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The Global Growth of 'Sustainable Diet' during Recent Decades, a Bibliometric Analysis

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Abstract: The term 'sustainable diets' (SDs) was first introduced in the scientific literature in 1986 and later defined in detail by the Food and Agriculture Organization (FAO) as pertaining to those diets that can promote environmental health ad effectively ensure food and nutrition security as well as a healthy lifestyle in humans, combining the notion of sustainability with dietary patterns and their beneficial impacts. Since then, various international events have been held promoting sustainability as a significant component of food production, nutrition, and human health. These events have enhanced the knowledge transition and awareness between the scientific community and policymakers concerning the importance of SDs. In this aspect, this is the first study that aims to identify trends and turning points over time concerning the research on SDs. We performed a comprehensive bibliometric analysis of 1407 scientific documents published in Scopus during the period 1986–2022. The documents were screened following the PRISMA guidelines, and bibliometric analysis was conducted using the Bibliometrix R-package and VOSviewer and the detection of Sustainable Development Goals with the text2sdg R-package. Overall, there was an exponential growth in the literature on SDs that followed international events from 2009 onward. Among the most impactful journals were *Sustainability*, *Nutrients*, and *Frontiers in Nutrition*. The leading countries in research were pointed out, as well as the high rate of collaborations and partnerships between them. The research interest was mainly focused on (a) climate change, greenhouse gas emissions, and environmental impact; (b) food systems, security, and consumption; and (c) health, Mediterranean Diet (MD), and dietary guidelines. The significance of these keywords changed over time, following the evolution of SDs concepts from the planetary environmental impact of food production to the healthier dietary habits of individuals. Among several dietary patterns, MD was identified as the most popular among the local SDs, with synergies among scientists in the Mediterranean region. Overall, the novelty of this study is the mapping of the expansion of knowledge over the last 36 years regarding the term SDs while taking into consideration international events and their impact on scientific research.

Keywords: sustainable diets; bibliometric analysis; Scopus; bibliometrix; VOSviewer; text2sdg; Sustainable Development Goals

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1. Introduction

1.1. Definition of the Term

As mentioned by the Lancet Commission in 2019: "Food is the single strongest lever to optimize human health and environmental sustainability on the Planet. However,

food is currently threatening both people and the planet" [1]. Many terms have been considered to describe the efforts of humankind to produce and consume food in a more sustainable manner. Terms such as: 'sustainable diet' [2], 'econutrition' [3], 'sustainable food consumption' [4], 'ecological diet', 'resilient diet', 'biodiverse diets' [5], 'climate friendly diets' [6], 'sustainable nutrition' and 'nutritional sustainability' [7,8] are those more reported in the international scientific literature.

The most commonly used term is 'Sustainable Diets' (SDs) which was introduced by Gussow and Clancy in 1986 [2]. Twenty-five years later, the term SDs was defined by the Declaration of the World Summit of Food and Agriculture Organization (FAO) [9] as "those diets with low environmental impacts that contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe, and healthy, while optimizing natural and human resources.". This definition is widely accepted by the scientific community and is usually mentioned in most papers published on SDs [10–12].

From the SDs definition by FAO [9], six 'key components' are derived: (1) well-being and health; (2) biodiversity, environment, and climate; (3) equity and fair trade; (4) eco-friendly, local, and seasonal foods; (5) cultural and heritage skills; and (6) food and nutrient requirements, food security, and accessibility [9,13,14]. The components were represented in the literature as flower-like figures [13,14]. These crucial elements were developed taking into consideration the three intersecting pillars of Sustainable Development: the biological (and other resource) system, the economic system, and the social system as described by a Venn diagram from Barbier in 1987 [15].

1.2. Background on Key International Events

It should be noted that sustainability and sustainable development have been a focus of the United Nations (UN) for more than three decades. These terms were undoubtedly implied in the Brundtland Report in 1987 and articulated later in 1992, during the 'Earth Summit' in Rio de Janeiro when Agenda 21 was adopted [16]. Ten years later, in 2002, in Johannesburg, 'The World Summit on Sustainable Development', strategies were outlined to obtain a more efficient and effective implementation of Agenda 21 [17]. Hence, sustainable agriculture has gradually become a significant aim at a global level [18].

Due to the rise in awareness about the inequality between world hunger and obesity [9], International and European Organizations have adopted several measures (Table 1). In 1996, during the World Food Summit held by the FAO in Rome, the Rome Declaration on World Food Security and the World Food Summit Plan of Action were signed to promote food security. Four years later, in 2000, at the Millennium Summit, the Millennium Development Goals (MDGs) were set.

An important link between biodiversity, food, and nutrition was established in 2006 by the Convention of Biological Diversity, creating an early definition of SDs [12]. Food security was underlined not only in this initiative but also in the World Food Summit on Food Security, where the Declaration of the World Summit on Food Security was adopted in 2009 with the commitment that all countries in the world will work to minimize or even end hunger.

Evolving from the MDGs, after the Conference on Sustainable Development in 2012 that took place in Rio de Janeiro, Brazil, with the outcome document 'The Future We Want', and the Open Working Group in SDGs, we were led to the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015 and the Sustainable Development Goals (SDGs) [19]. In reference to the 2030 Agenda, 17 individual SDGs aim as an 'indivisible whole' to solve severe issues such as poverty, education, and climate change [20]. Out of the 17 goals, SDG 2 aims to 'end hunger, achieve food security, improve nutrition, and promote sustainable agriculture'. This goal is characterized by multiple dimensions (social, economic, and environmental) that go much further than food security [21].

Table 1. International Events, Conferences, Summits, and Treaties related to Sustainable Development Goals and Sustainable Diets.

Year		Event	Abbr.	Place	Notes
1992	UN	Earth Summit	UNCED	Rio de Janeiro, Brazil	Conference on Environment and Development, Agenda 21 [1]**
1996	FAO	World Food Summit	WFS	Rome, Italy	Rome Declaration *
2000	UN	Millennium Summit	MDGs	New York, NY, USA	Millennium Development Goals (MDGs) [2]**
2002	UN	World Summit on Sustainable Development	WSSD	Johannesburg, South Africa	The Johannesburg Declaration on Sustainable Development and the Plan of Implementation **
2006	UN/FAO	Convention of Biological Diversity	CBD	Rome, Italy	Initiative on Biodiversity for Food and Nutrition *
2009	FAO	World Summit on Food Security	WSFS	Rome, Italy	Declaration of the World Summit on Food Security *
2012	UN	Conference on Sustainable Development	UNCSD	Rio de Janeiro, Brazil	Rio+20, 'The Future We Want' **
2013		Open Working Group on SDGs	OPWG SDGs	-	Proposal on the SDGs **
2015	UN	Sustainable Development Summit	SDGs	New York, NY, USA	2030 Agenda for Sustainable Development [3], SDGs **
2015	UN	Climate Change Conference	COP21	Paris, France	Paris Agreement on Climate Change **
2019	EU	European Green Deal [4]	EGD	European Union	'Farm to Fork' Strategy *
2021	FAO	Food Systems Summit	UNFSS	New York, NY, USA	Food Systems Summit of FAO *

[1] Agenda 21: Program of action for sustainable development; Rio declaration on environment and development; statement of forest principles; the final text of agreements negotiated by governments at the United Nations Conference on Environment and Development (UNCED), 3–14 June 1992, Rio de Janeiro, Brazil (2. print). (1994). Conference on Environment and Development, New York, NY, USA. Department of Public Information, United Nations. [2] General Assembly resolution 55/2, United Nations Millennium Declaration, A/RES/55/2 (18 September 2000), available online: undocs.org/en/A/RES/55/2 (accessed on 2 July 2023). [3] General Assembly resolution 70/1, Transforming our world: the 2030 Agenda for Sustainable Development, A/RES/70/1 (21 October 2015), available online: undocs.org/A/RES/70/1 (accessed on 2 July 2023). [4] European Commission, Communication from the Commission The European Green Deal, (11 December 2019) COM (2019) 640 final, available online: eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN (accessed on 2 July 2023). * SDs Related International Events. ** SDGs Related International Events and Treaties.

