

Review

# The Evolution of Food Security: Where Are We Now, Where Should We Go Next?

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**Abstract:** Food security is one of the most challenging topics globally; however, the concept of food security has taken on additional dimensions that are general and are less detailed. This study aims to identify the intellectual structure of food security research and the changes in this structure. This paper analyzed 3169 documents from the Web of Science database through a bibliometric review. A review of the published documents shows an increasing trend over the past 46 years. In accordance with co-occurrence analysis, 125 keywords were grouped into five clusters: food security and sustainable development; food security and socioeconomic factors; food security policy and governance; coping strategies for poverty, inequality, and hunger; and modern food security management. This study identifies four streams within food security research: sustainability and environmental, socioeconomic, cultural, and political factors. The paper concludes that even though food security might investigate many significant areas, other new dimensions should still be considered. Further gaps in the literature emerge that present avenues for future research directions. Reviewing indicators and techniques of food security assessment and identifying high-risk groups should be a priority.

**Keywords:** food security; bibliometric review; co-citation analysis; co-occurrence analysis



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## 1. Introduction

Concerns about food security arose very clearly a few years after World War Two (1939–1945), and some scholars point to Malthus' research (1798) as the beginning of studies on populations' food security [1]. Responding to the growing demand for food is, without a doubt, the most fundamental issue and the most striking demographic and environmental challenge [2]. The growing world population and nature's limited ability to produce food are at the root of growing food security concerns around the world [3]. There is a general concern that the size of the population may someday exceed the global food supply [2]. Food insecurity may result from the unavailability of food, insufficient purchasing power [4,5], improper distribution and improper use of food [6]. Poverty [7], natural catastrophes [6,8,9], political violence, and geopolitical factors contribute to a disproportionate distribution of food globally [10].

With the evolution of the concept of food security, many studies have been conducted to define [11,12], measure and evaluate food security [13–15], analyze the factors affecting it [16–23], and investigate the relationship between environment and food production [3,8],

dietary diversity and food security [24,25], and new strategies of food security [6,26]. Therefore, the literature associated with food security is inevitably expansive [27].

The initial focus of the research was on food supply problems such as the availability of basic foodstuffs and price stability nationally and internationally. Recently, the analysis of food security has shifted from the international to the local level, even with a focus on households and individuals [28,29]. Although these studies are essential for making sound scientific judgments about food security development, existing studies on the assessment of food security are mainly focused on a single factor or are aimed at the national and regional levels [30]. The field of food security suffers from severe dispersion and separate scientific circulation. In addition, since food security is affected by developments in various areas, understanding this issue and its evolution process requires studying different periods. Moreover, recognizing the drivers of food security and their interactions is needed to guide politicians in deciding on future directions [31]. Given this area's multidimensional nature [32], food security concepts and theories are essential for policymakers.

The food security literature still needs studies that use advanced bibliographic techniques to analyze, map, and visualize scientific products. This study seeks to help complete previous work and provide a broad perspective on food security research by answering the following questions: (RQ1) what is the current publication trend in food security?, (RQ2) which are the most influential documents on food security?, (RQ3) which themes containing food security are the most popular among academics?, (RQ4) what is the current state of collaboration involving food security?, (RQ5) what is the intellectual structure of food security? and (RQ6) what areas involving food security need additional study?

To answer these questions using a bibliometric review, the intellectual structure of food security research from 1974 to 2020 was investigated. A bibliometric review can present a systematic, reproducible review process and, therefore, improve the quality of the review [33,34].

This study's structure is organized as follows: the research methods are described in the second section, then, by explaining how to identify and select appropriate scientific documents, we review general and descriptive information on previous research, such as the number of published articles, year of publication, citations, and scientific categories. The next section contains the findings based on co-citation and co-occurrence analysis. The following section discusses the results and conclusion. Finally, based on the result of bibliometric analysis and the critical aspects and approaches that appeared in the recently highly cited articles, a future model for the food security concept is presented.

## 2. Methodology

### 2.1. Methods

The bibliometric review suggests the general structure of a research stream by quantitatively discovering the distributed structure of publications and research status [35]. Given that few comprehensive studies have analyzed food security, this method allows researchers to discover the level of activity in a particular field. VOSviewer and CiteSpace software were used to illustrate the thematic structure, relationships among authors, organizations, and countries, and to analyze the co-occurrence of keywords as well as providing the possibility of analyzing intellectual structure in the form of thematic maps [36]. GunnMap2 software was also used to illustrate the world map based on the geographical distribution of publications [37].

In this study, the most cited articles on food security are identified. The geographical distribution of food security publications and the growing trend of food security studies are presented. Then, a co-citation analysis is performed to obtain a comprehensive view of historical changes in the intellectual structure of food security [38]. Co-citation networks can discover influential articles in the field of food security, which are often enlightening and lay a theoretical foundation for the research field [28]. Keyword co-occurrence analysis is used to extract the most used keywords in the articles and visualize the similarities between common keywords in the literature [39]. Co-occurrence analysis helps to discover the

comprehensive relationship between keywords of publications they have jointly authored and determine the evolution of the research topics [40]. Finally, a keyword timeline visualization and co-citation analysis is conducted to provide an intellectual structure in the field of food security [33].

## 2.2. Data Sources

The data for this study were collected from the Web of Science Core Collection (WoSCC) database, which contains thousands of scientific journals and bibliometric information. As a search strategy, we used the keyword “Food Security” to have comprehensive and meaningful coverage of this field. While choosing a keyword for bibliometric data collection and defining the scope of articles, we tried to be as comprehensive as possible to cover all facets of food security and related concepts such as food supply, food safety, and access to food. For this purpose, by searching for the keyword “Food security” limited to published article ‘Titles’, we reached 5479 documents. Then, by analyzing only ‘Articles’; we reached 3335 records. Finally, by analyzing based on the ‘English’ language, we obtained 3169 articles for final analysis. The journals *Food Security* and *Food Policy* published most of the articles. *Sieber S*, *Fasse A*, and *Nord M* have published the most articles. The research methodology and structure are summarized in Figure 1.

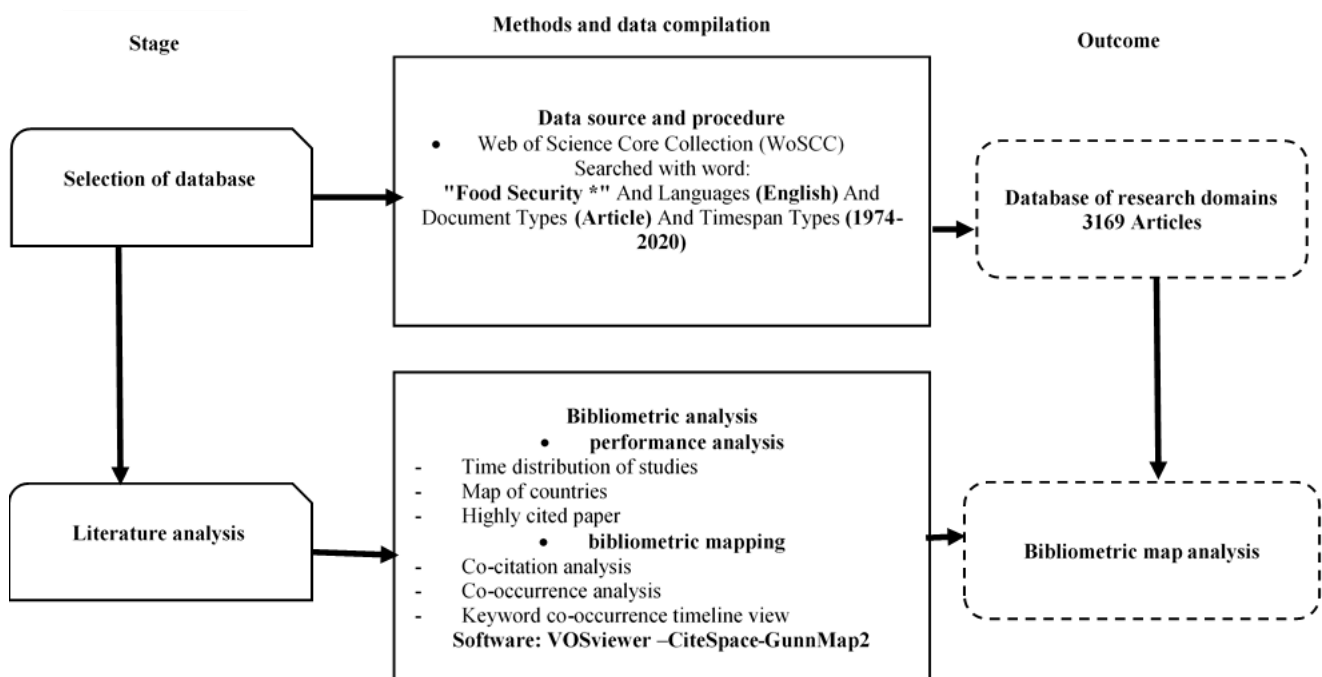


Figure 1. Research Methodology.

