



Water, Energy and Food Nexus: Policy Relevance and Challenges

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Connections between water, food, and energy are at the center of long-term economic and environmental development and protection. Water, energy and food are the keys to economic input and a necessary component of economic progress. The adoption of water management policies and techniques that support the sustainable use of resources while promoting economic growth is becoming an important concern, particularly in countries where water and food scarcity are critical or problematic. This study aimed at evaluating Water, Energy and Food Nexus (WEF), and as well as challenges of its implementation. This study looked at the articles that were published on WEF nexus between 2015 and 2021 acquired from the Scopus database, focusing on gaps and implementations. I searched for relevant key terms in the database and the search found hundreds of articles on WEF, of which 28 articles were relevant to the scope of the study and these articles were downloaded as BibTeX file for the analysis and the analysis was done using R programming. A number of insights and implications were identified based on the analyses of the findings of the reviewed research in order to increase the policy relevance and overall implementation of the WEF nexus by public policy and decision-making institutions. To boost uptake of the findings, the study gives an outline of the primary constraints and challenges that restrict the policy relevance of the WEF nexus.

Keywords: water, energy, food, WEF nexus, implementation, challenges

INTRODUCTION

Water, Energy and Food Nexus (WEF) or the linkages between the water, energy, and food (WEF) sectors, is becoming a major academic, policy, and sociological topic that is increasingly debated in a global society, including the relationship with ecosystems, livelihoods, and the economy (Hülsmann et al., 2019; Purwanto et al., 2021). The issues of managing water, energy, and food resources at the same time while meeting several possibly conflicting objectives without jeopardizing any sector's resource-base are important and must be addressed as soon as feasible (i.e., causing the least amount of damage to other sectors). This problem necessitates a holistic strategy in which all systems are evaluated. To add to the complexity, other sectors such as economic, social, political, and environmental factors, as well as effective implementation, influence and are influenced by the WEF nexus (Bizikova et al., 2013; Nhamo et al., 2020; Rosales-Asensio et al., 2020). At the Bonn 2011 nexus Conference, the basic concept of the WEF security-nexus strategy was created and widely discussed. The nexus method is characterized as a strategy that integrates management and governance across sectors and scales (Saidmamatov et al., 2020). To address policy difficulties, the confluence of academic ideas and actual execution is critical.

Initial guidance on how a nexus approach might improve the security of WEF resources by enhancing efficiency, minimizing trade-offs, developing synergies, and improving governance across sectors, as well as various policy proposals, was introduced in Hoff's study (Hoff, 2011). However, extensive investigations and critical evaluations by Endo et al. (2017) and Albrecht et al. (2018) claim that Hoff's background study and the 2011 World Economic Forum meeting (WEF, 2011) have propelled the WEF nexus to the forefront of global attention. Consequently, significant inadequacies in nexus approach frameworks and subsequent nexus studies have been found.

The WEF nexus is defined as the mutual interconnections between water, energy and food. The WEF nexus is critical to natural resource management and climate change policy because societal changes drive WEF demand increases, and continuous environmental changes are likely to impact water supply or accessibility (Mpandeli et al., 2018; Orimoloye et al., 2018; Busayo et al., 2019; Bakhshianlamouki et al., 2020; Dyosi et al., 2021). To deal with the WEF nexus, multi-sectoral water use must be harmonized and brought into line with water (basin) integrity reconstruction and/or preservation. The WEF nexus, in contrast to integrated water resources management (IWRM), emphasizes non-linear system analysis and dynamic feedbacks across water-intensive industries. The piece of knowledge relating to water in the WEF nexus has grown significantly during the last decade (Hack, 2015; Al-Saidi, 2017).