Additionally, all SDGs were meant to ensure homogeneity between different policy sectors [22]. Therefore, there is a link to nutrition among them; for instance, SDG 1 is related to nutrition as poverty makes it harder to meet nutritional recommendations and restricts access to proper food intake, and SDG 2 promotes that undernourishment is brought on by unsustainable food production and SDG 3 proposes that healthy and sustainable nutrition promotes health [23]. In another example, regarding food systems, SDG 12 promotes sustainable consumption and production patterns [24]. Furthermore, in the 'Fixing Food 2021' report from the Barilla Center for Food and Nutrition [25], it has been underlined that food sustainability is crucial for all SDGs and not only in the two mentioned as mainly food related.

There are other important initiatives linked to the SDGs at both international and European levels. At the international level, the Paris Agreement on Climate Change was finalized in 2015 during the Climate Change Conference in Paris, France, unraveling strong connections to the 2030 Agenda. At the European level, the European Green Deal, adopted by the European Member States in 2019 [26], promotes initiatives for the end of hunger, the achievement of food security, the improvement of nutrition, and the promotion of sustainable agriculture, especially with the 'Farm to Fork' Strategy.

Apart from International and European organizations, several other scientific events took place regarding SDs, and certain scientific documents were published [12] (see

Supplementary Table S1 for details). As a result of an international 'conversation' regarding the choice of indicators of a sustainable diet that began after 2009 [27], the Mediterranean Diet (MD) was selected as a characteristic example of SD [28]. The indicators were selected using strict scientific criteria and were categorized into four thematic areas: (1) nutrition and human health, (2) environmental health, (3) economy, and (4) favorable socio-cultural factors [29].

Furthermore, in addition to highlighting the importance of local traditional diets, there has been an effort to identify the total of the indicators that measure effectively and critically assess SDs [5,8]. In the same context and embracing the SDGs, more than 20 experts from the EAT-Lancet Commission have proposed a universal healthy reference diet [1].

In the present study, the bibliographic data are studied alongside international and European Organizations' activities regarding SDs specifically and SDGs, Climate Change, and Food Security generally, in a quantitative approach. The focus of the research did not remain solely to SDs related events as the disciplinarity of the term allows a more comprehensive approach. Furthermore, SDGs have become a framework widely accepted by United Nations Members and other International and Regional Organizations, creating partnerships forming policies, and becoming a driving force of research and innovation.

1.3. Objectives

This research's objective is to determine the underlying international 'dialogue' about Sustainable Diets through a methodical review and assessment of the international scientific literature. The goal of our research is to step on past analyses and define trends and progression of the term 'Sustainable Diets' for the previous 36 years, from 1986 to 2022. Furthermore, the dataset was critically analyzed and scrutinized to effectively detect the collaboration among the countries, the relationship between the corresponding authors' nationality and the type of diet they are studying, and the role of international organizations, international treaties, and funding in scientific production regarding the term Sustainable Diets. Finally, six query systems were used to detect the SDGs in our dataset.

2. Materials and Methods

2.1. Bibliometric Analysis and General Workflow

Defined as a field in 1934 by the librarian Paul Otlet, termed 'bibliométrie', bibliometry was described to measure all the factors concerning both publication and reading of books and documents [30]. Since the release of online databases that provide access to bibliographic metadata and the fast growth of scientific publications, the necessity of using bibliometric methods to assess the latest literature has highly increased [31].

The method explored in this study focuses on bibliometric mapping and content analysis by monitoring the SDGs in the selected papers. A bibliometric analysis was methodologically designed and carefully performed to investigate the literature addressing the terms 'sustainable diets' and 'sustainable nutrition' in the bibliographic database Scopus using a five-stage standard workflow [31,32]. Firstly, the study was designed; secondly, the data were collected; thirdly, the obtained were analyzed; fourthly, the derived data were visualized; then, in the fifth and final stage they were critically interpreted. In the data analysis stage, data networks were created for collaboration and co-occurrence analyses, in addition to the descriptive analysis of the bibliographic data. Moreover, network mapping was performed during the data visualization stage.

2.2. Data Sources

After posing the research questions, the bibliographic database Scopus was selected for the present study in order to identify potentially relevant documents. This database was selected because it indexes more journals than other popular electronic databases such as PubMed and Web of Science and provides approximately 20% greater coverage for citation analysis than Web of Science [33–35]. Scopus was comprehensively searched for peer-reviewed articles published between the periods of 1986–2022 in the English language

until April 2023. Titles and abstracts were carefully read and critically screened by two authors (M.G. and G.K.V.), who carefully identified and eliminated duplicates.

2.3. Protocol

The protocol was drafted using the PRISMA extension for Scoping Reviews (PRISMA-ScR) guidelines [36], which is an extension of the PRISMA 2020 statement [37], the updated version of the Preferred Reporting Items for Systematic reviews and Meta-Analyses [38].

2.4. Software and Analyses

The bibliometrics analysis was performed using the Bibliometrix R package [32]. Moreover, we used the text2sdg R package [39] to detect SDGs in the initial collection. We also used VOSviewer [40], a software tool for constructing and visualizing bibliometric networks, to perform the co-occurrences analysis.

For the bibliometric analysis, the shiny app Biblioshiny was used. This application provides a web interface for Bibliometrix [32]. We used Biblioshiny to import the final dataset and convert it to a dataframe collection. Furthermore, analyses and plots for sources, authors, and documents were performed, and the Conceptual and the Social Structure of the bibliographic collection were analyzed.

In particular, the main information of the collection was presented. Next, using Microsoft Excel Spreadsheet Software, the annual scientific production was visualized. In the same figure, the literature findings about major events related to SDs were added. The sources that made the publications were studied, and the country's production and collaboration were presented. Moreover, as for the keywords, the most frequently used keywords by the authors were retrieved, and the trending topics were identified. In this analysis, the words that were used in the search queries were not included by the authors (sustainable diet, sustainable diets, diet, diets, nutrition, sustainable nutrition, sustainable) in order to highlight the main trends related to SDs. By doing that, we focused mainly on the other keywords and themes that emerged in the bibliographic dataset studied than our original searches. Additionally, a thematic evolution chart was created using Sankey diagrams. Four cutting points were set by splitting the studied collection into five time slices: 1986–2006, 2007–2011, 2012–2015, 2016–2019, and 2020–2022. These cutting points derived from some of the major turning points of the upward trend of the scientific production of this collection. They were strategically selected to identify the new themes introduced in the literature after every increase in the number of published documents.

A co-occurrence network of the authors' keywords was visualized using VOSviewer software. VOSviewer creates maps using a co-occurrence matrix in three steps; (a) based on the co-occurrence matrix, a similarity matrix is created in the first stage, (b) using the VOS mapping technique, a map is created from the similarity matrix (c) the map is then translated, rotated, and mirrored [40].

Keyword co-occurrence revealed clusters in the research discipline providing auxiliary support to scientific research [41]. Out of the keywords in all articles, 49 with a minimum threshold of five co-occurrences. The threshold was chosen to ensure that enough research topics were obtained while effectively avoiding overcrowding. These sets of author keywords were separated into six clusters using the VOSviewer keyword co-occurrence algorithm. Each cluster contained nodes (circles) of the same color and included links or relationships (lines) between nodes. Nodes with similar colors belong to the same cluster. The size of each node and word in each cluster was proportional to the node's weight/frequency, and clusters with the most keywords were more centered on the study areas [42].

Lastly, apart from the bibliometric analysis, SDGs were also detected in the titles of the present bibliographic collection using the open source, multi-system analysis R package text2sdg [39] was used to identify SDGs in the titles of the documents included in the final dataset. A stacked barplot of absolute frequencies was visualized using six different individual query systems used for the identification (Auckland, Aurora, Elsevier, SDGO,

SDSN, SIRIS). This package allows to use text data in order to detect SDGs and compare the outcomes quantitively.

2.5. Data Collection, Eligibility Criteria and Screening

First of all, the eligibility criteria, both inclusion and exclusion criteria, were identified. Articles were eligible for inclusion in this review if they included the terms 'sustainable diets' or 'sustainable nutrition' or other derivatives of the terms in their titles, abstracts, or keywords, and referred to the sustainability of human diet and nutrition. Only articles (articles, data papers, reviews, and short surveys) published after 1986 in English were eligible for inclusion [43]. Articles were excluded if they did not fit the meaning of the search terms. Double citations were also excluded.

