

Review

Exploring the Integration of the Land, Water, and Energy Nexus in Sustainable Food Systems Research through a Socio-Economic Lens: A Systematic Literature Review

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Abstract: The efficient use of land, water, and energy resources in Africa is crucial for achieving sustainable food systems (SFSs). A SFS refers to all the related activities and processes from farm to fork and the range of actors contributing to the availability of food at all times. This study aimed to analyse the growth in the land–water–energy (LWE) nexus integration in sustainable food system research. The focus was on publication growth, the thematic areas covered, and how the research addressed the policies, programmes, and practices using a socio-economic lens. The study utilised a systematic literature review approach, following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. The study underscored the limited emphasis on the socio-economic perspective in the examination of the LWE nexus within sustainable food system research in Africa. Policies, governance, institutional influences, and social inclusion are crucial for addressing the region-specific challenges and achieving sustainable outcomes, but they seemed to be underrepresented in current research efforts. More so, this review revealed a paucity of research on key influencing factors like gender, conflict, culture, and socio-political dynamics. Ignoring these social factors might contribute to an inadequate management of natural resources, perpetuating issues related to food security and equity in resource use and decision-making. Additionally, the dominance of non-African institutions in knowledge production found in this review highlighted a potential gap in locally owned solutions and perspectives, which are crucial for effective policy development and implementation, often leading to failures in addressing region-specific challenges and achieving sustainable outcomes. Overall, the study highlighted the need for a more holistic approach that not only considers the technical aspects of the LWE nexus but also the social, cultural, and institutional dimensions. Additionally, fostering collaboration with local institutions and ensuring a diverse range of influencing factors can contribute to more comprehensive and contextually appropriate solutions for achieving sustainable food systems in Africa.

Keywords: food systems; water; energy and food nexus; Africa; social inclusion; policy



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1. Introduction

A limitation in the land–water–energy nexus research creates a setback for the evidence-based management of resources, which face a poly crisis of climate change; biodiversity loss; severe food, water and energy insecurity; and social inequalities [1,2]. The food value chain faces threats from socio-political and environmental factors globally, with most nations in Africa and other developing nations in different regions across the world being the hardest hit. The food sector is affected because it heavily depends on natural resources, such as land, water, and energy. These resources are threatened by increased pressures due to population

growth, macro and microeconomic processes, political instability, environmental change, and seasonal variability.

Various approaches have been employed to foster the sustainable management of food systems, including the land–water–energy nexus. The LWE nexus constitutes an approach that is applied to promote the efficient use and management of resources. The interrelatedness of the land, water, and energy resources (Figure 1) depicts their relevance in enhancing each of the resources' use and management as well as their contribution to food security and sustainable food systems. For instance, land offers multiple ecosystem services to support human livelihoods, such as food, freshwater, biodiversity, and climate change impact mitigation [3]. In addition, land is a key resource for the establishment of renewable sources of energy, including solar and wind energy [4,5]. Meanwhile, water is utilised in the agricultural value chain from production to manufacturing and distribution, as well as in the generation and transportation of different forms of energy [6]. Energy also plays a vital role in the production, transportation, manufacturing, preservation, and distribution of food as well as in the extraction, pumping, treatment, distribution, and collection of water [7].

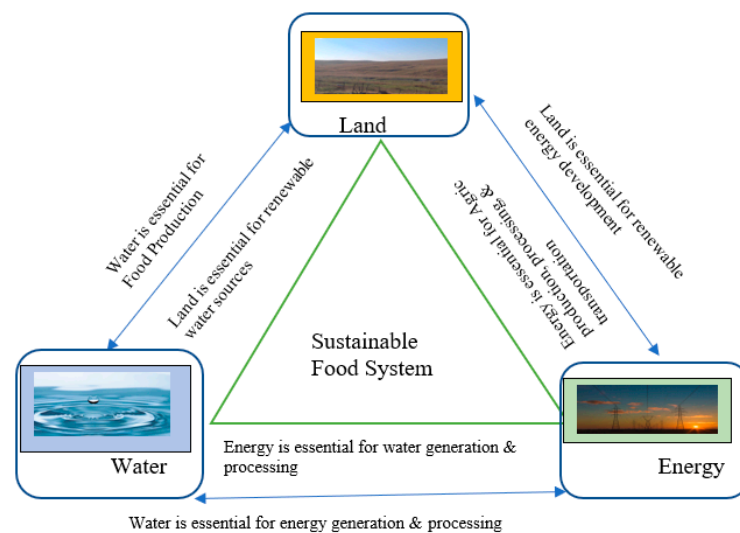


Figure 1. Land–water–energy nexus linkages (generated by the authors). (Open-source energy image by Matthew (<https://unsplash.com/@matthewhenry>, accessed on 2 August 2023); open-source water photos by Pixabay Photos (<https://pixabay.com/photos/drop-of-water-drop-impact-ripples-578897/>, accessed on 2 August 2023)).

However, water and energy insecurities and increasing land degradation have hampered sustainable agricultural growth in Africa [8]. For instance, the Intergovernmental Panel on Climate Change (IPCC) report pointed to water insecurity as the greatest threat in Africa, with 75–250 million people forecasted to be exposed to water stress in the coming decade [9]. The electricity access rate for Africa is approx. 40%, which is the lowest in the world and which translates to the lack of access to electricity for approx. 600 million Africans [10]. Water scarcity is predicted to be at the centre of national conflicts in the next 25 years [11]. Although the issues on land, water, and energy resources are often portrayed in terms of scarcity determined by availability and accessibility, there is more to that when aligned with affordability, utilization, and stability, which are determined by social inequalities [12]. Natural resources management by most governments in developing nations, particularly in Africa, has often been approached in a unilateral manner, which promotes siloed planning and management [13]. Land, water, and energy are interrelated in their support for human and economic development and, therefore, cannot be treated in isolation. Thus, the silo approach poses a huge challenge for designing policies which are usually fragmented and difficult to implement in resolving food security and sustainable food systems issues [14].

There has been a growth in water–energy–food (WEF) nexus thinking through a trans-disciplinary research approach with the intension of promoting the sharing of knowledge, collaboration, and partnership to foster high-level performance and organisational sustainability [15]. The WEF nexus in a broad sense refers to an approach that examines the relationships, commonalities, harmonisation, and trade-offs among the resources that need to be attended to in the management of the resources [16]. The launching of the World Economic Forum’s report “Water Security: The Water–Energy–Food–Climate Nexus”, and the background document developed by Hoff for the Bonn nexus conference, placed nexus thinking in the limelight [17]. Additionally, the WEF nexus builds on the Integrated Water Resources Management (IWRM) approach, which introduced the holistic view of assessing the competing and complementary demand for water across sectors and scales [18,19]. Nevertheless, the WEF approach exceeded the IWRM approach by integrating other key resources for analysing the interrelatedness between the resources and their responses to the drivers of change, including natural disasters, climate change, political instability, global economic crises, pandemics, varying management strategies, and development interventions [19–21].

Since its inception, WEF nexus research has transitioned from conceptualisation and discourse to analytical research [22]. Additionally, the WEF nexus has experienced growth in its operationalisation [22]. Botai et al. [23] noted a growth in WEF nexus research in both number and content since 2013. The authors specifically highlighted that WEF nexus research has experienced a growth of interesting concepts, such as systems modelling and optimisation, sustainable development, sustainable livelihoods, environmental and ecosystem services sustainability, and climate variability and change. Nevertheless, Botai et al. [23] identified a gap in the WEF nexus output and environmental governance. Adeola et al.’s [24] attestation of a limitation of concepts addressed in WEF nexus research buttressed the limitations pointed out by Botai et al. [23]. The WEF nexus review research mentioned above seemed to focus on the evolution of the nexus approach with an emphasis on resource management and the factors affecting food production in Africa. However, this research paper goes beyond food production by trying to understand how LWE or WEF nexus research promotes inclusive food systems development in Africa. The research was built on the assumption that the social dimension of the LWE nexus, which may potentially enhance sustainable food systems in Africa, has not been adequately researched. The social dimension of the LWE nexus is very critical in the resources use and management analysis because the accessibility and affordability of land, energy and potable water are not just a physical problem but also social and political problems [12]. Energy and water resources are unevenly distributed across social classes as well as between urban and rural communities, with the poor being the most disadvantaged [25]. The value of ecosystem services to society and the ecological environment necessitates a broader perspective of resource assessment and management. The broader benefits of the systems approach for ensuring the sustainability of the ecosystems have thus prompted academics to encourage an extended, dynamic, and inclusive definition of the WEF concept. Although various forms of nexus concepts exist with great similarities, research identified the WEF nexus as the most predominant concept [24,26]. This research utilised both the LWE and WEF nexuses since most of the identified articles used the WEF approach. The application of the LWE nexus approach for optimising sustainable food systems, which is also a social system, requires an understanding of the interactions of the resources and human actors.

