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Exploring food security as a multidimensional topic: twenty years of scientific publications and recent developments
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Exploring food security as a multidimensional topic: twenty years of scientific publications and recent developments

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Abstract

The scientific literature dealing with food security is vast and fragmented, making it difficult to understand the state of the art and potential development of scientific research on a central theme within sustainable development.

The current article, starting from some milestone publications during the 1980s and 1990s about food poverty and good nutrition programmes, sets out the quantitative and qualitative aspects of a vast scientific production that could generate future food security research. It offers an overview of the topics that characterize the theoretical and empirical dimensions of food security, maps the state of the art, and highlights trends in publications' ascending and descending themes. To this end the paper applies quantitative/qualitative methods to analyse more than 20,000 scientific articles published in Scopus between 2000 and 2020.

Evidence suggests the need to find more robust links between micro studies on food safety and nutrition poverty and macro changes in food security, such as the impact of climate change on agricultural production and global food crises. However, the potential inherent in the extensive and multidisciplinary research on food safety encounters limitations, particularly the difficulty of theoretically and empirically connecting the global and regional dimensions of change (crisis) with meso (policy) and micro (individual behaviour) dimensions.

Keywords: food security, food policy, text mining, food poverty, food access, literature review

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Abstract

The scientific literature dealing with food security is vast and fragmented, making it difficult to understand how the term is used and the potential development of scientific research on a central theme within sustainable development. The current article provides a comprehensive literature review. It sets out a vast scientific production's quantitative and qualitative aspects, analysing a corpus of more than 20,000 abstracts published between 2000 and 2020. It investigates the topics that characterize the theoretical and empirical dimensions of food security, maps state of the art, and highlights trends in publications' ascending and descending themes. Findings confirm heterogeneity in the way the concept is used and highlight six main thematic clusters. However, the potential inherent in the extensive and multidisciplinary research on food safety encounters limitations, particularly the difficulty of theoretically and empirically connecting more robustly the global and regional dimensions of change (crisis) with meso (public policies) and micro (individual behaviour) dimensions.

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1. Introduction

Food insecurity is a timely and multidimensional problem positioned at the crossroads between the right to food and health in both developing and rich, industrialized countries. However, it is unclear how scientific production reflects this multidimensionality overall and whether the recent COVID-19 pandemic has shed new light on the issues at stake. The analysis presented in this article aims to give a systematic review and meta-analysis of the vast amount of scientific food security research produced over the past twenty years. This work aims to offer an overview of the topics that characterize the theoretical and empirical dimensions of food security, map the state of the art, and highlight trends in scientific publications' ascending and descending themes. A systematic literature review sets out quantitative and qualitative aspects which could generate future food security research.

Since the 1960s, with the approval of precursor USA federal anti-poverty programmes (Esobi et al. 2021; Nestle 2019; Swann 2017), interest in preventing the adverse effects of poverty has broadened and deepened scientific interest in the field of food security. Since then, various food insecurity framings, reflecting differences in meaning and problem formulation and coming from different territorial and disciplinary perspectives, have highlighted the contested relationship between social, economic, and environmental circumstances to food access and nutrition experiences (Dowler and O'Connor 2012). In the 1960s, the creation of the World Food Program (WFP) was a prominent example of the institutionalization of the 'food for development' framework. The food crisis of 1972/74 marked a turning point in food security insurance schemes and led to better coordination between donor countries. In the 1980s and 1990s, food security was broadened to include physical and economic access to food and to consider the role of women in poverty alleviation. Therefore, what has come to be termed food security and nutrition security has been controversial, reflecting multiple, not always coordinated, governmental policies, as well as multifaceted theoretical and research fields.

The most commonly used definition of food security is that developed during the 1996 World Food Summit organised by the Food and Agriculture Organization (FAO) (Mechlem 2004). It resembles the definition of the right to food (Maxwell and Smith 1992; Smith, Pointing, and Maxwell 1993). Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 2003). Food security has become a priority focus for donor states and cooperation with developing countries to reduce poverty and systemic environmental, economic, and social causes of

hunger. It has five conceptual dimensions: nutritional status, utilization, accessibility, availability, and stability (Gross et al. 2000). Differently from food security, nutrition security refers only to the individual's (mal)nutritional status due to diet regime, food intake, and health status (Gross et al. 2000).

Academic research developed many approaches to food insecurity during the 1980s and 1990s. Of these, the right-to-food-based approach to food security suggested that human dignity, rights acknowledgment, transparency, government accountability, citizens' empowerment, food, and wellbeing should be considered in welfare programmes. The right-to-food approach required governments to adopt specific programmes and meet precise obligations to combat poverty (Maxwell 1996). The right to food was not regarded as merely a means to achieve food security; rather, it was seen as a broader, more encompassing, and distinct objective. The seminal works of Amartya Sen on poverty during the 1980s (Sen 1980, 1981, 1982) raised controversy over nutritional norms and intensified the debate on interrelations between food access and poverty reduction interventions. Food security is seen as an integral part of social security, understood as the "prevention by social means, of very low standard of living irrespectively of whether these are the results of chronic deprivation or temporary adversity" (Burgess and Stern 199:4). We should point out that this debate regarded not only achieving food security in the poorest developing countries but also in the richest developed ones, where obesity and malnutrition among low-income people had been increasing. The multifaceted nature of food security is entrenched in its measurement complexity (in terms of life expectancy or income). To understand the causes of deprivation and fragility associated w1992ith the lives of increasing portions of the population, food security scholars have striven to assess the validity of tools measuring food safety/insecurity and provide valid indications and suggestions to policymakers.

In the 2000 Plan for Action in regard to food and diet in Europe, the World Health Organization (WHO) argued that nutrition security in the 21st century depends on production that meets dietary needs and enables equal access to appropriate food, while controlling misleading promotional messages (Carlson, Andrews, and Bickel 1999). In this vein, food prices, policies, and education can significantly reduce malnutrition risks (Wekerle 2004).

Even though rising poverty and hunger levels have been a concern for many countries, acknowledgment and quantification of hunger has been disputed and hindered by the lack of an accepted definition and measure of food security. Before food security can be measured, the potential target of the intervention must be identified.

The first food security measure based on household experience at the individual level was developed in 1990 by Radimer and colleagues (1992) and based on a 12-item questionnaire. The 'hunger index' was developed through qualitative interviews with women from low-income households (Kendall, Olson, and Frongillo 1995). Since 1992, the literature has indicated that food security measurements may vary in their performance across different population groups and cultures and, moreover, that good practice and policy instruments are difficult to transfer across different contexts (Kendall, Olson, and Frongillo 1995; Leyna et al. 2008; Radimer and Radimer 2002; Zerafati Shoae et al. 2007). One of the main problems in rolling out food security interventions is that it is not easy to identify the target (households below the poverty line) (Carlson, Andrews, and Bickel 1999). Although such identification usually lacks accuracy, generalised subsidies (food stamps) – on commodities consumed by both the rich and the poor – have often been an attractive option for policymakers (Besley and Kanbur 1988).