We also performed several searches in the Scopus database (the last search was conducted in April 2023) (Table 2). The first two presented considered the term 'Sustainable Diets' (SD1, SD2) and the other two the term 'Sustainable Nutrition' (SN1, SN2). In these queries, we looked for the adjective 'sustainable' and the nouns 'diet' or 'nutrition' in the titles of the scientific documents (SD1, SN1). We also located the word 'sustainable' and the word 'diet' or 'nutrition' in the title, abstract, and keywords of the documents (SD2, SN2) within one word proximity using the proximity operator within W/n.

Table 2. Search strategy on Scopus database, where four different queries were conducted and the resulting number of articles before and after filtering.

Topic	Search	Search Query	Dataset [1]	No. of Docs
Sustainable Diets	SD1	TITLE (*sustainab* AND *diet*)	SD1—(SD2 or SN1 or SN2)	247
			(SD1 and SD2)—(SN1 or SN2)	462
	SD2	TITLE-ABS-KEY (*sustainab* W/1 *diet*)	SD2—(SD1 or SN1 or SN2)	841
			(SD1 or SD2) and (SN1 or SN2)	197
Sustainable Nutrition	SN1	TITLE (*sustainab* AND *nutritio*)	SN1—(SN2 or SD1 or SD2)	390
			(SN1 and SN2)—(SD1 or SD2)	185
	SN2	TITLE-ABS-KEY (*sustainanb* W/1 *nutritio*)	SN2—(SN1 or SD1 or SD2)	551
Total Dataset			SD1 or SD2 or SN1 or SN2	2873

[1] The column 'dataset' is displaying the logic behind the different sub searches that were performed in Scopus database using Boolean operators (AND, OR, NOT) according to set theory in order to identify the unique publications across the searches and duplicates.

The asterisk wildcard (*) was used because we wanted to include all the grammatical forms of the words diet and nutrition. After some trial tests, we noted that, except for the noun diet, other derived terms appeared in the results: the term appeared both in singular and plural (diet and diets) as an adjective (dietary, dietetic) as a noun (dietetics, dietitians, dieter, dietotherapy, dietand), and as a gerund (dieting, non-dieting). We excluded papers that in their title contained terms other than diet (e.g., diethyl, dietro, etc.).

To avoid the duplicated entries in the total dataset, several sub-searches were performed using the three Boolean operators; AND, OR, AND NOT. Explaining the column Dataset in Table 2, the word 'and' represented AND Boolean operator and the intersection of the two searches. The symbol '-' was applied for AND NOT excluding specific searches. Finally, the word 'or' was for OR; this Boolean operator expanded the search showing the union of two searches. These searches were made to identify the unique documents of the final dataset and eliminate the results that were recognized as common (Table 2). For example, we found 247 documents using the query string: (TITLE (*sustainab* AND *diet*) AND NOT (TITLE-ABS-KEY (*sustainab* W/1 *diet*) OR TI-TLE (*sustainab* AND *nutritio*) OR TITLE-ABS-KEY (*sustainab* W/1 *nutritio*))).

In order to perform a consistent review, three of the authors (M.G., A.Y.T., and G.K.V.) systematically screened the titles and abstracts of 20 same publications and discussed the results. The goal was to establish a common view and understanding. Subsequently, each author searched a subset of databases. All discrepancies between the authors were resolved by discussion. Three reviewers (M.G., A.Y.T., and G.K.V.) screened the title, abstract, and keywords and graded the relevancy of each entry of the database in a spreadsheet using a modified Likert scale (1–5). This scale was termed as Bibliometric Scale, where grade 1 was assigned to the highly irrelevant documents and grade 5 the highly relevant. The papers included in the final dataset should score 3–5 to be considered relevant.

Documents were excluded if they did not fit the meaning of the search terms and did not have a direct connection to human food consumption, as reported below.

- Nutritional sustainability of animal/sustainable animal nutrition feeding (e.g., camels, pigs, ruminants);
- Sustainability in cultivation methods (e.g., maize, corn, soybean);
- Sustainability in aquaculture methods;
- Animal breeding, Embryo development;
- Sustain weight or body mass (e.g., sustainable weight loss, sustainably preserve muscle mass);
- Weight loss sustainability;
- Use of the word sustainability in terms of continuity, viability, and feasibility.

As a result of the data charting process, the data collected were as follows: citation information (authors, year, doi number), bibliographic information (affiliation, correspondence address, language of original document), abstract and keywords, and funding details (number, acronym, sponsor, funding text).

A total of 2873 documents were initially identified through multiple searches (Figure 1). Duplicates were then removed (n = 4). Subsequently, 2869 documents were finally assessed for eligibility. Documents that did not fit the time period studied (n = 124), language (n = 93), and document type (n = 493) were then excluded. In the Screening phase, reports with no data available in the abstract and keywords domain were considered as not retrieved (n = 78). Finally, after the screening process, the papers were graded by using the 1–5 scale, which had been standardized by the three researchers (M.G., A.Y.T., and G.K.V.) as mentioned above. More specifically, 124 papers were graded with 1 as highly irrelevant, 480 papers were graded with 2, as likely to be irrelevant, and 70 papers were graded with 3 as more or less relevant. A total of 1407 studies were finally included in the bibliometric and content analyses.

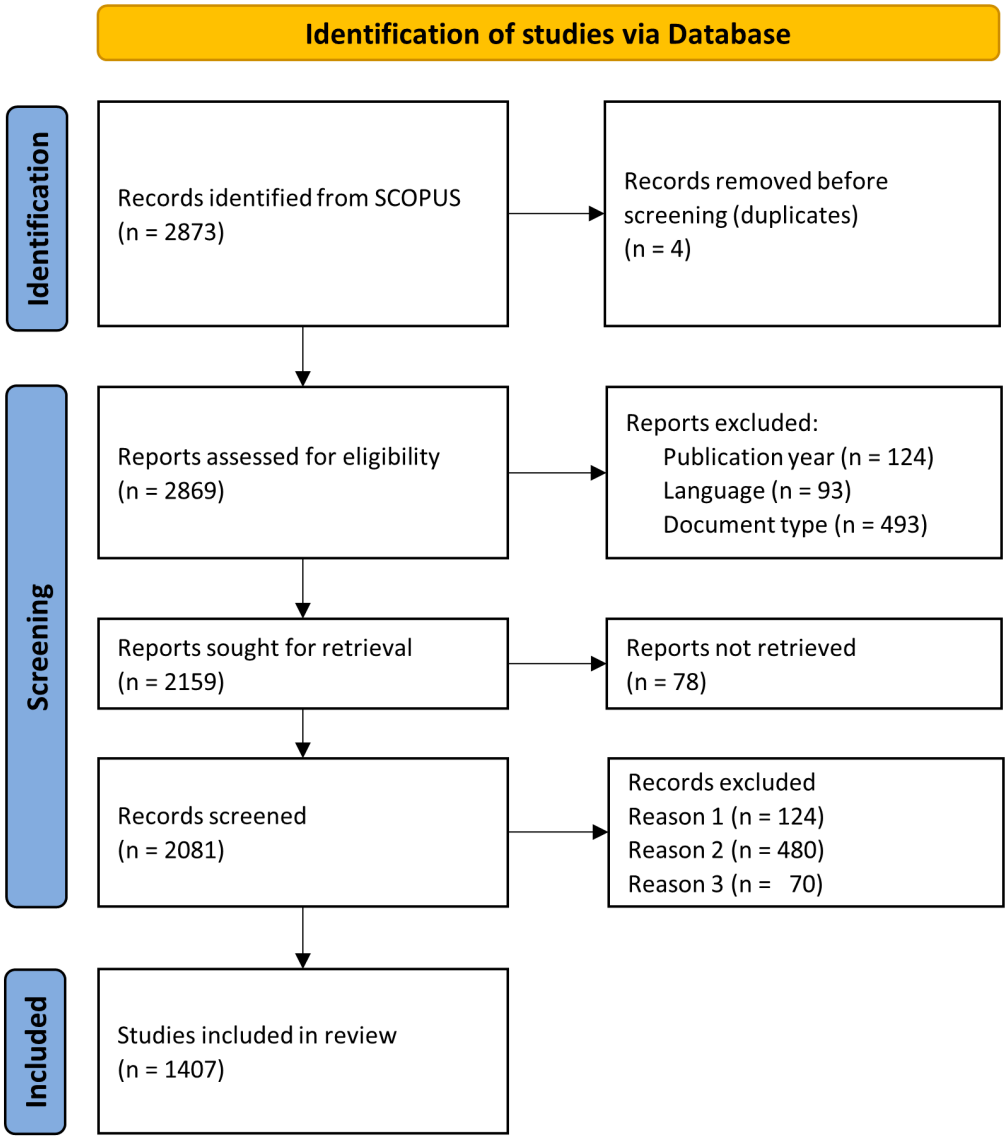

Figure 1. Flowchart indicating identification and selection of studies used in the present analysis following PRISMA statement guidelines.