LWE Nexus Research Support towards Sustainable Food Systems

Optimising sustainable food systems in Africa entails an efficient management of resources which can only be attained through effective policies, programmes, and practices. The nexus approach employed in the management of LWE resources is critical because the issues arising from poor decisions made in one sector has a ripple effect on the other sectors [27] and, subsequently, on the food system. As defined by the Food and Agricultural Organisation of the United States (FAO) [28], ‘food systems (FS) encompass the entire range

of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal, and natural environments in which they are embedded'. By the implication of the definition, the FS approach takes into consideration what happens to the food from the farm to the disposal stage (including the production, distribution, consumption, and waste management stages). Conversely, food security is characterised by the availability of adequate, safe, and nutritious food, along with the economic means to access it, ensuring that all individuals can meet their dietary requirements and food preferences [29]. Food systems constitute a component of the Sustainable Development Goals developed in 2015 aimed at promoting agricultural and food systems transformation to mitigate hunger and malnutrition and improve food security by 2030. Attaining the SDGs requires that global food systems be transformed into productive, inclusive, resilient, and environmental systems capable of continually ensuring healthy and nutritious diets for all [30]. Due to the complexity of food systems, holistic and coordinated approaches are required to understand how the systems interact and synergise and the necessary trade-offs that are essential to maintain their sustainability [31]. This implies the adoption of multidisciplinary approaches and interactions at various scales from the grassroots, country, and regional to global scales to engage the problems affecting the sustainability of food systems.

The application of the LWE nexus approach in food system analysis, therefore, seeks to determine how these resources affect the food value chain either positively or negatively and how they could be optimised to achieve the goal of sustainable food systems in Africa. With the competing demand for resources to address the food, energy, and water needs of Africa, understanding the synergies and trade-offs in the management of these resources and taking into consideration the needs of future generations is paramount. Africa is undergoing a transformation in the agricultural and energy sectors with a corresponding increase in the demand for land, water, and energy. The food system is composed of the following sub-systems: farming systems, waste management systems, and inputs. These systems interact with other key systems and drivers of change, such as energy, water, trade, health, climate change, population, and economic growth [28,32]. This implies that any structural changes in any of the key systems will have an impact on the food system. For instance, the discourse and policies in favour of the expansion of renewable sources of energy, which is critical for sustainable energy generation and climate change impact mitigation, will require more land, which might result in a reduction in agricultural land. The synergy and trade-offs approach applied in systems analysis that encompasses social, ecological, and economic perspectives makes the WEF nexus an ideal theoretical approach for resolving challenges with the implementation of earlier natural resource management and sustainable development approaches [20,21,33–35]. Nexus planning seeks to promote equality and efficiency in resource use with the intention of addressing the issues of poverty, hunger, and malnutrition in Africa [36].

Despite the growing interest in the WEF nexus approach, there is still great concern about the slow pace at which research in this area is progressing in Africa [37]. Although great scientific work has been done in the nexus area, it is largely dominated by technical approaches with less focus on social science or policy research, according to Portney et al. [38]. There is limited research on social, economic, and policy dimensions of the WEF nexus. Mabhaudhi et al. [37] also postulated the need for transboundary water–energy nexus studies to promote regional integration and policy development. Moreover, most of the review articles on nexus research have focused on content and themes, with little or nothing done on the actors who are doing the research and their level of collaborations. Thus, this research seeks to address the following research question: How has research on the LWE nexus application in food systems in Africa addressed the issues of policies, programmes, and practices from a social dimension? The overarching research question is further split into the following sub-questions. (1) How has LWE and SFS research integrated policies, programmes and practices? (2) Which thematic areas does the research on LWE

and SFS address? (3) How are the researchers collaborating to generate knowledge on how LWE could promote SFS in Africa? (4) What are the prevailing challenges and research gaps? The research questions are translated into the following objectives: (1) to analyse the growth of LWE nexus applications in sustainable food system research in Africa in terms of quantity and thematic areas and (2) how it addresses policies, programmes, and practices using a socio-economic lens. The specific objectives are as follows: (1) to determine the extent to which LWE and SFS research integrates policies, programmes, and practices; (2) to identify the thematic areas covered by the research on the LWE application in SFS in Africa; (3) to investigate the interrelationship and levels of collaboration between the research experts; and (4) to ascertain the research challenges and gaps.

2. Materials and Methods

The research employed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) approach to conduct a systematic literature review of the existing research outputs on LWE and FS in Africa. The PRISMA approach was useful in this research for conducting a transparent systematic literature review to justify why the research was conducted, the methods through which the research was done, and the outcome of the research [39]. The PRISMA approach provided guidelines for conducting systematic research, including how the abstract, introduction, methods, results, and conclusions should be framed in a manner that could be easily replicated. Employing the PRISMA approach increased the confidence level in the research outcomes. The literature was sourced from the Web of Science (WOS) and Scopus databases for two main reasons. Firstly, the WOS and Scopus databases constitute the most popular credible database sources for peer-reviewed articles. Secondly, they are compatible with the R-studio tool employed in this research for qualitative analysis to minimise risks and bias in the data analysis process. The distribution of the sources and records of the articles is displayed in Figure 2.

The search was guided by a set of criteria and different combinations of search terms. The search criteria included the geographical location (Africa), publication years (2010–2022), type of publication (research articles, review articles, and conference papers), and language (English and French). Restricting the search to Africa was guided by the research's objective, which aimed to establish a profile of experts and their contributions to the development of LWE and SFS research in Africa. Additionally, the research was focused on identifying current experts in the field to facilitate future collaborations and multidisciplinary research, which justified why the publications were limited to between 2010–2022. Furthermore, the research was focused on identifying peer-reviewed articles, which explained the delimitation to research articles, review articles, and conference papers. Since Africa is diverse in terms of language, the study also endeavoured to identify resources presented in both English and French languages, which are the most predominant languages on the continent. The search terms included the following:

(Land, water, and energy* OR water, energy, and food* OR land and water* OR land and energy* OR water and energy) AND (Nexus) AND (Food system or sustainable food system OR food security) AND (Africa* OR Sub-Saharan Africa OR North Africa). The use of an asterisk (*) added to the main concepts was essential to widen the search and ensure the inclusion of all the relevant articles befitting the search criteria.

Additional screening was done by checking the abstract and ensuring that the selected articles were focused on LWE or WEF and food systems or food security in Africa. Furthermore, the contents of the articles were screened for eligibility based on the Critical Appraisal Skills Programme tool (CASP) [40,41] (refer to Table 1). The content-based screening outcome led to the exclusion of 18 more articles and yielded 73 records of eligible articles for analysis (Figure 2). The last part of the screening was done to identify experts in the research thematic area of African origin. Articles that did not clearly specify the region were highlighted for further investigation by examining the content of the articles. General articles with global coverage, including Africa or review articles, were taken into consideration for selection.