The more recent Food Insecurity Experience Scale (FIES), developed by the Food and Agriculture Organization (FAO), focuses on food consumption experience, life conditions, and individual contexts (Cafiero, Viviani, and Nord 2018). It consists of eight dimensions regarding people's access to adequate food, and it is based on various kinds of population surveys. Its global reference scale is based on results from the application of the FIES survey module in countries covered by the Gallup World Poll in 2014, 2015, and 2016. Food insecurity prevalence rates allowed comparison between different countries, and the FIES is designed to measure unobservable traits such as aptitude/intelligence, personality, and a broad range of social psychology- and health-related conditions (Cafiero, Viviani, and Nord 2018).

The food security issue has gained greater cross-cutting relevance in academic and policy circles in connection to public health issues related to the economic and social crises raised by the Covid-19 pandemic (Ahn and Norwood 2020; Arouna et al. 2020; Béné 2020; Cable et al. 2021; Mishra and Rampal 2020; Moseley and Battersby 2020; O'Hara and Toussaint 2021). Economic and social stresses generated by the pandemic led to the formulation of renewed public interventions in response to food insecurity in developing and rich countries.

The literature review presented in the following sections aims to fill a gap in our knowledge of the vast amount of scientific food security research which has been produced, its theoretical and research dimensions, and trends in the last twenty years. Furthermore, the fully electronic search carried out intends to illustrate the main lines of scientific interest within the topic and indicate the most transversal issues and promising areas of scientific interaction. This article is organized as follows. Section 2 illustrates the research questions and methods adopted to build the datasets that comprise

articles addressing food security. Section 3 describes the Reinert method and topic detection applied to the dataset and the evolution of the strand of literature regarding food security over time. Section 4 delves into how the literature on food security connects to a policy approach and variable dimensions of public intervention. Finally, Section 5 discusses the main findings and limits of the meta-analysis and evaluates the contribution of the food security literature to unlocking the future research potential of transboundary policies and governance.

2. Research questions and methods

This article aims to answer the three following main research questions: in a systematic literature review, what are the main thematic dimensions linked to the issue of food security? How do these dimensions evolve, and how do they relate to each other? And, finally, does the literature highlight new dimensions of the problem concerning the Covid-19 pandemic?

To achieve its scope, this article develops a topic detection analysis of the articles on food security using Reinert's method (Reinert 1990, 2001) to identify thematic clusters in the literature and analyse their evolution over time(Sbalchiero 2018). This methodology uses a mixed-method approach which combines a quantitative semi-automatic textual analysis of the literature with a more in-depth qualitative analysis of the thematic dimensions (Giordan, Saint-Blancat, and Sbalchiero 2018; Tiozzo et al. 2019). Automatic and semi-automatic textual analyses have been increasingly used by researchers to study large bodies of text and data made available by the internet(Sbalchiero and Eder 2020). The constant improvement of the technologies and software that perform such analyses makes computer-assisted textual analysis an evolving trend in the literature. However, while its application to the analysis of social media and political documents is growing, it remains marginal in literature reviews. Still, automatic and semi-automatic analyses allow researchers to overcome the biases which can be involved in literature reviews when the selection and analysis of articles are performed by the authors. In many cases, the selection criteria for the articles are not clearly specified, so there is a risk that important studies will be left out and a self-reinforcing mechanism will be perpetuated around a limited number of articles. Conversely, automatic and semi-automatic analysis considers the whole body of literature, thus allowing researchers to explore the variety of theoretical framework and methodologies that unravel undetected patterns.

Following research domain analysis (RDA), which enables the study of the entirety of publications in a given research domain (Janssen 2007; Janssen et al. 2006; Janssen and Ostrom 2006), we describe multiple strands of literature, in particular interdisciplinary and inter-sectoral ones, to highlight dimensions and research agendas linked to the food security theme.

To construct the database of the articles, we decided to use the Scopus database because of the multidisciplinarity of the food security literature and the exploratory nature of the analysis. The Scopus database comprises a comprehensive collection of publications from multiple disciplines, making it a suitable choice for the analysis. Moreover, it was preferred to Web of Science (WoS) because it does not include grey literature (position papers and institutional documents) and books.

We conducted the database search using "food security" as a search term to identify the literature that specifically deals with this issue. To select the most comprehensive keywords, we proceeded by compiling a list of words and concepts related to food security, such as food security, food insecurity, food aid, food poverty, food safety, nutrition quality, nutrition security, and food stamps. We then performed multiple searches on the Scopus database using different combinations of words and Boolean operators. "Food security" (in quotation marks) was the combination of words that returned by far the highest number of articles. Hence, we could confidently assume that this concept is the most comprehensive and that it contains other relevant frames, such as food poverty, nutrition poverty, and, to a lesser extent, food safety.

Due to the wide consistency of the database and the marked increase in number of articles per year, we decided to focus on literature published during the last two decades, thus analysing the articles produced between 2000 and 2020. We decided to analyse separately the literature published between January and July 2021 (the current year) to avoid a misinterpretation of the results. The analysis of the 2021 literature is relevant for the scope of this study to identify a variation in themes and focuses after the Covid-19 pandemic.

A first search using the selected keywords returned 34,931 documents. To narrow the analysis, we decided to focus the search on peer-reviewed articles written in English, as they constitute the core of the international literature. In addition, we cleaned the resulting database by removing articles with no abstract and duplicates. In order to select which duplicate would be kept in the database, we respected the following criteria: the most recent, the longest abstract, and correct formatting. The final database contained 21,574 articles. For a first basic analysis of the database, we used the automatic analyses provided by Scopus and complemented them with analyses made through Microsoft Excel. The aim was to list the academic journals, countries, and scientific areas within which the articles were published.

The second step of the analysis aimed to identify the thematic dimensions covered in the food security literature. To achieve this aim, we performed topic detection on the articles' abstracts, using automatic content analysis. The latter process allowed us to identify the main topics and themes without any prior knowledge of the literature analysed; thus, we were guided only by the results to understand how the literature had developed. To conduct the topic detection, we used Reinert's (1983) method, implemented with Iramuteq software (Ratinaud 2014; Ratinaud and Marchand 2012, 2015).

Reinert's (1983) method was developed to deal with large quantities of text and to "analyse the co-occurrences of words as they appear in portions of text, and thereby identify lexical worlds, or semantic classes" (Sbalchiero 2018, p. 202). The algorithm constructs a contingency matrix of words per abstract based on the co-occurrences of words in each abstract. It then uses a clustering procedure that hierarchically identifies the "factors (clusters) that best represent a lexical world from the distance of the $\chi2$ between the classes" (Sbalchiero 2018, p. 203). Co-occurrences of words are analysed in such a way as to understand their relationships in the contexts of scientific discourse and to construct vocabularies of co-occurring words that are specific to each semantic class. Through this analysis, we were able to identify the different thematic dimensions discussed in the literature and the topics covered, as well as the relationships among different clusters. This analysis allowed us to answer the first research question.

In a subsequent step, we used the results of the analysis to measure the grade of association between the topics and the modalities of other variables, such as the publication year. A positive difference, and a threshold of significance set at $\chi2$, indicated that a topic had received greater attention in a particular year. Hence, by looking at the grade of association between year and clusters, we were able to determine the evolution of the topics over time and, thus, answer the second research question.