Several concepts, theories, and methodologies have been done using a nexus approach to look at the links between water, energy, and food (Mohtar and Daher, 2012; El-Gafy, 2017; Bizikova, 2019). Study has provided a thorough analysis of the WEF nexus, including basic linkages as well as institutional and policy implementation difficulties and enhancing adaptive capacity to complex global challenges (Scott et al., 2015; Busayo et al., 2019). In support of food security, sustainable agriculture, and human development, the United Nations Food and Agriculture Organization (FAO., 2014) offered a conceptual approach to the WEF nexus, balancing diverse user purposes and interests. In the nexus approach, the environmental effect has been analyzed while evaluating the relationships and balance between water, energy, land, and food, as well as the importance of wellbeing (Ringler et al., 2013; Orimoloye et al., 2019).

In an effort to examine the green economic growth potential of a nexus approach, Hoff (2011) presents preliminary evidence on how a nexus approach might boost water, energy, and food security by increasing efficiency, eliminating trade-offs, developing synergies, and improving governance across sectors (Tantoh et al., 2020). With this knowledge gap especially on WEF nexus implementation and policy relevance, it is critical to include relevant studies outcomes in the decision-making processes, this will help in effectively implementing WEF nexus. The role of scientific research in bridging the nexus knowledge gap, quantifying nexus critical interlinkages and interactions, and identifying trade-offs and possible synergies to support evidence-based policymaking is very important, especially in developing countries (Wichelns, 2017; Tantoh et al., 2021). Consequently, this study aimed at evaluating studied on WEF nexus and how this nexus

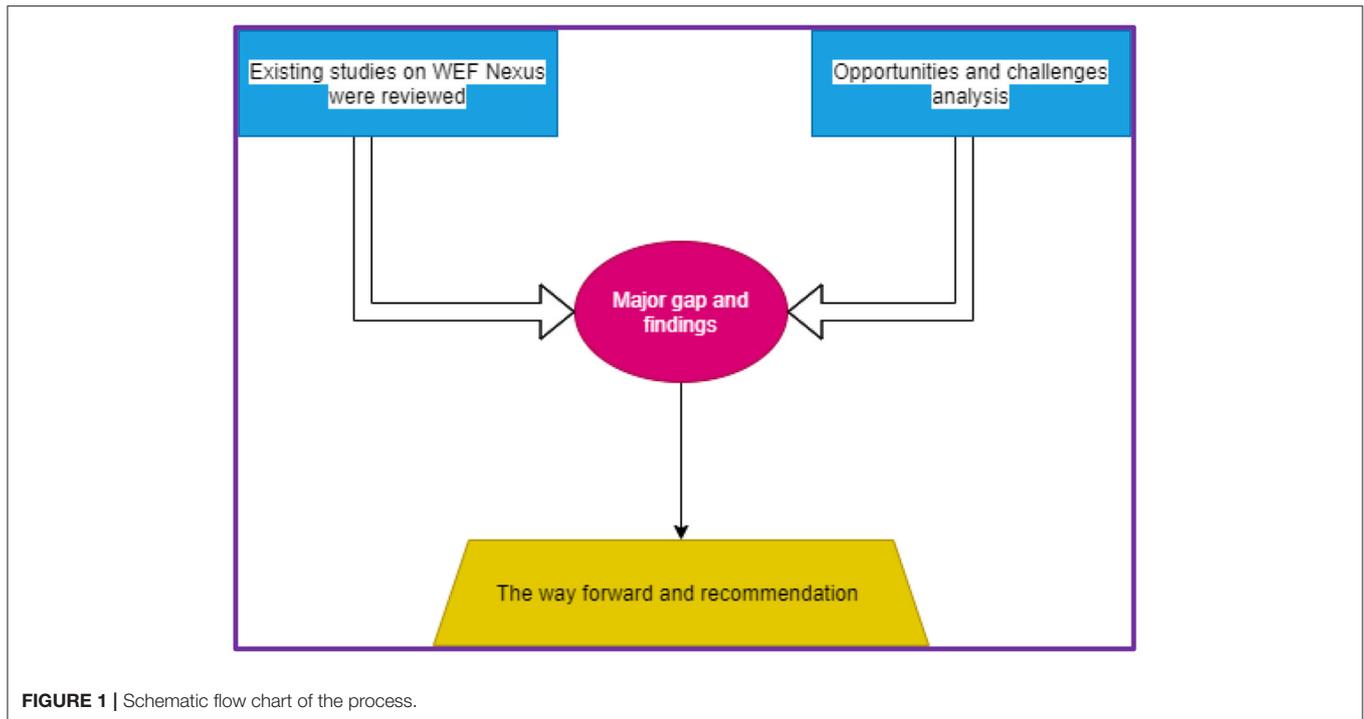
has been implemented over the years as well as identifying the potential barriers to its implementation. The issues of managing and implementing water, energy, and food resources policy and meeting several possibly conflicting objectives without jeopardizing any sector's resource-base are important and must be addressed scientifically this will help in causing the least amount of damage to other sectors. This problem necessitates a holistic strategy in which all systems are evaluated.