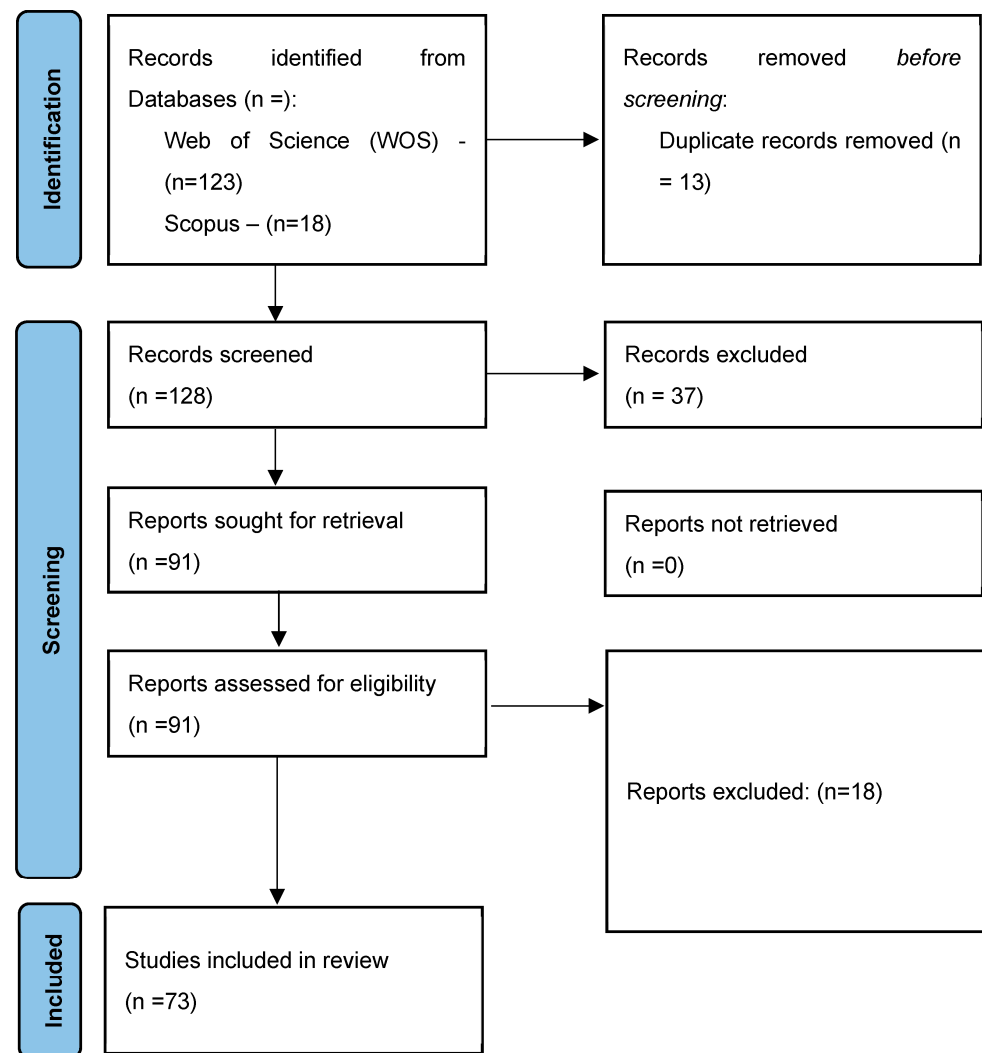


Figure 2. PRISMA diagram depicting the article selection approach and results.

Table 1. Critical Appraisal Skills Programme (CASP) Tool [40].

Qualitative Checklist	Quantitative Checklist
1. Were the aims of the research clearly stated?	11. Did the study address a clearly focused issue?
2. Was a qualitative approach an appropriate method for the study?	12. Was the cohort recruited in an acceptable way?
3. Was the research design suitable to achieve the aims of the research?	13. Was the exposure accurately measured to minimise bias?
4. Was the strategy employed for the recruitment of participants suitable for achieving the research aims?	14. Was the outcome accurately measured to minimise bias?
5. Was the data collection procedure adequate to address the research issue?	15. Did the authors identify all the important confounding factors?
6. Was the relationship between the researcher and participants taken into consideration?	16. Did they take into account the confounding factors in the design and/or analysis?
7. Were ethical issues clarified?	17. Was the follow up of the subjects complete enough?
8. Was the data analysis sufficiently rigorous?	18. Was the follow up of the subjects long enough?
9. Were the findings explicit?	19. What were the results of this study?
10. Did the research make valuable contributions to the existing body of knowledge?	20. How precise were the results?
	21. Did you believe the results?
	22. Could the results be applied to the local population?
	23. Did the results of this study fit with the other available evidence?
	24. What were the implications of this study for practice?

Data Extraction

The data extraction process was done with the aid of the Critical Appraisal Skills Programme (CASP) tool, which constituted a set of questions to guide the selection of illegible articles based on the quality of their contents. The tool also constituted of a set of questions for screening the contents of the quantitative research (14 questions) and qualitative research articles (10 questions) (Table 1). This procedure was followed to minimise risks and bias in the selection of the illegible articles for analysis. In assessing the contents of the articles based on the CASP checklist, the following responses were utilised, namely yes, no, or uncertain, to ascertain the illegibility of the articles.

Following the selection of published records in the research area was the identification of the experts in the field of land, water, energy nexus and food systems research in Africa. The experts were selected based on their contributions to the African-focused LWE or WEF publications. This was essential to show who the African authors were collaborating with internationally in their research. The identification of the experts was informed by the following key questions, as shown in Figure 3.

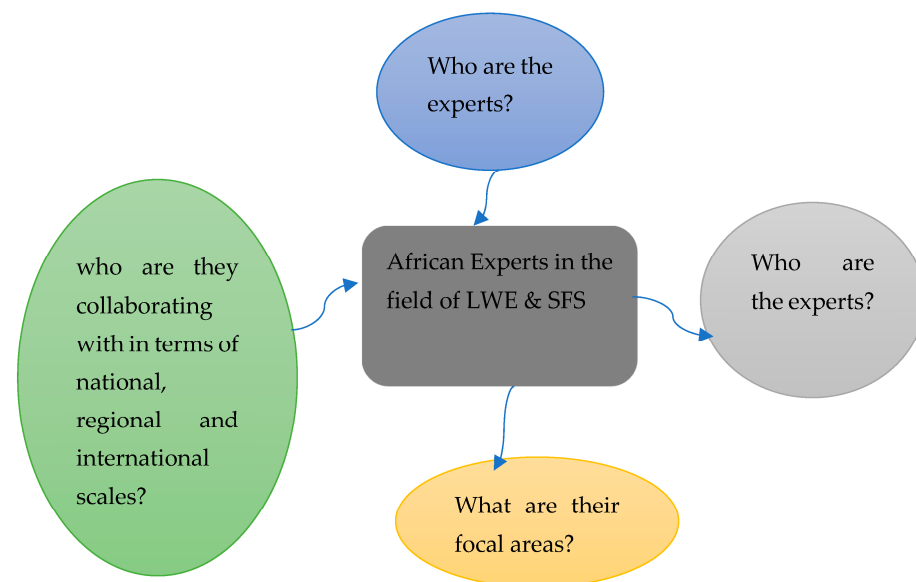


Figure 3. Profiling the experts in the field of LWE and food systems in Africa.

The analysis comprised the application of the bibliometric technique to analyse the thematic coverage, co-occurrence network, most published authors, degree of publication relevance, country-based collaboration network, word frequency over time, affiliation production over time, country scientific production, corresponding authors' countries, and country production over time. The bibliometric analysis was essential for identifying the evolution of the publications, both quantitatively and qualitatively, and the network of themes and authors working on similar thematic areas. Furthermore, content-based analysis was done to ascertain the extent to which the existing research on LWE and SFS addresses policies, programmes, practices, social inclusions, governance, and institutional interventions. The socio-economic-based analysis identified gaps in LWE policies and practices and proposed recommendations to narrow the gaps.

The research analysis was guided by the application of the Africa Food System (FSNet) Framework (Figure 4) [42]. The FSNet-Africa framework constitutes a comprehensive framework designed to promote the rigorous analysis of food systems research in Africa. The FSNet-Africa framework was designed by an FSNet research team and based on the adaptation of the Transango framework [42] to align with African food system research (Figure 4). The framework consists of the following components: the Earth sphere, which includes climate change and the environment; livelihood capitals; and institutional arrangements.

These components are influenced by drivers, such as political and governance structures, which include all the actors involved in the food value chain from production to consumption. Additionally, the framework defines the outcomes, such as food and nutrition security and health, environmental sustainability, livelihoods, and territorial balance [42]. The FSNet framework was employed in this research to investigate the extent to which LWE nexus research projects address institutional arrangements, policy, social and gender equity, politics, and governance to achieve sustainable food systems in Africa.