To strengthen these analyses, we also studied the keywords authors had listed in the articles. The analysis of the keywords was useful in identifying the most studied issues related to food security, as well as geographic focuses.

Finally, we analysed the articles published in Scopus between January 2021 and July 11th, 2021 (the last search conducted). The search found 3,672 documents, which were filtered to obtain only articles written in English and cleaned to eliminate duplicates and articles with no abstract. After the selection, the 2021 database consisted of 2,533 articles. We studied the automatic analyses performed by Scopus, and we conducted further analyses with Microsoft Excel. Moreover, we implemented topic detection with Iramuteq software to identify differences in the thematic clusters. The application of Reinert's (1983) method did not result in a statistically significant analysis, as the percentage of text segments retained (69.16%) was lower than the minimum retention indicated by the literature (70–

75%). Still, it was possible to use the analysis to identify new topics and trends in the literature on food security after the Covid-19 pandemic. The analysis of the keywords complemented this analysis and allowed us to answer the third research question.

Due to the high number of articles included in the dataset, this review did not aim to investigate the specific content of articles. Rather, its aim was to identify the main trends in the literature and the topics that constitute the core of the theoretical and methodological debate around food security.

3. Publications over time and across scientific areas

The present section describes some characteristics of the dataset analysed, namely the corpus dimension, science areas, and journals most interested in food security, as well as how food security articles published between 2000 and 2020 developed over time.

Table 1 – Publications, Science Area, and countries (2000–2020)

Search term	No. of Articles	No. of Journals	Science Area	%	Countries	No. of Articles
"Food security"	21,574	3,817	*Agricultural and Biological Sciences*	21.7	USA	6363
			Social Sciences	17.5	UK	2505
			Environmental Science	16.6	CHINA	2327
			Medicine and Health	8.1	AU	1550
			Economics	5,1	INDIA	461

Table compiled by authors

Table 1 shows a first analysis of the database on food security. Between 2000 and 2020, 21,574 articles were published in English in 3,817 different journals. The high number of both articles and journals is representative of the attention that this topic has received over the last two decades and the multiple angles adopted for its analysis. The multidisciplinary of the literature is also evident in the distribution among different scientific areas. Agricultural and biological science (ABS) is the most prominent subject area, closely followed by social sciences (SS) and environmental science (ES). An important percentage of articles also deals with medicine and health (MH) and economics (E). Therefore, we can affirm that the issue of food security cuts across disciplinary boundaries. Authors have analysed the issue from a variety of theoretical and methodological perspectives.

It is also worth noting that geographically, the publications are mainly concentrated in the Anglo-Saxon countries, with U.S. academia producing almost 30% of the literature. Other than the obvious issue of the English language, the strong preponderance of articles published by British and U.S. universities can be linked to the long tradition of these countries in food security and food assistance programmes and evaluation. The automatic analyses performed by the Scopus website allowed us to identify the most relevant scientific areas explored in each country. Both the USA and UK distribute their production rather evenly among different scientific areas (USA: 18.3% ABS, 17.7 % SS, 14.9% ES, 13.3% MH; UK: 21.4% ABS, 18.9% ES, 18.5% SS).

China represents an exception to the English-speaking countries, being the third most prolific producer. China has seen a rapid increase in articles published since 2009, with more than half of the studies focusing on ES and ABS. This timing in Chinese scientific production may be due both to the first major food security policy document released by the Chinese central government in 2004 to combat food poverty (Ghose 2014) and the effects of the global food crisis after the global increase

of food prices in 2007. The instability was due to smaller amounts of food being available for human consumption because farmers devoted more of their crops to biofuel production in the USA and Europe (Bohstedt 2016).

As shown in Figure 1, the number of articles published every year has strongly and steadily increased since the beginning of the century, with rapid growth in the last decade. The number of publications grew from 156 in 2000 to 658 in 2010 to over 3,500 in 2020. The growth index represented in Figure 2 (calculated as [(PresentValue – Past Value)/PastValue] *100) shows more clearly a strong increase in 2006 (global food crisis) and two peaks in 2013 (effects of the second financial crisis) and 2020 (Covid-19 crisis). These figures show how the food security issue has been gaining in importance in the literature over time, a trend that is also confirmed by the number of articles published in 2021. In addition, they confirm the strong link between economic and social crises and food security. These crises increase food insecurity, thus sparking new debates and studies on the issue of food security.

Figure 1 – Articles on food security published per year (2000–2020)
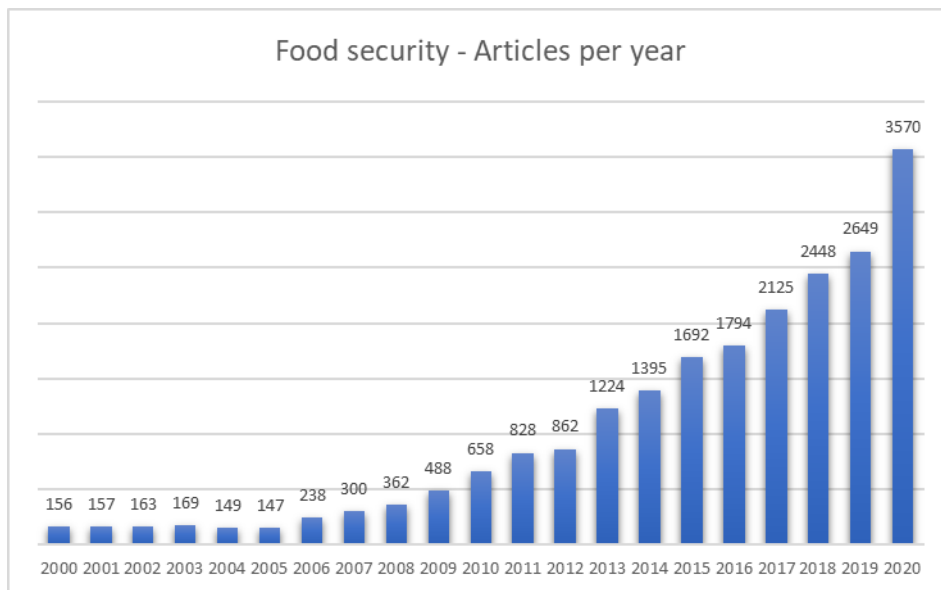
Figure compiled by authors

Figure 2 – Yearly growth index of articles on food security (2000–2020)
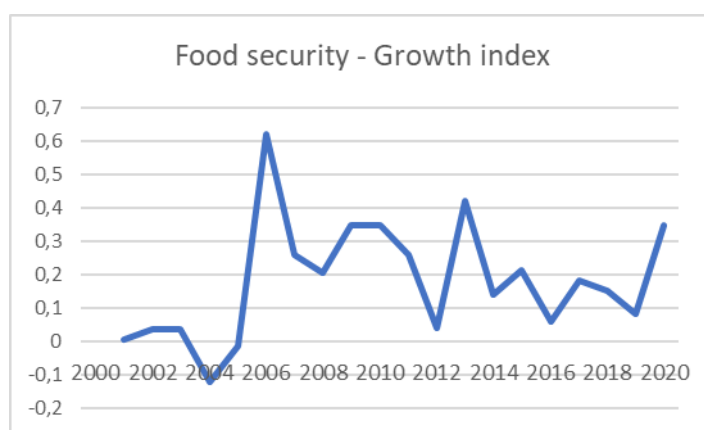
Figure compiled by authors