## 3. Results

### 3.1. The Geographical Distribution of Food Security Publications, the International Collaboration Network between Countries, and the Growing Trend of Food Security Studies

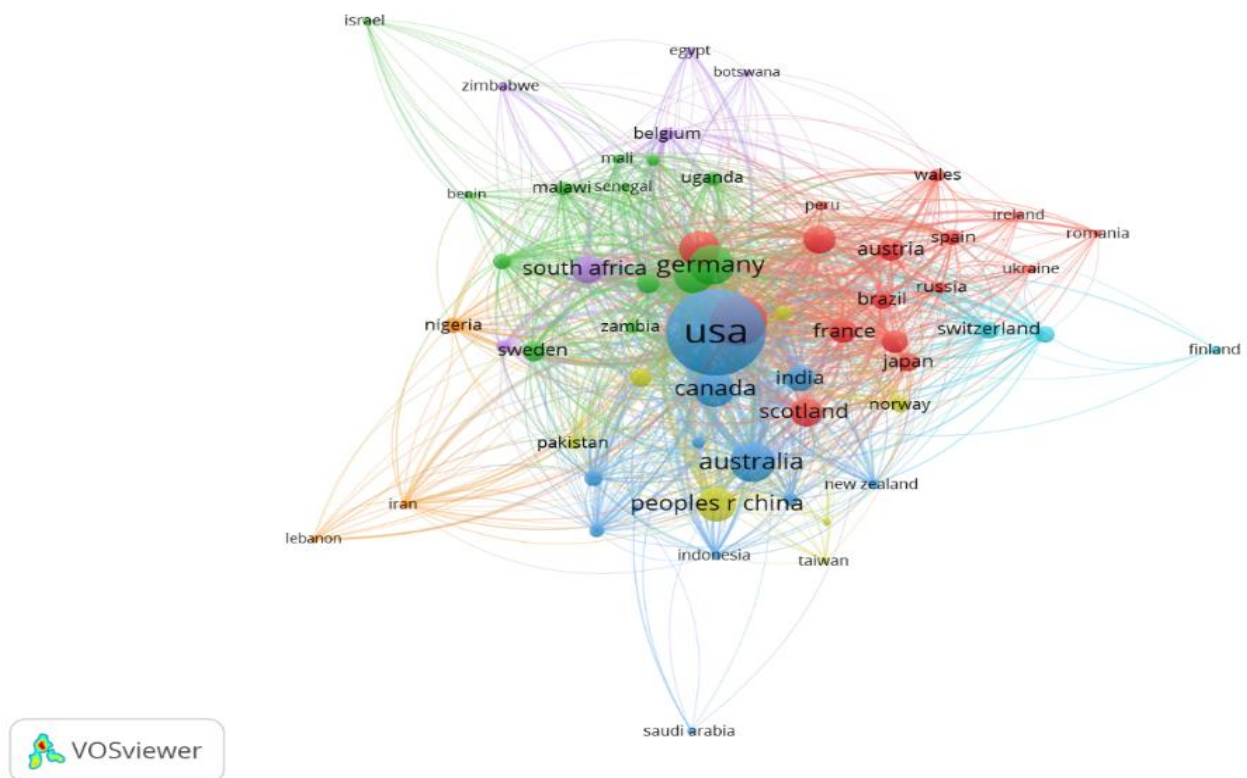
The geographical distribution of food security publications, as shown in Figure 2, indicates that the most published articles are from the ‘United States’ ( $n = 1042$ ), the ‘United Kingdom’ ( $n = 302$ ), and ‘Canada’ ( $n = 277$ ). The United States solely accounts for 31.72% of articles that were published between 1974 and 2020. The highest number of citations is related to the United States (29,703), and the lowest to Benin (19). It is noteworthy to mention that the lowest number of published articles is in Africa and South America.

Using mapped clustering visualization, a network of collaborations between countries with at least ten articles was designed (Figure 3). According to this map, the highest citations and total link strength out of 60 countries are related to the ‘United States’ (total

link strength, 4079–citations, 29,703), the ‘United Kingdom’ (1648–8573), and ‘Canada’ (1139–4822).



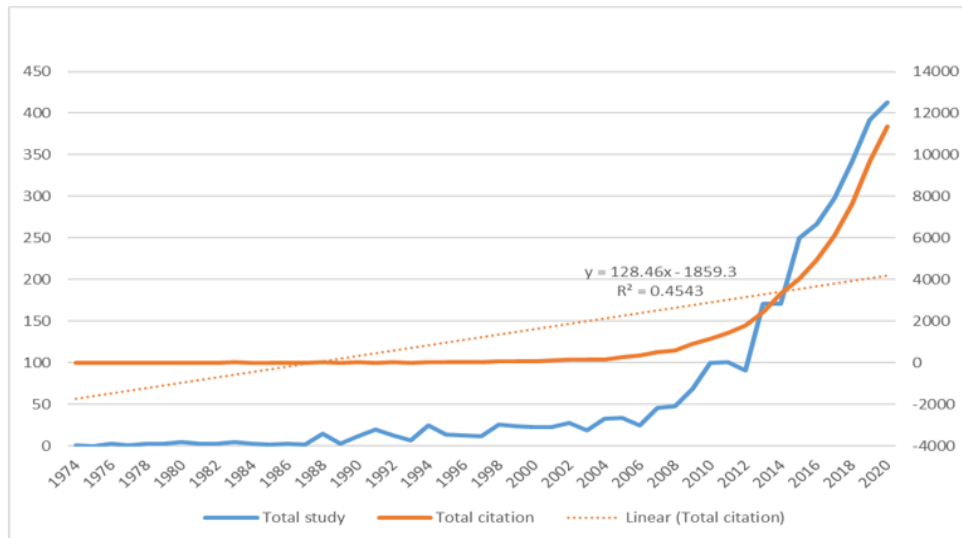
**Figure 2.** Distribution of the total number of articles by country/region. The color of each country represents the number of its publications on food security.



**Figure 3.** The international collaboration network between countries. The minimum number of documents of a country is 10.

Figure 4 shows a set of published articles, citations, and articles’ growth trends over 1974–2020. The first study on food security was published in 1974. Remarkably, the number of studies was minimal before 1980 (fewer than 16 articles); however, a review of the number of published articles shows an increasing trend over the past 46 years, so that after 2015, the number of published documents increased dramatically. Since the number of

citations indicates the impact of studies, the result revealed that with 11,417 citations, the most effective year in this period was 2020.



**Figure 4.** The growth trend of food security studies. TS = total study; TC = total citation.

### 3.2. The Most Highly Cited Publications on Food Security

Identifying highly cited publications in food security serves as an important criterion for understanding the author’s rankings and is the basis for further analysis. Lal’s (2004) study used the most citations in the field of food security. This article focuses on the effects of soil carbon sequestration on food security and agriculture [41]. The second study attempts to explain how the impacts of climate change affect food security through food availability, accessibility, utilization, and affordability [17], and the third study discusses the potential effects of climate change on food security [42]. Table 1 shows an overview of the most cited articles on food security over the past 46 years.

