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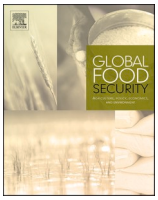

Uncovering research streams on agri-food supply chain management: A bibliometric study

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ABSTRACT

This study carried out a bibliometric analysis to critically review the evolution of the agri-food supply chain (AFSC) research field over the period of 2008–2019. A set of 1236 articles was analyzed from the Web of Science database. Besides using different analytical scientometric tools (topic mapping, co-citation, co-authorship and overlay visualization networks), this study identified frequently-used keywords, new and hot research topics and frequently-studied supply chain management (SCM) practices. Frequently used keywords are food supply chain, food waste, sustainability, food safety, SCM, food industry, and food security. New research themes include contract, blockchain, internet of things, resilience, and short food supply chain, a topic that demands further research especially due to the international COVID-19 pandemic and the need of farmers to be closer to the consumers. Hot research topics, that is, subjects that have been studied in highly cited papers were also identified include life cycle assessment, environmental impact, packaging, water use, food waste prevention, food waste generation, blockchain and carbon footprint. Among SCM practices, this study observed that risk and sustainable SCM are frequently used keywords. Procurement and reverse logistics were observed in fewer studies. SCM, food waste, food quality, GHG emissions and risk management are sustainable SCM practices frequently observed.

1. Introduction

Agri-business plays a critical role in the world economy (Sufiyan et al., 2019) since it is the key source of food supply to the world population. An agri-food supply chain (AFSC) comprises various stages related to supply, production, post-harvest, storage, processing, distribution, and linkages between components (Behzadi et al., 2018). The management of this kind of supply chain has received considerable attention over the last decades both from practitioners and researchers (Onggo et al., 2019).

The agri-food chain is a complex system responsible for moving agri-food products from the initial stages of production to the final stage of consumption (Zhao et al., 2019). Although AFSCs have similarities to conventional manufacturing supply chains, they have specific characteristics that make their management more challenging (Onggo et al., 2019). This is due to the fact that food is a perishable commodity. Ali et al. (2019) state that AFSCs have faced continuous challenges due to different factors such as food price volatility, climate controlled variability, food wastages, food and nutrition security, power and governance issues.

Previous studies have performed analysis or reviews on topics related to the AFSCs. Zhao et al. (2019) employed a systematic literature network analysis to review the state-of-the-art of blockchain technology in AFSCs. Their findings suggest that blockchain technology together with advanced information and communication technology and internet of things (IoT) have been adopted for the improvement of AFSC management in traceability, information security, manufacturing and sustainable water management. Dania et al. (2018) applied a systematic review to investigate the research on sustainable AFSC management grounded on Resource Dependency Theory and content analysis. As a result, 10 key behavioral factors to enable an effective collaboration system for sustainable AFSC management were identified. Bouzembrak et al. (2019) reviewed the use of IoT technology in food safety through a literature review bibliometric analysis. Chen et al. (2017) consolidated the state of the art of research on food waste, based on a bibliometric study. Bartolini et al. (2019) carried out a comprehensive overview and classification of the existing research on green warehousing and identified key trends.

In spite of a great number of reviews, to the best of our knowledge, no previous study has characterized the research community of AFSC as a whole, considering the characteristics of its publications and its scientific community. Understanding patterns of publication and

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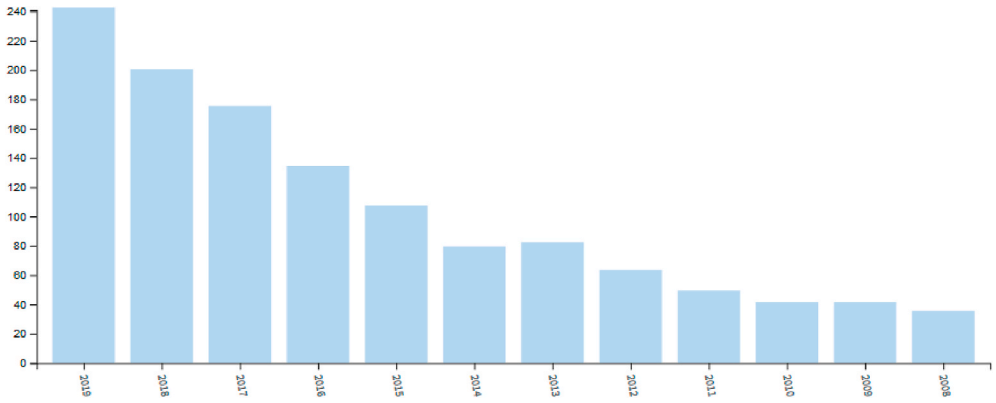