METHODOLOGY

This study looked at the academic articles that were published on WEF nexus between 2015 and 2021, focusing on gaps and implementations. The first step was to go over the existing WEF nexus studies and see where they have been improved or failed to be implemented, as well as critical areas that were left out of most, if not all, of them. The second stage was to identify numerous important phrases that appear in WEF nexus studies in order to identify the knowledge, research, and application gaps. These procedures enable the most pressing concerns in current nexus research to be identified. Following that, several WEF nexus case studies were evaluated, demonstrating the extent to which WEF nexus approach practices and impediments to adoption exist. **Figure 1** depicts the steps taken in this research. The framework of this study reflects these steps.

Primarily, the search term was WEF nexus and it was refined by excluding other irrelevant studies and document types: (article) timespan: all years' indexes: SCI-expanded, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC. The title-specific algorithm only retrieved primary articles and excluded other document types for the primary reasons that they were pre-article items that could be published in other forms or post-publication synthesis of primary articles. Manual validation of the total articles was further done to ascertain the specificity and efficiency of the search algorithm in recovering the subject keyword from the database (Orimoloye and Ololade, 2021). On overall, the dataset contained 28 relevant articles and was downloaded as BibTeX file.

The existing WEF nexus implementation was selected in this study based on studies published in an academic database such as Scopus databases. The databases were used to identify peer-reviewed scientific documents and other publications that used the WEF nexus concept during the period 2015–2021. Further investigation was conducted to clarify the main concerns, key terms frequently used words and variables of the studies. While not meant as comprehensive, the results are representative of the commonly presented WEF nexus available in the literature, and many gaps and barriers were identified in this study. The information on the articles on WEF nexus used in this study is presented in **Table 1**. The annual Growth Rate of research studies published during the period of study per year is 24.57%, while the annual average citations as presented in **Table 1**, is 17.36. different authors and researchers were involved in these studies, for instance, total authors of about 115 with author appearances of 127 were recorded in the studies used in the study.



RESULTS AND DISCUSSION

Practices and Barriers to Implementing WEF Nexus Approach

The WEF nexus has the potential to provide new opportunities in any region where the nexus is well-implemented in general. However, there is also concern that these opportunities created in the medium term will only be for a small number of talented individuals, experts, causing opportunities in other competitive areas (e.g., agriculture and energy sectors). A significant barrier to the technical implementation of the WEF nexus is the absence of precise and uniform data for the whole world. No specific organization providing WEF nexus information to set up a uniform database and provide links to water-related initiatives, papers, events, etc., requires greater contributions from various regions of the world especially in developing countries. Several countries have only low levels of data availability and accuracy, while detailed socio-economic and climate data are necessary to conduct a regional and inter-regional WEF nexus analysis. Furthermore, some countries may be unwilling to share certain types of required data, as they could be considered nationally strategic (Markantonis et al., 2019).

In terms of potential WEF trade-offs, since product systems are so intertwined, measures taken at the local level to improve one aspect of the WEF nexus may cause burdens to be shifted to other areas, resulting in negative consequences for water, energy, or food security. To avoid this, when evaluating different policy options, a lifecycle perspective should be used. Industry, for example, uses lifecycle methodologies and procedures to address water risks. Water security impacts extend beyond manufacturing sites throughout the entire supply

TABLE 1 | Information on the articles on WEF nexus used in this study.