**Table 1.** Overview Top 15 highly cited papers in food security in order.

Source	Keywords	Motivation	Methodology
Lal [41]	Food security, Climate change, Carbon	Impacts of carbon on food security and climate change	Perspective based conceptual modeling
Tscharntke et al. [17]	Land sparing vs sharing, Wildlife-friendly farming, Land grabbing, Biofuel directive, Food wastage	Investigating the effects of agricultural products on world food security	Literature-based
Schmidhuber & Tubiello [42]	Hunger, Vulnerability, Food supply, Agriculture	The potential effects of climate change on food security. Also, the identification of the four main components of food security (availability, sustainability, consumption, and accessibility)	Literature-based

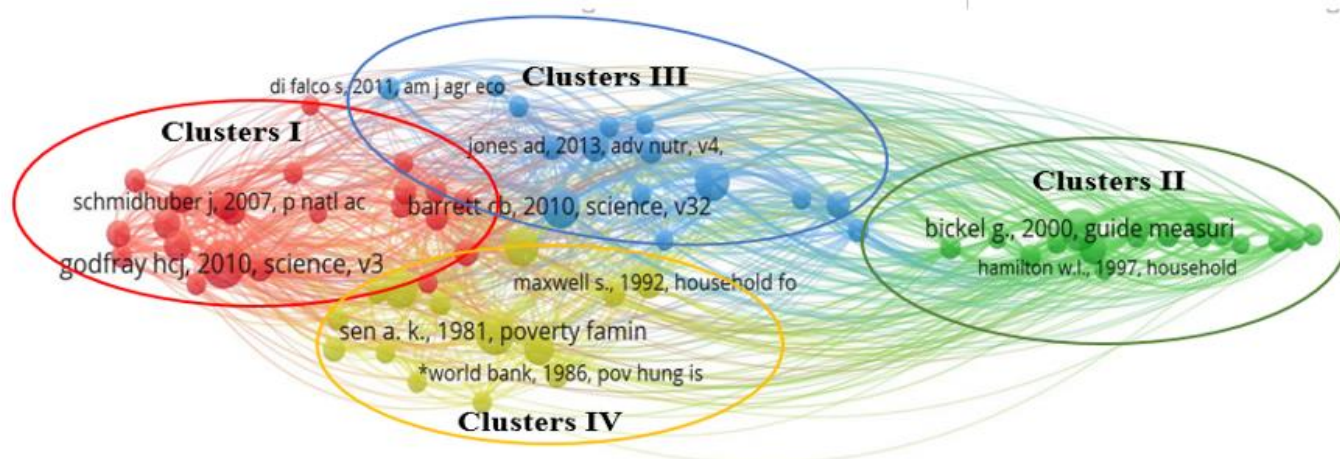


**Table 1.** *Cont.*

Source	Keywords	Motivation	Methodology
Chen [43]	Urbanization, Cultivated land, Soil resource, Food security; China	Impacts of urban and industrial consumption on agricultural lands and food security	Literature-based
Hanjra & Qureshi [44]	Climate-resilient, Energy crisis, Credit crisis, Irrigation, Food trade, Prices	Examining the overall role of emerging forces including climate change, water scarcity, energy crisis as well as the credit crunch and population growth in redefining global food security	Literature-based
Rosegrant & Cline [45]	Food security, Promising agriculture, Weather changes	Impacts of climate and agricultural approaches on food security	Literature-based
Pauly et al. [46]	Overfishing, Overcapacity, Trophic levels, Food web	Global trends in the effects of fisheries on marine ecosystems and food security	Literature-based
Lipper et al. [47]	Climate-smart, Food security, Agriculture,	The impact of agricultural climates on food security	Literature-based
Blumberg et al. [48]	Short form, Food security scale, Effectiveness	Impacts and effectiveness of the short form of food security scale in households	Literature-based
Di Falco et al. [49]	Adaptation, Climate change, Endogenous switching, Ethiopia, Food security, Productivity, Spatial data	Effects of driving forces on farm households' decisions to adapt to climate change and the impact of adaptation on food productivity	Conceptual modeling
Fan et al. [50]	Food security, Environmental quality, Genetic improvement, Integrated soil-crop systems management, Resource use efficiency	The vision of the challenge of knowledge and technology in agriculture as well as increased crop productivity using resources and ensuring food security	Conceptual modeling
Bell et al. [51]	Population growth, Allocation of fisheries resources, Coastal fisheries management, Access to tuna, Pond aquaculture	Planning the consumption of fish for food security in the Pacific	Perspective based conceptual modeling
Béné et al. [52]	Contribution, Poverty reduction, Food security	The impact of the fish trade on food security and poverty reduction with a focus on international trade	Literature-based
Parry et al. [53]	Climate change, Food security, Crop yields	The impact of climate change on agriculture and food security	Conceptual modeling
Sheffield et al. [54]	Drought monitoring, Water resources, Food security	Impact of violence monitoring and prediction system on Sub-Saharan Africa's water resources and food security	Conceptual modeling

### 3.3. Co-Citation Analysis

The results of the co-citation network are shown in Figure 5. From 115,144 cited references, 68 top articles with four different clusters were extracted. Within each network, each node or circle represents an article; the lines connecting the circles are the links between the citations. The nodes with the highest number of links (in degree) are the most cited ones. They also appear more central within the graph [55]. Based on the content of the articles, each cluster is labeled with a specific color and title. The results reveal that food security literature is divided into four clusters (see Table 2).



**Figure 5.** Co-citation network of cited references of food security documents. Within each network, each node or circle represents an article; the lines connecting the circles are the links between the citations. The nodes with the highest number of links (in - degree) are the most cited.

A brief review of the identified articles indicates that the term *food security* has been interpreted differently over time and has been examined from different dimensions [15]. Although the concept of food security was initially interpreted according to the “access to adequate food and eradication of hunger” [56,57], new concepts such as “food safety and hygiene” and “food sustainability” [11,58,59] have been added to the definition of this concept. The results indicate that researchers pay attention to various dimensions and components related to food security [11,13,60–62]. Hence, despite the similarities and overlaps between the contents, it is possible to distinguish the four clusters:

**Cluster I:** The first cluster was documented as the largest cluster (22 articles). Studies such as Godfray [63] and Schmidhuber and Tubiello [42] were among the most frequently cited articles. This cluster’s focus is to examine *sustainability and environmental factors*. In this cluster, the interaction between food security and climate change has been considered. For instance, the concept of food security from the perspective of food systems and its multiple interactions with global environmental changes has been examined [64]. This study demonstrates food systems that can be used to identify the main processes and factors that determine food security in a given place or time (i.e., environmental change). A large number of researchers have examined the impact of population growth and food demand [65], climate change [42,45,66–68], and global environmental change [64] on food security.

The overall impact of each factor on diverse aspects of food security will vary in different regions and over time. Climate change will increase the dependency of developing countries on imports and accentuate the existing focus of food insecurity in Sub-Saharan Africa and South Asia [42]. The results of many studies also show that the socio-economic consequences of climate change are far more important than the impacts that can be expected from biophysical climate change [21,42,67].

Since climate variability and extremes are key drivers behind this rise, together with conflict and economic downturns, and are threatening to erode and reverse gains made in

ending hunger and malnutrition, in recent years climate resilience for food security has been discussed [59]. Accordingly, many studies have planned to improve food security and provide different solutions for adaptation to various environmental factors. For example, multiple strategies have been suggested, such as building agricultural resilience or 'climate-smart agriculture', through improvements in technology and management systems [66], small pond aquaculture development and the use of fish in the diet [51], increased sustainability practices through improving agricultural resource efficiency [65,69], dietary modification, and waste reduction [70]. However, no single strategy is sufficient; the implementation of many of the strategies requires overcoming considerable economic and governance challenges. For example, reforming global trade policies, including eliminating price-distorting subsidies and tariffs, will be critical to the success of these strategies [71].

Some researchers believe that, in addition to approaches related to agricultural development and crop production, an investment increase in research and related infrastructure can significantly improve food security in developing countries [45,66]. Examples of this include the improvement of livelihoods and income sources of the poor, the increase of the productivity of resources available to smallholder farmers, fisheries and forest operators, as well as things such as social protection, increasing human capacity and improving income security. This is the most effective way to fight hunger and food insecurity [58].

**Cluster II:** *Socio-economic factors* are important areas discussed in the second cluster. Of the 17 articles in this cluster, two studies were most cited in this field [72,73]. The focus of this group of studies was measuring food insecurity and classifying individuals into different groups. These studies were conducted mainly using various indicators such as the US Household Food Security Scale and National Health and Nutrition Examination Survey/NHANES data [74,75]. These studies show the evolution of indicators and methods of measuring food security in terms of socio-economic factors [48,73,75,76]. A group of studies has examined the relationship between food shortages and physical, mental and social health. According to the results, with decreasing income, the likelihood of reporting food insufficiency increases dramatically as income adequacy deteriorates [77].