Table 2 – Distribution of articles on food security (2000–2020) per journal and scientific area

Journal	Scientific area	% Articles per journal
Sustainability	Interdisciplinary (Social Sciences, Environmental Science)	2.25
Food Security	Interdisciplinary (Social Sciences, Agricultural and Biological Science)	2.25
PLoS ONE	Interdisciplinary (Science, Medicine and Health, Social Sciences)	1.31
Food Policy	Interdisciplinary (Social Sciences, Environmental Science, Agricultural and Biological Science)	1.27
Journal of Hunger and Environmental Nutrition	Medicine and Health, Social Sciences (Health)	0.99
Science of the Total Environment	Environmental Science	0.82
Public Health Nutrition	Medicine and Health	0.80
Land Use Policy	Interdisciplinary (Social Sciences, Environmental Science, Agricultural and Biological Science)	0.77
International Journal of Environmental Research and Public Health	Medicine and Health, Environmental Science	0.70
Remote Sensing	Science and Technology	0.70

Table compiled by authors

As observed in Chapter 2, the issue of food security has been treated in a high number of different journals and from a wide variety of perspectives. The plurality of approaches to the problem is also evident in the ranking of the journals that have published the most articles. As we can see in Table 2, the ten most active journals publish literature which is either interdisciplinary or pertaining to different scientific areas. It is interesting to observe that the first journal is *Sustainability*. This reflects the strong link between the issue of food security and sustainability, in particular with regard to the environmental and social aspects of the latter. In addition, food security has a dedicated journal, thus confirming once again its importance in the academic world.

4. Food security thematic dimensions

After mapping publications on food security, we can observe the empirical data that allow us to answer the first research question:

RQ1: What are the main thematic dimensions linked to the theme of food security?

A first attempt to identify the most recurrent issues analysed by the food security literature can be made by looking at the keywords proposed by the authors, which outline the focus of the articles. As we can see from Table 3, the focus proposed by the keywords is rather composite. The presence of climate change as the second most frequently used keyword is significant of the importance that adaptation (n. 13), resilience to climate change (n. 15), and the sustainability (n. 6) of food systems play in the academic discourse. Food production, represented by words such as agriculture (n. 4), rice (n. 11), and maize (n. 16), is also an important element of food security. It is also important to note the countries that appear as keywords and, thus, represent the main geographical focuses of the literature. The African continent is represented by three keywords: Africa (n. 8), sub-Saharan Africa (n. 12), and Ethiopia (n. 14). The strong presence of Africa in the literature can be linked to both the problem of food security in the continent and the FAO's strong focus on the region. It is also interesting to observe that China (n .9) is the first country to appear as a keyword. This finding is in line with the fact that China is among the most prolific publishers and among the most studied countries, alongside Africa and India.

Table 3 – Most frequent authors' keywords in articles on food security (2000–2020)

	Keywords	Frequency
1	*food_security*	6017
2	*climate_change*	1194
3	*food_insecurity*	1047
4	*agriculture*	840
5	*nutrition*	489
6	*sustainability*	460
7	*poverty*	428
8	*Africa*	334
9	*China*	324
10	*livelihood*	269
11	*rice*	266
12	*sub_Saharan_Africa*	254
13	*adaptation*	252
14	*Ethiopia*	250
15	*resilience*	233
16	*maize*	233
17	*India*	230
18	*gender*	227
19	*drought*	225

Table compiled by authors

After a first analysis of the most discussed topics in the literature, we proceed to the analysis of the thematic clusters discussed in the literature. The application of Reinert's (1983) method to the corpus of food security articles resulted in a division into six thematic clusters that represent six different focuses of the literature. As shown in Figure 3, the division into clusters follows a hierarchical procedure which divides the texts based on their semantic classes, until the homogeneity of the texts makes a further division impossible. Hence, we can observe three major subdivisions: a first isolated cluster (1), a second macro-cluster (2 and 3), and a third macro-cluster (4, 5, and 6).

Figure 3 – Descending hierarchy of thematic clusters in the food security literature (2000–2020)
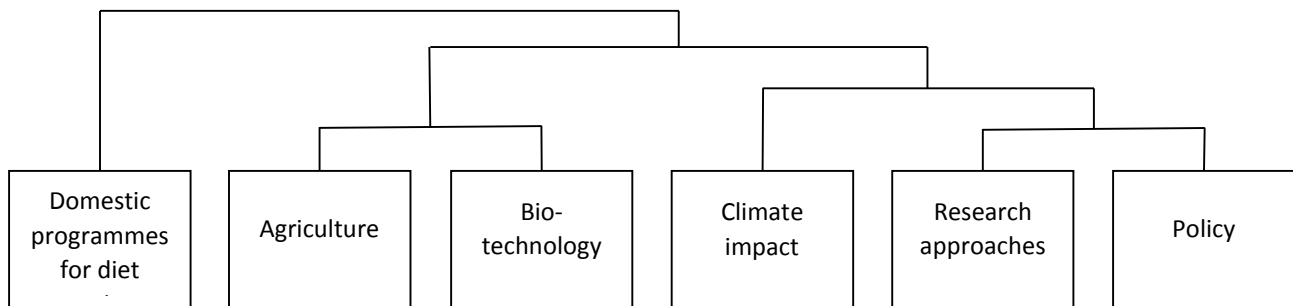
Figure compiled by authors

Table 4 shows the percentage of texts that belong to each cluster and the words that best characterize it. The titles were assigned to each cluster by the authors based on the analysis of the content, to simplify their identification.

Table 3 – Title, percentage and characterizing words of the thematic clusters describing the food security literature (2000–2020)

Cluster n.	Title	% of texts	Characterizing words
Cluster 1	Domestic programmes for diet quality	19.5%	Interview, Survey, Questionnaire, Household food security, Obesity, Low income
Cluster 4	Climate impact	18.1%	Food security, Agriculture, Food production, Climate change, Energy
Cluster 6	Policy	17.92%	Strategy, Adaptation, Promote, Tool, Implementation, Capacity, Participatory
Cluster 2	Agriculture	16.38%	Yield, Temperature, Season, Crop, Rice, Rainfall
Cluster 5	Research approaches	15.64%	Concept, Political, Governance, Debate, Food system, Justice, Case studies
Cluster 3	Biotechnology	12.45%	Gene, Plant, Resistance, Tolerance, Stress, Pathogen, Breed

Table compiled by authors

Below is a short description of the content of each cluster and its perspective on food security:

- Cluster 1: "Domestic programmes for diet quality" is the biggest thematic cluster in the literature. Moreover, as shown in Figure 3, this cluster stands as a separate stream of the literature. It deals with food security programmes and diet quality, linking food security to household food security. It focuses on programmes designed to secure a good dietary intake, with a specific focus on *low-income[1]* families, gender (*woman, female)*, and *schools*. The American Supplemental Nutrition Assistance Program (SNAP) receives considerable attention within this cluster, as one of the oldest and broadest national food security programmes. Hence, food security is analysed in its dimension related to nutritional quality (*nutritional status, dietary diversity),* observing the impact of different factors (*income, education, age)* on food insecurity at the individual level. The measurement of food insecurity is central in this cluster, as highlighted by words such as *survey, score, questionnaire,* and *interview*. Through these methods, the literature aims to measure the impact of food security programmes in contrasting food insecurity and improving the nutritional status of the participants. Due to its size and its separateness from the rest of the literature, we analyse this cluster in greater depth in the next section.