Description	Results
Documents	28
Sources (Journals, Books, etc.)	18
Keywords Plus (ID)	212
Author's Keywords (DE)	119
Period	2015–2021
Average citations per documents	17,36
Authors	115
Author Appearances	127
Authors of single-authored documents	3
Authors of multi-authored documents	112
Single-authored documents	3
Documents per Author	0,243
Authors per Document	4,11
Co-Authors per Documents	4,54
Collaboration Index	4,48
Document Types	
Article	17
Book Chapter	4
Conference Paper	1
Editorial	1
Review	5

chain, particularly in the case of agricultural products, which frequently require considerable amounts of water and energy for management and harvesting. The virtual water content of traded products could be a useful indicator for assessing supply

TABLE 2 | Challenges and gaps in the WEF concept.

	Main Challenges and gaps	Description	References
1	The combined components in the nexus are too broaden	The Water-Energy-Food (WEF) nexus is currently being promoted and developed in response to this challenge, providing a tool to improve these elements through an interdisciplinary approach that recognizes the inherent synergies and trade-offs involved in the management of these components	Fernández-Ríos et al. (2021) and Proctor et al. (2021)
2	Different regions face different issues among the three components in the WEF nexus	Water, energy and food issues, sometimes all three components may not be problematic as one may not be impacted. Some countries, particularly those in underdeveloped countries, have faced security issues as a result of the WEF. Water security is a hotspot issue in WEF security, with just around 3% of the world's estimated 1.4 billion km ³ of water available for consumption. The Middle East is dealing with both water and food security issues at the same time but not necessarily energy. Furthermore, more problematic locations such as North Africa and West Asia must deal with water, energy, and food security issues.	Fedoroff et al. (2010) , Antonelli and Tamea (2015), King and Jaafar (2015), Yillia (2016) and Hua et al. (2021)
3	Interdisciplinary concepts of WEF nexus	The nexus welcomes multidisciplinary dialogue between complex system methodologies capable of quantifying resource relationships and policy analysis addressing coherence and integration tools as an analytical notion. On a practical level, the nexus necessitates transdisciplinary collaboration with people concerned with water, food, and energy management. In this context, gaps in social-science-driven multidisciplinary nexus assessments and how multiple knowledge systems might be braided into nexus research and can be problematic in terms of different perspectives.	Mohtar and Daher (2012), Albrecht et al. (2018), Hoolohan et al. (2018), Venghaus and Hake (2018), Zhang et al. (2018) and Cabello et al. (2021)
4	Climate change and the increasing complexity of modern WEF	WEF nexus is challenged by climate change and the increasing complexity of modern WEF relationships, some systems and irrigation schemes have survived for millennia and still exist in recognizable form. This is due in large part to the persistence of governance systems that devolved significant decision-making authority to those who used water and energy for food production.	Pueppke (2021)
5	Normative	The current debate over the WEF nexus principle raises many questions, including the depth to which such conceptualizations are truly new, whether they substitute (or complement) existing environmental governance approaches, and how the nexus can be strengthened in national contexts if it is considered normatively desirable.	Purwanto et al. (2021)
6	WEF nexus does not usurp integrated water resources management (IWRM) models	It has been identified that the integration between water, energy, climate and agricultural policy objectives is still generally limited, even with the existence of the WEF nexus.	Purwanto et al. (2021)
7	Applicability	Low-level applications by the supposed to be users such as farmers, fishers.	Endo et al. (2017)
8	It is mostly a narrative concept	In most cases, the WEF nexus concept resulted in unforeseen changes in issues based on context, place, and size, with no way to fix the issues.	Bell et al. (2016)
9	Culture and politics	The implementation of WEF nexus policies in some regions especially in developing nations may be hampered by cultural and political issues. Due to the complex political situation and socio-cultural traditions, it is unclear how communities would react to the implementation of WEF nexus policies. Interest in integrated resource management could be sparked by participatory initiatives, increased awareness, and capacity building.	Mabhaudhi et al. (2018)
10	Poor education, urbanization, and poverty	The WEF nexus may encounter several challenges that could hinder the effective implementation of its associated policies and guidelines. Inequality remains an issue, particularly in terms of access to quality education and resources.	Mabhaudhi et al. (2018)