Fig. 1. Evolutionary trend in the number of publications covering Food supply chain.

collaboration may help direct new research and detect research gaps and trends. In order to fill in this gap, this study was aimed at critically reviewing the evolution of the AFSC research field over the period of 2008–2019, using data from the Web of Science (WoS) database. The characterization of the research field also includes the identification of supply chain management (SCM) and sustainable (SCM) practices studied in this research field. In particular, this study uses the following analytical scientometric tools: topic mapping, co-citation, co-authorship and overlay visualization analyses. The analyses were performed with the aid of the VOSViewer software, which has been successfully used in several bibliometric studies (Hernández-Torrano and Ibrayeva, 2020; Kosmützky and Krücken, 2014; Yilmaz et al., 2019).

This study presents several contributions to scholars and practitioners. To scholars, this work identified research trends to prepare for future AFSC studies. The identification of gaps in the study of SCM and SSCM practices might redirect future research efforts. Besides, the study can help developing international research collaboration alliances and projects. Comprehending the structure of the co-authorship networks in a research field is important to better understand how researchers interact and also to develop new partnerships with important individuals in the area (Gomes and Barbosa, 2018). Practical implications are identified to aid organizations, policy makers, investors, and institutions in understanding the themes that have been studied in the area.

The remaining sections of this article are organized as follows. Section 2 provides the theoretical background of this work. Section 3 describes the research method used and Section 4 presents and discusses the results found by this study. Finally, Section 5 finishes the article presenting our conclusions, research limitations and suggestions for further studies on the subject.

2. Theoretical background

The term “agri-food” is related to the business of producing food agriculturally. AFSC consists of all the activities involved in the movement of agricultural food from the producers/farmers to customers (Mangla et al., 2018). AFSC covers the entire chain of activities from production on the farm to processing, distribution, and retailing to the consumer (Naik and Suresh, 2018).

AFSC involves a complex network of stakeholders with common objectives such as ensuring food quality, food safety and sustainability. However, there are also conflicting goals such as inventory management (Sufiyan et al., 2019). The primary stakeholders who are directly involved in the logistics process in AFSCs are farmers, food industries, distributors, retailers, and consumers. Moreover, secondary stakeholders, such as government agencies, not-for profit organizations, food and industrial associations, and financial institutions are some of the indirect partners. Although these stakeholders do not necessarily engage in the supply chain activities, they often have various impacts on the business system and processes that manage material, information, and financial flows among all stakeholders (Dania et al., 2018). Chemical dealers, input suppliers, cooperatives that support farmers, transport companies, research institutions, importers and exporters are also stakeholders in AFSCs (Akhtar et al., 2016). Moreover, the society plays various roles in the agricultural sector, being both consumers and stakeholders (Mazur-Wierzbicka, 2015).

In addition to the general considerations of SCM, AFSCs often have to deal with issues surrounding perishability, product deterioration and waste. The products within these chains deteriorate in value and quality once they are produced (Chen et al., 2020). Agricultural systems show a high degree of variability due not only to their dependence on farm characteristics such as the type of soil, the availability of water and the climate, but also to the different management decisions and variety of agricultural practices (Ribal et al., 2019). In addition to challenges related to product deterioration, Chen et al. (2020) state that AFSCs also face increased regulation and environmental pressures, for example, those related to traceability, packaging, sustainability issues, waste reduction and recycling.

