual benefit and fair resource distribution.

The bibliometric analysis highlights the interdisciplinary nature of research in co-operative irrigation farming and household food security, reflecting a broad range of thematic areas. The clustering of key terms in the study underscores the complexity of food security challenges, which require integrative approaches encompassing economic, environmental, and social dimensions. This multifaceted perspective is consistent with prior studies that have emphasized the necessity of addressing food security through systemic and holistic strategies. For instance, Ref. [45] illustrates the importance of sustainable agricultural practices that consider environmental impacts alongside economic and social factors. Similarly, [46] emphasize the need for comprehensive frameworks that integrate technological innovation, policy reform, and community-level interventions to address food insecurity effectively.

The identified clusters in the analysis, ranging from systemic development approaches to household-level dynamics, mirror the diverse factors influencing food security. Studies such as those by [46] further corroborate the importance of interdisciplinary approaches, highlighting how agricultural systems, climate change, and socioeconomic factors are deeply intertwined in shaping food security outcomes. The emphasis on climate change within these clusters is particularly noteworthy, aligning with the growing body of literature that underscores its pervasive impact on agricultural productivity and food availability. Research by Refs. [47,48] documented how climate variability exacerbates food insecurity, particularly in vulnerable regions, necessitating adaptive strategies that are both locally relevant and globally informed.

This study identifies a research gap in co-operative irrigation farming and food security among smallholder farmers in Africa, which has been under-explored compared to other regions in the globe. This calls for further investigation. The findings offer clear implications: For academics, there is a need for interdisciplinary research that addresses the social, economic, and environmental aspects of food security. For practitioners, the study underscores the potential of co-operative irrigation to improve food security and the importance of capacity-building initiatives to enhance smallholder farmers' access to resources. For governments, it the importance of investing in research infrastructure and creating policies that support equitable collaborations and sustainable farming.

5. Conclusion

The purpose of this study was to explore the intricate relationships between co-operative irrigation farming and household food security, particularly within the context of African smallholder farmers. By employing a bibliometric approach, the study systematically analyzed a significant body of literature to uncover trends, collaborations, and thematic focus areas in this research domain.

The results revealed a marked increase in scholarly attention toward co-operative irrigation farming and household food security, particularly in recent years. This growth in publications underscores the growing global recognition of the importance of sustainable agricultural practices in addressing food security challenges. The visualization of co-authorship networks highlighted the disparity in research collaboration between developed and developing countries, with institutions from developed nations playing a dominant role in advancing knowledge and shaping research agendas. Despite this, partnerships between these regions have facilitated knowledge transfer and capacity building, contributing to the progress observed in developing regions.

The study concludes that while significant strides have been made in understanding and promoting co-operative irrigation farming as a means to enhance household food security, there is still a need for more inclusive and equitable research collaborations. Strengthening partnerships between developed and developing countries, alongside targeted policy interventions, could further bridge the research and resource gaps, ultimately leading to more effective and sustainable solutions for food security in vulnerable regions especially Africa where smallholder farmers remain the major producers of food. Future research should continue to focus on these

disparities, aiming to foster greater global collaboration and innovation in agricultural practices.

CRedit authorship contribution statement

Beatrice J. Kimaro: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Data curation, Conceptualization. **Rehema G. Kilonzo:** Validation, Supervision, Software, Data curation. **Benta N. Matunga:** Validation, Supervision, Software, Data curation.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Beatrice Judica Kimaro reports financial support was provided by Moshi Co-operative University. Beatrice Judica Kimaro reports a relationship with Moshi Co-operative University that includes: If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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