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RESEARCH ARTICLE

The Food-Energy-Water Nexus Optimization: A Systematic Literature Review

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ABSTRACT

The sudden rise in population and the need to sustain natural resources have subjected many researchers to another dimension of an interesting study, such as integrating food, energy and water into a single entity. Tampering with natural resources, especially food, energy, or water, could be an aspect that hinders the requirement to meet the world's growing city needs. The food-energy-water nexus has become even more difficult due to agricultural globalization, the essential task of which is to secure regional food and water. Therefore, the systematic literature review in this article critically investigates food interactions with energy and water optimization for sustainable development and illustrates the key points, networks, and gaps within this literature. The databases from Scopus, Web of Science, and ScienceDirect were the key retrieved data in this study from 2010 to 2024. A total of 641 research journals, book chapters and conference papers were systematically reviewed. The results based on country mapping analysis strongly favour advanced countries, for example, Germany, the United States , and the United Kingdom, recording almost more than 40% of published articles; while China, including other developing countries, record more than 5% of food-energy-water nexus research. In addition, several food-energy-water nexus articles are restricted to about one-quarter of subject categories, such as water resources, environmental sciences and green sustainable science technology. The results also depicted that the food-energy-water nexus method encourages inter-sectoral and multilevel governance, scholarly and private sector, thereby supporting the intricacies and inadequacies in attaining the sustainable development goals. The prioritization of the food-energy-water nexus

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approach, particularly during the incident of COVID-19, can be a complete method to sustainably exploit natural resources to support the attainment of environmental sustainability. Thus, studying the integration of food, energy and water would produce better knowledge in advancing the flexibility of natural resources and decreasing multi-faceted global poverty.

Keywords: Sustainability; Food-Energy-Water Nexus; Resource Efficiency; Optimization; Policy-Making

1. Introduction

Globally, the calls for food-energy-water (FEW) are on the exponential rise to about 50% as a result of urbanization, differences in consumption style, climatic change and population growth [1]. In 2019, the United Nations (UN) recorded that approximately 821 million people in 2017 were underfed compared to 784 million inhabitants in 2015. Unfortunately, supplying food to these undernourished people worldwide will require more land than is presently available [2]. Similarly, accessibility to water is not out of the woods in the global community, as the statistical reports show that in 2019, 785 million people lacked safe drinking water, while about 2 billion inhabitants had no water supply. Also, the UN projected that about 700 million inhabitants would drift or search for refuge in another setting because of the strict scarcity of water [3]. In another strict view, the World Bank reported that in 2019, about 840 million rural dwellers lacked electricity supply [4], while around 3 billion people had no means to refine cooking fuels, including renewable energy [5]. Studies show that the surface earth's temperature in 2018 was around 1 °C, which is higher than the estimated measure by the Paris Agreement [6]. Hence, if the present situation persists, it is assumed that the Arctic glaciers will dissolve, causing seas and oceans, and the submergence of 150 million populations by 2050 and 360 million by 2100 [7].

Regarding this situation, the demand for FEW has started gaining popularity because of the rising socio-economic pressures that are surpassing the capacities of the environment to recover, creating terrible costs for sustainable development goals. To this end, research in the area of optimizing environmental resources is gaining worldwide attention to mitigate dangers such as waste, depletion of resources and emissions. Previously, researchers have learnt the complicated corroboration of the FEW in the environment, as presented in **Figure 1.** This knowledge was piloted by the idea of nexus [8]. The term "nexus" was initiated as a requisite to serve a complete and joint to the entire system, rather than its individual elements to advance towards a viable result for the prospect of the society [9]. Therefore, the idea of the FEW nexus has become a focus of interest in academic literature, workshops, policy-making platforms and conferences as a better way to comprehend multipart correlations among numerous resource systems.

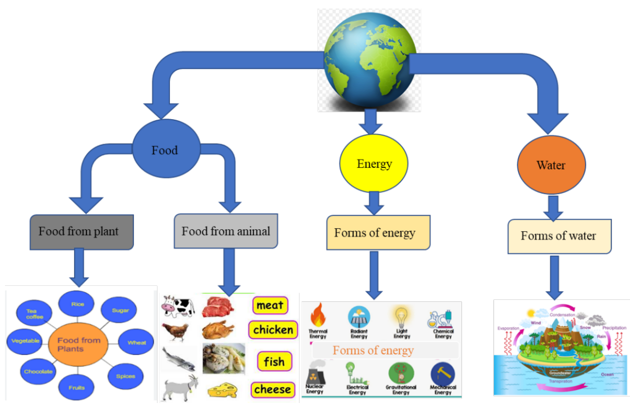

Figure 1. Description of food, energy and water structure.

The resource management in **Figure 1** highlights the FEW nexus as a vital trio nexus that represents the complex and symbiotic relationships among these crucial resources, which are essential to human well-being, economic growth, and environmental sustainability [10]. Thus, optimizing the FEW nexus has become a key challenge and opportunity for researchers and industry leaders globally. The FEW nexus captures the difficulties of resource management where practices in one area always have substantial effects on the others [11]. For example, agricultural practices need considerable energy for irrigation, water inputs, processing, and transportation. In the same way, energy production always depends on water for cooling procedures, while water withdrawal and distribution need significant energy. This interrelation requires an integrated method to resource management that can complement the contending demands and reduce trade-offs. However, research and innovation are vital in developing our knowledge of the FEW nexus and emerging optimization approaches. Quantitative models, including systems dynamics models and integrated assessment models, are influential in simulating intricate connections and forecasting the results of several interventions [12]. Furthermore, interdisciplinary study combining understandings from engineering, environmental science, social sciences and economics is important for creating inclusive solutions. The nexus method to resource allocation systems equally addresses land and soil use by considering socio-economic elements. Carvalho et al. stress the need for systemic rationale to create multipurpose strategies dedicated to the FEW nexus [13]. A systemic method could also allow the consideration of crucial indicators, including sustainability and resilience by concentrating on the interconnections across several fields rather than viewing them as isolated elements [14]. As the global community continues to experience growing challenges, a determined effort towards FEW nexus optimization will be crucial for developing a sustainable future.

Several optimization models have been established for FEW management, each directed to various objective functions, geographic scales, and modeling methods. For example, Di Martino et al. developed an optimization framework for screening reverse osmosis plants under FEW nexus perceptions, using it for a regional case research in South-Central Texas with three separate circumstances [15]. Their model utilized three objective functions within a mixed-integer nonlinear optimization problem. Cansino-Loeza and Ponce-Ortega presented a multi-objective optimization model for developing FEW systems, integrating a multi-stakeholder analysis to formulate solutions built on diverse stakeholder significances [16]. This model, a mixed-integer linear programming challenge with three objective functions, was used in a regional case study in Mexico, where industrial activity struggles with resource demands because of low water accessibility. Wicaksono et al. conducted an optimization module for the WEF nexus simulation module (WEFSiM-opt), containing four objective functions meant to exploit the user dependability index for water, energy, and food sectors [17]. This model, evaluated using single- and multi-objective genetic algorithms, was used in a national case analysis in Korea to find out optimal resource allocation and management under a drought situation. Li et al. presented a multi-objective optimization model under uncertainty for sustainable agricultural water, food, and energy nexus management [18]. This model combined Random Boundary Interval and fuzzy set theory to tackle uncertainties and was utilized in a city-scale case study in the Jinxi irrigation district of Fujin City. Memarzadeh et al. presented an innovative multi-agent management optimization method that combines uncertainty and stochasticity through game theories and decisions to optimize multi-agent FEW system procedures [19]. Their model, a nonlinear, nonconvex programming challenge concentrating on operational costs, was confirmed in a Ventura County, California, regional case study. Despite the several proposed optimization models with variable characteristics for FEW nexus management, no complete literature analysis presently study them all in a single article.