Food insufficiency is more likely to be reported by single parent families' households in western Canada and those who do not own their own homes. It is noteworthy that their main source of income is provided via unemployment insurance, welfare or workers' compensation. On the other hand, as income adequacy deteriorates, the probability of food insufficiency report is increased significantly [78]. Food shortages are one of the dimensions of the vulnerability to a wide range of health problems among households struggling with economic constraints. Individuals from food-insufficient households have higher odds of reporting poor functional health, a variety of chronic conditions, and restricted activities. Besides this, they suffer significantly from psychological problems such as major depression, distress, and not having sufficient social support [75,78,79].

However, because socio-economic factors affect food security in a complex way, it is difficult to deduce the causal relationship between these factors and food security. For example, psychological problems in mothers may cause socio-economic problems, such as reduced success in education and employment or relationship difficulties with the child's father, which ultimately leads to food insecurity [80]. Several studies examined food security status as well as the consequences of hunger and food insecurity on educational and psychosocial performance [74], economic, social, and physical development [81], and adverse health outcomes of children [82]. Some studies have also associated food security with obesity [79], chronic diet-sensitive diseases [75], physical, mental, and emotional well-being [78], and anxiety in mothers and behavioral problems in children [80].

**Cluster III:** Of the top 15 articles in this cluster, three studies are among the most cited [13,83,84]. The main causes and processes of food security and the strategies to fight food insecurity in terms of *cultural factors* organize the mainstream research in this cluster. This group of researchers has sought to develop methods for assessing household food security. As income adequacy was exacerbated, the probability of food insufficiency reports increased dramatically [15,85]. In this group of studies [15,61,86], the trend of changes



in food security concepts and practical approaches can be seen. These studies aim to assess changes focusing on macro- and micro-cultural factors such as lifestyle and food diversity [87–89], as well as diet and cultural commonalities [15,85].

**Cluster IV:** The fourth cluster emphasizes the concept of food security and strategies to overcome hunger and food insecurity from the perspective of *politics and governance*. Food insecurity and hunger [56,57], deprivation [60], food rights, sovereignty, and food policy [90,91] are the key topics of discussion in this cluster. The study by Sen is one of the most cited articles that have the most relevance with other research in this field. Referring to the famines of the past decades, including the Great Famine of Bengal in 1943, the famines of Ethiopia in 1973 and 1974, the famine of Bangladesh in 1974, and the famine on the African coasts in the 1970s, Sen attributes the famine not only to food shortages but also to inequalities in food distribution mechanisms. Sen believed that the traditional analysis of famines concentrating on food supply was theoretically unreasonable and empirically inefficient, and dangerously misleading for policy [56].

**Table 2.** Co-citation network of cited references.

Clusters	Representative Citations	Research Areas/Topics
I	Bell et al. [51]	Development of aquaculture and food security
	Ericksen [64]	Food systems, food security and global environmental change
	FAO, IFAD, UNICEF [59]	Food security perspective and general recommendations for improving
	Foley et al. [71]	Practical solutions enhancing food production and sustainability
	FAO [58]	Investigating food security in the world
	Godfray et al. [63]	Strategies for sustainable and equitable food security
	Gregory et al. [92]	Climate change and food security
	Lobell et al. [68]	Identifying compatible strategies for climate change and food insecurity
	Parry et al. [67]	Climate change and its effect on the agricultural sector
	Rosegrant & Cline [45]	Challenges and policies of global food security
	Schmidhuber & Tubiello [42]	Implications of climate change on food security
	Tilman et al. [69]	Sustainable agriculture and sufficient food supply
	Tilman et al. [65]	Alternative methods to respond to the trend of increasing production demand crops
	Wheeler & von Braun [66]	Climate change and food security policy
	FAO et al. [93]	Working towards coherence of policies, programs, and practices to address climate variability and extremes
	FAO [94]	Economic growth, hunger, and malnutrition
	FAO [95]	Impact of rising food prices on global food security
	FAO [70]	Climate change and food security
	FAO [96]	Addressing food insecurity in protracted crises
	FAO [97]	Agricultural innovation and resilience to shocks and sustainable food security
FAO [98]	Hunger and mortality	
FAO [99]	The multiple dimensions of food security	

Table 2. Cont.

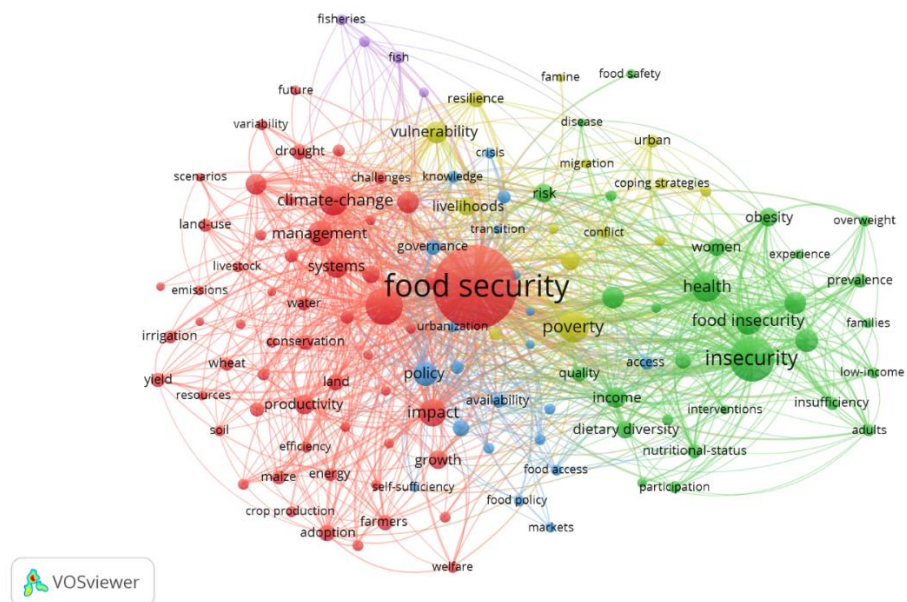
Clusters	Representative Citations	Research Areas/Topics
II	Alaimo et al. [74]	The effect of food shortages and food insecurity on physical growth and students' cognitive and academic development
	Anderson [76]	Examples of scales for measuring hunger and food insecurity
	Bickel et al. [73]	Household food security scale
	Blumberg et al. [48]	Household food security scale
	Cook et al. [82]	Adverse effects of food insecurity on infants and toddlers
	Rose & Frongillo [100]	Measuring food insecurity and hunger in the US
	Hamilton et al. [72]	Food security measurement
	Jyoti et al. [81]	The effect of food insecurity on children's physical, social and educational development
	Kendall et al. [101]	Relationship of hunger and food insecurity to food availability and consumption
	Rose & Frongillo [100]	Validation of measures of food insecurity and hunger
	Radimer et al. [102]	Development of indicators to assess hunger
	Rose [77]	Measuring food insecurity and hunger
	Seligman et al. [75]	Food insecurity associated with chronic disease among low-income NHANES participants
	Townsend et al. [79]	Relationship between food insecurity and obesity
	Vozoris & Tarasuk [78]	Relationship between food insufficiency and physical, mental, and social health
III	Whitaker et al. [80]	Food insecurity and the risks of depression and anxiety in mothers and behavioral problems in their preschool-aged children
	Arimond & Ruel [87]	Associations between dietary diversity and child nutritional status
	Barrett [13]	Measuring food insecurity
	Maxwell [91]	Measuring food insecurity and coping strategies
	Carletto et al. [61]	Review of the most common definitions and indicators used to measure food security
	Coates et al. [85]	Identifying cross-cultural commonalities of the food insecurity experience
	Coates [15]	Deconstructing food security for improved measurement and action
	Coates et al. [83]	Questionnaire for measuring food security and access to food
	Di Falco et al. [49]	Strategies to tackle climate change and adaptation
	Headey & Ecker [86]	Dietary diversity indicators
	Leroy et al. [103]	Measuring household food security in terms of food access
	Jones et al. [84]	Review of approaches and indicators for measuring food security
	Ruel [88]	Food security and socio-economic status of the household
	Swindale & Bilinsky [89]	Household Dietary Diversity Score (HDDS) for measurement of household food access: indicator guide
	Swindale & Bilinsky [104]	Development and improvement of household food security measurement indicators
Webb et al. [14]	Measuring household food insecurity	

**Table 2.** *Cont.*

Clusters	Representative Citations	Research Areas/Topics
IV	World Bank [105]	The world economy and the policy framework required for sustained growth
	Drèze & Sen [57]	Hunger and public action
	Lang & Barling [62]	Food security and food sustainability
	FAO [106]	Planning and global action for food security
	FAO [107]	Towards the World Food Summit commitments and acting to combat hunger
	FAO [108]	Economic crises – impacts and lessons learned
	Lang & Barling [62]	Food security sustainability policy
	Maxwell et al. [12]	Household food security
	World Bank [109]	Agriculture for development
	Maxwell [91]	Food security policy
	Pinstrup-Andersen [11]	Food security, definition, and measurement
	Patel [90]	Food sovereignty
	Sen [56]	Poverty, famine, and deprivation
	Shaw [60]	Dimensions of poverty and food insecurity

**3.4. Co-Occurrence Analysis: Hot Issues in the Food Security Research**

To show the main structure of the co-occurrence network, keywords that had at least 20 occurrences were analyzed (Figure 6). Finally, 125 keywords were grouped into five clusters. The clusters were then labeled according to the keywords and content of each cluster (Table 3).