chain trade-offs. The lack of lifecycle-based data to supplement local databases in various regions is a critical issue (Table 2) that would require significant improvement in national accounting. Issues with water, energy, and food are sometimes not critical in some places since only one of the three components is affected. As a result of the WEF, certain countries, particularly those in developing countries, have had security difficulties. Some of these activities or issues may not be applicable to or adopted by all

countries; however, this does not negate their importance as food for thought.

WEF Nexus Opportunities: A Review of Current Approaches and Policies

A number of insights and implications have been identified based on the analyses of the findings of the reviewed research in order to increase the policy relevance and overall implementation of the



FIGURE 2 | Wordcloud.

WEF nexus by public policy and decision-making institutions. To boost uptake of the findings, the study identified various challenges in facilitating effective implementation of the WEF nexus as well as the acceptability between researchers and policymakers. This study also gives an outline of the primary constraints and challenges that restrict the policy-relevance of the WEF nexus analyses in this study.

The information in **Figure 2** summarized the evolution of WEF nexus-related research used in the studies examined in this study in a wordcloud. Wordcloud was used on the titles of the published papers selected based on the search words. It indicates the predominant word or term used in the WEF coupled with its potential implementation studies. It is easy to distinguish and figure out different areas of associations and prominent terms within the wordcloud (Afuye et al., 2021a; Orimoloye et al., 2021a). This was done to know the research trends in the WEF nexus research field and to identify the most emerging and frequent keywords used in the field. For instance, the relevant words or frequently mentioned words in the WEF nexus studies were water, food, decision making, sustainable development which were mentioned 11, 10, 9, and 7 times respectively in the author's key terms used in WEF nexus studies (**Figure 2**). These connote that all these prominent themes are relevant in WEF nexus studies.

The information in **Figure 3** depicts the word dynamics of WEF nexus studies. Word dynamics analysis is a tool for classifying things that focuses on existent (rather than calculated, such as through profiles) linkages between them, such as in WEF nexus investigations. In WEF nexus research, a scientific article merges numerous existing networks, such as themes or word co-networks, into a new original network (based on objects). The word dynamics were produced using the top 10 most often used words (**Figure 3**). In order to analyze word dynamics, frequent words were also extracted each year. The function "mk.test" in the package "word dynamics" was used to execute trend analysis (growing or decreasing over the last few years), with the significance level of the Mann Kendall test set at 0.05 (Liu et al., 2019; Afuye et al., 2021b). In year 2018, water, food, sustainable

development, energy and water supply was mentioned 3, 3, 3, 1, and 2 respectively (**Table 3**).

Identified WEF Nexus Approach Practices and Barriers to Its Implementation

In economic terms, water is considered a common good with no substitutes. The equitable distribution of this natural resource is controlled by social fairness and efficient allocation (Markantonis et al., 2019). Through trade-offs and an understanding of the multiple stakes involved, the Nexus can provide ways forward in some specific regions where freshwater supplies are limited and need to be allocated efficiently to feed the industrial, residential, agricultural and energy sectors. Individually addressing productive sectors and related natural resources results in high opportunity costs across a variety of uses, as well as higher transaction costs between nexus sectors. As a result, minimizing high transaction costs should be at the forefront of any economic measures considered when adopting (or designing) a WEF nexus approach. Furthermore, water and energy distribution are monopolies with highly regulated externalities that produce both positive and negative externalities. Water provision may have positive externalities in terms of public health benefits, but energy and food production may have negative externalities (point and diffuse pollution). Water pricing should encompass social, environmental, and cultural aspects which are difficult to assess or put into monetary terms when it comes to water management. Water services are heavily subsidized in most parts of the world, particularly in developing countries, and water rates mostly reflect investment and maintenance expenses rather than the resource's potential cost or scarcity. Although water pricing is an important tool, it is insufficient due to the inelastic nature of water demand (raising prices would not significantly reduce usage) and the necessity for sufficient subsidies to help consumers and farmers minimize their expenditures.