- Cluster 2: "Agriculture" focuses specifically on agricultural production, investigating the influence of different factors on food production. Specifically, it observes the impact of climatic events (*temperature, season, rainfall*) and agricultural practices (*fertilizers, manure, experiment)* on *yield* productivity of different *crops (maize, wheat, rice, grains).* The approach

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[1] The words that belong to the cluster are written in italics.

to food security in this cluster is purely scientific, and it aims to increase and improve food production to guarantee access to food.

- Cluster 3: "Bio-technology" is closely related to Cluster 4, as it deals with the *genetic* and biological aspects of food and its production. The analysis focuses on the genetic modification of *plants* and *species* to improve their *resistance* and *tolerance* to *pathogens* and external *stress*. The approach is purely scientific, and it focuses on improving the resistance of food production to the impact of climate change.

- Cluster 4: "Climate impact" relates to a dimension of *global demand* for *food production*, mostly related to the impact of *climate change* and *population growth. Agricultural production* is essential for ensuring food security and global access to food. However, it is facing challenges on two fronts. On the one hand, it needs to deal with the impact of climate change and how it *threatens productivity, biodiversity*, and *water* resources. On the other, it is challenged by changes in *land use,* both under the *pressure* of *urbanization* and in relation to land conversion for producing *energy,* in the form of *biofuel.* Thus, this cluster investigates a global dimension of food security, analysing the challenges posed to food access by climate change and simultaneous growth in demand for food production and bioenergy.

- Cluster 5: "Research approaches" is a rather composite cluster which includes the different *frameworks* and *perspectives* adopted by the food security literature. The approaches and methodologies are very diverse, ranging from *political discussions* and *debates (agenda, discourse),* to *social* and *justice* perspectives (*movement, human rights*), to *food systems* and *food sovereignty* (*governance).* It uses both empirical *case studies* and *theoretical* approaches (*theory)* to discuss the *issue* and *concept* of food security. The diversity of approaches reflects the multidisciplinarity of the literature, as previously observed.

- Cluster 6: "Policy" deals with the *strategies* and *policies* that *governments* adopt for food security and *adaptation*. Agricultural policies are central in this cluster, with natural resources and land *management* as essential elements of adaptation strategies and *farmers' support.* The cluster analyses all phases involved in the policy process, examining the definition of an *agenda,* the *decision-making* process, the *planning* of a *strategy*, the identification of *tools*, and the *adoption* phase, which includes the *implementation, strengthening*, and *building* of *capacities. Participatory* practices, as well as *technology* and *innovation*, receive much attention within the cluster. Thus, this cluster focuses on the improvement of food security through the adoption of strategies that mainly aim at strengthening the resilience, productivity, and sustainability of food production.

It is interesting to observe the role that the word "poverty" plays in the food security literature. While it is one of the most used keywords listed by authors, it does not appear as a frequent word in any of the clusters (Cluster 2 is the one in which it first appears, n. 223). An explanation of this difference in importance could be that while poverty is considered a central issue in the food security literature, the articles focus on the causes, effects, and different dimensions of poverty, rather than on poverty itself. Causes and effects are treated in different clusters within the literature. Cluster 2 deals with the impact that climate change has on the increasing number of people falling into poverty globally. Cluster 6 and, to a lesser extent, Cluster 5 deal with its effects through programmes that aim to alleviate food and nutrition poverty.

5. Evolution over time and relation between thematic dimensions

Figure 4 shows the evolution over time of the different thematic clusters. We can see a rather stable trend in the evolution of the clusters.

Figure 4 – Evolution of thematic clusters on food security by year (values are the association of χ2 topics x years)
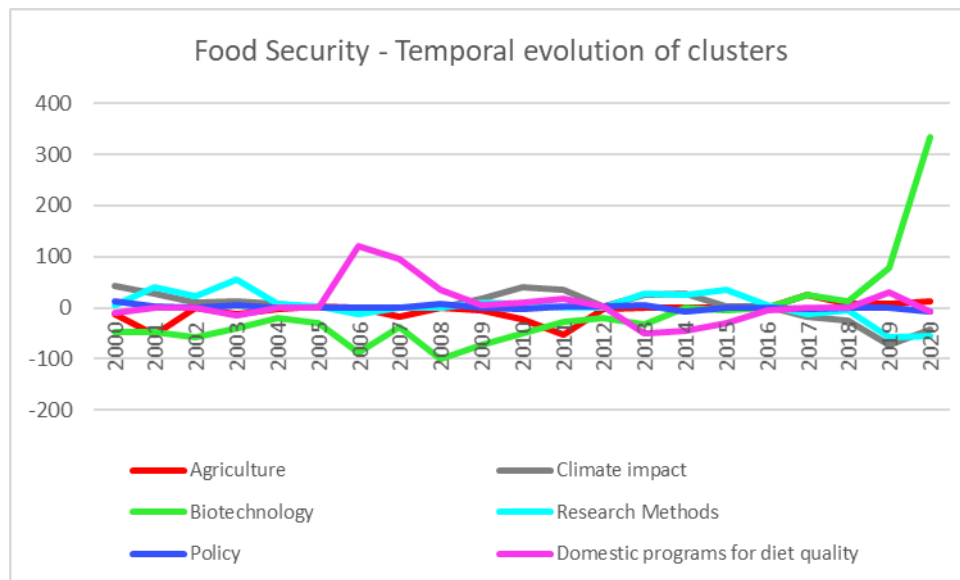
Figure compiled by authors

Still, we can observe how the "biotechnology" cluster has started to receive increased attention in the past five years, with a growing trend. The "domestic programmes for diet quality" cluster saw a spike in attention between 2006 and 2007. As mentioned above, this increase is likely to be linked to the

global food crisis caused by a shift in land use, from food production for human consumption to biomass production for biofuel. The drop in food production caused a spike in the prices and a consequent increase of food insecurity, thus putting programmes to improve food security high on the policy and scholarly agenda.

Therefore, after the analysis of the thematic clusters and their evolution over time, we can answer the second research question:

RQ2: How do these dimensions evolve over time, and how do they relate to each other?

The food security literature has seen a co-existence of multiple topics in the last two decades. The "policy" cluster has had the most stable presence in the literature, while other clusters have seen fluctuating trends. It is worth noting that the "diet quality" cluster received considerable attention in 2006–2007, and that a growing strand of literature focuses on the technological and biological aspect of food production for food security.