**Figure 6.** The network of cited keyword co-occurrence. The size of the circles denotes the number of citations that each keyword has received. Keywords which are close and in the same color demonstrate a stronger relationship, as they tend to be related to each other.

**Table 3.** Core topic recognized in each cluster.

Cluster	Keywords and Topic
I	57 items: Adaptation, Adoption, Agriculture, Agroecology, Agroforestry, Biodiversity, Biofuels, Challenges, Climate Change, Conservation, Crop Production, Demand, Diversification, Drought, Dynamics, Ecosystem Services, Efficiency, Emissions, Energy, Farmers, Food Availability, Food Production, Food Security, Future, Growth, Impact, Intensification, Irrigation, Land, Land-Use, Livestock, Maize, Management, Nitrogen, Performance, Poverty Reduction, Productivity, Resources, Rice, Scenarios, Science, Smallholder Farmers, Soil, Strategies, Sustainability, Sustainable Agriculture, Sustainable Development, Sustainable Intensification, Systems, Technology, Temperature, Variability, Water, Welfare, Wheat, Yield Topic: Food security and sustainable development
II	29 items: Adults, Behavior, Children, Community, Consequences, Consumption, Dietary Diversity, Disease, Experience, Families, Food Insecurity, Food Safety, Health, Household Food Security, Hunger, Income, Insecurity, Insufficiency, Interventions, Low-Income, Nutrition, Obesity, Overweight, Participation, Prevalence, Program, Quality, Risk, Women Topic: Food security and socioeconomic factors
III	21 items: Access, Availability, Countries, Crisis, Economy, Environment, Food Access, Food Policy, Food Sovereignty, Food Systems, Governance, Knowledge, Markets, Policy, Power, Self-Sufficiency, Sovereignty, Trade, Transition, Urban Agriculture, Urbanization Topic: Food security policy and governance
IV	14 items: Conflict, Coping Strategies, Developing-Countries, Famine, Gender, HIV, Inequality, Livestock, Malnutrition, Migration, Poverty, Resilience, Urban, Vulnerability Topic: Coping strategies for poverty, inequality, and hunger
V	4 items: Aquaculture, Development, Fish, Fisheries Topic: Modern food security management (Development of fisheries and aquaculture for food security)

**Cluster I:** Themes and keywords in this cluster, such as agriculture ( $n = 326$ ), climate change ( $n = 197$ ), and sustainability ( $n = 109$ ), reveal the focus on *food security and sustainable development*. Given the current trend of population growth, changing diets, food production, and climate change, it can be acknowledged that food security and sustainable livelihood have been some of the concerns of researchers. On the other hand, integrating food security and sustainable development into national and international policies and a significant increase in investment in sustainable agriculture and food systems are inevitable [110]. The potential impacts of climate change on various aspects of food security [42], sustainable agricultural development, and climate-smart agriculture [111] are some of the most important issues in this group. Topics such as investing in research and the development of sustainable technologies [112], sustainable agricultural production [113], improving biodiversity and nutrition [114], and reducing greenhouse gas emissions [65], have led to the development of targeted policies and programs to help communities that are most at risk of climate change and food insecurity [115]. Reshaping consumption patterns and reducing waste in the global food system [110] have been other key concerns in this field. However, climate change will affect all four dimensions of food security [66,92].

**Cluster II:** The fundamental concepts in cluster II illustrate the *food security and socioeconomic factors*. Keywords such as nutrition, health, food insecurity, consumption, income, behavior, dietary diversity, and household food security refer to the indicators that affect household food security. Many studies are based on measuring the concept of food security, social and economic factors such as health and food status [116,117], beliefs, attitudes, eating behaviors, and participation in food assistance programs [118], as well as household income [119,120].

**Cluster III:** Concepts such as economy, food access, food policy, food sovereignty governance, market power, self-sufficiency, sovereignty, and trade indicate the inclusion of *food policy and governance* in food security studies [121]. The increase in global food prices, inefficiencies in food production and distribution systems, and marches against the economic policies of wealthy and industrialized countries have paved the way for the formation and development of the concept of "right to food" in studies related to food security [122].

Food sovereignty is defined as a vital option for food security, meaning the right of the native public to control their food systems [123]. In other words, the program has moved from its initial focus on national self-sufficiency in food production (the right of nations) to local independence (the right of the people). It also emphasizes the rights of deprived peoples [124]. Food governance aims to rebuild the variety of independent food systems in rural and urban areas, based on this idea that farmers and other people can make decisions about their food and agriculture policies. The concept of food sovereignty may be best understood as a transformational process that seeks to rebuild the democratic realm and the diversity of local food systems based on justice, social justice, and ecological sustainability [125]. Specific components in food sovereignty mainly include diets and rights-based and citizenship approaches to food and food sovereignty [123].

**Cluster IV:** The main keywords of cluster IV are poverty, vulnerability, gender, and resilience. Hence, the most related topics in the cluster are *coping strategies for poverty, inequality, and hunger*. The use of the terms 'poverty' and 'vulnerability' and their extensive association with other terms in the cluster, such as 'conflict, coping strategies, developing countries, famine, livestock, malnutrition, migration, and resilience', indicate the importance of this issue in food security studies. The starting point of this group of studies is to address the issue of poverty and coping strategies with food insecurity in developing countries [126,127].

**Cluster V:** The *development of fisheries and aquaculture for food security* is a topic that has attracted limited research focus (cluster V with four identified keywords). This cluster seems to be limited to strategies such as fish farming and aquaculture and their role in improving nutrition, food security, and the economic development of communities [52]. In developing countries, several economic and social analyses have been conducted on the impact of various commercial fishing and aquaculture activities on low-income households [128,129]. However, more studies are needed on how aquaculture contributes to the diet of poor people as part of their dietary strategies. Gender relations, health, and safety in the fisheries sector also need further investigation [52].

### 3.5. Keywords Timeline Visualization

The keyword timeline view is provided in Figure 7. Keyword timeline analysis is an effective way to show emerging trends and track research topics over time, because the keyword timeline provides an accurate summary of the documents [130]. Keywords used in the early time series are presented on the left and vice versa. The color of the links between keywords reflects the time of occurrence; 'impact, agriculture, empowerment, nutrition, health, insecurity' were among the keywords used in the most recent articles. On the other hand, keywords such as 'intersectionality, low-income, genetic resource, sustainable development goal, fragmentation, import-substitution, agriculture commercialization, household income, driver, indigenous' are the most important hotspots of research.