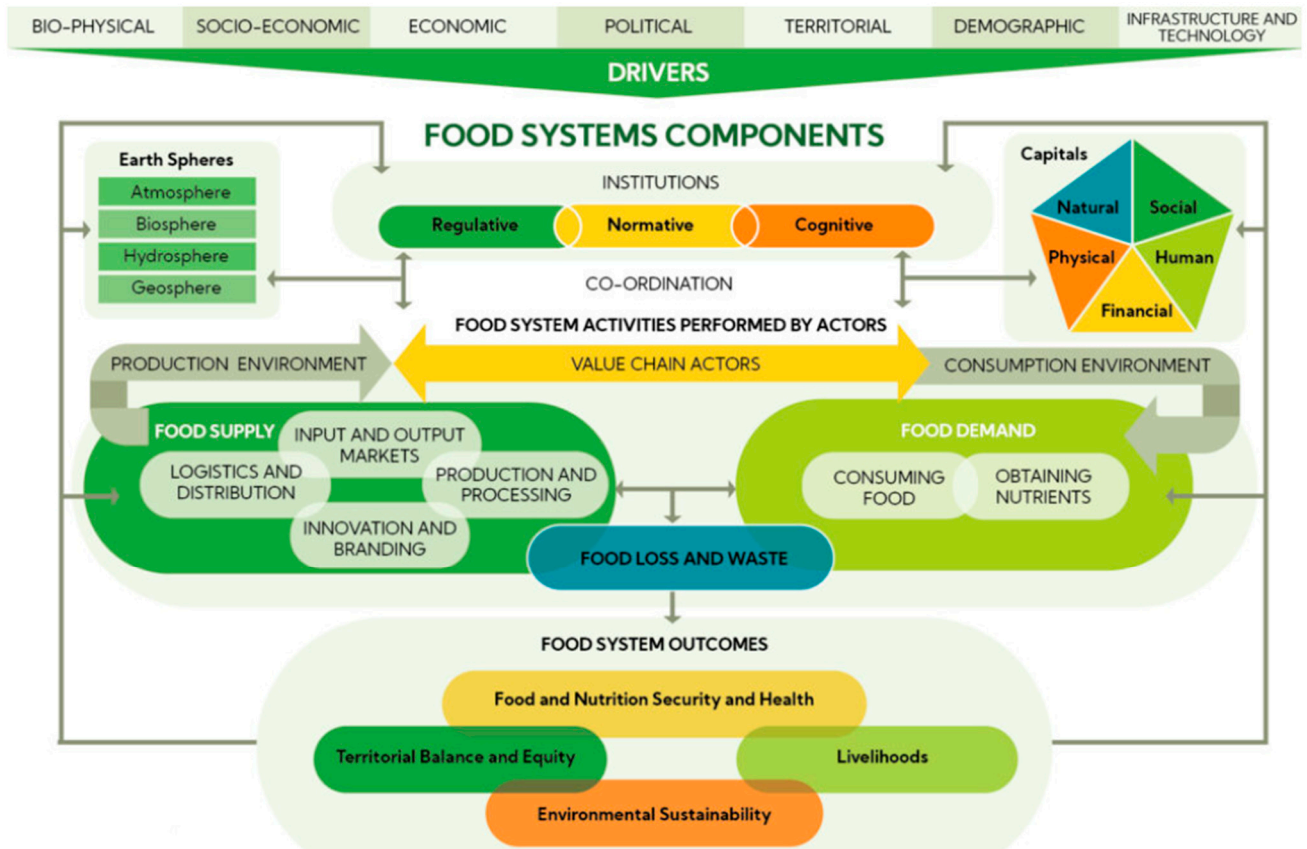


Figure 4. The FSNet Africa food system framework.

3. Results

3.1. Bibliometric Analysis of the Trends in LWE and SFS Nexus Research in Africa

This section presents the outcomes of the bibliometric analysis, illustrating the expansion of the LWE nexus and SFSs research through commonly used terms and the interplay of the concepts and themes. Additionally, it explores the geographical locations of the authors and their institutional collaborations in the realm of the LWE nexus and SFS research.

3.1.1. Thematic Growth Analysis

Land, water, and energy (LWE) or water, energy, and food (WEF) research have evolved over the years. The analyses depicted in this section in terms of the word cloud (Figure 5) and co-occurrence networks (Figure 6) illustrate the frequency in the use of concepts related to nexus research over time using the author's keywords. For instance, the concepts in bold print in the word cloud (Figure 5), including security, management, food security, nexus, systems, sustainability, and climate change, exemplify the most frequently used terms. Alternatively, the terms represented in smaller print depict a slow growth of research conducted in those areas. For instance, the representation of irrigation in small print depicts the slow pace of research conducted on the nexus perspective of alternative water sources for the growth of food crops during seasonal stressed eras. Similarly, policy and governance

are depicted in smaller print, demonstrating limited research accomplished in these thematic areas relative to the concepts highlighted in bold prints.

On the other hand, the co-occurrence network elucidates the conceptual structures of the terms used in the keywords (Figure 6). The high occurrence keywords are depicted in terms of larger and darker nodes while the low occurrence keywords are depicted by smaller and brighter nodes. Similarly, the shorter lines depict a stronger relationship between the concepts while the longer lines show a weaker relationship [43]. In addition to the co-occurrence keywords illustrating the variety of themes, it also depicts the multidisciplinary nature as well as the direction which the research went [44]. For instance, Figure 5 represents a cluster of the frequently used keywords grouped into five streams and symbolised by different colour representations. The densest cohort is represented in colour purple, which shows how food security and sustainability have been researched frequently and approached from a multidisciplinary perspective. On the other hand, the low density of the climate change clusters, for example, implies its low consideration in land, water, energy, and food systems or food security nexus research. From a policy and governance perspective, the results show that limited research has been done on these themes (Figure 6).



Figure 5. Word cloud (generated using the R-bibliometric tool developed by Aria and Cuccurullo [45]).

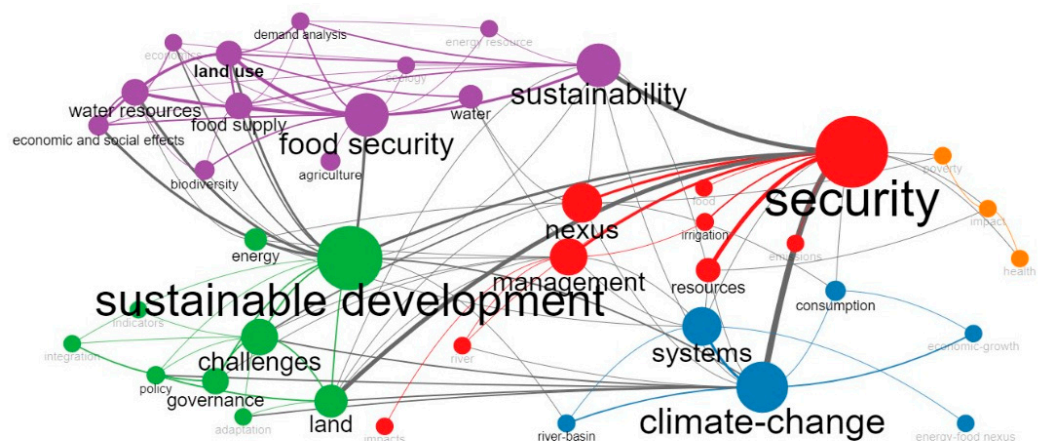


Figure 6. Network of concepts used in LWE and SFSs research (generated using the R-bibliometric tool developed by Aria and Cuccurullo [45]).

3.1.2. Evolution of Research in the Land–Water–Energy Nexus and Sustainable Food Systems

This section of the paper discusses the transition of research in the area of LWE and SFSs. The section seeks to establish a trajectory for how research in the aforementioned thematic area has evolved and the area that is trending. Figure 7 reveals a steady growth in water, energy, and food nexus research with particular emphasis on food and water security. The expansion of research in the LWE nexus, with a particular emphasis on food and water security, could be attributed to two key factors. Firstly, there is a concerted effort to align with the UN Agenda 2030, aiming to achieve the Sustainable Development Goals. Secondly, the escalating scarcity of water for agricultural purposes, compounded by increased drought occurrences and prolonged dry seasons, is driving this research. Despite growing challenges in the natural resource management associated with socio-economic, cultural, and environmental factors, the research is evolving at slow speed. For instance, the low dense lines in Figure 7 particularly in the year 2023 shows that not much research was done.