Therefore, regarding the literature studies, it is observed that there is a deficiency in the three areas of the FEW nexus. Similarly, less interest is given to reviewing the FEW nexus optimizations. In view of this, the paper considers the SLR of FEW nexus optimizations with the following contributions: (a) to examine the evolution of the existing articles that published the growth of contending demands for food, energy and water nexus. (b) to design plans, the FEW nexus methods could be adopted to connect and advance coherence in decision-making. (c) to bring it up in a conversation about the nexus concept used for problem-solving and encouraging regional collaboration. (d) to gain ideas on optimizing natural resources through the FEW nexus in local areas. The paper is organized herein by first introducing the context of nexus and an overview of FEW nexus advancements in Section 2. Section 3 describes the state of the arts both in developed and developing countries, and the methodology is presented in Section 4. The review results were discussed in Section 5, and the conclusions, recommendations and future works were presented in Section 6.

2. The Context of Nexus

The rate at which water is extracted and the strengths of energy utilization determine the procedures for food production. Just like food and water are the requirements for generating energy, nice food and energy applications are required for water security. Meanwhile, electricity generation, such as hydropower, fossil fuel extractions, purifications, and feedstock nurturing as applied to biofuel generations are powered by water. Birol and Das stated that almost 15% of international water extractions are used for energy generation[20]. In the same vein, energy is vital for extracting, supplying, treating and transferring both consumed and unconsumed water for societal utilization. On the other hand, in the global community, approximately 8% of energy is used during water drives[21]. Water is essential to food generation and refining (crop irrigation, pond filling for aquaculture generation, and food refining); it relates to food generation and river systems by conveying excess sediments, agrochemicals, saline trading and organic trading matter[22]. Chakkaravarthy and Balakrishnan projected that approximately 70% of international water extractions enter food generation[23]. For instance, the description of the decline in the quality of water due to the rise in seafood generation (aquaculture) and pollution of water as a result of nutritional pileups through releases of unused fish food and fish misuse in the body of water[23–25]. Similarly, the energy required by the food generation systems, including food generation and transportation, applies to approximately 30% of international energy generated[26]. **Figure 2** demonstrates the relationship between the FEW nexus.

Similarly, food can be utilized for energy generation, as in the case of biofuel, and a study shows that approximately 1% of food supplied is utilized for a particular objective[27]. Additionally, these offer the undesirable outwardness of FEW applications, such as contamination of water systems and the discharge of greenhouse gases[28]. However, reactions from climate change, such as temperature increase, differences in the pattern of rainfall and extreme weather conditions, influence FEW generations. For instance, an increase in temperature causes air to warm up, which retains more moisture and can increase the chances of rainfall, causing flooding and reducing food yield[29]. On the other hand, differences in climate, such as warmer weather conditions, cause a high rate of evaporation, the depletion of groundwater and surface, as well as more droughts and a lack of water. Consequently, a straight danger to animals, the widespread parasites and ailments associated with the fluctuations in weather conditions pose a risk to food yields[30]. Equally, the decreasing water system due to excessive climate conditions influences hydroenergy generation and biomass utilized in biofuel generation[29].

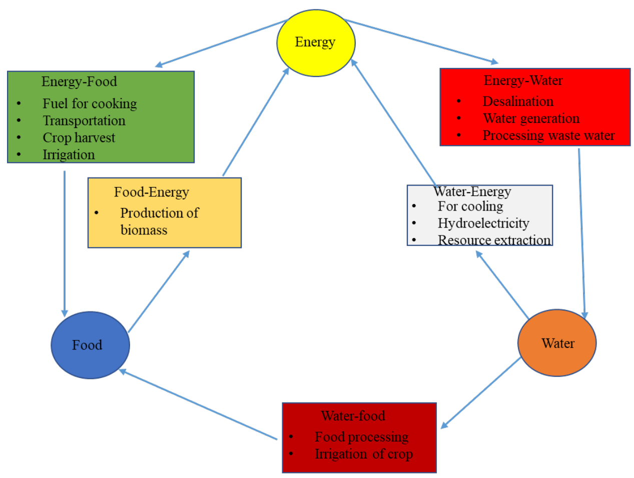

Figure 2. The connections among the domain of FEW nexus.

2.1. The Overview of Food-Energy-Water Nexus Advancement

There have been the perspectives of FEW proposals for over a decade now, with noticeable applications in different scientific fields, including water for food and the nexus of political and socialist civilizations[31, 32]. The scientific domain has stressed the relationship among FEW since the oil disaster in the 1970s. The research study by Mul et al.used a system dynamic simulation method on the sudden increase in the population and financial system with limited water and food, and the results showed that a constant increase in the economy would bring about a serious shortage of resources[33]. Afterwards, another research work deliberated on the circumstances leading to energy pressure and water generation in three developing nations[34]. As the three-point FEW nexus evolves, the researchers steadily neglected separated analytical methods and implemented systematic approaches, creating the study viewpoint for successive FEW nexus activities [35]. However, from 1980 to 2010, there was a noticeable gradual research interest and project growth on the FEW nexus globally, including nations like India, Brazil, the USA, and Japan. Between 1983 and 1986, a sequence of strategies regarding the nexus of energy-food was instituted by the United Nations University (UNU) to regulate their connection, such as the food-energy relationships [36]. Concurrently, some international establishments tried to deliberate the FEW nexus's social, economic, environmental and political frameworks. For example, in 1986, the next global conference, titled "The Food-Energy-Nexus and Ecosystems", concentrating on energy-feeding strategies and their result on ecosystems and agricultural supply, was hosted by UNU [37]. Bonn's conference titled "The Water, Energy, and Food Security Nexus—Solutions for the Green Economy" remained a breakthrough such that the idea of the FEW nexus was noticed in the global programme [38]. Right from the conference, nearly 300 establishments across the globe inaugurated FEW nexus ambitions between 2011 and 2015 [39], and the number of FEW nexus journal articles has started growing histrionically. **Figure 3** presents 530,185 research articles identified and retrieved between 2000 and 2023 based on the popular ScienceDirect database.

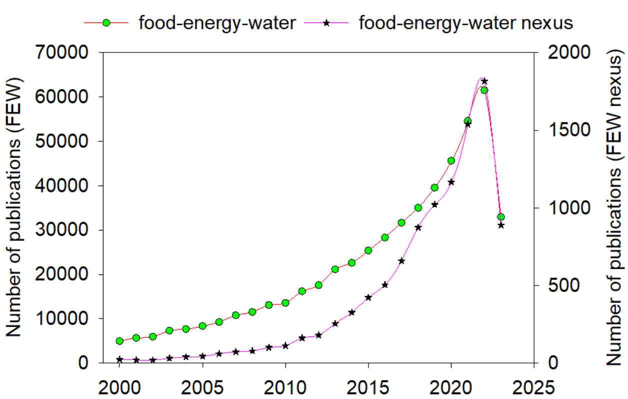

Figure 3. Description of FEW and FEW nexus documents from 2000 to 2023.

It is noticeable in **Figure 3** that several articles were recognized and published with more concentrations on the food-energy-water rather than food-energy-water nexus until 2011 when the nexus of food-energy-water started increasing. Concurrently, the three-branched FEW networks have steadily drawn researchers' attention, and research publications in this area have risen suddenly. Several studies on the FEW nexus focus on international, transborder, and national measures.