3. Results

In this section, we demonstrate the main results of the descriptive bibliometric analysis, the annual scientific production of this collection, the main journals that published the scientific papers of the collection, the countries involved, the main keywords, their connection in a co-occurrence network, their thematic evolution, and the connection between the SDGs and the titles of the papers of the final dataset.

3.1. Main Information

Table 3 summarizes the main information of the present bibliographic collection. The total number of examined documents (papers) examined was 1407. Most documents were articles (1116 documents), and reviews (283 documents). Data papers (1 document) and short surveys (7 documents) were also included. The 5191 authors used a total of 3397 keywords. Furthermore, the number of single-authored documents was 122, while the number of co-authors per document, that is, the mean number of authors' appearances per document, was 4.99. Both indicators (authors per document and co-authors per document)

evaluated the level of author collaboration [44]. Finally, the level of international co-authorship reached the percentage of 34.68%.

Table 3. Main information regarding the final collection of documents.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1986–2022
Sources (Journals, Books, etc.)	428
Documents	1407
Annual Growth Rate %	17.65
Document Average Age	3.89
Average citations per doc	27
References	93,027
DOCUMENT TYPES	
Article	1116
data paper	1
Review	283
short survey	7
DOCUMENT CONTENTS	
Keywords Plus (ID)	4590
Author's Keywords (DE)	3397
AUTHORS	
Authors	5191
Authors of single-authored docs	109
AUTHORS COLLABORATION	
Single-authored docs	122
Co-Authors per Doc	4.99
International co-authorships %	34.68

3.2. Annual Scientific Production

The publication trends of the 1407 documents were systematically studied from 1986 to 2022. Figure 2 shows the number of publications on SDs for this period and the major international events related to the SDGs and SDs that took place. The number of publications began to increase in 2007 (5 documents) and significantly increased over the examined period of time. Figure 2 shows an escalation in publications from one document in 1986 to 348 documents in 2022, which is noted as the peak number of publications. The annual production since 1986 fits an exponential trend line with an R^2 value of 0.9843, while the annual growth rate was 17.65%. Taking the above under consideration, research on SDs appears to be at the stage of exponential growth, implying that SDs are highly increasingly receiving the attention of the scientific community, particularly in the last few years.

Additionally, we compared annual scientific production with literature findings and major international events, such as summits and treaties related to sustainability, food, nutrition, and SDGs. Approximately 5% of the articles were published between 1986 and 2012 (27 out of 1407). After 2012, there was an upward trend in the number of publications. This happened after the official definition of SDs by the FAO during the International Scientific Symposium 'Biodiversity and Sustainable Diets: United against Hunger' in 2010 [45]. Moreover, almost 95% of the documents (1332 out of 1407) were published in the last ten years and especially after 2015, when the Paris Agreement on Climate Change took place and the 2030 Agenda for Sustainable Development was set, promoting the 17 SDGs.

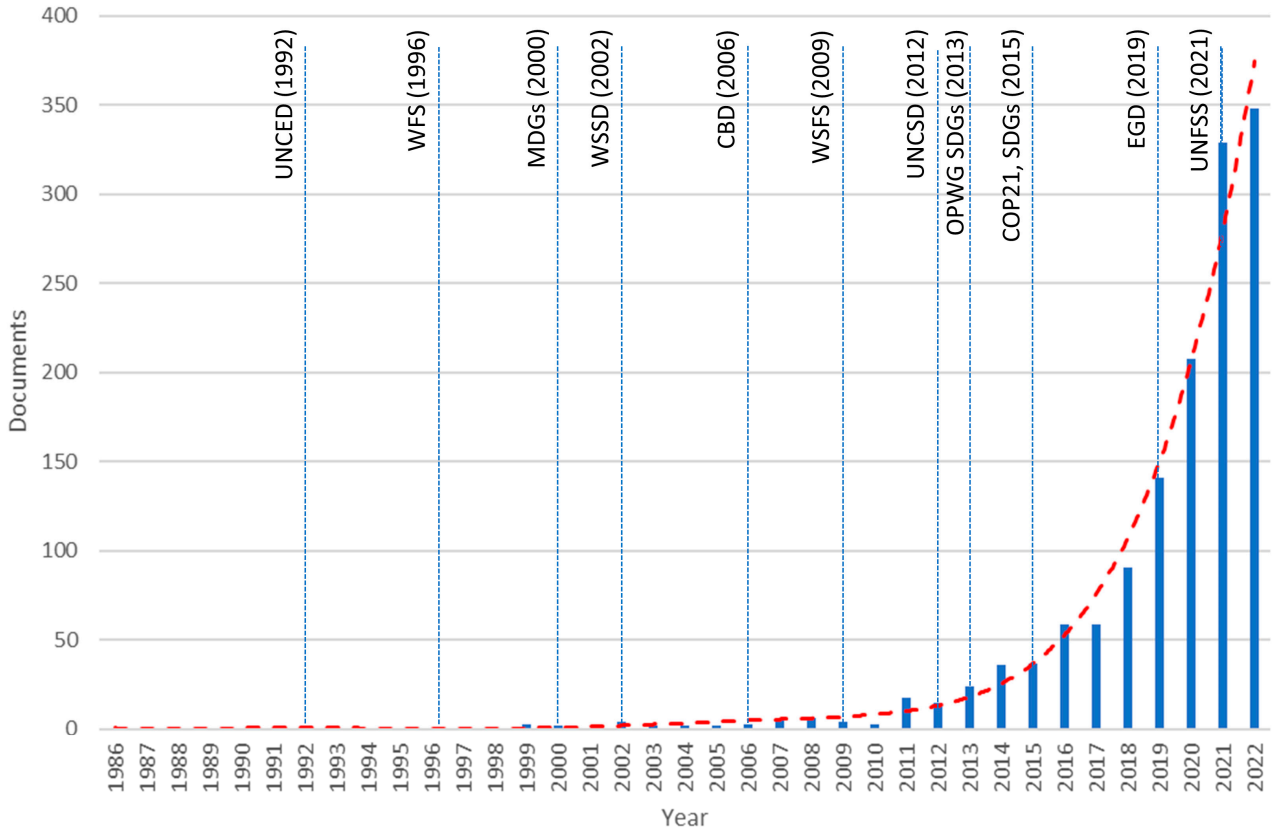

Figure 2. Annual scientific production of articles on the terms 'sustainable diets' and 'sustainable nutrition' and international events occurred during the studied period. The annual production since 1986 fits an exponential trend line (red dash line) with an R^2 value of 0.9843, while the annual growth rate was 17.65%.(UNCED: UN Earth Summit, WFS: World Food Summit, MDGs: Millennium Development Goals, WSSD: World Summit on Sustainable Development, CBD: Convention of Biological Diversity, WSFS: World Summit on Food Security, UNCSD: UN Conference on Sustainable Development, OPWG SDGs: Open Working Group on SDGs, SDGs: Sustainable Development Goals, COP21: Climate Change Conference, EGD: European Green Deal, UNFSS: UN Food Systems Summit).

3.3. Sources

In our collection, we found 428 sources (journals) and cited sources included in the 1407 documents' bibliographies. According to Table 4, the five most relevant sources for the terms under study are *Sustainability* (111 publications), *Nutrients* (91 publications), *Frontiers in Nutrition* (58 publications), *Public Health Nutrition* (44 publications), and *Journal of Cleaner Production* (39 publications) (Table 4). The main subject areas covered by these sources are agricultural and biological sciences, environmental sciences, social sciences, nursing, and medicine. According to Bradford's Law, these ten journals (2.34% of the total number of journals) were also the core–nucleus journals that were particularly devoted to the subject. These ten journals have published 495 articles in total, representing 35% of the entire collection.