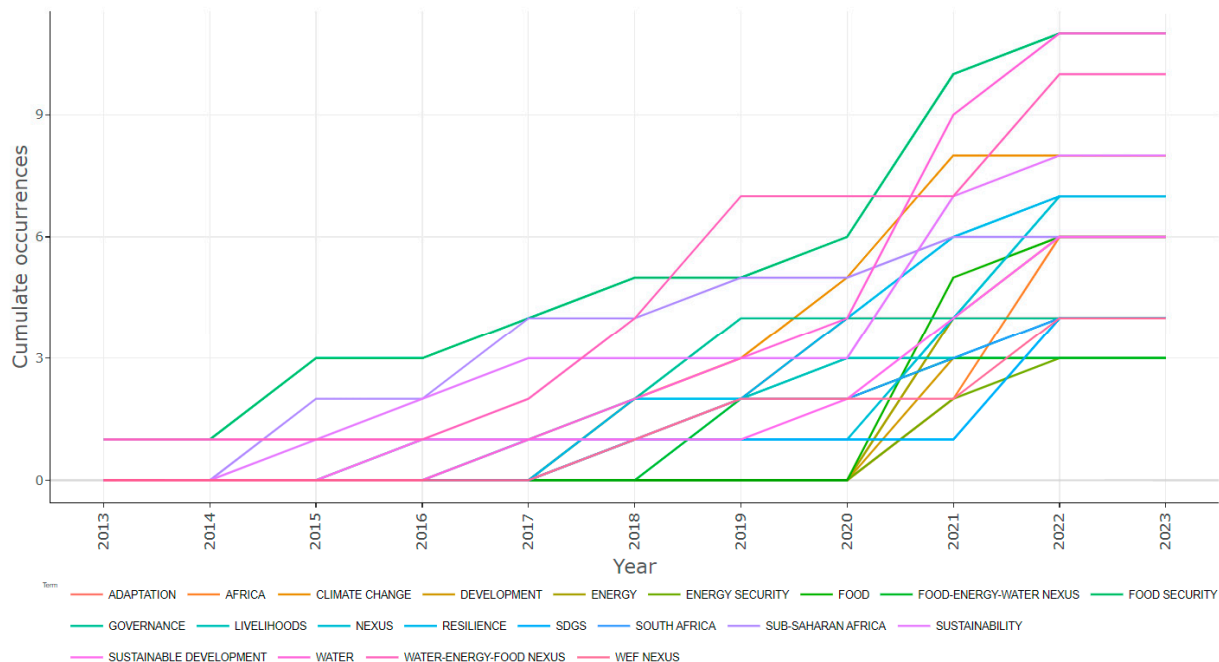


Figure 7. Frequently used terms in LWE and SFS research over time (generated using the R-bibliometrix tool developed by Aria and Cuccurullo [45]).

However, the results shown in Figure 8 showed the growth in affiliation engagement in LWE and SFSs. Most of the high-ranking affiliations undertaking this research were based in South Africa. Generally, the rated affiliations both in Africa and internationally included the University of KwaZulu Natal, University of Johannesburg, University of Witwatersrand, International Water Management Institute (IWMI), Vanderbilt University, and Institute of Geoscience and Natural Resources, which are listed in order of merits. However, African scholar participation in this thematic area in terms of the author's country of residence was narrow when compared to a global scale. It was of great concern to see that, except for South Africa, the country production over time on African-based research was dominated by foreign nations, including the USA, China, United Kingdom, and Italy (Figure 9). This outcome goes to show that the discourse on knowledge decolonisation has not gained acceleration in this research area.

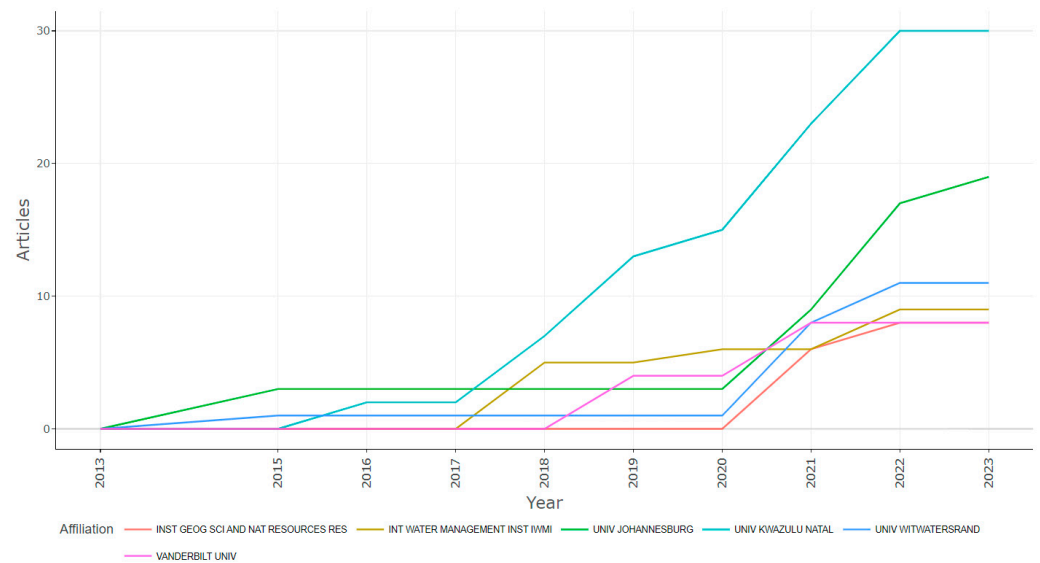


Figure 8. Temporal distribution of the affiliation contributions to LWE and SFS research (generated using the R-bibliometrix tool developed by Aria and Cuccurullo 2017 [45]).

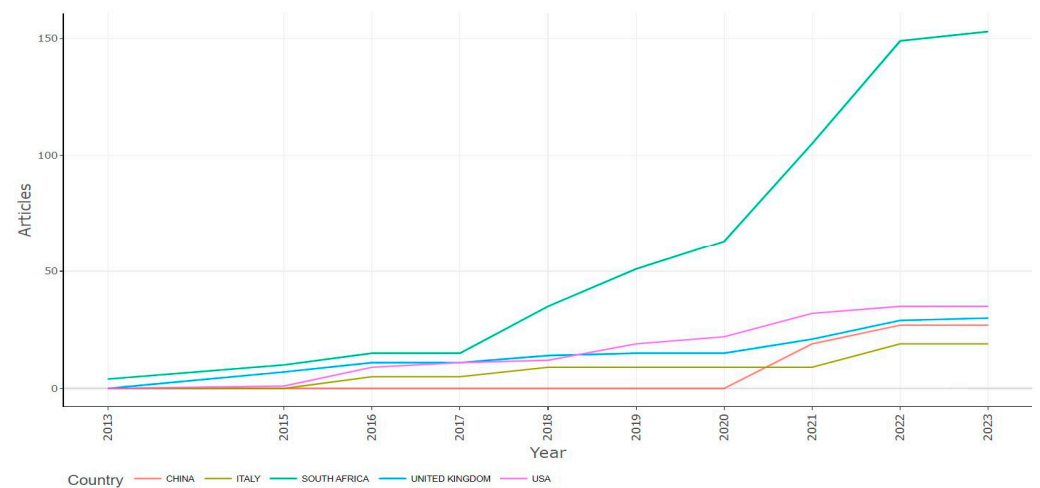


Figure 9. Temporal distribution of the country contributions to LWE and SFS research (generated using the R-bibliometrix tool developed by Aria and Cuccurullo 2017 [45]).