3. State of the Art of Food-Energy-Water Nexus

Presently, research on FEW nexus optimizations is relatively scarce. Most researchers have assumed the optimization as a separate resource instead of the optimization of FEW as a complete resource. With regards to an individual resource or two resources optimization, the research work performed by Javadinejad et al. utilized diverse means and algorithms for water resource optimizations [40, 41]. In contrast, Ju and Su et al. presented a multiple-design procedure for energy optimization [41, 42]. Also, Guo and Cai separately developed algorithms for food structure optimization and establishment, aiming to improve the differences in demand [43, 44]. In another development, optimization was carried out at the limitation of water resources by Cao et al. [45] to design and establish a business in arid regions. The studies performed by Zhen et al. [46] controlled hybrid interval two-stage fuzzy reliability coding algorithms to sustain interactions of energy-water scheme organization. Likewise, Chen et al. [47] studied the nexus of the energy-water algorithm, an optimization system with double risk aversion, with the ability to produce healthy optimization results. However, considering the complete optimization of food, energy, and water, Endo et al. [38] improved water and energy application, and food generation was centred on the complete assessment process. In the same vein, Karan et al. [48] proposed a model and designed a mathematical algorithm for predicting demand and generation, including food, energy and water. The study by Fan, Lin and Hu [49] established a combined assessment of the FEW nexus for two parts with various stages of development through several linear regressions in a simultaneous equation method. Also, Li et al. [18] proposed an optimization algorithm aiming to exploit financial profits with negligible environmental effects. At the same time, Peng[25] optimized the correlations among food, energy and water channels by initiating the theory of agreement. Bazilian et al. emphasize the complex interaction among food, energy, and water, promoting their communal deliberation[50]. The World Economic Forum (WEF) was among the first to emphasize the interrelation of these sectors[51], a sentiment reverberated by subsequent studies[52–54]. Laspidou et al. described the 'nexus' as the intricate network of connections inherent in resource systems[55]. Besides physical relationships, researchers like Hussey and Pittock stated the tight interconnection of FEW policies, usually stored[56]. The literature broadly explore this insight, highlighting the symbiotic and antagonistic relationships among the resource sectors[57]. Deliberations often spin around the significance of FEW resources, emphasising water, particularly its availability, frequently taking interest[38]. Similarly, Urbinatti et al. presented the concept of "virtual water" to discourse nexus pressures, influencing cross-sectoral collaboration[58].

Different organizations, such as the FAO, have identified food as the focus of the FEW nexus and have recognized its crucial connections to guarantee socioeconomic and environmental sustainability from a food security viewpoint[59]. In the same way, IRENA is regarded as an energy-focused method by whom that maintain renewable energy technologies cannot only address some trade-offs among FEW systems but also produce huge incomes using the three-pronged nexus method[60]. Some researchers extend the nexus to incorporate the association between humanity and nature[61], perceiving it as a critical driver of economic development. The FEW nexus is likewise viewed through the lens of economic activities and global trade, highlighting its part in meeting demand at various points[62, 63]. It is obvious that the implications of the FEW nexus are wide, which can be revealed by the various understandings of this conceptual terminology. Notwithstanding its extensiveness of interpretations, the nexus concept remains in its infancy, needing deeper study[54]. It is vital to approach nexus thinking from several approaches and scales in policy making and technology solutions, avoiding unbending definitions.

The research emphasized the relationship of FEW at the individual or household scale, mainly observing footprint analysis and sustainable management of FEW resources. For example, Xia et al. studied water consumption related to food consumption among residents of Chinese cities, disclosing more water footprints in thickly inhabited urban regions compared to less urbanized areas[64]. Moreover, recent research investigates the impression of policies and strategies on reducing FEW uncertainties at the household level[65]. Spiegelberg et al. utilized socio-ecological system analysis, measuring 176 households to propose policy involvements for improving water and food establishment while determining possible user wars within the FEW nexus[66]. Also, Wa'el A, Memon and Savic presented a novel risk-focused method to evaluate FEW relations, stressing trade-offs between water and energy when using recycled grey water for non-potable drives[67].

3.1. The Food-Energy-Water Nexus Viewpoints in Africa as a Case Study for Developing Country

The FEW nexus is studied in various regions. For example, climate change is assessed in Africa from a fresh perspective based on studies undertaken through the FEW nexus[68]. It is based on many factors, including resource deficiencies, the high price of resources and input costs, which might threaten the security of the grassroots. The creativity of the public, well-managed governance, and natural resources might secure FEW growth in the community while encouraging sustainability and lowering domestic liability[69]. In sub-Sahara Africa, the research conducted was based on the consequences of climate change on food supply, energy generation and water management[70]. The result indicates that several rich natural resources in Africa, such as mineral and energy resources, are presently in the framework of the African condition. Nevertheless, their mismanagement is either totally cogent or entirely irrational, and the materials are frequently migrated out of Africa. In 1990, the region lacked infrastructural development, organizational and managerial competencies, and societal growth ratea decreased; all of these brought about a flock of challenges. Africa relies on agricultural products not only for local utilization but also for export incomes as well. Unfortunately, agriculture is prone to deforestation, erosion and the affordability of international markets. The area requires international support as well as growth strategies focused on FEW security [71]. Even if the viewpoint is meagre, the region will nevertheless transform. In Northeast Africa, for example, Ethiopia is advancing in agricultural innovation. The energy supplies to the country are mainly from biomass, which, in the context of climatic change, is assessed in Africa's hydroelectric power services built by the government. There is interference between water and agricultural services, and energy supply occurs in the country, as in Asia [72]. There are different challenges in the locality of Lake Tana, Ethiopia, because of the increase in agricultural products as well as the rise in demand for energy uses such as transport, storage, and irrigation. Hence, to solve this challenge, migrating to hydroelectricity becomes an alternative. This is because the waste produced by the agricultural activity can be used to generate bioenergy; this condition can generate synergy or competition between sectors of FEW. Although lots of water is used up for both bioenergy and agriculture, the country lacks enough to deliver [73]. Other African countries are equally encountering this issue. Climate change affects different African cities, such as Bulawayo in Zimbabwe, Cape Town in South Africa, Dar-es-Salam in Tanzania, and Cairo in Egypt. The water supplies for the production of hydroelectricity are in danger because of these challenges, and agricultural activities are not left out in those cities as well. Moreover, in different areas, the power given to the local government institutions needs to be increased, and the financial limitations coupled with the lack of technical knowledge to discourse climate change equally add up to the challenges in implementing the FEW nexus. The result brings a broad gap between the higher financial capabilities and the underprivileged, with the rise in food and energy prices and limited means of clean water [74].

On the other hand, South Africa follows a team of international communities for food price increments. Presently, 60% of South Africa's families are challenged with some levels of food uncertainty [75]. In 2007 and 2008, the cost of power rose by approximately 24%, upsetting all financial areas, including all customers. The Producer Price Index (PPI) shows that water and gas prices were up by around 96%, and electricity prices rose by approximately 177% in a year interval. Meanwhile, the prices of other food industries and processing materials have risen equally; while food prices have also increased. Because of the energy price increase, both water supply and agricultural outputs, transportation, and delivery are undesirably increased. Consequently, the situation increased the cost of water by 60%.

Regarding food production and safety, increasing water prices have brought about more difficulties because of the scarcity of water [76]. Several fresh strategies have evolved to solve South Africa's nexus problems. The aim of some studies is to more competently moisten grasslands and supply nitrogen, bringing about a drop in fertilizer consumption and more operative in irrigation apparatus. Suitably, animal dung collection from rainwater could be applied to produce water-soluble fertilizer and biogas, with the former utilized for domestic uses [76]. Generally, water use is a serious environmental and social reserve in the African region. Other resource usage and climatic change stress the ecosystem as the population of the Nile basin increases. The extra pressures comprise inside conflict, with countries neighbouring the Nile entirely partaking in considerable productive riparian regions Africa has the Nile at the top among the essal river schemes, and its Blue Nile tributary produces a total annual income of about 60% [77]. At the Blue Nile River corner, Allam et al. generated the FEW nexus to exploit all the advantages by proficiently tackling water resources and land. The method researched, in this case, can assist in concealing parts of the basin with rain-fed agriculture, refining the soil in the system. Consequently, the yearly algorithm performed at the Blue Nile River water [78] produces savings of about 7.55 km^3. Moreover, among the eleven irrigation systems that were designed from the master project in Ethiopia, three are projected to be beneficial. Water stored for hydropower generation arises at the cost of possible rain-used agriculture in the basin. The collaboration of the countries in the area aims to grow effective agriculture and distribute the benefits and expenses. Hence, the transaction will definitely result in collaboration with other regions [78]. To progress further, the minor schemes require implementation at a greater level to assist the country and their counterparts. Water-use policies, simulated water commerce, technology and transboundary supervisory of water resources are gaining ground to struggle with the FEW nexus challenges. As a result of this, the nexus system becomes essential to enable longstanding approaches and policies for food security and lasting sustainability in Africa.