Table 4. Most relevant sources by the number of articles they published.

Sources	Articles
Sustainability	111
Nutrients	91
Frontiers in Nutrition	58
Public Health Nutrition	44
Frontiers in Sustainable Food Systems	39
Journal of Cleaner Production	39
Foods	32
Appetite	30
Global Food Security	29
International Journal of Environmental Research and Public Health	22

3.4. Country Production and Collaboration

Between 1986 and 2022, 110 countries published publications on the studied subject. In Figure 3, the color intensity is proportional to the number of publications. The map shows the country based on the authors' affiliation. Countries in the Mediterranean basin have published a lot of scientific documents, with Italy in the first place, followed by other countries of the region, such as Spain, Greece, and Portugal (Supplementary Table S2). Nordic countries (Sweden, Denmark, Norway, and Finland) that could relate to the New Nordic Diet were also at the top places. The countries with the largest scientific production were the USA (n = 777), the UK (n = 437), Italy (n = 337), Australia (n = 274), and France (n = 251).

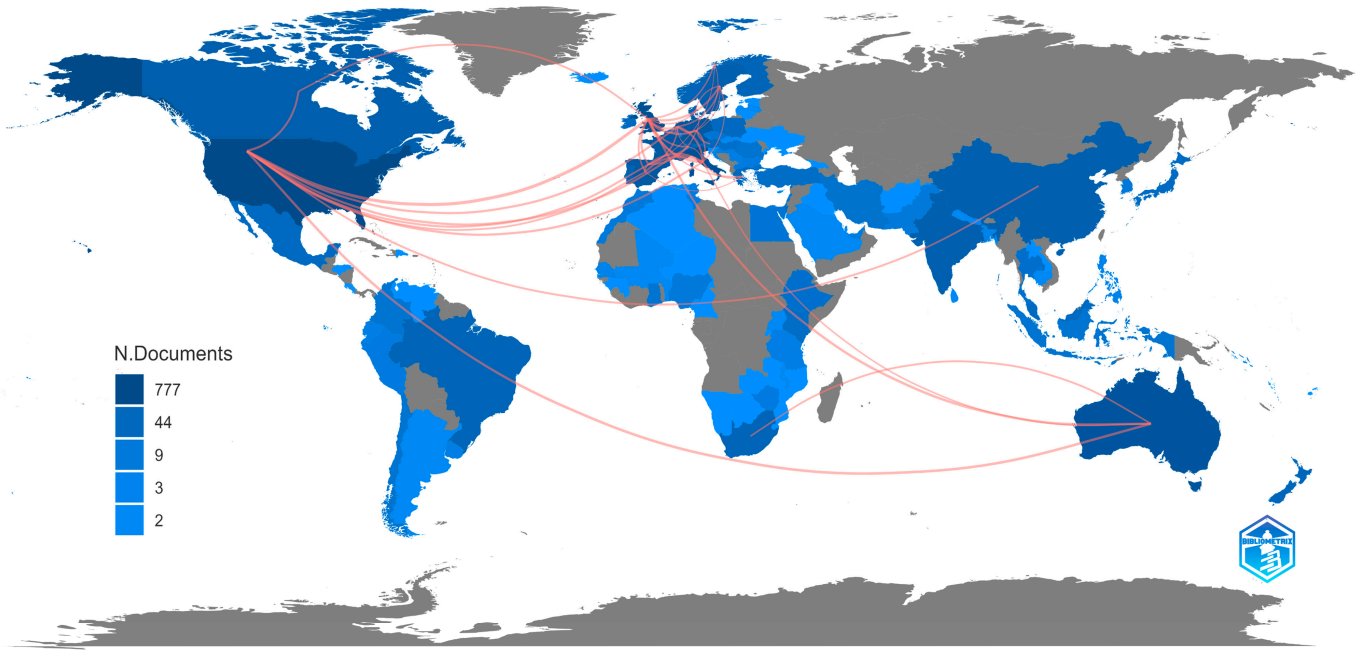

Figure 3. World maps showing the number of documents per country; the color intensity is proportional to the number of publications. The red lines indicate the collaboration among countries.

The research collaborations among countries are also presented in Figure 3, where countries with equal or more than ten shared papers are shown by connectors. The countries with the strongest linkages were the USA with the UK (40 links), the UK with Italy (27 links), the USA with Australia (27 links), and Italy with France (23 links). Most of them were from English-speaking countries. Italy is a Mediterranean country with a great tradition in the Mediterranean Diet. Moreover, the FAO headquarters are located in Rome, Italy.

Finally, there was also close collaboration between countries in the Mediterranean basin; for example, Italy and Spain shared 20 collaborations.

3.5. Keywords and Trend Topics

Table 5 highlights the most frequently used keywords by the authors in their publications. Some of the first results (sustainable diet, sustainable, nutrition, nutrition and diet) are trivial because they were included in the set of terms used to be built up the search query in the bibliographic database. However, they reveal that diet as a term is used more often than the term nutrition in combination with the term sustainable. In addition, the food system had the highest number of occurrences (99 occurrences), followed by food security (87 occurrences). The next three authors' keywords, greenhouse gas emission (74 occurrences), climate change (65 occurrences), and environmental impact (60 occurrences), connect global warming with dietary choices. The next word was health (60 occurrences). Mediterranean diet (60 occurrences) and Sustainable Development Goals (43 occurrences) were also in the top twenty list.

Table 5. Most frequent words (Author's Keywords).

Words	Occurrences
sustainable diet	326
sustainable	293
nutrition	141
food system	99
food security	87
diet	85
greenhouse gas emissions	74
climate change	65
environmental impact	60
health	60
Mediterranean Diet	60
environment	47
food	45
Sustainable Development Goals	43
carbon footprint	42
life cycle assessment	42
food consumption	40
sustainable food system	40
sustainable nutrition	40
water footprint	40

Alarmingly enough, climate change and greenhouse gas emissions became trending topics in 2017 (Figure 4), soon after the Climate Change Conference (COP21) in Paris in 2015, where the Paris Agreement on Climate Change was adopted by 196 Parties. Even though the Mediterranean Diet has been identified studied as a Sustainable Diet Model since 2009 in the collection. It mainly appears to be a trending topic 10 years later, in 2019. In the last few years (2019–2021), they have become popular topics regarding vegetarianism and plant-based foods. Lastly, food and nutrition security has become a well–studied topic since 2016, as mentioned in the second Goal of SDGs (SDG 2: Zero Hunger).

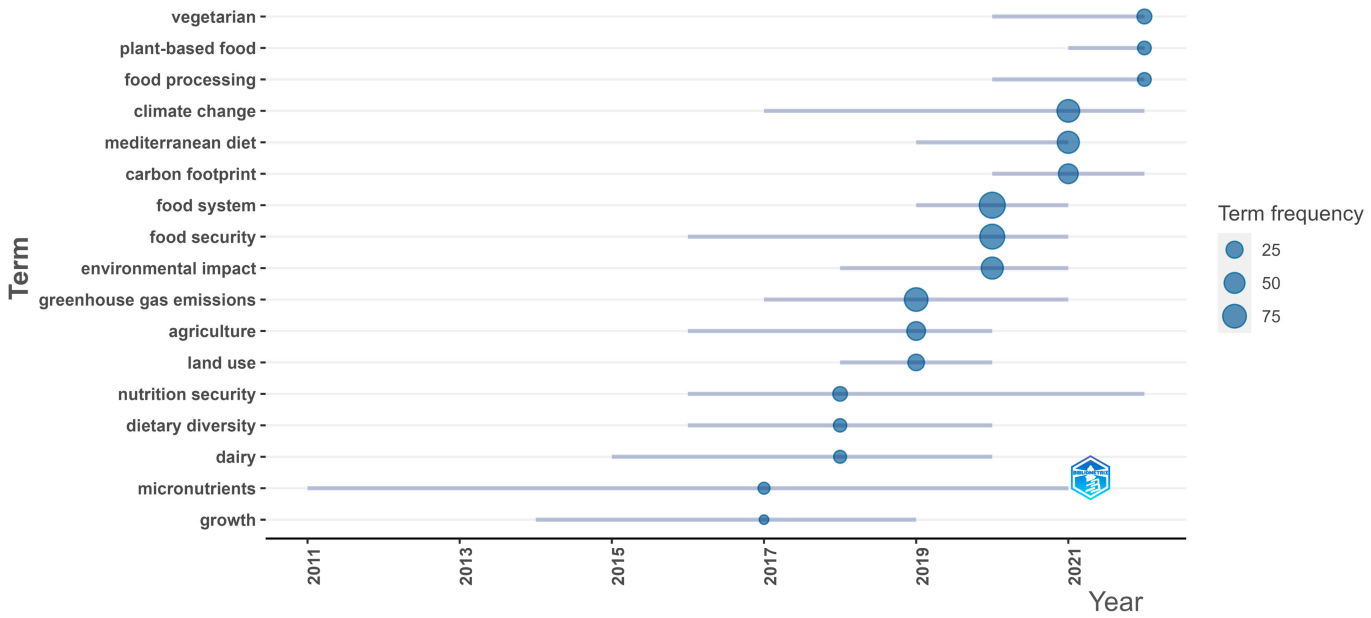

Figure 4. Trend Topics for the period 2011–2022 representing the evolution of the authors' keywords.