To better appreciate the significance of the themes, a thematic map was very useful. The thematic map constituted two axes, including the *x*-axis development degree (density) and the *y*-axis relevance degree (centrality) (Figure 10). The thematic map was structured into four quadrants: niche themes, motor themes, emerging or declining themes, and basic themes. The niche themes, such as sustainable development, SDGs, food–energy–water nexus, and renewable energies, represented highly specialised and well-established topics within the field. The motor themes, which encompassed food security, energy security, climate change resilience, and adaptation, were pertinent research areas that have witnessed substantial growth. The emerging and declining themes encompassed newly introduced research areas and those that are gradually fading into obscurity. Finally, the basic themes, including water–energy–food nexus governance and water sustainability, are fundamental subjects that are relevant to research but still require further development.

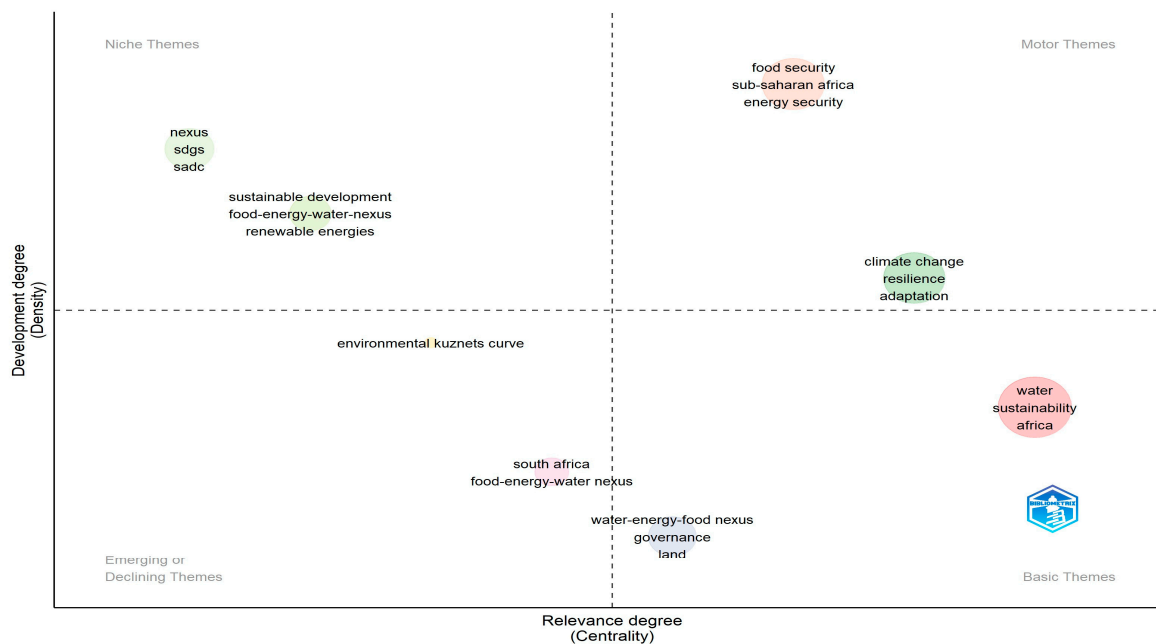


Figure 10. Diagram depicting the development and relevance of the themes used in LWE and SFS research (generated using the R-bibliometrix tool developed by Aria and Cuccurullo [45]).

3.1.3. Research Collaboration Networks in the Domain of the LWE Nexus and Sustainable Food Systems in Africa

The growth of research collaboration is gaining traction in Africa and the world at large with the eminent aim of pooling human, financial, and material resources to solve common challenges that have become global issues. Nevertheless, based on the 73 analysed articles, Figures 11 and 12 show a tendency for African researchers to collaborate with researchers in the global North rather than the global South. For instance, Figure 11 reveals several clusters showing the fragmentation of research collaboration between African countries and nations in the global North. The outcome revealed the domination of international researchers in the research collaboration, which supported the assumption that African researchers tend to collaborate more with international researchers than their colleagues in Africa [46], which was also corroborated by the findings in Figure 12. This was due to the fact that research growth in Africa faces impediments, primarily categorised as institutional and individual factors. The institutional challenges encompass restricted funding, inadequate support and collaboration networks, government disinterest in research, and a deficiency in mentorship. Conversely, individual hindrances involve low self-motivation, limited research capacities and self-efficacy, and a burdensome workload [47–49]. Furthermore, South Africa, which has led multiple collaboration publications (MCPs) as shown in Figure 12, indicated a significant level of researcher collaboration both within Africa and internationally. In contrast, Rwanda and Tunisia, identified by single collaboration publications (SCPs), suggested limited external collaboration among their researchers.

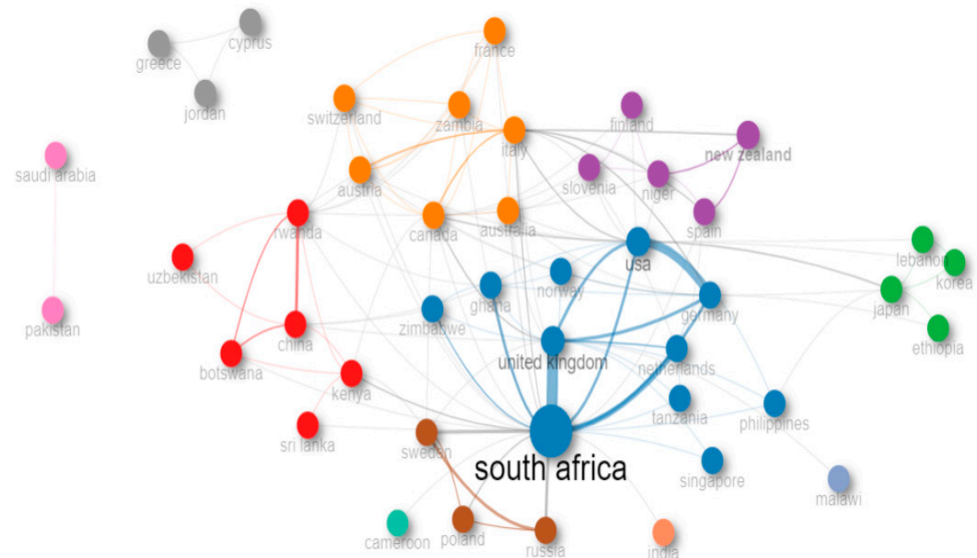


Figure 11. Diagram depicting the country collaboration network in LWE and SFS research (generated using the R-bibliometrix tool developed by Aria and Cuccurullo [45]).

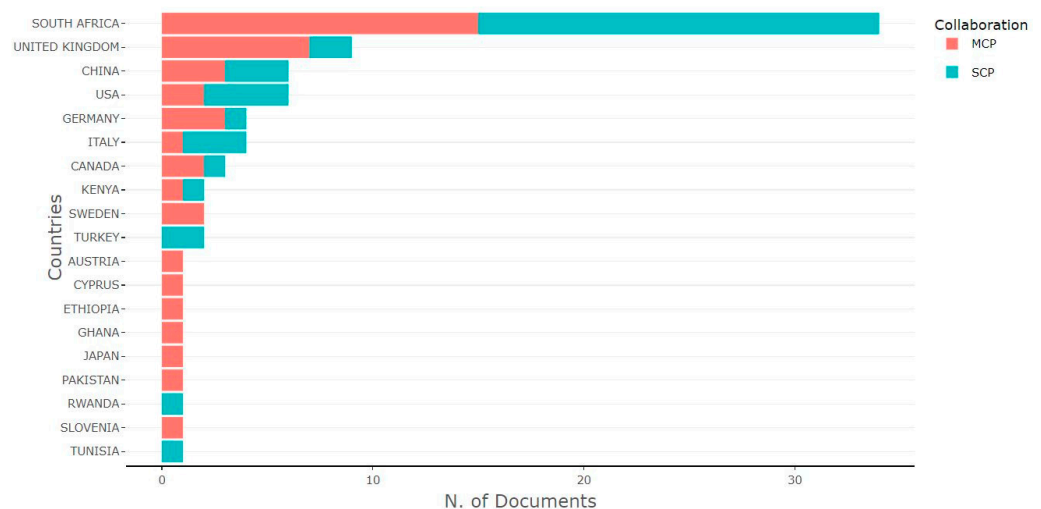


Figure 12. The countries of the authors contributing to LWE and SFS research (generated using the R-bibliometrix tool developed by Aria and Cuccurullo [45]).