3.2. The Food-Energy-Water Nexus Viewpoints in Europe as a Case Study for Developed Country

One of the major difficulties in Europe regarding the FEW nexus is equating the energy costs for agriculturalists while authorizing them to pay for irrigation costs. Also, supplying water to smaller societies is a core issue, particularly for hydropower, and making it known to the community is needed, too [73]. Uncertainty has become a repeating argument in the Global Economic Forum administration. Consequently, European countries must implement concepts and plans to avert disaster, improve assets, and prevent problems related to the security of the World Economic Forum. The idea of nexus regarding the World Economic Forum shows complicated interactions between investors and areas. However, few countries have strategies and policies prepared to solve the FEW nexus as an entirety. For instance, the UK lacks strategies that impact the FEW nexus relationships, encouraging balance across FEW systems and infirming the capacity of the nation to resist climate change [79]. Even with the latest improvements in the European Union (EU) in recognizing nexus challenges, a majority that produces the reliable basis of the policies is at sector-explicit, challenging average and longstanding issues regarding resource administration and climate change adaptation. Science, dynamism, multidisciplinary and adaptability should be the focus of recent strategies and policy making. The study undertaken in conjunction with UK professionals suggest that evaluation and examination in the framework of the FEW nexus demand a multi-investor and collaborative method across the information and policy-making procedures. This approach requires the dynamic involvement of investors from every segment [71].

The increase in global requests for natural resources in Europe, accompanied by climate change, has generated considerable problems in urban advancement and viability. For instance, among Germany's main cities, Munich is deeply dependent on food importation. Regarding this matter, green agriculture can utilize vertical agriculture as a method to enhance viable food production [76]. The vertical agricultural crops might generate 66% of Munich's vegetable and fruit, which nearly meet the average requirements the city needs. Moreover, more advantages can be seen from vertical agriculture from the perspective of heat islands being on the decrease and hence assisting in lowering energy utilization, which brings about cooling during summer. Likewise, treatment of wastewater and re-utilizing may cause water reserves equal to 26% when mixed with rainwater storage. Since the water stored might be used for vertical agriculture in urban farming, the plan for water consumption has been established. It can utilize the combined FEW nexus procedures to expand the urban's viability; besides FEW security by resolving the most variety of FEW resources investors, a civilized and comprehensive structure of transmission allows contributors to decrease symbiotic dangers. On the other hand, the aftermath of COVID-19 on the several sectors of the FEW nexus and accomplishment of the SDGs were likewise examined.

4. Methodology

The idea of SLR has been established in educational systems to help researchers create sophisticated outline data or information on a particular study area [80]. Thus, this type of review offers a systematic method for classifying, separating and combining a group of published research papers, journals, conferences and books in search of sufficient evidence related to particular research objectives or questions.

4.1. Bibliometric Analysis

The bibliometric study has often been utilized for systematic analysis of scientific publications and documentation to explore information in a certain area of study, and the analysis was first conducted in 1968 by Chen et al.[81]. It is a statistical research technique for publications. Furthermore, Cite Space software, as an instrument for advancing information domain visualization, was applied along with bibliometric examination in this research. CiteSpace assists in the temporal and structural studies of hybrid node kinds, networks and cluster sights on scientific papers[82].

4.2. Database, Search Terms and Search Procedure

The article did a critical assessment and detailed investigation of appropriate research journals, books and conferences from the database from Web of Science, Scopus and ScienceDirect, using the keywords "food", "energy", "water", and "nexus" in the title, abstract, and keywords of the database articles. During the search process, English was the only language used to examine peer-reviewed journal articles published from 2010 to May 2023. The search yielded 417 documents, which were retrieved on 20th May 2023. However, the search methods' limitations were also taken into account by using alternative words, including electricity, power, agriculture, hydrolysis, and irrigation, to search for related articles in the title, abstract, and keywords to acquire 24 extra papers. Hence, an overall of 641 articles were recorded. Even though the papers chosen were restricted to peer-reviewed articles, tools and procedures for nexus uses were initially established by intergovernmental or non-governmental studies and policy organizations. **Figure 4** shows the bibliometric analysis and procedures of the methodology used.

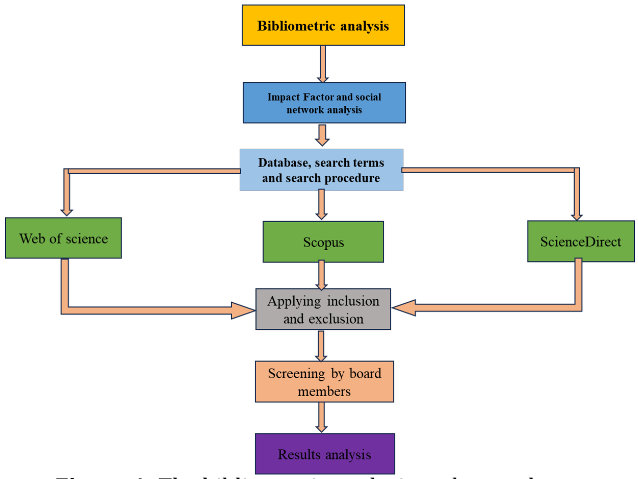

Figure 4. The bibliometric analysis and procedures.

4.2.1. Article Inclusion and Exclusion Criteria

Three criteria were chosen in selecting the articles, and they include:

- the articles clearly use the idea of nexus regarding the sustainability of natural resources;
- the articles expressively comprise the three resource areas: food, energy, and water;
- all the articles propose or test detailed systematic tools for assessing the nexus.

Henceforth, if articles passed just the first two conditions but failed to propose or test systematic tools, the situation was considered as "conceptual". Out of the 641 articles presented, 50 articles, representing 7.8%, were categorized as "conceptual", 146 articles, showing 22.7%, were categorized as 'methodological', and the excluded articles were 147, representing 45.8%. To confirm that the review process was reliable, articles were excluded once they failed to pass single selection conditions. Take, for instance, some articles that failed to meet up with the sustainability of natural resources but "nexus" was included just as a tinkle term. Even though all three terms indicated were common, articles were excluded once resource nexus interactions between two terms were noticed such as articles that concentrate mainly on water–energy relationships. In this case, the emphasis is placed on addressing the three-branched nexus because food, energy, and water systems are integrally more complicated compared to the two-branched nexus and the systematic methods for evaluating the FEW nexus are required in studying this extra intricacy. Lastly, since the key purpose of this research is to sustain extra advancement of healthy nexus approaches, articles that failed to propose or test exact systematic tools for assessing the nexus were equally excluded. The subsection of 73 "methodological" papers was coded for material connected to publication (for instance, country, keywords, year, discipline and journal) and nexus approaches (for example, quantitative, single discipline and interdisciplinary). Similarly, the assessment included:

- whether the papers demanded a "new" technique, uniting several approaches in a discipline, or applying a single technique;
- whether the papers presented a preference for a specific area;
- whether the articles had case studies;
- if the articles have an aim or end purpose;
- the scale of study was all about;
- main limitations or challenges in using nexus technique(s).