The WEF nexus operationalization constraints must be overcome if the WEF nexus sustainability targets are to be met. Complex collaboration between interconnected sectors, diverse sectoral institutional frameworks and interests, insufficient governance frameworks, and a lack of incentive to collaborate with multiple stakeholders from many disciplines and government levels are all challenges that must be overcome (Urbinnati et al., 2020). Uncertainty and anxiety, which are brought on by the fear of the unknown as a result of changing from the usual to creative ways of doing things, are other challenges to WEF nexus implementation.

The WEF nexus has the potential to create new job opportunities particularly in water-stressed regions in general. However, there are some concerns that the new opportunities created in the medium term will only be for a small number of skilled workers, causing unemployment in other competitive sectors (e.g., agriculture) (Markantonis et al., 2019; Nhamo et al., 2020). The lack of exact and uniform data for the entire world on WEF is a key hurdle to the technical implementation of the WEF nexus. The European Environment Agency (EEA) provided the Shared Environmental Information System (SEIS) to set up a

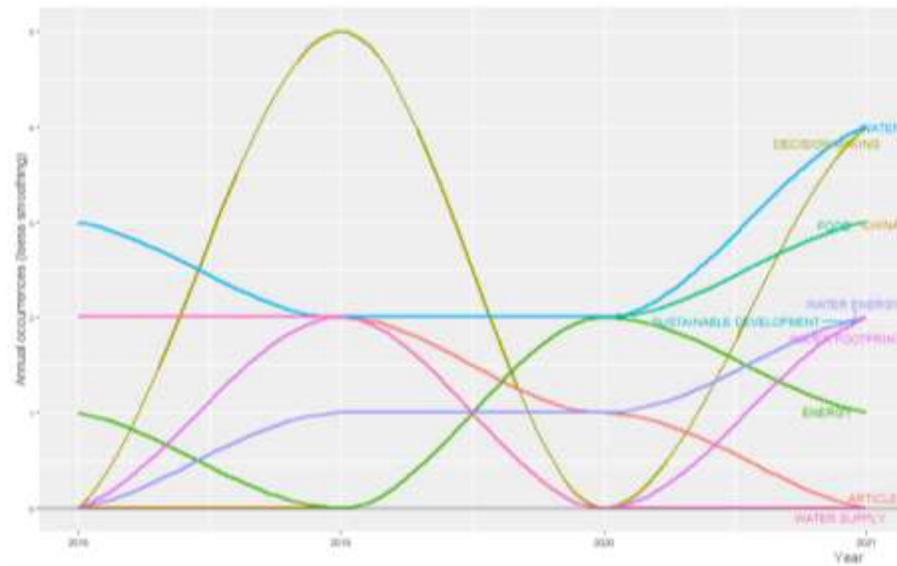


FIGURE 3 | Word dynamics.

TABLE 3 | Frequent key words plus in WEF nexus.

Year	Water	Food	Decision making	Sustainable development	Energy	Water energy	Water footprint	Water supply
2018	3	3	0	3	1	0	0	2
2019	2	2	5	2	0	1	2	2
2020	2	2	0	0	2	1	0	0
2021	4	3	4	2	1	2	2	0

uniform database and provide links to water-related initiatives, papers, events, and so on (Markantonis et al., 2019). These systems require more contributions from countries especially, developing nations. Several nations have poor data availability and accuracy, despite the fact that precise socioeconomic and climate data are required to undertake a WEF nexus study on a sectoral and intersectoral scale (Boluwade, 2021). Furthermore, some countries may be hesitant to release particular sorts of essential data since they may be regarded as strategically important to their countries.