3.6. Thematic Evolution

Moreover, the evolution of the main themes in SDs research was systematically explored by the use of a timeline view analysis of the authors' keywords (Figure 5). The first period (1986–2016) begins with the first definition of the term sustainable diet and ends the year of the Convention of Biological Diversity. There have been merely a few publications throughout these 30 years; therefore, there are two themes: sustainable and food systems. In the next period (2007–2011), these two themes remained, but food security emerged as a new theme. It should be mentioned that in 2009, FAO held the World Summit on Food Security. During the following period (2012–2015) there was an appearance of eight new themes ((1) climate change, (2) environmental impact, (3) environmental sustainability, (4) sustainable food system, (5) food consumption, (6) food production, (7) nutrition security and (8) biodiversity). During these years, the Conference on Sustainable Development took place in Rio, Brazil (RIO+20) with the outcome document 'The Future We Want', where the importance of sustainable food production, food, and nutrition security was underlined. Beginning in 2013, and as a result of RIO+20, an Open Working Group on SDGs started a dialogue about the sustainability of food production and consumption, among others. Subsequently, between 2016–2019, SDGs were identified as a new theme. Sustainable diets play a major part in this time slice, but sustainable nutrition also makes an appearance as a novel theme. The newly emerged themes are strongly related to the production and consumption of meat ('livestock' and 'meat reduction') and other sustainable protein sources (edible insects, plant proteins, legumes). In the last two years (2020–2022), 'sustainable diet' has prevailed as a term. Several branches of the previous period were brought together in the 'carbon footprint' theme. Lastly, 'vegetarian' is one of the new themes that have risen in popularity (see Supplementary Figure S1 for a detailed thematic evolution).

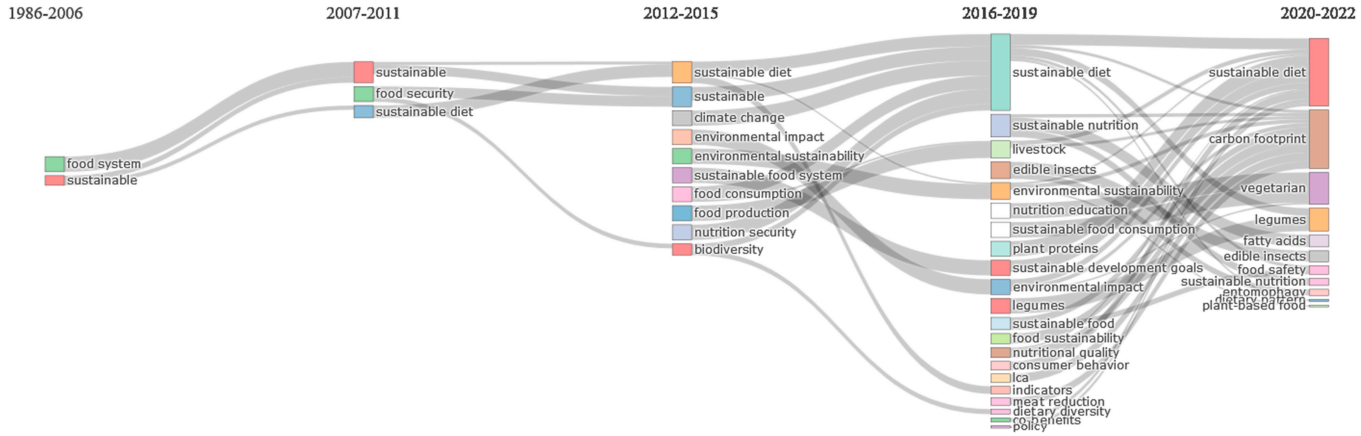

Figure 5. Evolution of the main themes in research using authors' keywords in five time slices: 1986–2006, 2007–2011, 2012–2015, 2016–2019, and 2020–2022.

3.7. Authors' Keyword Co-Occurrence

As shown in Figure 6, there were 49 items and 633 links with a total link strength of 27,612, assigned into six clusters by the VOSviewer algorithm. The name of each cluster noted in bold letters is our interpretation:

1. General overview of SDs with a focus on the environmental pillar: (red color) sustainable diet, carbon footprint, COVID-19, dietary change, environmental footprint, environmental sustainability, food choice, food consumption, food sustainability, greenhouse gas emissions, healthy diet, Mediterranean diet, nutritional quality, sustainable consumption, sustainable food system, sustainable healthy diets, and water footprint;
2. Linkage SDs with health: (green color) dietary patterns, children, food safety, food waste, healthy diets, obesity, public health, sustainable nutrition;
3. Sustainable Nutrition and meat consumption: (blue color) sustainable, nutrition, diet, environment, food, health, meat, protein;
4. SDGs with a focus on SDG 2 (Zero Hunger): (yellow color) food system, agriculture, climate change, food and nutrition security, food security, malnutrition, Sustainable Development Goals;
5. Environmental impact of dietary choices: (purple color) environmental impact, biodiversity, diet quality, dietary guidelines, land use, life cycle assessment;
6. Consumer behavior and plant-based food choices: (bright blue color) food policy, consumer behavior, vegetarian.

The keyword with the largest node is 'sustainable' (with 12,091 total link strength) and follows 'sustainable diet' (with 9219). The strongest link is between the keywords 'sustainable' and 'nutrition' with 3721 link strength. However, these keywords were expected to be in high places as they were included in the keywords searched in the Scopus database. The first word after them was 'food system', which belonged in the fourth cluster and has a total link strength of 3403.