Meanwhile, a quantitative study regarding the drifts and features of nexus approaches described in the literature was conducted (for instance, applications of quantitative methods, number of publications over time, and variety of disciplines). All 50 "conceptual" articles were reviewed to collect the exact data gaps, study requirements, and prescriptive qualities connected to nexus methods and tools. These prescriptive qualities of nexus approaches presented in the literature are termed "key features" of nexus approaches. The key features represent the required qualities, for example, how techniques assist in accessing nexus study, what data and information are excluded or included, how interdisciplinary relationships are explained, and who is included in the study. In the same vein, the normative attributes of the nexus approach or study requirements from the "methodological" papers, where appropriate, were collected.

5. Results and Discussion

SLR is an essential technique to clarify the uncertainty regarding the authenticity of a topic in connection with the key aim of describing some matters in an organized and detailed method. The social network analysis used in this research supports the generation of visualizations and analyses of various comparative techniques that assist research hypotheses. Regarding the FEW nexus, the social network analysis aims to produce clear, complicated relationships. However, **Table 1** illustrates the top 10 published articles based on the subject category. Out of the 236 publications from the Web of Science, articles (156), reviews (66), proceeding papers (11) and book chapters (8) were the main contributions recorded about 66.4% of the overall publications. Different other published documents recorded approximately 34%, such as abstracts and editorial materials. The top productive category is the Environmental sciences, accounting for 64.831% of all publications, followed by green sustainable science technology, accounting for 21.61%, and water resources, recording 17.797%. These journals in the subject categories of environmental sciences and water resources are the most influential.

5.1. Most Frequently Cited Papers and Features of Publications

The most frequently cited articles can reproduce the hot spots of research attention in the area of FEW nexus studies. Since newly published articles may need more suitable citations for their rapid publication time, utilizing the most cited article per annum for assessment purposes is sensible, as presented in **Table 2**. Fifty concepts regarding the food-energy-water nexus were recognized in the papers studied by ScienceDirect. They applied various techniques to look at a similar matter, the governance of food, water and energy together. For example, the highly cited articles with a total yearly citation of 264 and an average per year of 44 were published in Review of Geophysics in 2018, entitled "The global food-energy-water nexus". Its major contribution is the need to prioritize nutrition, not just food, in examining the nutritional significance of various climate and management schemes. The second top from the list has 167 and an average of 27.83 citations and is entitled "Understanding and managing the food-energy-water nexus—opportunities for water resources research". It was also published in 2018 and elaborated on the opportunities in food-energy-water nexus management. The third and fourth articles are "Renewable & Sustainable Energy Reviews" and "Nature Sustainability", published in 2018 and 2019, respectively. While the third article has 166 and an average of 27.67, the fourth article has 160 and an average of 32 citations.

Among the publications presented in **Table 2**, there are only two articles in each of 2015 and 2016, but the yearly publication rose steadily with a sharp increase in 2019. The average publication length changes fairly, with a total average of 12.78 pages. The average number

Table 1. Publications of top 10 subject categories.

Web of Science Categories	Record Count	% of 236
Environmental sciences	153	64.831
Green sustainable science technology	51	21.61
Water resources	42	17.797
Environmental studies	40	16.949
Engineering environmental	33	13.983
Energy fuels	15	6.356
Engineering civil	14	5.932
Meteorology atmospheric sciences	14	5.932
Engineering chemical	11	4.661
Geosciences multidisciplinary	11	4.661

Table 2. Hierarchy of articles according to their annual citations.

Title of the Article	References	Journal Title	Publication Year	Total Citations	Average per Year
The global food-energy-water nexus	[83]	Reviews of Geophysics	2018	264	44
Understanding and managing the food-energy-water nexus— opportunities for water resources research	[11]	Advances in Water Resources	2018	167	27.83
Improving the sustainability of organic waste management practices in the food-energy-water nexus: A comparative review of anaerobic digestion and composting	[84]	Renewable & Sustainable Energy Reviews	2018	166	27.67
Agrivoltaics provide mutual benefits across the food-energy-water nexus in drylands	[85]	Nature Sustainability	2019	160	32
Food waste and the food-energy-water nexus: A review of food waste management alternatives	[86]	Waste Management	2018	158	26.33
Food-energy-water (FEW) nexus for urban sustainability: A comprehensive review	[54]	Resources Conservation and Recycling	2019	151	30.2
The food-energy-water nexus: Transforming science for society	[87]	Water Resources Research	2017	148	21.14
Sustainability in the food-energy-water nexus: Evidence from BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries	[88]	Energy	2015	117	13
An urban systems framework to assess the transboundary food-energy-water nexus: implementation in Delhi, India	[89]	Environmental Research Letters	2017	94	13.43
A food-energy-water nexus approach for land use optimization	[90]	Science of The Total Environment	2019	90	18

of citations per article grew from 3.63 in 2016 to 44 in 2018, disregarding the years with fewer articles (2015 and 2016). The number of authors is growing equally from 1 in 2015 to 236 in 2021, with the average number of authors per article of 4.72. **Figure 5** shows the number of citations and publications from 2015 to 2023.

Hence, these features show that the FEW nexus is a hot-spot research field with great interest from academia and experts.

5.2. Countries Mapping

Some countries have devoted more attention to the new research approach than others. The development of overlay visualizations was to assist researchers in visualizing countries committed to FEW nexus optimizations. The unit of study was on countries; while bibliography coupling was based on the method of analysis. Five were set out as a country's threshold requirement for this paper, and 57 of the 103 countries met the thresholds. Most of the citations were found in the US, recording 12,608. The next country was the UK, with values of 6,101 citations; while Germany and China recorded 4,521 and 4,154 citations, respectively. Similarly, the US had the most published articles accounting for 355 papers, seconded by China, which recorded 224 articles. The UK and Germany recorded 157 and 95 articles, respectively. A country's impact in advancing the recent research field is based on the number of articles published, overall link strength and number of citations recorded. The overall strength of the correlation portrays the extent to which the published articles of a certain nation impacted the published articles of the other nations covered in this research. As a result, the under-listed countries were regarded to possess the most effect on FEW nexus optimizations. **Figure 6** presents the countries' relationships and overlay visualization of countries linked by citations. The size of the circle shows the country's commitment to the area. Moreover, the overlay graph depicts that the nations with the highest contribution were more prominently featured.

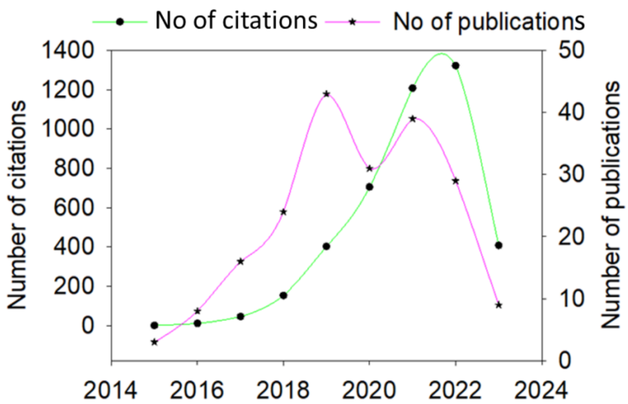

Figure 5. The number of citations and publications from 2014 to May 2023.

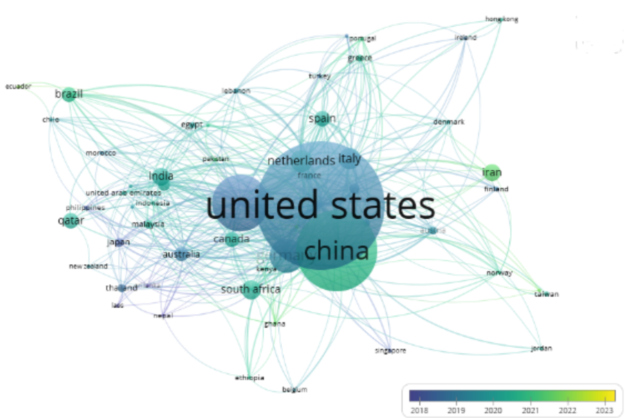

Figure 6. Density visualization among countries in food-energy-water influence.