3.1.4. Scientific Publications

This section discusses scientific production on the LWE and sustainable food systems research area with the aim of identifying the lead authors and countries in this thematic area. It is very important to identify the lead authors of African origin to encourage them to take up the responsibility of promoting the African perspective as well as accelerating research collaboration amongst African scholars in this area of research. The ten most published authors in order of merit, as denoted in Figure 13, include Nhamo L., Mabhaudhi T., Mpandeli S., Modi A., Naidoo D., Hirwah F., Muhirwa F., Senzanje A., Conway D., and Elshkaki A. Furthermore, the country scientific production, as depicted in Figure 14, buttresses the fact that South African institutions are dominating the research in this thematic area in Africa while, on the other hand, painting the dominance of foreign nations in Africa-based research. Moreover, the grey colour represent countries which have not conducted any research in LWE nexus and SFSs.

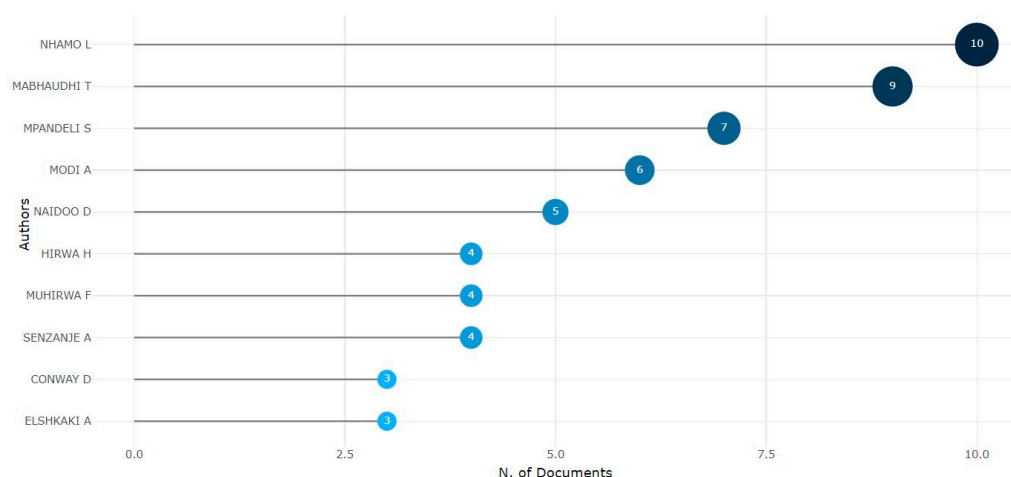


Figure 13. Most published authors in LWE and SFS research (generated using the R-bibliometrix tool developed by Aria and Cuccurullo [45]).

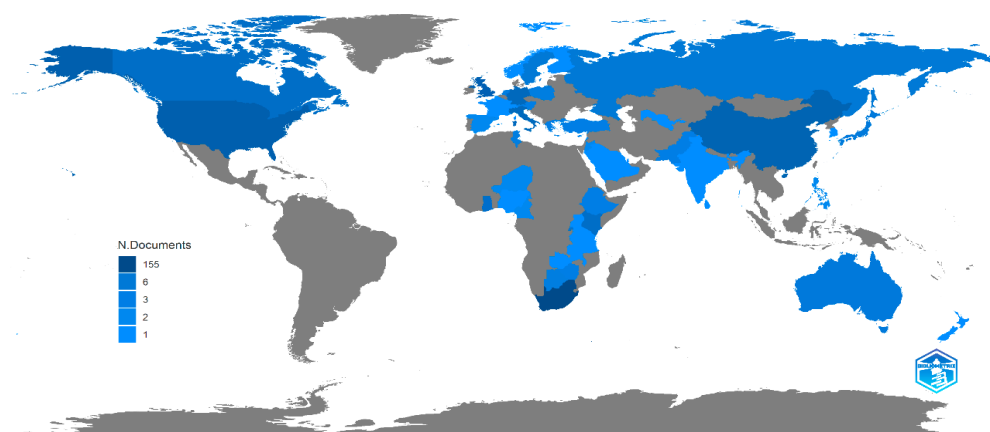


Figure 14. Global spatial distribution of LWE and SFS scientific production (generated using the R-bibliometrix tool developed by Aria and Cuccurullo [45]) (<http://127.0.01:6225/#shiny-tab-collabWorldMap>, accessed on 10 August 2023).

3.2. Content Analysis and Thematic Distribution

3.2.1. Thematic Coverage

In addition to analysing the LWE/WEF research productivity in Africa in the preceding sections, this section discusses how the LWE/WEF nexus approach has evolved qualitatively in terms of thematic coverage. The thematic analysis was done based on the application of some components of the FSNet framework, as explained in the methods section. The LWE research attention on policies, programmes, and practices in addition to specific thematic areas were examined to ascertain the extent to which the existing research covered these thematic areas. Figure 15 depicts a larger focus on LWE/WEF practices and a marginal focus on policies and programmes. In other words, a significant portion of LWE/WEF research focuses on implementing or putting into practice this approach for attaining sustainability in agriculture, enhancing food security, optimising food systems, and managing resources.

Article focus in terms of policy, programme, & practices

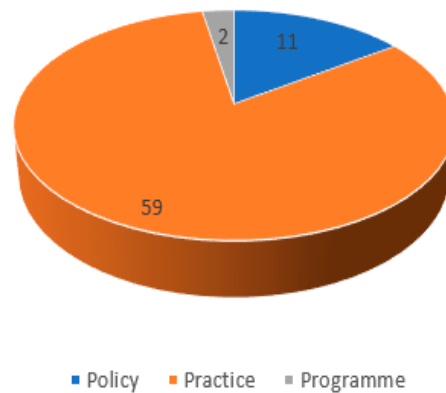


Figure 15. Sectoral distribution of LWE and SFS research.

3.2.2. Thematic Distribution of LWE Research Articles

The content review of the articles' thematic coverage (Figure 16) revealed a dominance in socio-ecological research. Research within the socio-ecological perspective primarily centered on the examination of social factors. These factors included the effects of population growth on the operationalization of the nexus, the consequences of energy policies on land availability for human well-being, as well as the socio-economic and environmental challenges associated with the implementation of nexus programs. In addition to the research concentrated on sustainability and technology, there was a notable scarcity of research in several vital thematic areas. These areas included conflicts, governance, gender, policies, socio-political dimensions, and culture. These gaps aligned with the findings from the bibliometric analysis.

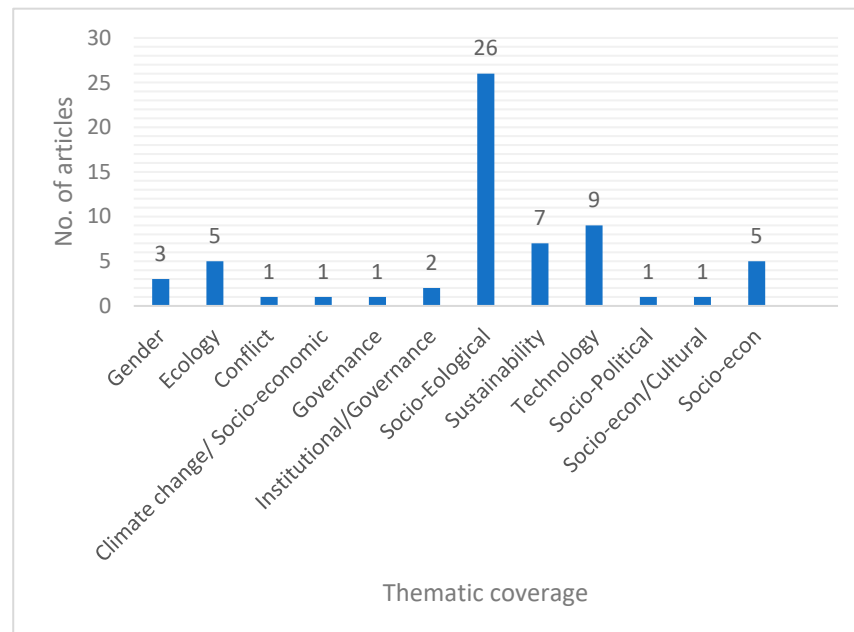


Figure 16. Thematic coverage of the LWE and SFS articles.