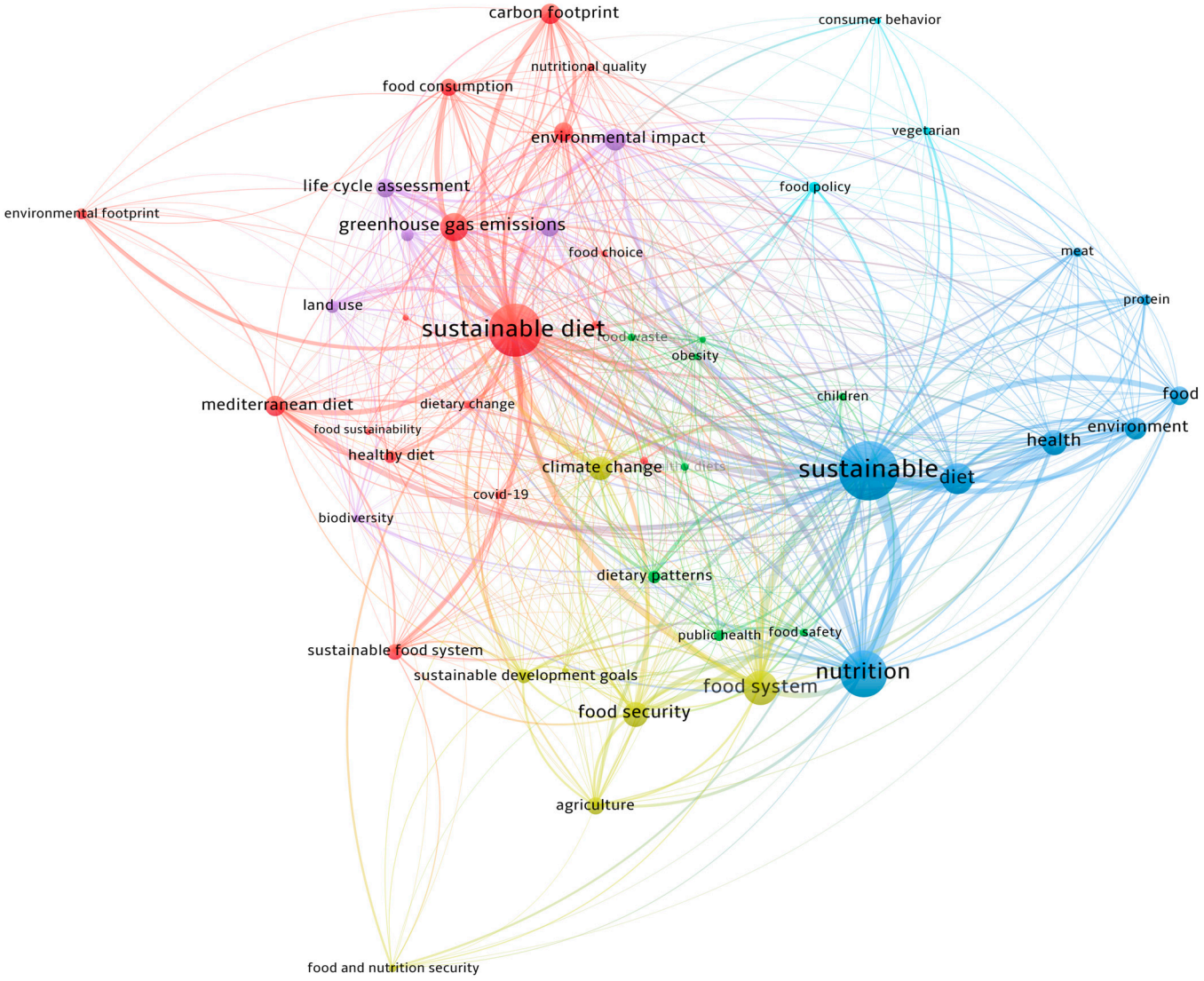

Figure 6. Co-occurrences network of Author keywords of Sustainable Diets and Sustainable nutrition in the final dataset (n = 1407) using the VOSviewer software.

3.8. Detecting UN Sustainable Development Goals in Text

As depicted in Figure 7, the papers included in the final dataset were mostly related to SDG 2 (Zero Hunger), with almost 2500 hits, SDG 12 (Responsible Consumption and Production) followed by almost 1500 hits, SDG 3 (Good Health and Well-being), and SDG 11 (Sustainable Cities and Communities), followed by approximately 1000 hits each. However, all SDGs were represented in the titles of this collection, some more and some less, revealing a clear interconnection among them.

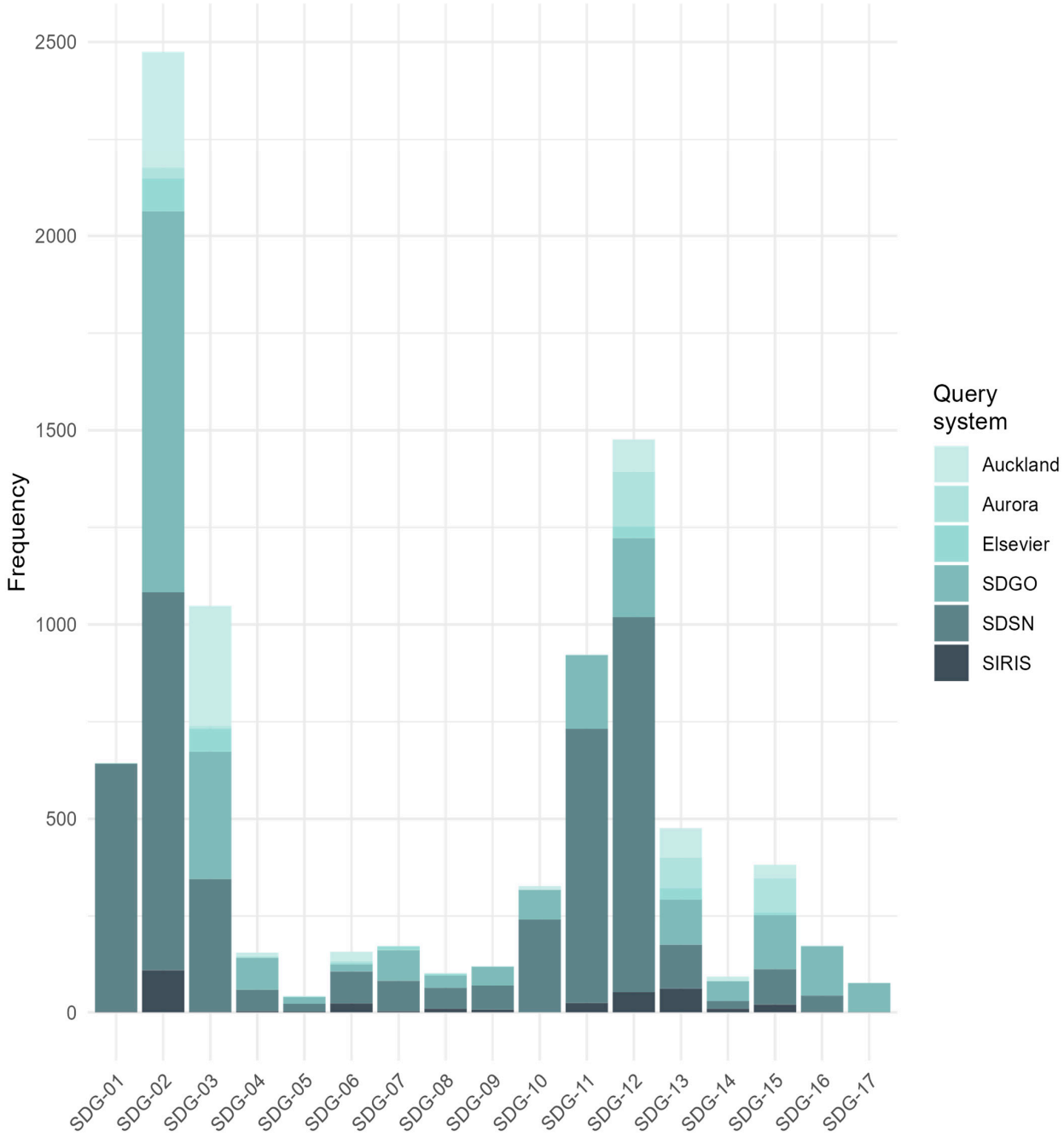

Figure 7. Relative number of hits per SDG from the papers' titles cumulatively across 6 query systems using R package text2sdg in the final dataset (n = 1407).

4. Discussion

4.1. Summary of the Findings

The international events that took place in recent years exerted a considerable impact on scientific knowledge and production soon after 2012 when there was an increase in the production of scientific documents. The definition of SDs by FAO played an important role in this issue. In 2015, there were two important key-point events: the Paris Agreement on Climate Change and the 2030 Agenda for Sustainable Development, which was set to promote the 17 SDGs. Therefore, the turning points in the production of scientific literature corresponded to some of the major international events, revealing an interaction between policymaking and scientific research.

The core journals publishing about SDs have as main subject areas the agricultural and the biological sciences, the environmental sciences, the social sciences, nursing, and medicine, confirming the interdisciplinary nature of this field and the connections between nutrition, health, food systems, agricultural production, and environmental protection as main subject areas.

Regarding the two terms 'sustainable diet' and 'sustainable nutrition', the first one was more highly related to environmental issues compared to the latter one, which was directly connected with health. The term 'sustainable diets' is broadly used as a phrase and is often characterized by additional adjectives (e.g., healthy). Furthermore, the geographic distribution of studies could be related to the different dietary patterns studied for their sustainability (e.g., the Mediterranean Diet and New Nordic Diet).