The research trends in **Figure 6** describe that from 2018 to 2020, FEW nexus optimizations were studied mainly by countries such as the New Zealand, UK, Egypt, Australia, India, Mexico, South Korea, France, Japan and the Netherlands. However, the top three countries in recent research interest from 2021 to 2023 are the US, China and Germany, with total link strength recorded as 327, 187 and 146, respectively. This graphical illustration of the contributing nations will support prospective researchers in creating scientific relationships, building mutual project collaborations, and participating in fresh methods.

5.3. Keyword Mapping

The keywords are indispensable in research areas because of their support in recognizing and deliberations on the subject being researched. In this article, keywords analysis was studied, and the "kind of analysis" was found as "co-occurrence"; while the "unit of analysis" was ascertained as "all keywords". A threshold number was limited to 50 times to ensure that no keywords were utilized less than 50 times. Because of these limitations, it was noticed that only 135 out of a total of 2581 keywords passed the threshold for inclusion. The result depicts the frequently occurring keywords: water, food, energy, nexus and climatic change. The network of visualization of the co-occurrence of keywords is presented in **Figure 7**, with their correlation with one another. Even though the keyword node location shows how frequently a word occurs in articles, the size also indicates the frequency of occurrence in those articles. Moreover, the result depicts that some keywords have larger nodes than others, showing their relevancy in the food–energy–water nexus research area.

According to the network analysis in **Figure 7**, the term "optimization" is not a focal point from the primary keywords gathered. The result shows that the idea of FEW nexus optimizations remains under-researched. Also, from the result obtained, the predominant study areas are "water-energy nexus" or "energy-water nexus", "food-energy-water nexus", and "water-food". Due to the FEW-centred trend in most research, some scholars have condemned that the network's recent examinations are inadequate and subdivided. The study on energy-water, water-food or food-energy alone weakens the authentic plan of advancing specific interdisciplinary viewpoints to succeed in traditional areas. The decision has been reached that different keywords could be clearly differentiated in the network to show their co-occurrence in various research works. Hence, **Table 3** shows the co-occurrence analysis of clusters of keywords.

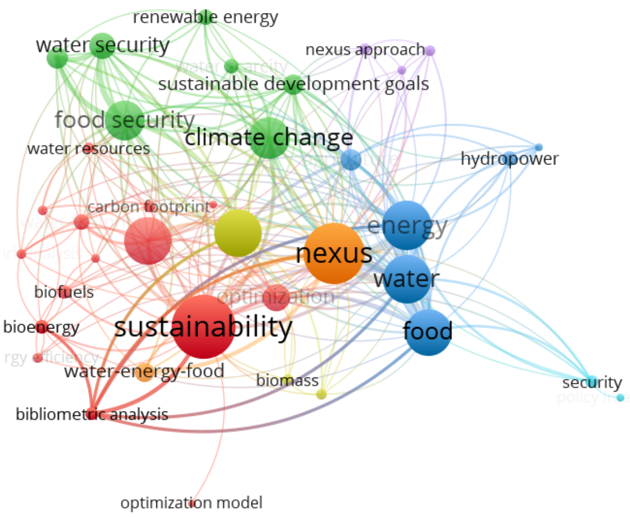

Figure 7. Network visualization describing the relationship among keywords in the food-energy-water nexus.

The prevailing keywords emerge in the red cluster and occur as the highest number of keywords, comprising 15 keywords. As a result, this cluster produces an area with the highest research concentration in FEW nexus optimizations.

5.4. A Nexus Optimization Approach

As development continues to spin around the world, an effort is needed to uphold the nexus generation based on community study with the government, private sectors, municipalities and scholarly. Nexus-based studies may generate new perceptions into possible deals and alliances of investments in infrastructure, guidelines, or reserve management opportunities.

5.4.1. Accessibility to Water Quality and Energy Application in Rural Agricultural Sectors

One of the essential and prospective research areas comprises cost evaluation, techno and socioeconomic advantages of fresh drinking water analysis and its circulatory set-up, and water waste administration. Providing solutions caused by poor water quality on societal health remains a serious global concern, and nexus agendas can provide the main perception. The current water quality challenges are better accountable to the ground and surface water systems by water testing, which could aid in future examination by administrative or scientific involvements. The benefits of the perspectives obtained through the FEW nexus system and future advancement could enhance access to reliable and safe drinking water, particularly by encouraging residents on hygiene and community health programmes in rural settings. These aims are obtainable through organizing agricultural policing with an energy and water advancement agenda and encouraging the accountable utilization of pesticides and fertilizers to avoid extra water pollution. This promotes financial inducements to reliable water organization, changes water-concentrated technologies with competent ones and controls the release of unprocessed industrial wastes. Moreover, systems modeling that connects hydrologic simulation devices that attract the spatiotemporal supply of water through financial means that reproduce the prices and advantages of water distributions can be utilized to assess socio-economic effects through a series of freshwater treatment remedies. Such contexts can likewise reproduce energy-linked charges and necessities of water treatment and supply organizations that help in installing modern energy projects such as the present renewable energy development strategies.

5.4.2. Irrigation and Energy Accessibility

Access to irrigation and energy could be another main nexus approach in reaching smallholder farmers in rural areas to enhance their livelihood. While the total volume of water on the earth's surface is about 70%, the yearly spatial supply of the resources can restrict chances of increasing the means of crop irrigation. Additionally, smallholder farmers may possibly have no finance to advance in farm- or public-based irrigation distribution systems, including ground or surface water drainage or storage facilities. To this end, international collaborations could aid investors in comprehending the possible financial worth of increasing access to irrigation while pondering the prospective prices of abridged water availability and the energy needs of aforesaid schemes. A combined examination may assist in recognizing critical spatial areas for energy sustenance and access to irrigation. Such reserves are possibly a significant adjustment in climatic change mech-

Table 3. Clusters of keywords co-occurrence mapping.

Colour of Clusters	Selected Keywords	Number of Keywords	Comments
Red	bibliometric analysis, bioenergy, bioenergy, biofuels, carbon footprint, decision-making, energy efficiency, food waste, food-energy-water nexus, network analysis, optimization, optimization model, sustainability, water footprint, water resources, water stress	15	The interest of the researchers is highest in the field of FEW nexus optimization
Green	climatic change, energy security, food security, renewable energy, sustainable development, water scarcity, water security	7	The interest of the researchers is highly focused on the field of FEW nexus optimization
Blue	agriculture, ecosystem, energy, food, hydropower, water	6	Researchers focus moderately on the field of FEW nexus optimization
Yellow	biomass, integration, sustainable development	3	The interest of researchers is less in the field of FEW nexus optimization
Pink	food-energy-water, nexus approach, transdisciplinary	3	The interest of researchers is less in the field of FEW nexus optimization
Light blue	policy integration, security	2	The least interest is observed from the researchers in the field of FEW nexus optimization
Orange	nexus, water-energy-food	2	The least interest is observed from researchers in the field of FEW nexus optimization

anisms for agriculturists, though more studies are required to help categorize structural reserves and rules.

5.4.3. The Effects of Renewable Energy

Presently, the world is striving for energy accessibility through renewable energy development strategies, and more study is required to comprehend how the aforementioned plans can relate to food or water distributive schemes. Increasing means of energy may enable irrigation growth, reducing worries regarding the security of local food; while intensifying agriculture might increase the concerns for quality water. Moreover, rules benefiting biomass or biofuel electricity as a remedy from renewable energy might add extra pressure on the execution of agriculture in the global communities, which may perhaps worsen local water rivalry. Systems modeling and involvement with local stakeholders could assist in comprehending and analyzing these main nexus networks and balances.