One common research subject in the AFSC research field is sustainability. AFSCs commonly face significant and complex challenges in achieving sustainable development, including economic, environmental, and social aspects (Dania et al., 2018), which are of increasingly awareness and growing concern for food production and consumption (Kamble et al., 2020). Socially responsible farmers should pay special attention to high standards for agricultural production, sustainable production, the welfare of farmed animals, food security, job creation, and the continuous development of employees (Mazur-Wierzbicka, 2015). There is also growing pressure on businesses and governments to pay more attention to the environmental and resource consequences of the ever-increasing production, distribution and consumption of agri-based products (Naik and Suresh, 2018). Such pressures corroborate the importance of understanding the characteristics of the AFSC research field.

3. Methodology

To construct the dataset for this bibliometric study, articles were extracted from the Web of Science (WoS) database. This database is recognized as covering a notable range of high-ranking journals and peer-reviewed articles of high quality (Skute, 2019). This methodological approach has been adopted in previous research (Ferramosca and Verona, 2020).

The topic of AFSC has been discussed using a number of terms in the literature depending on the context and focus of each study. Considering such variances and the objective of this study, the search was performed with the following string: *“agri* supply chain” OR “farm* supply chain”*

Table 1
Number of articles and citations by country.

Country	# of Articles	# of Citations	# of Articles Rank	# of Citations Rank
USA	226	3943	1	1
England	195	3838	2	2
Italy	151	2381	3	4
China	146	1754	4	7
Netherlands	110	3146	5	3
Germany	86	1894	6	5
Australia	71	1025	7	11
Spain	66	1248	8	7
France	58	845	9	13
Canada	56	856	10	12
Belgium	45	840	11	15
Sweden	44	1046	12	10
India	42	462	13	18
Scotland	32	740	14	16
Denmark	31	1220	15	9
Brazil	29	339	16	23
Switzerland	27	632	17	17
Finland	26	1242	18	8
Greece	24	754	19	15
Austria	22	311	20	26

Table 2
WoS categories.

Wos Category	#	%
Food Science Technology	313	25,32
Environmental Sciences	217	17,56
Green Sustainable Science Technology	146	11,81
Engineering Environmental	123	9,95
Operations Research Management Science	116	9,39
Economics	112	9,06
Management	103	8,33
Agricultural Economics Policy	102	8,25
Engineering Industrial	102	8,25
Environmental Studies	85	6,88

OR "food supply chain". The search was performed for journal articles, published in English between 2008 and 2019. An amount of 1236 unique articles were found. Therefore, a quantitative bibliometric study is suitable since it can examine this amount of data, which would be unapprehensive, time-consuming, and overwhelming to analyze with scrutiny otherwise.

The network visualization was achieved through VOSViewer software (van Eck and Waltman, 2010). Unlike programs such as SPSS and Pajek, which are commonly used for bibliometric mapping, VOSviewer pays special attention to the graphical representation of bibliometric maps. Besides, VOSviewer is especially useful for displaying large bibliometric maps in an easy-to-interpret way (van Eck and Waltman, 2010).

4. Results and discussions

4.1. Sample profile

As explained previously, 1236 were retrieved on the research subject. Fig. 1 presents the number of articles published between 2008 and 2019. An exponential growth in the publication of studies on AFSC can be observed.

The vast majority of the studies were published by affiliated authors from USA universities. Other countries with a relevant number of publications on the theme are England, Italy, China, and Netherlands. Considering the number of citations, USA authors have been more frequently cited. Table 1 displays the number of articles and citations by the 20 countries with more publications on the subject. One can also observe that country ranking for the number of articles does not exactly correspond to the country ranking for citations. Finland researchers, for instance, are positioned in 18th considering the number of articles, but are ranked 8th when the number of citations is taken into account.

Table 3
Leading journals – Co-citation.