Figure 5 – Distance and interconnections between thematic clusters related to food security (2000–2020)
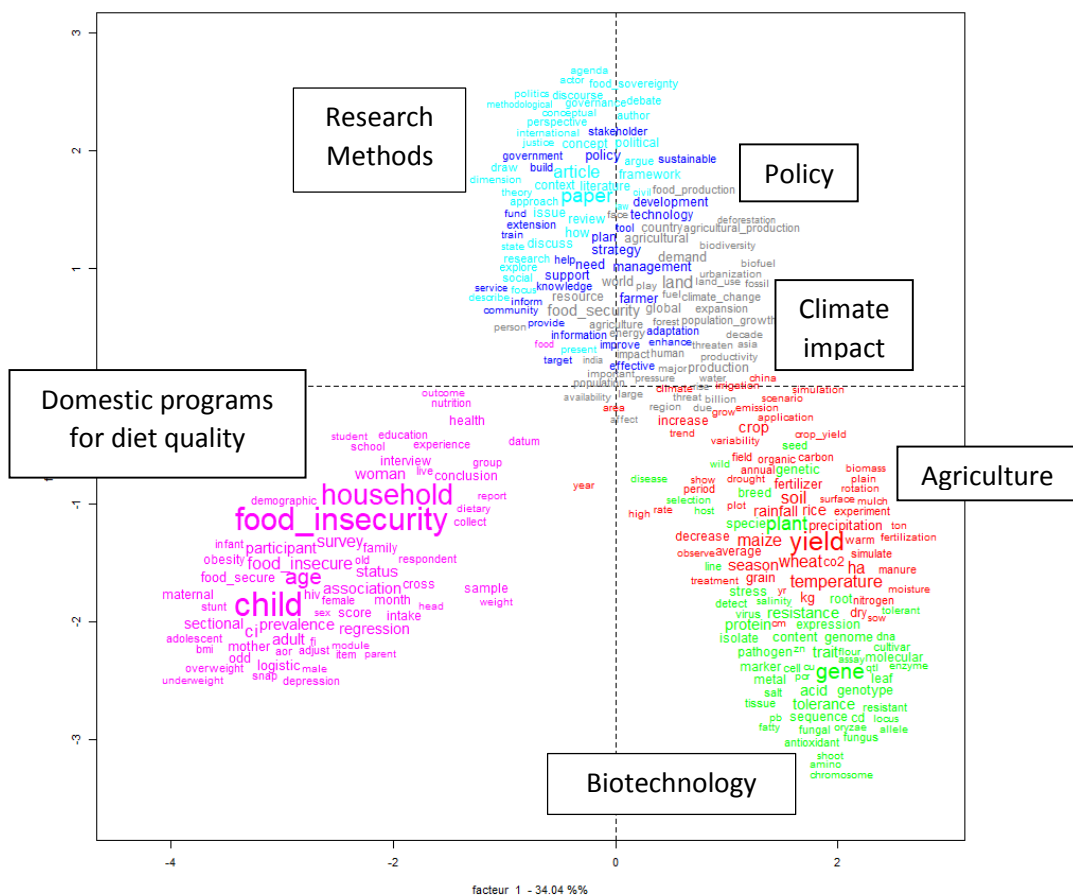
The Cartesian planes (Figure 5) reflect the relationships between different clusters and among the most frequent words belonging to the clusters themselves. Clusters with a higher co-occurrence appear graphically close to each other, while clusters that are graphically distant from each other are treated as separate issues in the literature. Moreover, words that are used most frequently within a cluster appear bigger in the graph.

As already observed in the descending hierarchy of the cluster (Figure 3), the six clusters can be grouped into three macro-clusters. The cluster "diet quality programmes" stands alone, with little integration with the other clusters. The "agriculture" and "biotechnology" clusters form a macro-cluster that deals with food production. The articles pertaining to this macro-cluster focus on the improvement of agricultural production to increase its resistance to the changing climate and guarantee food security in a world with a fast-growing population. The third macro-cluster includes the methodological aspects and combines the thematic dimension with the impact of global warming. The articles in the macro-cluster, then, focus on the policies that have been implemented to face the challenges proposed by climate change, mostly concerning land management and strategies to prevent and adapt to climate change. The second and third macro-clusters show similarities, but while the second one adopts a techno-biological perspective on the issue, the third employs a socioeconomic perspective.

Hence, the thematic dimensions that can be identified in the food security literature comprise a) domestic programmes to tackle food insecurity; b) policies to fight the challenges posed to global food security by climate change; and c) analysis and technological improvements in food production to guarantee global food security.

Domestic programmes for diet quality: an in-depth analysis

It is interesting to observe Cluster 6 in greater depth, as it represents a consistent part of the literature as well as a stand-alone cluster. To better understand its content, we applied Reinert's (1983) method of analysis to its sub-corpus of text segments. The result of the analysis showed a division into five clusters, two dedicated to methodologies and three dedicated to an analytical dimension.

The methodological clusters show a clear division between qualitative methods, which focus on nutrition security (i.e., dietary diversity) at the individual level, and quantitative ones, which deal with

food security (i.e., access to food and poverty) at a more macro level. The qualitative methods, which represent the majority, present a strong link to interviews and participatory approaches, as well as a temporal dimension (name of months), highlighting the fact that attention is given to developing countries and the impact of seasonal cycles on agricultural production. Conversely, the quantitative methods investigate the statistical correlation among different phenomena (e.g., food security and obesity) at the macro, national level.

The analytical clusters can be divided into two different streams in the literature: one with a methodological approach and the other that develops an in-depth analysis of the issue of food security. The first analyses how to measure food security, identifying the best instruments to assess its causes and effects, using a comparative approach. The second stream adopts a policy approach that aims to answer the question of how to intervene from an institutional and strategic perspective. Intervention strategies are defined through the analysis of food security's risk factors, which can be semantically attributed to a health dimension (i.e., obesity, diseases, and mental health), and a behavioural and social dimension (i.e., purchasing habits, income, and education). These two dimensions are discussed together within the literature, showing how they are intrinsically connected in determining food security.

The relevance of the methodological dimension, as well as the attention to risk factors, confirms the importance of developing appropriate tools to measure food security, both in terms of causes and effectiveness, to design more appropriate food security programmes.

New thematic dimensions in the aftermath of Covid-19

The global Covid-19 pandemic has had a consistent impact, not only from a socioeconomic standpoint but also in academic production. Great attention has been paid to the impact of Covid-19 on a global and local scale, alongside an increased focus on issues closely linked to the pandemic. Hence, it is interesting to analyse the 2021 literature on food security to observe whether the crisis has impacted academic production on the issue and new thematic dimensions have emerged.

Thus, we can answer our third research question:

RQ 3: What new dimensions of the issue does the literature highlight in relation to the Covid-19 pandemic?

The analysis of articles published in 2021 provides us with an understanding of the impact that the Covid-19 pandemic has had on the issue of food security and whether it has caused a change in focus in the literature.

As mentioned above, in the first six months of 2021, 2,533 articles discussing food security were published in 977 journals. The saliency of the topic and its multidisciplinarity are also confirmed by the 2021 data. However, while ABS remains the main area of focus (21.9%), we observed increased attention paid to ES (19%) and a decrease in focus on SS (13.8%). This result is in line with the growing trend in the cluster that deals with bio-technological aspects of food security. This trend is also highlighted by the journals that published the highest number of articles on food security in 2021. Four out of five of the most active journals deal with ES (*Sustainability*, *International Journal of Environmental Research and Public Health*, *Science of the Total Environment*, and *Journal of Cleaner Production*). However, it is more likely that these trends are linked to the increased scholarly and public attention paid to climate change. In addition, China has confirmed its importance as a publisher of food security literature.