5.4.4. Enterprises and Encouragements in Local Regions

The local communities are always neglected whenever opportunities and creativity are demanded. Presently, few or no authorized FEW nexus enterprises exist in local communities. The National Action Plan for Climate Change (NAPCC) was the closest initiative reported in Spanish and established in conjunction with non-government and governmental organizations to organize diligence on climate change adjustment and moderation for effective utilization of food, energy, and water topics. Although there was no clarity of policies that indicated the FEW nexus, but it rather identified the networks of connectivity existing in each field. Similarly, the FEW nexus enterprises in the local region that was backed up by the Deutsche Gesellschaft für Internationale Zusammenarbeit and the European Union formed the Caribbean and Latin American unit in alliance with the Economic Commission for Latin America and the Caribbean (ECLAC) to grow healthy conversation relating to FEW nexus challenges in local policies. Furthermore, fiscal and financial encouragement might be another requirement to kickstart investigations on enterprises and related schemes to nexus matters. Generally, study approaches that concurrently discourse the nexus might assist in forming plans that solidify the resilience of the FEW nexus in the global community.

5.5. Optimization Analysis

5.5.1. Food Optimization for Sustainable Development

The frequent challenges in food have led to suggestions to stop the additional increase of land utilized for agriculture and to grow products on lands where crops underachieve while advancing the resource contribution capability, such as adding fertilizers and irrigation process [91]. Also, food mutilation and misuse should be on the decrease to grow for food utilization ratio and a change in interest by shifting from meat consumption to generating additional food for societal use while the crops are utilized for livestock consumption [92]. Meanwhile, Keating et al. have arranged the proposals in 14 so-called "food wedges" in groups of activities to justifiably accommodate the demand for food predicted for 2050, organized into three major sets [93]. However, these three sets are "reducing food demand", including meat demand and overfeeding, decreasing misuse, and moving biofuels to renewables without contending with food. The next is "filling the production gap", such as an increase in supply, productivity and proficiency, and finally "reducing wastes in generation possibility", for example, conservation against dilapidation, dangers to supply by virus and resistance, and influences of climate change moderation [93]. **Figure 8** shows a classification in the food sector for a required sustainable transformation.

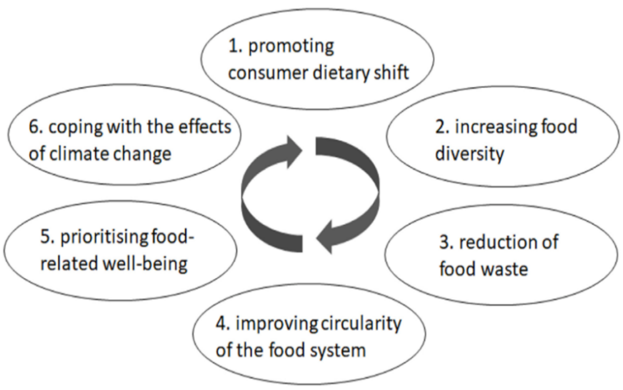

Figure 8. The six essential development revolutions towards sustainable food sector [91].

Moreover, in 2016, the Global Network Against Food Crises collaborated with humanitarian and development to stop, formulate and proffer solutions to global food crises. This association tries to decrease susceptibilities related to severe hunger, attain food security, enhance nutrition and encourage sustainable agriculture and food systems, using a 3 × 3 approach as presented in **Figure 9**.

This method includes working at the global, regional and national levels to sustain collaborations within the present systems and optimize support, policy-making, strategy, and programming using a measurable approach.

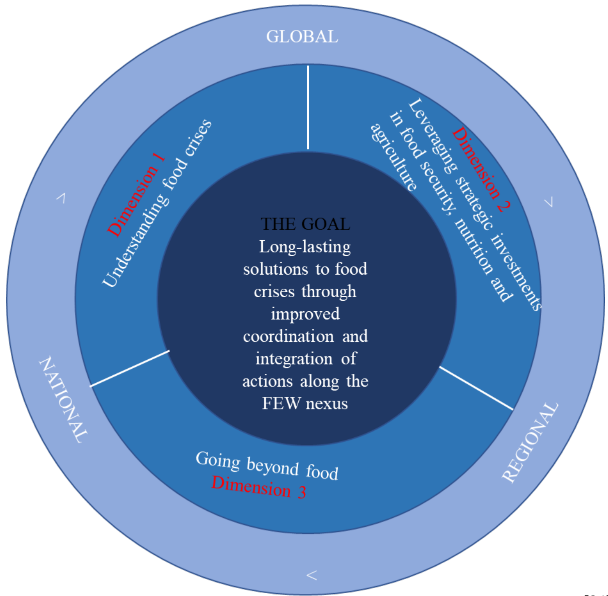

Figure 9. The 3 × 3 method to addressing food challenges [94].

5.5.2. Energy Optimization for Sustainable Development

Energy systems are complicated structures where the generation and consumption should be harmonized in a well-organized method. This is because there are several energy sources, and only a few transformation technologies are available for their development. For energy sustainability, the means for diffusing renewable energy resources should be regarded as a top priority. Several research works were executed in power systems deliberating on the wind, natural gas and solar as a means of power supply. Komušanac, Ćosić and Duić [95] analyzed the effect of more solar PV production and wind infiltrations on the nation's load power system research in Croatia. The result depicted a high share of wind power plants and installed solar PV capacity of 1.65 GW and 1.6 GW, respectively, as means of sustainability. Similarly, Zeng et al. [96] executed a fixed-state combined electric power system and natural gas with reversing energy transformation. The projected system was authenticated/ established by IEEE-9 assessment with the 7-node natural gas system. The findings were convincing, and the correctness was satisfactory. Additionally, the time series of power load and wind power is utilized to examine the moderation result of the combined energy network. Eventually, the impact of power demand and wind power on the Power Gas output and gas-fired energy production has likewise been examined. Prebeg et al. [97] studied the long-term energy development of Croatian power systems through multi-purpose optimization concentrating on renewable energy and electric vehicle integrations. In another development, Falke et al. [98] studied a multi-purpose advancement and simulation approach to build a large-scale circulated energy network with over 100 houses. The established system is used in a region of an average-sized town in Germany to examine the impacts of various productivity analyses concerning full prices and releases of equivalent carbon (IV) oxide (CO_2). With the Pareto-efficient techniques, technologies and proficiency solutions that can contribute more resourcefully to decrease greenhouse gas releases are recognized.

5.5.3. Water Optimization for Sustainable Development

The means to safe water, cleanness, and sanitation remain the most fundamental humannecessities for well-being and healthy living [99]. It is predicted that billions of human populations will have a scarcity of water supply in 2030, unless improvement quadruples. The demand for water is increasing because of urbanization, rapid growth in population and growing water demands from energy, industry and agriculture. **Figure 10** demonstrates the effective water utilization by the three major sectors: energy, industrial and agricultural.

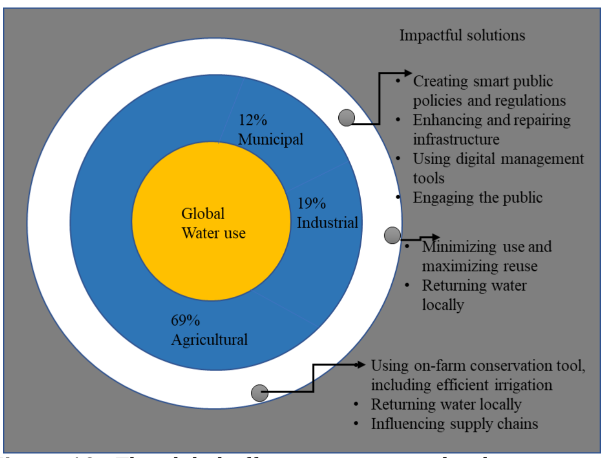

Figure 10. The global effective water uses by the energy, industrial and agricultural sectors.