Journal	Publisher	Citations	Impact factor	Best rank	Number of articles
International Journal of Production Economics	Elsevier	1275	5.134	Q1	39
Journal of Cleaner Production	Elsevier	1275	7.246	Q1	66
Food Control	Elsevier	791	4.258	Q1	41
European Journal of Operational Research	Elsevier	775	4.213	Q1	10
Food policy	Elsevier	770	4.189	Q1	25
Supply Chain Management	Emerald	633	4.725	Q1	11
British Food Journal	Emerald	549	2.102	Q2	76
American Journal of Agricultural Economics	Wiley	506	3.028	Q1	3
International Journal of Production Research	Taylor & Francis	473	4.577	Q1	20
Journal of Rural Studies	Elsevier	452	3.544	Q1	9
Journal of Food Engineering	Elsevier	420	4.499	Q1	10
Trends in Food Science & Technology	Elsevier	290	11.077	Q1	4
International Journal of Life Cycle Assessment	Springer	287	4.307	Q1	8
Resources, Conservation & Recycling	Elsevier	285	8.806	Q1	17
Sociologia Ruralis	Wiley	277	2.540	Q1	8
International Journal of Operations & Production Management	Emerald	273	4.619	Q1	4
Journal of Food Protection	International Association for Food Protection	266	1.600	Q3	4
International Journal of Food Microbiology	Elsevier	256	4.187	Q1	4

Table 2 depicts the distribution of papers in terms of WoS Categories. It is possible to observe that research has been mainly published in journals under the categories of Food Science Technology, Environmental Sciences and Green Sustainable Science Technology. Publication in Operations Research Management Science and other Management-related journals is also relevant.

4.2. Co-citation analyses

A co-citation exists when two references appear together in the same publication. The number of co-citations defines the content similarity between two documents. The more co-citations two documents have,

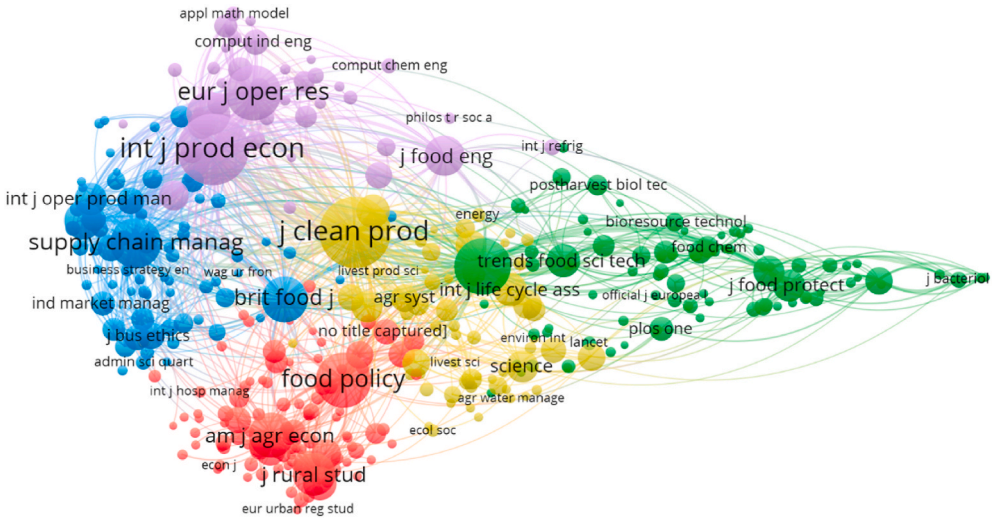

Fig. 2. Journals co-citation networks.