Covid-19 appears as the fourth most frequent keyword proposed by the authors, after food security, food insecurity, and climate change. This result shows how Covid-19 has become the focus of a large number of articles. Still, climate change remains a stronger concern for academics dealing with food security, as is also highlighted by the subject areas and journals.

Reinert's (1983) method of analysis can better explain the impact of Covid-19 on the literature, showing how the topic is treated in articles and how the clusters have changed in the aftermath of the pandemic. Except for the disappearance of the methodological cluster, the thematic clusters of 2021 present many similarities with those of the period 2000–2020. However, we observe some significant differences in topics within the "policy" and "climate impact" clusters. While the 2000–2020 "policy" cluster focused on support policies for agricultural adaptation to climate change, the 2021 "policy" cluster has a stronger focus on sustainability policies, with governments seeming to have more importance and the social and environmental dimension being more directly debated. The 2000–2020 "climate impact" cluster became broader in 2021, including different global challenges. On the one hand, as expected, we saw attention clearly paid to the Covid-19 pandemic. On the other, we saw a switch in attention from agriculture to fishery, as an important source of food for the global population that is currently under threat due to climate change and unsustainable fishing practices. In addition, a warming planet has disrupted and depleted fisheries worldwide, drawing scientific attention to overfishing as a factor increasing the vulnerability of fisheries.

In terms of relations among the different thematic clusters, we can observe that the "bio-technology" cluster has become more separate from the "agriculture" cluster, while the latter has become more closely linked to the "policy" and "climate impact" clusters. The closer link between food production and the global political dimension may be due to the increased public and political attention paid to

the issue of climate change, as well as the growing impact of drastic climate events on food production.

Moreover, we observed that the "domestic programmes for diet quality" cluster remains an isolated theme in the literature, confirming the silo approach to food insecurity on a domestic scale and the global issue of food production for a growing population and in a warming planet.

6. Discussion and Conclusions

The systematic literature analysis addressed by the current article increases our knowledge of the vast and multidisciplinary food security scientific production, as well as of its theoretical and research dimensions and trends during the last twenty years. Furthermore, it traces the main lines of scientific interest in the topic and indicates the most transversal issues, weaknesses, and opportunities for future development.

In the period considered, we observe how the issue has become increasingly relevant in conjunction with and due to the impact of the economic and financial crises and climate change on the weakest segments of the population, both in developing and rich countries.

The main literature trends highlighted by our research can be summarized as follows:

a) The number of articles published has increased enormously in the last two decades, with peaks in 2006, 2013, and 2020, all linked to the outbreak of financial and social crises and their effects on food systems and market prices. The place of the issue of food security within the literature has grown in importance over time and become sensitive to the increasingly frequent global economic and health crises (Dodds et al. 2020; Galanakis 2020; O'Hara and Toussaint 2021) and the local environmental impact of climate change (Bohle, Downing, and Watts 1994; Lang, Barling, and Caraher 2009).

b) Domestic programmes for diet quality are the most explored dimension of food security and stand as a separate branch of the literature, considerably ahead of the next most discussed macro-dimension of food production, which addresses policies, climate impact, and agriculture.

c) Despite a rather stable trend in the evolution of the main topics detected, we can observe how the "biotechnology" cluster has started to receive increased attention in the past five years.

d) The general scientific attention to the "diet quality" issue was highly concentrated in 2006–2007, along with a growing strand of literature that focused on the technological and biological aspect of food production for food security.

e) The household food security measurement and indicators are the most important scientific topics and, at the same time, completely separate from other arguments addressed by scholars. This separation indicates the difficulty of theoretically and empirically linking the micro nutritional aspects of food security to meso and macro elements, such as government agricultural policy and climatic impact on local diet change. Thus, even though food security is widely recognized as a multidimensional and cross-sectoral issue, academic analyses still seem affected by silo approaches in one of the most important fields of scientific analysis as well as public intervention.

f) The analysis of the articles published in 2021 confirms that ABS remains the central area of focus; increased scholarly and public attention to climate change impact on agriculture production and fishing has emerged in 2021.

Our analysis suggests some conclusive reflections concerning the need to link more solidly micro studies on food safety and nutrition poverty to macro changes such as climate change impact on agricultural production. However, the potential inherent in the extensive and multidisciplinary research on food safety has limitations, particularly the difficulty of connecting theoretically and empirically the global and regional dimensions of change (crisis) with the meso (policy) and micro (individual behaviour) dimensions. Nevertheless, this greater connection can only benefit the action of governments and policies that have long been committed to this front.