Limited arable and land water resources are among some of the barriers to the implementation of WEF nexus. Several measures, such as the installation of greenhouses and the use of tankers to transport water to the greenhouses, have been made to address the challenges connected with limited arable and land water resources (Adedeji et al., 2020; Adetoro et al., 2020; Orimoloye et al., 2021b). Natural phenomena such as excessive rainfall caused by cyclones and other climatic events, however, pose many obstacles to the long-term viability of these programs (Martinez et al., 2018; Boluwade, 2021). Due to a lack of a relevant database, the effects of these extreme events produced by climate change on the WEF nexus are not fully known. To the best of our knowledge, few if any research has attempted to give quantitative

indicators or metrics from the perspective of climate change's effects on the WEF nexus.

In terms of potential WEF trade-offs, because product systems are so intertwined, measures taken at the local level to improve one aspect of the WEF nexus may cause burdens to be shifted to other areas, resulting in a negative consequence for water, energy, or food security. To avoid this, when evaluating different policy options, a lifecycle perspective may be used. Industry, for example, employs lifecycle methodologies and procedures to address water risks. Water security impacts extend beyond manufacturing sites throughout the entire supply chain, particularly in the case of agricultural products, which frequently require considerable amounts of water and energy for management and harvesting (Ozdogan et al., 2017; Zhao et al., 2018). The virtual water content of traded products could be a useful indicator for assessing supply chain trade-offs. The lack of lifecycle-based data to supplement local databases in the water-scarce region is a difficult problem that would require significant improvements in national accounting systems. The other aspects of the WEF nexus are subject to similar considerations. In terms of energy, for example, activities such as manufacturing processes and product transportation contribute significantly to the whole system's energy and carbon footprints. The lack

TABLE 4 | WEF nexus implementation.

SN	Country/Region	Practices	References
2	Portugal	WEF nexus index: Portugal has a value of 70.2 for the Water pillar, 51.1 for the Energy pillar and 72.4 for the Food pillar.	https://wefnexusindex.org/PRT
2	Netherlands	Green Deals Netherlands: Green Deals ideally serve as an inspiration to others and pave the way for future efforts. Green Deals ensure broad follow-up and impact on Dutch society, energy, food, water, resources, biodiversity, mobility, bio-based economy, climate, and construction are the main issues.	Marchand et al. (2015); https://www.greendeals.nl/english
3	European Union	Because decarbonisation relies on water-demanding energy technologies like biofuels, carbon capture, and nuclear power, the EU has aggressive decarbonisation goals for the future, which could be impossible to meet if the European water system becomes too stressed.	European Commission (2019)
4	Italy	Waste regulation: The Italian legislation imposes very strict limits to the use of waste water in irrigation.	Markantonis et al. (2019)
5	South Africa	Irrigation: South Africa aims to increase the area under irrigation by 149 000 ha in order to ensure food security. However, there is a disjoint in this process as they failed to consider the impacts on water and energy by analyzing all possibilities through the WEF nexus analytical framework. before implementing such initiatives	National Planning Commission. (2013)

of engagement and trust in various stakeholders, particularly civil society, impedes the development of a nexus approach that requires a high level of cooperation and mutual trust. The responsibility for the water, food, and energy is frequently delegated to various ministries or agencies, obstructing the close contact and cooperation required to address the WEF nexus (Markantonis et al., 2019). Innovative partnerships (such as Plan Blue) must be improved at the regional or national level, while this may be difficult given the region's geographical, political, and social contrasts. Through the WEF nexus, science and policy should collaborate to initiate and promote sound planning of solutions for tackling difficulties. However, science and policy have historically had a poor level of cooperation, as they typically have opposing aims, agendas, and priorities. There is also significant doubt about governments' roles, as they do not appear to be ready or equipped to establish a WEF nexus strategy (Oludare et al., 2020). In such circumstances, innovative research may be able to assist in the advancement of the nexus discourse, with national governments responding in accordance with their interest and readiness.