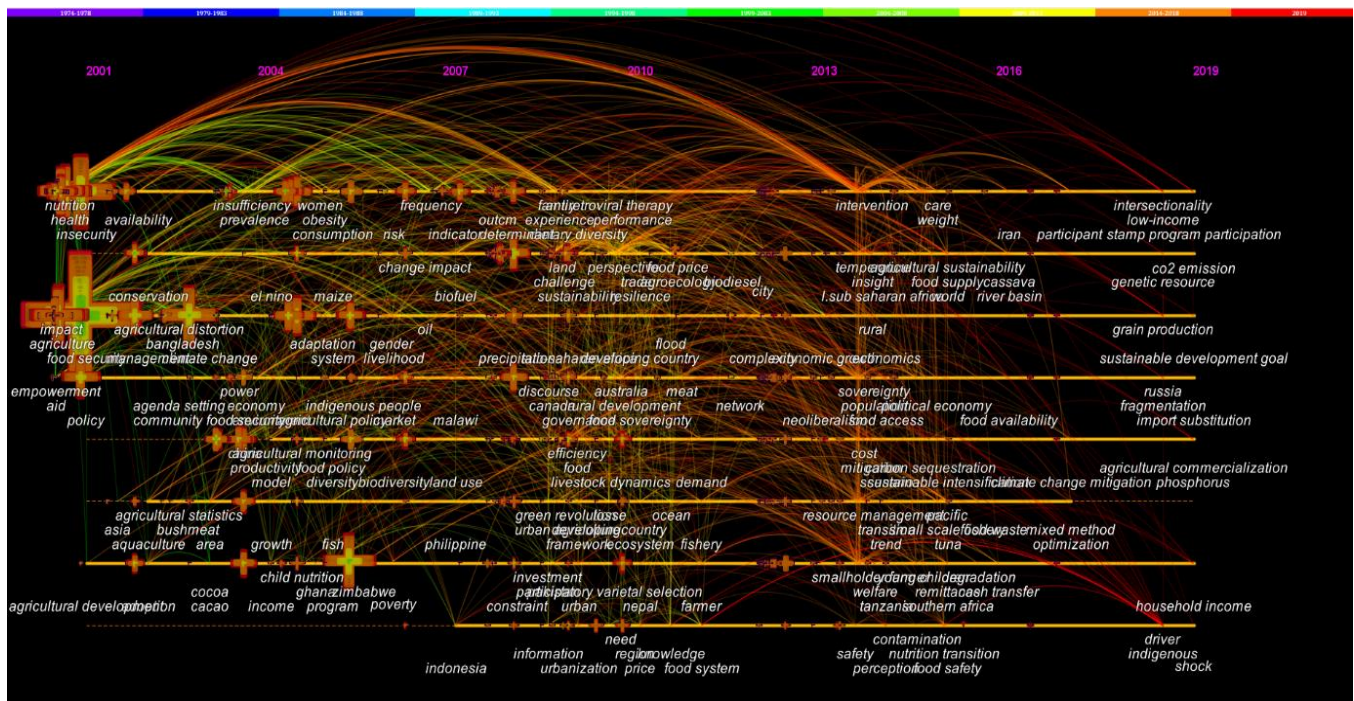


Figure 7. Keywords timeline visualization.

## 4. Discussion

In this study, to identify the main research fronts and opportunities for advancing this field of study, the highly cited documents identified with the use of bibliometric analysis have been discussed. The results of the study of the intellectual structure of food security and highly cited documents are presented as a future model. In this model, the definitions of food security and the key concepts, along with the basic intellectual structure of previous studies, were examined: (1) components and factors affecting food security; (2) plans and measures that are taken to eliminate hunger and ensure sustainable food security; and (3) the consequences of food insecurity and future food security challenges. Each of these dimensions is described below:

### 4.1. Effective Factors

To expand the issue and consider all the key factors affecting food security, these factors were classified into four dimensions: socio-economic, political, cultural, and environmental.

#### 4.1.1. Socio-Economic Factors

Socio-economic factors affect the level of access to food [131]. Some researchers have used different methods to study the association between food security and household income [15,82], food prices [132], nutritional status, and dietary diversity [15,89], physical and mental health status [80,133], poverty [86,131], gender and household size [134], family knowledge about food and nutrition [135], food behaviors [136], and demographic factors [88,96]. A review of these studies suggests that most studies' primary focus is on economic variables such as household income and purchasing power [62]; however, the role of factors such as eating behaviors, nutrition knowledge, and education has received less attention. Therefore, more research is needed on learning methods and food-related knowledge in individuals through experimental interventions and longitudinal studies [136]. On the other hand, the concept of food security encompasses very broad and accurate assessments of the causal direction and type of relationship between different variables and their impact on food security and requires consideration of the interaction of ecological, socio-economic, political, and cultural factors [137]. For example, purchasing power

depends on pricing policies, income, subsidies, and household welfare. Thus, rising prices for many people in the community, especially in the lower-income bracket, can reduce physical access to food, variety, and diet quality [60].

#### 4.1.2. Political Factors

Given that ensuring food security is of high importance for many governments and societies [15], it is necessary to examine it from the dimension of politics and governance. A growing body of research has studied the association between food security and food policy [138], food sovereignty [60,62,90], governance [139,140], self-sufficiency [90,123], food production and distribution systems [13,64,71], and global trade [15]. Due to its important role in ensuring food security at different levels, governance has received more devotion from scholars in this field, since the root of many factors affecting food security, such as political, economic, social, and environmental components, can be sought in governance [141]. That is why, in recent years, food sovereignty has become one of the most important elements of governance [122]. However, current knowledge about food governance is fragmented. Therefore, complementing this area of literature with alternative governance perspectives in future research may strengthen the current understanding of food security governance [140].

#### 4.1.3. Cultural Factors

The impact of culture on food security is a complex and challenging issue that has received less attention [142]. Indeed, the dynamics and relative importance of cultural influences on food security are not well studied. Nevertheless, physical and economic access, preparation, and selection of food baskets are influenced by culture, eating habits, and lifestyle [85,88,142]. Instead, culture can lead the way to better implement food security policies [142].

#### 4.1.4. Environmental Factors

Climate change as one of the key factors affecting food security has been considered by many researchers [18,143]. There is a dual connection between climate change and food security [42,66]. Climate change affects all dimensions of food security, such as physical and economic access, dietary patterns and food use, and the stability and flexibility of food systems [115]. Striving for food security in terms of climate change has far-reaching implications for endangered communities [68]. In addition, efforts to ensure food security by increasing agriculture and expanding agricultural land lead to increased greenhouse gas emissions from deforestation and land-use changes [16,113]. Alternatively, by affecting production and supply, climate change can lead to rising prices of food and agriculture, which in turn worsens the global hunger crisis [144]. In addition to climate change, the decline in agricultural production for various reasons, including the prevalence of pests and diseases, endangers the livelihood and welfare of farmers and producers and related businesses, especially small-scale farmers, foresters, ranchers, and fisheries [19,93].

### 4.2. Coping Strategies (Actions, Plans, and Policies)

One of the important indicators of sustainable development is eliminating hunger and ensuring sustainable food security [145]. International organizations such as the UN, FAO, IFAD, UNICEF, WFP, and the WHO have various programs and actions measurements to achieve this goal [93]. Studies in this field have provided practical strategies by focusing on each period and geographical area's specific conditions and requirements. Coping strategies of this study can be classified into four dimensions: food quantity and quality improvement, food safety, and socio-cultural and environmental acceptance [128,146–148].

A group of studies in the field of food security, one that has a long history and extensive volume, has examined various strategies, programs, and policies to improve economic and physical access to food. The starting point of this group of studies is to address the issue of poverty and strategies to combat food insecurity in various societies,

especially in developing countries. Researchers have tried to use practical strategies by relying on food supply through domestic production or imports and improving people's purchasing power, especially vulnerable groups. Various approaches have been considered to increase the performance and efficiency of the agricultural sector to ensure sustainable food security. Focusing on the existing agricultural lands with priority given to climate-friendly agriculture, transfer of new high-yielding technologies to these croplands [65], integrated water resources management, increase in product efficiency, and agricultural waste management [71] are examples of the strategies mentioned in these studies.

Many farmers worldwide use the maintenance of biodiversity as it provides both food security and sustainable livelihoods for users and greater resilience to the dangers of climate change or other natural shocks [149]. However, to feed the growing population, innovative and acceptable ways of combining biodiversity conservation and food production must be identified. To this end, one study [129] has considered the development of fisheries and aquaculture. A limited number of studies have observed the relative influence of urban agriculture on sustainable food security [150,151], the approach of diversification and the use of micronutrients to improve dietary quality [15,152]. However, despite the importance of nutritional quality in sustainable food security, limited studies have been conducted to improve nutrition quality, especially for disadvantaged and low-income areas [52,146].