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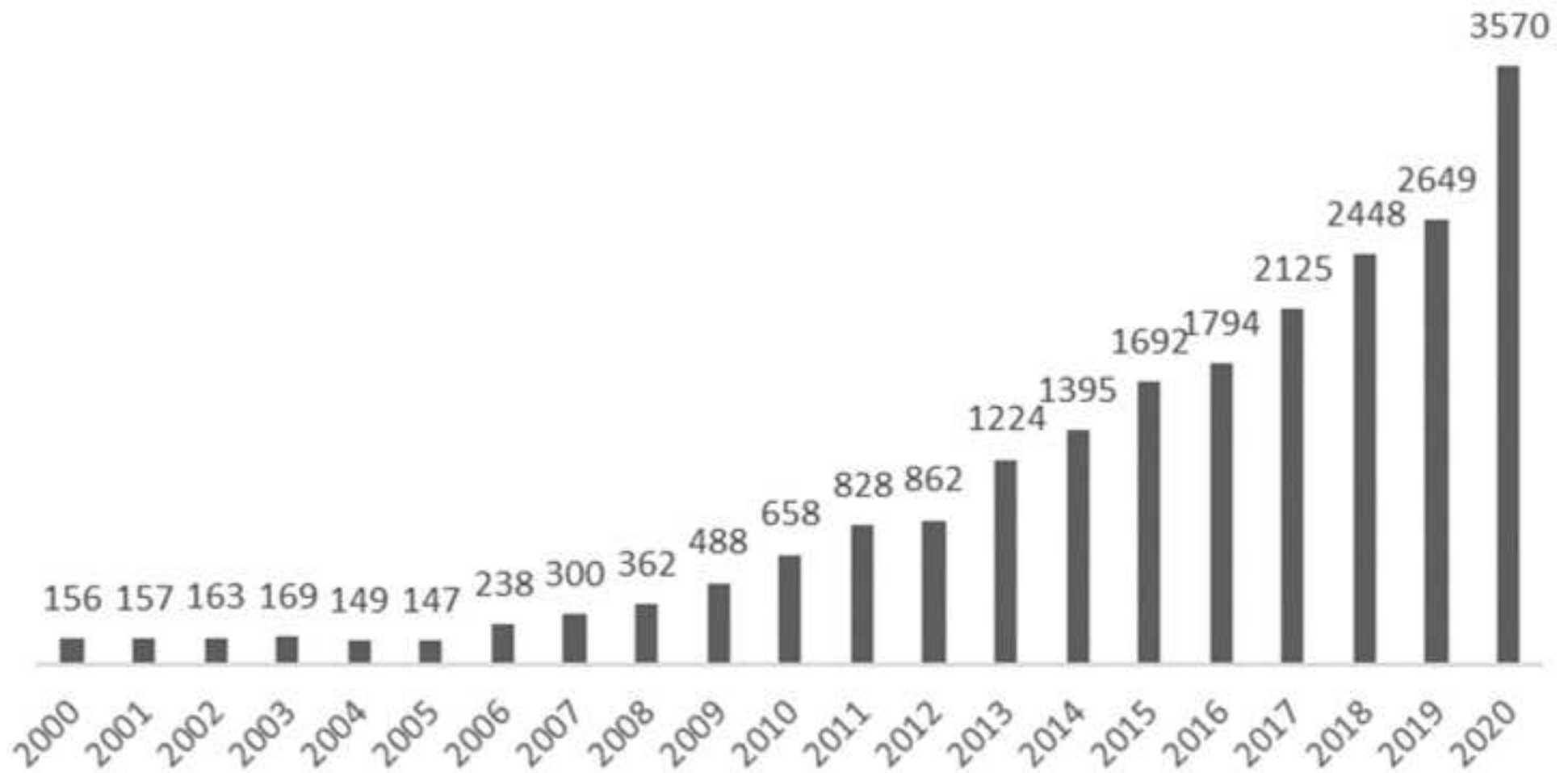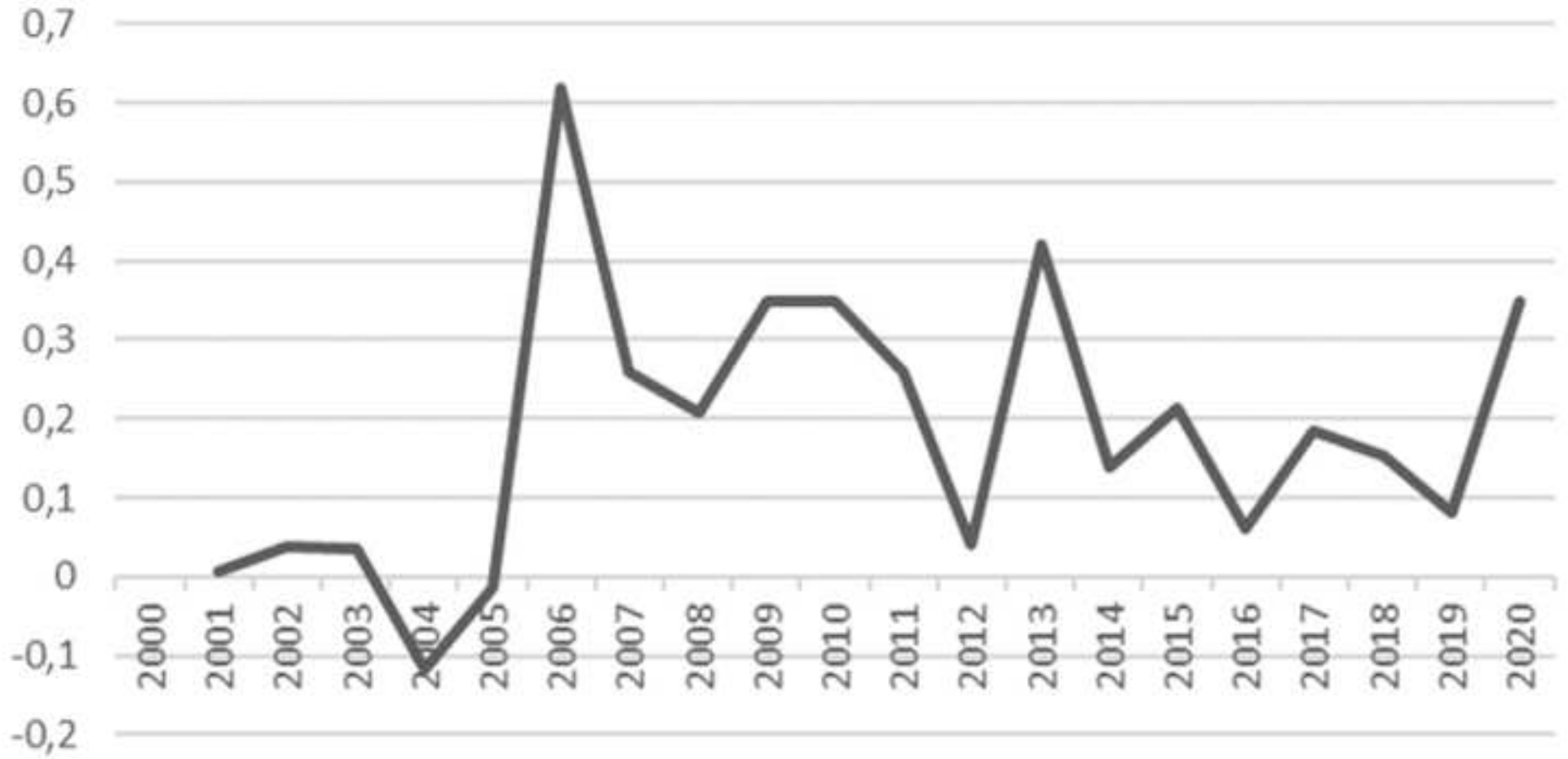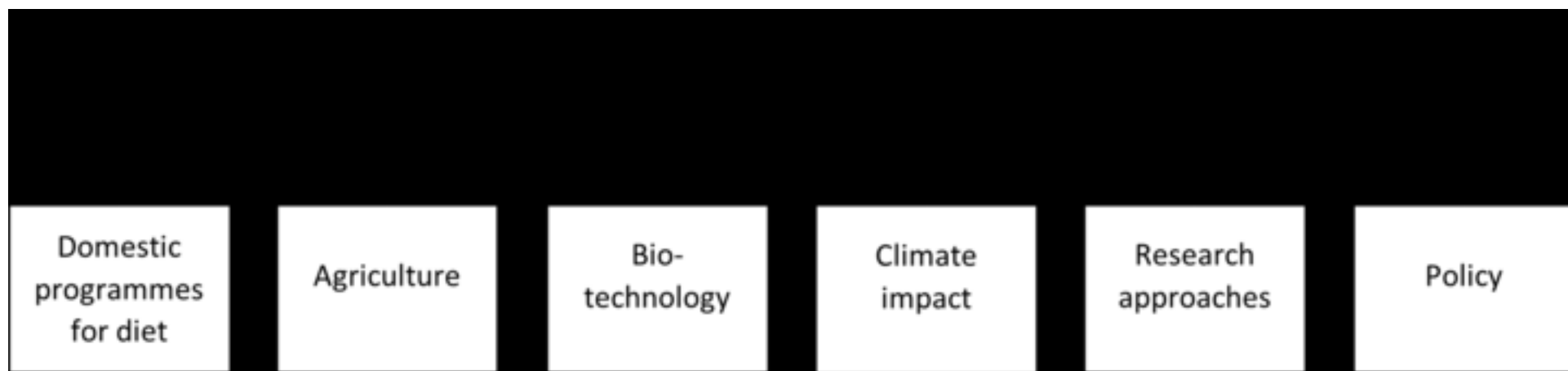
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