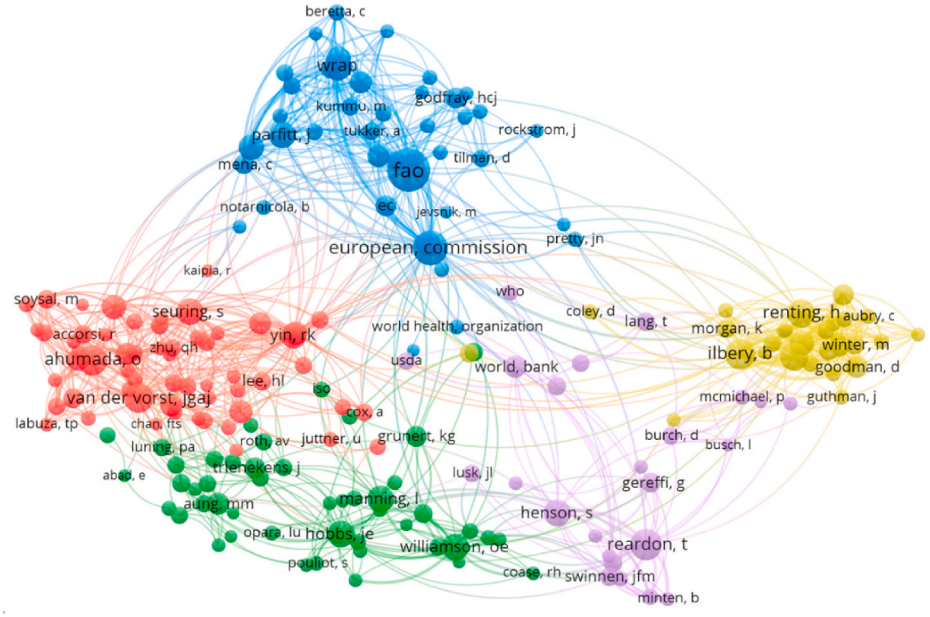

Fig. 3. Researchers co-citation analysis.

the higher the degree of similarity between them (Mora et al., 2019). When two references or two journals are more strongly related, they are more frequently cocited (Barbosa et al., 2017; Ferramosca and Verona, 2020).

In a co-citation network, nodes represent the cited articles and links between nodes represent the number of times citations appeared together in the articles of the dataset. In this study, we produced journals and authors co-citation networks. First, journal co-citation networks were produced. Table 3 displays the top leading journals in terms of co-citations that have published articles that are in the analyzed dataset. Along with the number of citations, the number of articles published in each journal is also displayed. The journals that have published more articles on AFSC are the British Food Journal and the Journal of Cleaner Production. Table 3 also displays information on the quality of these journals: their impact factor (year 2019) and best rank according to the categories in which they are indexed in Web of Science. The impact factor of a journal reflects the annual average number of citations to recent articles published in that journal (Garousi and Fernandes, 2017). The vast majority of journals is positioned in the first quartile of at least one WoS category.

Our journal co-citation map provides an overview of the structure of the scientific world. Clusters of related journals can be identified in the map, and these clusters can be linked to scientific fields. Clusters that are located close to each other in the map indicate closely related fields (van Eck and Waltman, 2010). Fig. 2 shows the journal co-citation network for this period of time. It clearly depicts 5 clusters of journals. The cluster on the top side is formed by journals in the fields of Operations Management, Engineering and Computer Science, such as International Journal of Production Economics and European Journal of Operational Management. The cluster on the left side is composed of journals of different scopes and is centered around the Supply Chain Management journal. The cluster on the bottom of Fig. 2 comprises journals related to Agriculture, such as Food Policy, American Journal of Agricultural Economics and Journal of Rural Studies. The fourth cluster, at the center of Fig. 2, is organized around the Journal of Cleaner Production. The fifth cluster, on the right side, comprises Food Science journals, such as

Table 4
Leading authors – Co-citation analysis.

Author name	Number of citations in the dataset	Google Scholar		
		Number of citations	h-index	i-10 index
Thomas Reardon	108	35413	86	266
Jack G.A.J. van der Vorst	93	9212	48	103
Henk Renting	84	8592	28	40
Jill E Hobbs	82	7241	42	100
Louise Manning	80	1993	24	43
Stephen Seuring	77	20632	58	108
Kannan Govindan	69	27767	91	232