However, global studies have confirmed the negative impact of chemical residues on soil and terrestrial and aquatic ecosystems and their toxic effects on humans [153]. Some researchers have turned their attention to the issue of safe and healthy food. Their main purpose is to increase people's access to health services and health care along with food security [58,59,154,155]. However, there are still serious concerns about the overuse of pesticides and chemical contaminants and the development of genetically modified foods that need to be carefully studied [147].

Other studies have focused on socio-cultural and environmental acceptability. In addition to discussing the physical and economic improvement of food, food hygiene and various strategies in opposition to socio-cultural values (consumer acceptance) have been proposed [156,157].

A review of studies shows that due to researchers' efforts and participation in various fields such as economics, agriculture, sociology, nutrition, and medicine, the literature on food security has become richer over time. There are still many questions that determine the future direction of food security programs. For example, food insecurity measures are generally defined at the household level, not for individuals [14,85,127,134]. Some studies have attempted to measure the food security of particular groups such as children and pregnant women [133,158]. Instead, depending on how the food distribution system in different regions affects food security, the proposed measures and strategies will be different. The USA has an advanced food distribution system that allows food prices to be lower than other high-income countries; as a result, the rate of food insecurity in this country is much lower. Therefore, research on improving the food distribution system to deal with food insecurity, especially in underdeveloped or less developed areas, can be pursued [159].

Furthermore, it is essential to pay attention to the research needs and priorities in different areas. According to the World Map on Food Security in 2020, many regions are located in high-risk zones. Given the widespread effects of the COVID-19 pandemic, it is estimated that this epidemic will decrease access to food [160] and increase the number of hungry people in the world to 840 million by 2030 [161]. In this regard, policies related to social protection, increasing purchasing power, and making healthy diets affordable for the most vulnerable populations are a priority [162].

#### 4.3. Consequences (Impacts and Outcomes)

The consequences of food insecurity, including hunger, malnutrition, and its direct or indirect effects on health and quality of life, have always been considered [163]. A group of studies has evaluated the effects and consequences of hunger and food insecurity on

physical, mental, and social health [80,159,164]. These studies suggest that food shortages are one of the dimensions of the individuals' pervasive vulnerability to a wide range of physical, psychological, and social problems among households struggling with economic constraints. People who do not have enough access to healthy food are significantly more likely to face issues such as chronic heart disease, diabetes, high blood pressure, major depression, and anxiety [75,78,79,81,82,165]. Alternatively, continuing the cycle between food insecurity and various diseases will lead to decreases in job productivity, learning capacity, and ability to grow physically, mentally, and intellectually [15,81]. However, most research on food insecurity has relied on cross-sectional data. This is partly due to the lack of longitudinal data that households and their food security status follow over time [20,81,84,159]. Therefore, to understand the long-term effects of food insecurity, the association between food security, policy, income, consumption instability, and other variables should be examined. It should also be considered how food insecurity is transmitted from childhood to adulthood and its long-term effects on adults' health and human capital [159]. The Panel Study of Income Dynamics, Fragile Families and Child Well Being, and the Early Childhood Longitudinal Survey, are some exceptional examples, both of which have multiple reports of food insecurity over time. However, we need to do more research on correlations between food security and income and consumption volatility, using longitudinal data.

## 5. Theoretical and Practical Implications

The present study sheds light on the emerging scientific research process on food security. Existing food security literature emphasizes the consideration of food security indicators in different dimensions. Reviewing indicators and techniques of food security assessment and identifying high-risk groups can be a priority. In addition, due to the potential differences among household members, monitoring and measuring the food security status of vulnerable individuals compared to household food security can be considered for future studies [159].

The results of this study predict that most studies will focus on identifying the short-term and long-term consequences of food insecurity and coping strategies. Because cross-sectional crises and long-term crises have different consequences around the world, a variety of strategies need to be developed to achieve food security. Furthermore, the results indicate the existence of a gap in food security research at the level of individuals, families, and nations. Therefore, managers and policymakers who constantly deal with research, planning, implementation, and assessment of food security interventions can make the best decisions based on the new perspectives of food security. New perspectives for implementing policy and planning decisions should be based on sound databased analysis. Such analysis should be founded on a systematic bibliometric review that provides an inferential foundation for assessing, refining, and, sometimes, rejecting the existing policy and planning interventions of food security in developing and developed countries.

It is noteworthy that food security has always been one of the main topics considered by many researchers in various fields; however, the available studies indicate occasional and cross-sectional scatterplots in this area. For example, researchers in the nutrition and medicine fields have prioritized aspects such as calorie deficiency and micronutrients and their effects on body health. In contrast, food supply and distribution policies, food pricing, and governance have been issues for researchers in the fields of economics and politics. Accordingly, there are apparent inconsistencies between the international definition of food security and how it is used in measurement and policy-making [15]. Previous studies have not comprehensively considered all aspects and components related to food security as well as different strategies and policies for its provision and the long-term consequences of each strategy. The local food supply system, lifestyle, and food culture are important topics that can attract the attention of various researchers and planners. In addition, given that different groups in society, especially low-income households, are expected to use different



coping strategies, it is recommended that future studies identify the coping strategies of these groups and their effects on health and food security.

Given that various disasters and crises such as climate change, land-use change, biodiversity loss, and diseases, including the COVID-19 pandemic, will affect all dimensions of food security, future studies may consider their associated effects on future food supply and demand. Although the impact of COVID-19 on food security has also been of interest to researchers [166–168], most studies have addressed the direct effects of the disease on physical and economic access to food, and there has been limited information on the impacts of COVID-19 and associated lockdown policies on the overall food system such as food safety, food policy and governance, and sustainable food supply [160].

Given that the food security of each member of the household may differ depending on demographic characteristics, for example, men versus women or adults versus children, how food security is distributed among family members and the identification of high-risk groups need to be investigated [15]. In addition, most household food security assessment research has been undertaken based on occasional and cross-sectional scatterplots [159]. Therefore, the food security situation of individuals and households over time and the long-term consequences of food insecurity can be prioritized in studies.

The social and political acceptance of traditional foods and the methods of their production can also provide a useful perspective for future research [169]. Empowerment mechanisms of food system participants, especially low-income groups, women, migrant workers, displaced people and refugees, and other vulnerable people and communities, to access a variety of nutritious and safe foods, are important issues that can attract the attention of various researchers. In this regard, conventional solutions to access food and traditional policies such as charitable aid and social support are not enough to achieve sustainable food security. Finally, ensuring food security and nutrition for the growing population requires joint actions, policies, cooperation, and accountability of all countries. Therefore, the governance tools of sustainable food system management and the role of governments, various national and international actors, as well as public and private actors in the global food system and a wide range of food policy concepts, can motivate researchers and planners in future actions.

As with any study, this research could not evade having some limitations. First, the food security keyword was used for extracting the documents from the WoS database. Using diverse keywords could result in retrieving a different number of articles. Second, because of the language limitation of our research, some excellent non-English documents were not included in this analysis. Third, data reduction needs the definition of thresholds that ultimately change the results [166]. Future research should cover other databases as well, such as Scopus, to validate the findings of the study. Although food security has always been one of the main topics considered by many researchers in various fields, much remains unknown about many aspects and components related to food security as well as different strategies and policies for its provision and the long-term consequences of each strategy. Therefore, several questions can be answered in the future research agenda of food security. The present study will help policymakers, development experts, and food security researchers understand the latest advances in food security research and identify research and evidence gaps (Table 4).



**Table 4.** Overview of key gaps facing policymakers, development practitioners, and researchers and future research agenda.