4. Discussion

Sustainable food systems do not entail just physical and environmental components but have a human dimension in terms of how resources are distributed, managed, and

used [50]. The LWE nexus approach constitutes a contemporary measure aimed at managing resources effectively to attain food security, water security, energy security, and sustainable food systems goals. Nonetheless, there is a mounting concern regarding the limited integration of stakeholders who are responsible for the utilization and management of nexus resources in the current research efforts. This study aimed to perform a comprehensive scoping assessment of the development of nexus research in Africa, with a specific focus on evaluating the extent to which this research addresses human dimensions from policy, program, and practical perspectives. Utilizing both bibliometric and content-based analyses, this research delved into the prevailing concepts and themes within LWE research and their interconnections, with the objective of deriving potential solutions for the food, water, and energy challenges in Africa. Additionally, the study explored the authors who were involved and their collaborative networks. The research yielded the following significant findings. There was a notable emphasis on operationalizing the nexus approach, while aspects like policy, governance, and institutional support, which are pivotal for the effective application of this approach, received comparatively less attention. Additionally, LWE research was predominantly authored by individuals from outside Africa, with African-based authors displaying a higher inclination to collaborate with international counterparts rather than their regional colleagues. Furthermore, the integration of social diversity, particularly concerning gender-related issues in access to and control of nexus resources, has not received substantial consideration.

The operationalization of LWE has predominantly revolved around proposed frameworks, technologies, appropriate methodologies, and socio-economic factors that influence the effective planning, management, and utilization of nexus resources [51–55]. While these measures are valuable, their successful implementation hinges on additional factors, such as policies, institutional interventions, and governance mechanisms. The scarcity of research examining how policy, governance, and institutional interventions interact with nexus approaches to either facilitate or hinder their application has created a barrier to effective decision-making and resource allocation. For instance, [56] highlighted the constraints impeding the operationalization of the WEF nexus approach, including the ambiguity of the concepts, variations in the challenges related to nexus resources across nations, the diversity of multidisciplinary perspectives, global challenges, and cultural and political barriers. Policies play a critical role in promoting agricultural development by facilitating farmers' investments in acquiring LWE nexus resources. As an illustration, Simpson and Jewitt [57] documented how South Asian countries implemented policies that provided subsidies to enable farmers to access irrigation, energy, and inputs to enhance productivity, consequently stabilizing the prices for staple crops like wheat and rice. Nevertheless, Ringler et al. [20] cautioned that poorly regulated subsidies could lead to the wasteful use of groundwater resources, posing a threat to agricultural productivity if the utilization of water and energy is not properly managed. In light of these arguments, it has become evident that policy is indispensable for promoting the operationalization of the LWE nexus. However, the policies should be thoughtfully designed to avoid inadvertently creating new challenges while attempting to address existing ones.

The policy engagement is further weakened by the lack of governance elements in the nexus debate, as observed by [58] and confirmed in this study. The governance in LWE nexus research implies a set of norms, rules, strategies, and services set by both private and public systems to ensure the planning and management of the demand and supply of land, water, and energy, [59]. It was also noted that good governance in nexus application implies enhancing the synergies between the resources while adequately managing the trade-offs and minimising resource conflicts [60]. Governance and institutional interventions constitute essential pillars for the successful implementation of the LWE or WEF nexus approaches alongside policy. It is worth noting that governance and institutional approaches vary across different nations influenced by different systems of governance, cultures, and economic situations, and above all they are not static. Ferreira et al.'s [61] study conducted in Brazil revealed a bias in the state mechanism for water allocation in favour

of agribusiness against small scale farmers. However, this research underscored that the integration of social inclusion into the operationalization of the LWE or WEF nexus, aimed at achieving sustainable food systems in Africa, remains a relatively unexplored and ambiguous domain. The findings may be explained using an example from Ibrahim et al.'s [62] observation of the absence of policy and governance frameworks to ensure the effective implementation of green stormwater infrastructure. The barriers to policy and governance design and implementation are associated with unresponsive culture, a lack of collaboration, a lack of knowledge, adequate political will/leadership, and insufficient funding, according to Ibrahim et al. [62]. The failure to understand and enhance the policy, governance, and institutional roles for promoting the implementation of LWE and WEF may exacerbate the issues of inequality in negotiating trade-offs and distributing resources. This limitation is a serious concern, especially at a critical juncture with a growing population, ongoing climate change, and other planetary challenges such as pollution and desertification.

Furthermore, the study's findings highlighted a dearth of research concerning the integration of gender considerations in the nexus discourse. This is a particularly crucial aspect to ensure inclusivity in the planning and management of nexus resources. Given that gender roles and decision-making authorities often differ between women and men in many African societies, understanding these gender dynamics is essential for achieving equal participation in resource synergies and negotiating trade-offs. Integrating gender into discussions on resource synergies and trade-off negotiations has the potential to safeguard equitable benefits from the decision outcomes. Hlahla [63] advocated for a transformation in gender relations and an enhancement of both women's and men's active involvement in the decision-making process. Hlahla [63] contended that these steps are effective approaches to reduce women's vulnerability to climate change and promote equity in access to and the use of natural resources.

In addition to the limitations in the research conducted in the LWE or WEF and food systems nexus studies in Africa, the dominance of foreign authors in the research arena also stood out. Apart from South Africa, which plays a dominant role in the nexus research in Africa, LWE and food systems research in Africa was largely dominated by countries such as the USA, Britain, and China, which were identified based on the authors' geographical location. The fact that African-based authors were found to collaborate more with authors in Europe, America, and China than within the African continent is still of great concern. The dominant role of foreign authors in African-focused nexus research, though essential in terms of knowledge exchange and capacity development, may also have a detrimental impact on the development of knowledge systems not tailored to African realities. These concerns aligned with the ongoing debate on the influence of Western-centric knowledge systems on African development and the drive towards the decolonisation of African knowledge systems [64,65]. The infiltration of the Western-centric nexus models for addressing resource use and management in Africa may likely influence the decisions and actions that do not suit Africa's realities. More in-depth research is required to investigate how successfully the Western-centric nexus model works for Africa to achieve sustainable land, water, and energy security.

5. Conclusions

The research primarily focused on analysing the growth and application of the LWE (land–water–energy) nexus within the context of sustainable food systems research in Africa. The study delved into both the quantitative and thematic aspects of this subject, with a particular emphasis on how the policies, programs, and practices relating to the LWE and food systems nexus were addressed from a socio-economic perspective.

The research employed a systematic literature review using the PRISMA approach for data collection, and it utilised R-bibliometric and content-based analyses as the analytical methods. The research's findings indicated that while there has been a significant emphasis on the practical implementation of the LWE nexus, there was comparatively less attention given to the policy and program aspects. This suggested that the effectiveness of these

policies and programs has not been thoroughly examined, even though they were pivotal for the successful operationalization of the LWE nexus.

Furthermore, the research revealed a gap in the inclusivity aspect of the nexus discourse, indicating that the perspectives of various stakeholders may not have been adequately captured. Additionally, the study noted that African-based authors were underrepresented in this research, with many of the contributions coming from non-African authors. The increased participation of non-African scholars relative to African researchers could impact the applicability and relevance of the findings to an African context.

In light of the challenges posed by population growth and resource depletion, this research strongly recommends an increased investment in capacity development and funding for LWE or WEF (Water–Energy–Food) nexus research. Such investment is vital to ensure the sustainable and harmonious utilization of resources. The study also underscores the critical importance of coordinated decision-making to prevent trade-offs that could jeopardise the sustainability of any of the resources within the nexus.

To enhance regional and continental collaboration, the research findings suggest the creation of platforms where local LWE researchers can collaborate in the co-production of knowledge.

In summary, this research underscores the significance of taking a holistic approach to comprehend and manage the intricate interactions among land, water, and energy resources in the context of sustainable food systems in Africa. It stresses the need for more comprehensive examinations of policies, programs, and practices, as well as an imperative greater inclusivity and representation of African perspectives in research endeavours related to the LWE nexus.

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