To attain the global supply of consumable water, hygiene and sanitation by 2030, the present tolls of growth would require to intensify four times. As a result, accomplishing these goals would save 829,000 inhabitants yearly, whose deaths might result from illnesses directly caused by unclean water, insufficient hygiene and poor sanitation exercises. However, to hasten the energies employed in encountering water security problems, the United Nations General Assembly pronounced 2018–2028 the Water Action Decade for Sustainable Development (WADSD). This agrees with and matches the 2030 Programme for Sustainable Development Goals (SDGs 2015–2030). This agenda is noticed half-way into the Water Action Decade and the SDG period, this account—started by the United Nations University Institute for Water Environment and Health (UNU IWEH), the UN's simply deliberate tank on water—offers an initial measurable international evaluation that estimates the condition of water security for 7.78 billion individuals across186 nationals.

5.5.4. Food-Energy-Water Optimization for Sustainable Development

It has become imperative that one of the agenda in international research organizations is to optimize FEW by growing the food supply as well as access to energy and water to revitalise the rural people out of poverty [100]. In line with this aim, they have funded energy and water for rural inhabitants, majoring in ineffective utilization and dilapidation of resources. With regard to state programmes for socio-economic growth in rural communities (by funding energy and water), it is important to confirm that the resource base is continued, greenhouse gas releases are controlled, and water-borne diseases are checked. Therefore, international bodies are deliberating on the food, energy and water nexus—which discourses the relationship between the three essential resources to improve daily incomes and encourage socio-economic growth—when undertaking development activities [101]. This is frequently delayed by the fact that various administrative agencies control these resources. However, integrated concerned agencies are trying to strategize and devise progressive schemes, but these plans are usually not viable in the short to medium term. Therefore, it is necessary to figure out the methods to optimize the effectiveness of these three resources. The following possibilities are suggested for FEW optimizations:

- Governments and development ministries should integrate food, energy and water in their scheduling for socio-economic expansion.
- Executive bodies for food, energy and water should ensure a close relationship with higher authorities, including the economics or developmental departments, which might have a broader knowledge and order.
- Implant the common food, energy and water ethics into plan design and application.
- While developing fresh projects, it is necessary to analyse methods to combine the present government enterprises with the fresh project. For instance, assume a government parastatal is eager to develop high-voltage distribution systems to reduce outflows and supply dependable electricity to farmers to supply groundwater. Therefore, supplying constant electricity will release farmers' worries about irrigating crops. The farmers will as well supply water above revitalize to the aquifer, causing unmaintainable groundwater utilization. Nevertheless, if a high-voltage distribution system is integrated with drip irrigation and optional irrigation facilities, water and electricity will be applied professionally and sustainably.

5.6. Aftermath of COVID-19 on the Food-Energy-Water Nexus

The outbreak of COVID-19 has had a huge impact on the FEW nexus and interrupted the balance between the food, energy and water sectors [102]. The effect can be categorized into direct and indirect impacts [103]. Direct impacts began from the consequences of circulation or infection of the virus into food and water supplies; whereas indirect impacts originated from environmental and socio-economic consequences of lockdown measures [103]. Following the inception of the outbreak, there was a notable surge in water usage because of sensitive hygiene necessities, like sanitation efforts and handwashing associated with COVID-19 treatment materials and fumigation of containment areas [104]. The increase in water consumption extended to both domestic and medical sectors, reflecting a change in water demand patterns compared to pre-outbreak levels [105]. This upsurged the consumption in water resources was as a result of the lockdown brought by stay-at-home and recreational activities such as gardening [48]. On the other hand, industrial water consumption reduced meaningfully because of postponed processes within lockdown measures [105]. The energy sector experienced the same challenges, with unstable demands perceived as an instant effect of COVID-19 [106]. Previously, the industrial sectors were mostly in control of the increased demand of electricity. Hence, industrial closures resulted in a large cut in electricity demand, though global energy demands finally recovered as lockdown limits reduced to arouse industrial and economic activities [107]. Similarly, the pandemic affected the renewable energy sector mostly because of the interruption of incentives and subsidies [107]. Agricultural sectors faced interruptions in food accessibility and distribution, particularly for marginalized populations in rural areas [108]. According to studies, COVID-19 left local inhabitants under critical socioeconomic pressure due to their limited access to native food sources [109, 110]. Notwithstanding, global food consumption upsurged during the outbreak, intensifying inequalities in food access and distribution [111]. Movement limitations caused undesirable effects on farmer livelihoods, employment, and local incomes, additionally deepened by interruptions in agricultural exports [112]. These interruptions triggered across the food supply chain resulted in wastage and shortages. Besides, the COVID-19 outbreak interrupted advancement towards attaining the SDGs, mostly those connected to food security (SDG 2), water resources (SDG 6), and energy resilience (SDG 7) [113]. The interconnection of the FEW nexus with SDGs emphasizes the extensive effects of the outbreak on global sustainability efforts.

6. Conclusions, Recommendations and Future Works

The present systematic review shows that up till now, the study in FEW nexus optimizations remains at an early stage, without an exerted method for solving the challenges encountered. This article was systematically reviewed, focusing on data retrieved from ScienceDirect, Scopus and Web of Science databases. During the screening and review process, 258 published papers were retried from Web of Science, 355 papers came from Scopus and 50 articles were procured from ScienceDirect. Publications from the Web of Science revealed that only 66 papers were review articles, none of which clarified the optimization of the FEW nexus. In addition to the scant coverage of this review paper, several authors addressed themes and topics within the FEW nexus frameworks and neglected optimization. Although there were few review articles, the number of citations and publications for FEW nexus has steadily improved over the period. Many articles concentrate on the subject categories of environmental sciences, which record 64.831%, green sustainable science technology accounting for 21.61%, and water resources recording 17.797%. The number of citations increased nationally, with the US as the most productive country recording 12,608 citations. The UK and Germany are next, accounting for 6,101 and 4,521 citations, respectively. Meanwhile, the US, China, and the UK recorded 355, 224 and 157, respectively, as the highest number of papers published. The result shows that research collaborations among countries and organizations are gaining widespread interest. The studies often cited articles and keywords that discovered the study hot spots and trends. Therefore, with this growing research focus on the FEW nexus, it is recommended that a better and complete knowledge of its challenges globally should be established, for instance, how to concurrently discourse challenges in water quality and distribution, enhance the security of food through extended means of irrigation and supply stable electricity in local sectors. These will need "systems-focused" methods that clearly identify important networks between segments. The integrated tactics regularly disclose interactions or imperfections in or even upset conservative understanding about relationships between food supply, water resources, and energy generation. Consequently, they provide more knowledge of policy-making and generate ingenious results. The recent COVID-19 outbreak has had a huge effect on food security, energy resilience, and water resources. Hence, the harmful effect of COVID-19 on the food, energy, and water sectors forced restrictions to be implemented, and water sectors forced restrictions on the realization of the SDGs.

Thus, with developments in machine learning, simulation and data analytics methods, future research works could emphasize incorporating these technologies to optimize the food-energy-water nexus. This could comprise advancing predictive models to better address complex interactions and optimize resource allocation.

Abbreviation

FEW	Food-Energy-Water
SLR	Systematic Literature Review
US	United State
UK	United Kingdom
PPI	Producer Price Index
UNU	United Nation University
EU	European Union
CO_2	Carbon(iv)oxide
SDGs	Sustainable Development Goals
WADSD	Water Action Decade for Sustainable Development
UNUIWEH	United Nations University Institute for Water Environment and Health
UN	United Nation
IF	Impact Factor
NAPCC	National Action Plan for Climatic Change
ECLAC	Economic Community for Latin American and Caribbean

Author Contributions

Conceptualization, O.O.A.; methodology, O.O.A.; resources, N.I.N.; data curation, O.O.A.; writing—original draft preparation, O.O.A.; writing—review and editing, O.O.A.; supervision, N.I.N.; project administration, N.I.N.; funding acquisition, N.I.N. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

Data will be provided on request.

Conflicts of Interest

The authors declare no conflict of interest.

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