In addition, the WEF nexus would necessitate tight collaboration with the private or commercial sector. The private sector possesses an in-depth understanding of manufacturing processes, management, and the marketplaces in which they operate. People who work in the private sector use natural resources or are in the business of producing or processing them, hence they must be included in the WEF nexus discussion (Lazaro et al., 2021; Naidoo et al., 2021). Because businesses rely on resources such as water, it is also in their financial interest to get involved. They can also give equipment and employees, as well as contribute to nexus solution research and development financing (Naidoo et al., 2021). Many businesses recognize the need to innovate in order to maintain long-term growth, but they are sluggish to establish the necessary links

with other stakeholders, such as the public sector and research organizations. Many obstacles can be recognized, such as a lack of communication, a lack of mutual understanding, or variations in the dynamics of the various sectors. To begin a productive dialogue on how the various interests might be matched into a project or program that can simultaneously boost the entrepreneur's business model while also helping to greatly lessen the WEF nexus difficulty (Markantonis et al., 2019; Barbarà Mir, 2020), extra effort is required to overcome these barriers. The circumstances, constraints, and opportunities for the private sector's effective engagement in promoting the nexus should be examined, and strategies for moving forward should be proposed.

Implementation and Practices

In different countries, different approaches and legislation can be found (Table 4). The use of wastewater in irrigation in Italy is strictly regulated by Italian law (Markantonis et al., 2019). This makes such use extremely difficult because the prices of treatments are too high for farmers to afford. As a result, wastewater is discharged into the sea without being utilized, and wastewater is unlawfully used by farmers without being monitored. Research can help us better understand the most appropriate limitations to be adhered to, the sorts of irrigation systems that can be employed, and the types of crops that can be irrigated with wastewater without causing any health issues for the general public (Hua et al., 2021). Overall, the study's findings could help policymakers make better decisions. The link between water, energy, food security and other sectors can contribute immensely to investments, job development, innovation, and competitiveness. It can be acknowledged that some of these techniques may not be appropriate to or chosen by some countries; nonetheless, this does not negate their significance as something that should be seriously considered (Hua et al.,

2021). The information in **Table 4** these activities and the regions where they were implemented. The difficulties of setting and implementing different prices for different sectors that use the same resources; a lack of collaboration between science, policy, and business; a lack of coherence and cooperation between various levels of government; a limited number of success stories and guidelines to help promote innovative partnerships; and a lack of public awareness and support for innovation on WEF nexus needs to be improved.

It is vital to identify the nexus economic and environmental sectors that can benefit from a shift in the planning process in order to go from concepts to implementation. This is a vital element that is missing from the literature. This will aid in identifying regions with developmental constraints, water availability or levels, uneven water allocations by different sectoral water consumers, and areas where food and energy demand is likely to rise in the next decades. The findings or results could help the region achieve long-term economic growth and environmental restoration, among other objectives.

CONCLUSION

While there is evidence that the water, energy, food nexus approach adds value to sustainable development and is generating interest, if not demand, from a number of countries and institutions, the most important step to take right now is to analyze and debate the related conditions, bottlenecks, opportunities, and paths forward through structured dialogues that lead to action. The main focus of this study is to evaluate studied on water, energy, food nexus and how the nexus has been implemented over the years as well as identifying the potential barriers to its implementation. In this study, challenges and gaps and implementation of water, energy, food nexus were examined most importantly from the perspective of water, energy and food,

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to see how they could help promote sustainable development. Themes or words dynamics in the water, energy, food nexus research field and the most emerging and frequent keywords used in the field were identified. For instance, the relevant words or frequently mentioned words in the water, energy, food nexus studies are water, food, decision making, sustainable development which were mentioned 11, 10, 9, and 7 times respectively in the author's key terms used in water, energy, food nexus studies. These connote that all these prominent themes relevant in water, energy, food nexus studies. More so, the lack of a unique or specific database for water, energy, food nexus contributed to the gaps in implementing water, energy, food nexus. In summary, it is important to establish an integrated data and analysis toolbox that incorporates existing global datasets on the water, energy, food nexus. This data or toolbox will be used to model and analyze water, energy, food resources and their interconnections at a regional or country level, this will help in having food-secured societies.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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