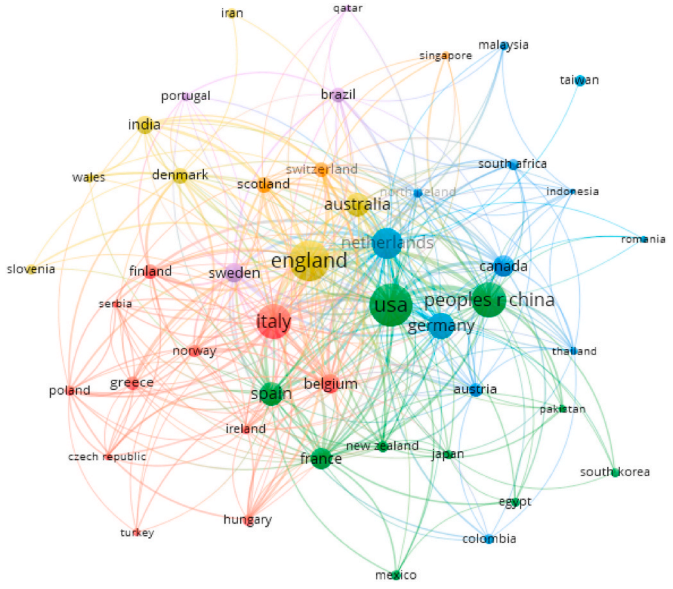

Fig. 4. Co-authorship country networks.

Trends in Food Science & Technology and Journal of Food Protection.

Then, researchers co-citation networks were produced. In terms of co-citations, international institutions have received the highest number of co-citations. The first two positions are occupied by the Food and Agriculture Organization (FAO) and the European Commission. Other prominent researchers are Thomas Reardon from Michigan State University and Jack G.A.J. van der Vorst from Wageningen University. Fig. 3 shows the authors' co-citation network. Again, 5 clusters can be identified. FAO and European Commission are located at the cluster on the top. As it can be seen, there is not a researcher whose number of co-citations is quite superior to the others.

It is difficult to make a merit list for authors (Sahoo, 2016). However, some productivity measures account for not only the total number of publications but also the quality of the researchers' work. Some of these measures are the h-index and the i-10 index. The h-index is an author-level metric that measures his/her productivity and citation impact of his/her publications. It is considered the best-known and most commonly used scientific performance for researchers. An author has an h-index h if h of his/her papers have at least h citations each, while the remaining papers have no more than h citations each. As so, this index is based on the ordered list of the researcher's most cited papers and the number of citations that he/she has received in other publications (Garousi and Fernandes, 2017; Simoes and Crespo, 2020). The i-10 index represents the number of publications by an author that have at least 10 citations each. These composite measures provide a more accurate representation of scholarly activity (Susarla et al., 2017). Table 4 shows the leading authors in terms of co-citations as well as their

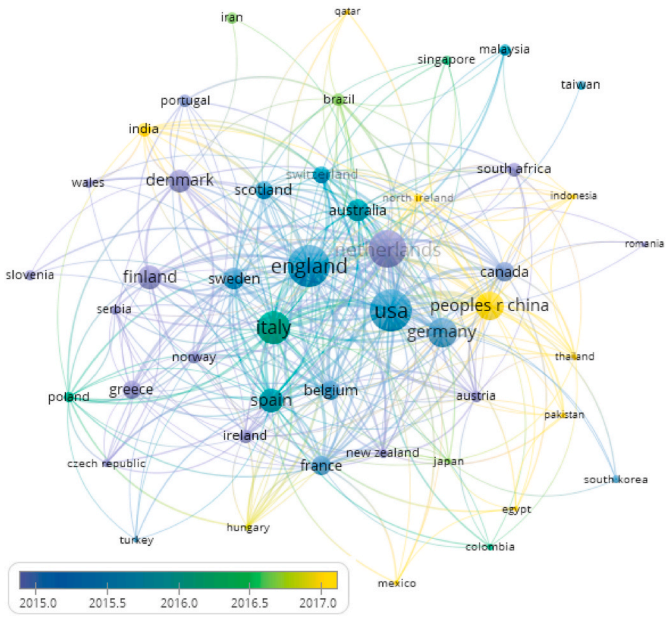

Fig. 5. Co-authorship country networks (overlay visualization).

productivity indexes (h-index and i-10 index). Table 4 considers only researchers that have published papers in the analyzed dataset of articles and that have accounts in Google Scholar, the platform from where these indeces are obtained.