Research Topic	Potential Research Questions
	Availability dimension
Building agricultural resilience/ Climate-resilient food systems	How will the agricultural production system respond to rising food demand, climate change, socio-economic and political change? What mechanisms, policies, and management programs can be used to improve the efficiency of the production system at different levels (local, regional, and national)?
Climate-smart agriculture/ Climate-smart food systems	How does future food security relate to water security, land degradation, and climate change?
Modern agri-food systems	How can a balance be struck between increasing food demand and decreasing water resources in a changing environment? How will the different levels of the food system (food production, processing, distribution, and consumption) respond to increased food demand, climate change, political, social, and economic change? What mechanisms, policies, and management programs can be used to improve the efficiency of the production system at different levels (local, regional, and national)?
Climatic shocks and food system resilient disasters and crises (land-use change, biodiversity, population at risk of hunger, climate change, droughts, and diseases such as the COVID-19 pandemic) and the future of food	How do changes in food production, imports, and exports affect the resilience of the household food system, particularly in light of recent climate change and the COVID-19 pandemic? How do the effects of the COVID-19 pandemic compare to the effects of climate change, changes in food production, and imports? How does the COVID-19 pandemic affect food production, processing, and marketing? How does the income shock from the COVID-19 pandemic affect the capacity of the food system to ensure food availability?
	Access dimension
The future balance between food demand and supply	What are the most concerning impacts of the COVID-19 pandemic on the demand side (economic and physical access to food)? How will food supply chains' vulnerabilities during the COVID-19 pandemic affect disparities in food access and the resulting inequities in food security?
Resilience strategies into agricultural, socio-economic, Cultural, and environmental policies	How do economic, social, cultural, and ecological differences affect food security at the national and household levels? How do local food behaviors and habits, culture, and food systems relate to food security (availability and sustainability of food production) at the national and household levels? What are the community-centered strategies for achieving food justice? What are the areas of intervention of the government and other actors in the food system to protect the food security of vulnerable households and groups?
Generate innovative ideas to transform food systems	How can innovations in food production provide sustainable alternatives to food access?
	Food Utilization dimension
Food security and gender equity/ Links between gender and food security/ Women's empowerment as a tool against hunger	How do gender differences, nutritional information levels, skills, and education of individuals and households affect the availability and use of food diversity? How should we pay attention to the various features of global food governance and strive for gender equality in this area? What are the empowerment mechanisms for food system participants, especially low-income groups, women, migrant workers, displaced people, refugees, and other vulnerable people and communities to access a variety of nutritious and safe foods?

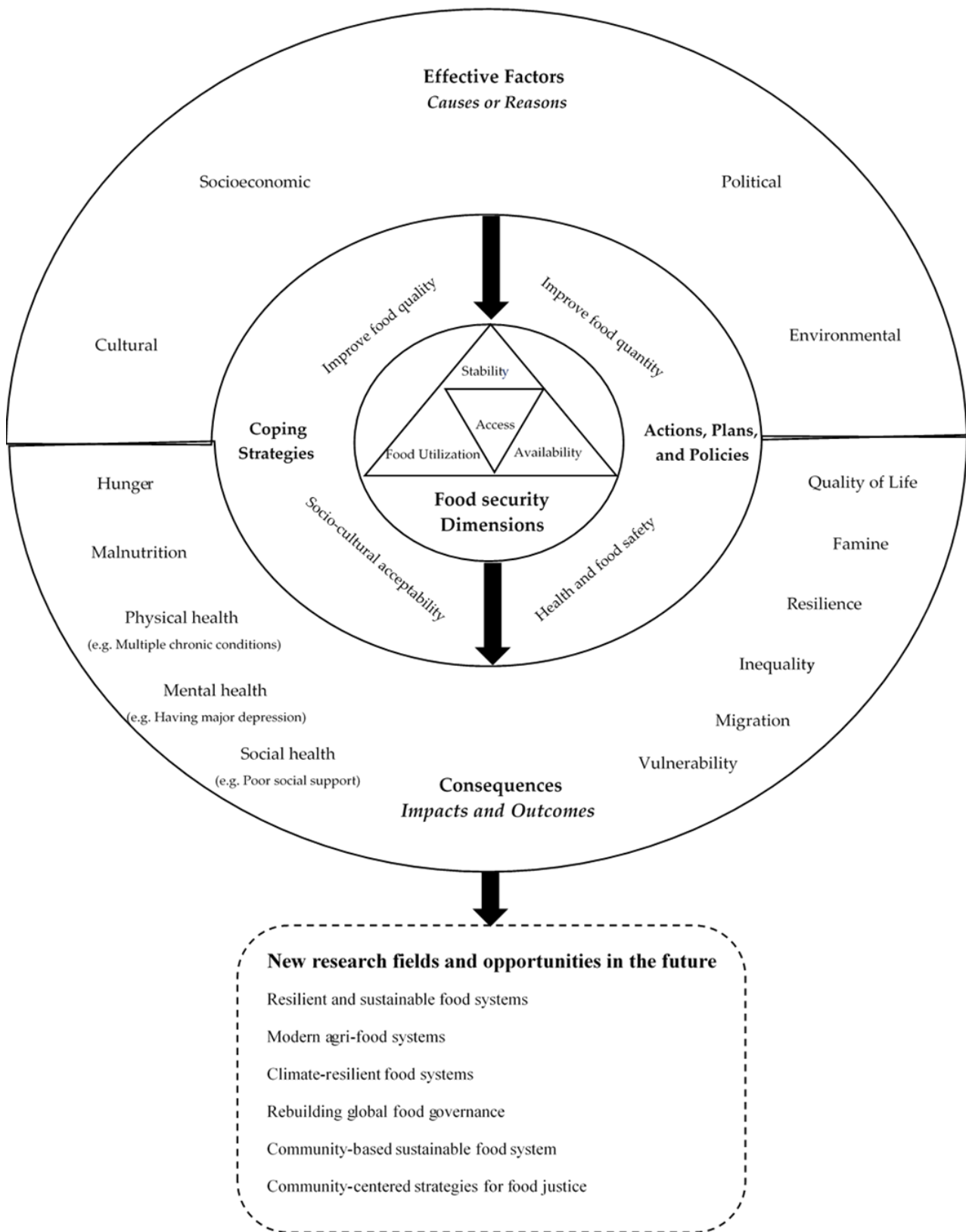
Table 4. Cont.

Research Topic	Potential Research Questions
food safety and quality	What are the real potentials, risks, and impacts of new plant breeding technologies, including genetically modified and gene-edited crops, for food security? What is the role of biotechnology and new plant breeding technologies for sustainable agricultural development and food security in the world? How do changes in food production, processing, import, and export affect food safety and quality?
Determinants of food choice for a healthy and sustainable diet	How does the local food system affect food diversity? What are the long-term effects of the COVID-19 pandemic on the eating habits, diet, and nutrition of households?
Behavior change for the adoption of a healthy and sustainable diet	What is the relationship between food cultural models (such as the manner of food preparation, food sharing, and dietary patterns) and food security in different regions?
Sovereignty, and food policy	What is the role of governments, various national and international actors, as well as public and private actors in the global food system and fulfilling the right to food? What are the challenges and opportunities facing good governance of food security?
Sustainability dimension	
Sustainable food security requirements for a new era/ Long-term global food security	How can a dynamic global network of producers, processors, and markets represent a sustainable food system? What are the governance tools for sustainable food system management? What is the impact of various crises such as climate change, epidemics, wars, and regional conflicts on increasing demand, supply chain disruptions, and the rapid and widespread rise in food prices?
Resilience against future environmental and economic shocks/ Resilient and sustainable food systems	How do biological, social, economic, and environmental changes affect supply safety, sustainability, and stability of the production system and food supply chains? What are the effective mechanisms for improving food security given the socio-ecological nuances found in particular places?

## 6. Conclusions

This study aims to identify the structure of food security and opportunities to advance this field of study. Our research uses a bibliometric method to analyze the research themes within this area. The number of annual records shows an increasing trend during this era. The first study on food security was published in 1974. After 2015, the number of published papers increased dramatically. The intellectual structure of food security research and analysis of highly cited articles are presented in the future model (Figure 8). In this model, not only are the orientation and approach of previous food security studies examined but the future research agenda is also summarized. The starting point and the intellectual structure of the studies have been shaped by addressing theoretical issues. The main dimensions of the model include effective factors, coping strategies, and consequences of food security. Recognizing the factors that directly and indirectly affect food security will enable future researchers to focus on and study important topics. One of the important indicators of sustainable development is eliminating hunger and ensuring sustainable food security. International organizations such as the UN, FAO, IFAD, UNICEF, WFP, and the WHO have various programs and measures to achieve this goal. Studies in this field have provided practical strategies by focusing on each period and geographical area's specific conditions and requirements. These studies can be classified into four dimensions: food quantity and quality improvement, food safety, and socio-cultural and environmental acceptance. Considering that future agricultural practices will have a significant impact on the global ecosystem, the development of sustainable agriculture and biodiversity as one of the solutions to provide adequate, safe, and sustainable food has been emphasized. The

consequences of food insecurity, including hunger, malnutrition, and its direct or indirect effects on health and quality of life, have always been considered.



**Figure 8.** The future model for the food security concept.

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