Notably, the countries belonging to the Mediterranean Region (Italy, Greece, Spain, and Portugal) had multiple publications in the relevant bibliographic collection. MD is a topic that has been highly studied by researchers in these countries. There was also identified a close collaboration between countries in the Mediterranean area (e.g., Italy and Spain). Mediterranean Diet was set as an example of SDs [28]. In this collection, 95 articles and reviews contained the term Mediterranean in their title, abstract, or keywords. Apart from its health benefits and economic viability, it has been studied as a dietary pattern with a low environmental impact [46–48], as its environmental footprints (energy consumption, water consumption, GHG emissions, and agricultural land use) and its ecological footprint are lower compared to that of other Western diets [49,50]. Interestingly, as mentioned by Gaforio et al., several studies have highlighted the beneficial healthy effects of extra virgin olive oil consumption for the prevention of several chronic diseases are highlighted making it a good choice both for human health and sustainable agriculture as verified by numerous clinical studies [51]. We also identified papers with different updates to the classic Mediterranean Diet Pyramid, the double pyramid model developed by the Barilla Center [49], and the updated Mediterranean Diet Pyramid [52]. Another considerable aspect of the Mediterranean Diet was the relevant indicators of its sustainability [27].

Alongside the MD, the New Nordic Diet (NND) was characterized as a sustainable diet in this collection (n = 13). It is a newly created diet with strong roots in Nordic culinary traditions, which principally aims at improving both human health and environmental health. Noticeably, it was founded in 2004 by a group of well-recognized Nordic chefs who set out to give prominence to regional, local products [53]. Although the NND mainly focuses on Denmark, Finland, Iceland, Sweden, and Norway, a new variant of the NND, called the Southern New Nordic Diet, has recently been discussed as a nutritional scenario in southern Europe (northwestern Spain and northern Portugal) [54].

In comparison with the Average Danish Diet, NND exerts significant environmental and social benefits [55]; however, it has been estimated as more expensive than other dietary patterns [56]; NND has been examined for potential effects on various aspects of childhood health and development [57,58], promoting healthy eating habits formed throughout pregnancy and infancy [59].

According to our findings, COVID-19 was found in the red cluster linked with MD (link strength = 9, total link strength = 109) (Figure 6). Given the various health advantages of the Mediterranean Dietary Pattern, it may be considered the most optimal dietary pattern for preventing COVID-19 infection in non-infected persons, as well as it could be rendered as an adjuvant therapy for improving disease outcomes while simultaneously favoring recovery in COVID-19 patients [60]. COVID-19 exerted a detrimental impact on food security, but it has also provided a 'window of opportunity' to initiate a shift to more sustainable diets in Palestine [61]. In this territory, the multiple crises alongside with COVID-19 pandemic influenced dietary and eating behaviors. Agricultural production and consumption were affected and limited on a local scale, and thus a policy for growing vegetables by households has highly been promoted for growing vegetables in spaces available close to peoples' homes. In Italy, during the first and second phases of the COVID-19 pandemic, there was a growing desire to consume certified sustainable food

products [62]. On the other hand, the lockdown caused significant changes in family dietary and eating patterns [63]. However, there are no adequate published studies so far to provide reliable and conclusive evidence about the potential benefits of MD against COVID-19. In this aspect, forthcoming studies are currently in progress, and they will publish their results in the next few years in order for more precise conclusion to be drawn in this topic.

Food security has widely been researched in 294 publications. As shown in Figure 5, a whole cluster is dedicated to this term, as it has extensively been studied due to the even more rapidly growing world population. Several human activities, such as the way governing food production and consumption, put the natural resources of our planet in danger, whereas climate change and environmental negative impacts are gradually being accelerated by unsustainable consumption choices [12]. Importantly, sustainability is linked to the viability of the food system, public health, and prosperity. Additionally, SDGs Agenda has increasingly promoted food security mainly by eliminating malnutrition [64–66]. Goal 2 of the SDGs is actually set to 'end hunger, achieve food security and improve nutrition'. FAO in Rome Declaration on World Food Security (1996) and in Declaration of the World Summit on Food Security (2009) set clear goals to eradicate hunger.

Climate change and greenhouse gas emissions constitute two terms that have been studied in relation to SDs since 2017, showing the impact of the Paris Agreement and the SDGs [67]. Alarmingly enough, climate change could also affect agricultural and livestock production [68,69]. Furthermore, greenhouse gas emissions could be associated with a reduction in agriculture and food production yields [70]. Therefore, it has been proposed that dietary changes may positively affect both human health and environmental health [71,72].

Meat production and consumption have attracted considerable scientific interest. At the same time, alternative sources of protein, such as edible insects, plant proteins, and legumes, have also appeared in the international scientific literature. Entomophagy is considered a controversial and alternative topic proposed mainly as a sustainable solution for protein intake in the fight against malnutrition [73–75]. Despite its long history in some cultures, the willingness to consume these novel food products remains still disputable [76,77]. Vegetarianism has also been studied as a plant-based diet with a low environmental footprint and a more accepted dietary pattern [75,78,79], whereas home cooking is studied as being more environmentally friendly and beneficial to health [80].

By observing the clusters emerging from the co-occurrence network, six separate categories have appeared: (1) a general overview of SDs with a focus on the environmental pillar, (2) a linkage SDs with human health, (3) sustainable nutrition and meat consumption, (4) SDGs with a focus on SDG 2 (Zero Hunger), (5) the environmental impact of dietary choices, and (6) consumer behaviors and plant-based food choices.

SDGs focusing on areas such as hunger, human health, and climate were identified as the most obvious beneficiaries of a shift toward sustainable food systems. However, there were found important linkages concerning food systems and less obvious linkages regarding SDGs, such as SDG 12 (Responsible Consumption and Production), SDG 3 (Good Health and Well-being), and SDG 11 (Sustainable Cities and Communities). The above findings support substantial evidence that food could be considered as a common thread linking all 17 SDGs. Earlier policymakers realized that reforming food systems may provide a potentially powerful lever for sustainable development, which may allow us to meet the SDGs.

4.2. Limitations and Future Research

There are certain limitations, mainly regarding the bibliometric analysis approach itself. We set a time limit for this study to the last 35 years by the first introduction of the term in the international scientific literature. However, it could be interesting to explore how the terms were used before that time limit and, in parallel, to study the thematic evolution throughout the previous decades if the documents before 1985 were digitally available. Second, in this study, the Scopus bibliographic database was used. However,

comparing the findings in other databases (for example, Web of Science, Dimensions) could provide additional information about the relevant study area. Beyond the limitations, the data in this study provide significant insights into the editorial activity of international scientific journals and the corresponding topics that have been discussed over the last few years. Moreover, this study clearly presents a quantitative analysis of the international scientific literature. Moreover, the present findings reinforce the fact that future research is strongly recommended to adopt a more qualitative approach.

5. Conclusions

This is the first bibliometric analysis study that provides a thorough overview of the international research concerning the currently available scientific papers on sustainable diets and sustainable nutrition published in peer-reviewed journals between 1986 and 2022. The research topics were answered by using two alternative methodologies. Firstly, a bibliometric analysis answered the questions regarding the article production growth in the field within almost 35 years, the trending topics, the journals, and their subject areas, as well as the geographic distribution of the studied papers. A co-occurrence network was derived to reliably identify the core author keywords and their relationships, while the trend topics and their evolution over time were explored. Secondly, a content analysis of the dataset was efficiently performed by using R-language to detect which SDGs were related to the terms under study.

Therefore, we have drawn the following main conclusions: The findings of this study clearly confirm the exponential growth of scientific interest in the undersigned subject area. Some of the turning points in the evolution of publications follow the international timeline of events, revealing whether they can impact scientific production. Considering the key components of SDs, the greatest emphasis of the scientific community in this bibliographic analysis was highly ascribed to food security, climate change, environmental impact (water footprint, carbon footprint, greenhouse gas emissions), food systems, and their sustainability, Mediterranean Diet, and Sustainable Development Goals. This study first presents a thorough overview of the current trends of the scientific community concerning the global interest in the SDs, which could be highly considered as an effective strategy to promote environmental sustainability and planet health.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su151511957/s1, Table S1: Main Scientific Events and publications (Burlingame et al., 2022 [12]); Table S2: The top 25 publishing countries in the SDs topic during 1986–2022.; Figure S1: Thematic Evolution using authors' keywords in in five time slices: 1986–2006, 2007–2011, 2012–2015, 2016–2019, 2020–2022.

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