4.3. International networks: co-authorship analyses

The recognition obtained from authorship of a scientific publication is a key element of how science works. The analysis of co-authorship enables the construction of observable and visual measures of a research field community. While citation analysis might help identify the central and important scientific papers of a research field, co-authorship analysis identifies who the important scientists are (Gomes and Barbosa, 2018; Hu and Racherla, 2010). In a co-authorship network, nodes represent authors and a connection between two authors exists if they have co-authored a study. Co-authorship networks showing collaborations among countries were produced. During 2008–2019, 47 countries that published studies in this research field met the threshold of 5 publications. Fig. 4 shows the country co-authorship network for this period of time. It is possible to observe 7 clusters. USA and China are located at the same cluster. Other countries located at the same cluster are England and Australia, Italia, Finland and Greece, and Netherlands and Germany.

VOSviewer also supports overlay visualizations, in which the color of a node indicates some property of the node (van Eck and Waltman, 2014). Fig. 5 depicts an overlay visualization of the co-authorship country network, considering when the node was first introduced in the network. Countries represented in blue have been publishing studies on AFSC since 2013 or before. Countries depicted in yellow have recently arrived to the community. China, India and Brazil were new members while Finland, Slovenia and Ireland are older members in this research community.

4.4. Text-mining abstracts and titles: Topic mapping analysis

In addition to the above-discussed citation-based and co-authorship networks, co-occurrences of keywords have also been studied. The number of co-occurrences of two keywords is the number of publications in which both keywords occur together in the title, abstract, or keyword list (van Eck and Waltman, 2014). In this study, keywords were extracted from the author-supplied keyword list of publications.

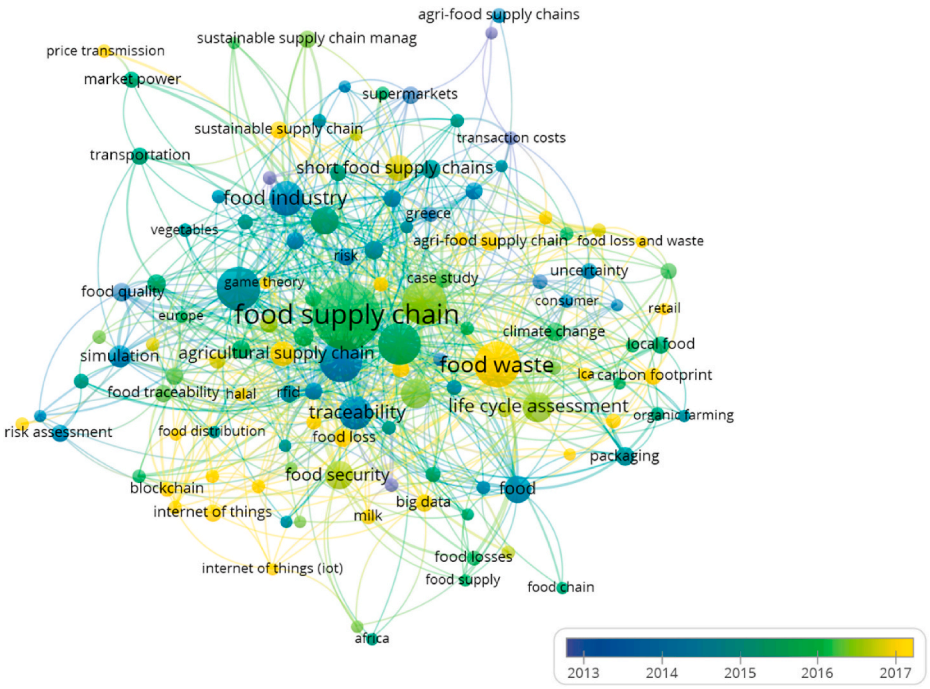

Fig. 6. Topic mapping analysis.

Keywords are not restricted to individual words; they also include terms consisting of multiple words. Fig. 6 depicts the topic mapping overlay network of articles keywords. In terms of keyword occurrence, relevant words in this network are food supply chain, food waste, sustainability, food safety, supply chain, supply chain management, food industry, traceability, agriculture, life cycle assessment and food security. Research on themes represented by these words is discussed as follows.

Food waste, an important research subject in the field, is a major global challenge not only from an ethical and social point of view, but also from environmental and economic ones (Caldeira et al., 2019). Literature on the subject recognizes two classes of waste: waste from inputs, such as water or fertilizer, and waste due to the incomplete conversion or processing of materials in the supply chain, from crop production to food consumption (Belaud et al., 2019).

Different stakeholders increasingly agree on the necessity of reducing food waste. Public, private and social institutions have been working towards this direction, generating and implementing alternative actions (Diaz-Ruiz et al., 2019). Food waste prevention measures can be taken in different scales (national, regional and local), involving different institutions, and include actions that vary from consumer awareness campaigns to new social enterprise models (Diaz-Ruiz et al., 2019). Food waste reduction efforts have two different focus: prevention of food from being wasted in the first place and diversion of wasted food from landfills for beneficial non-human uses (Dou et al., 2016).

In order to minimize food wastage, risk assessment techniques can be employed. They involve identifying and assessing supply chain risks and developing risk mitigation strategies and business continuity management plans. According to Ali et al. (2019), despite the importance of risk

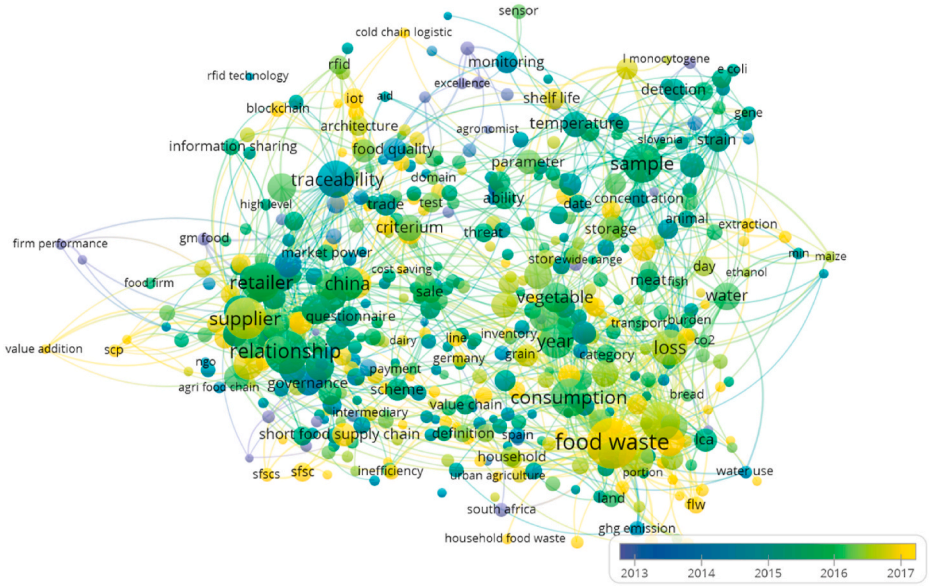

Fig. 7. New research topics.

management activities to prevent food waste, literature that combines both AFSCs risks and food waste is not current or well established. This should be explored by future studies.

Food waste is also associated with sustainability concerns, since the food system currently lies at the center of a global nexus of social, environmental and economic problems. Besides the world has to deal with several challenges such as sustainable food security in the face of human population growth, ecosystem degradation, resource scarcity and climate change (El Bilali, 2019). A sustainable AFSC is based on achieving a balance between economic growth, environmental protection, and social development (Kamble et al., 2020). In order to achieve such goals, AFSCs must eliminate current inefficiencies and focus on more sustainable production (Banasik et al., 2019).

4.5. Trend subjects: overlay visualization analysis

The identification of research tendencies was performed by identifying new and hot research topics. New words represent terms that have only recently been used as keywords. Hot research topics are research subjects that have been analyzed and discussed in highly-cited articles. The identification of new and hot research themes was done by mining the title and abstract of the published articles and such themes were displayed using overlay visualization networks.

To identify new research topics, we used a time-based overlay visualization mapping for all titles and abstract words over the period of 2008–2019. In Fig. 7, the color of a node indicates when the word was introduced in the network. To discern new topics from old ones, the terms were matched with the publication year for the paper from which they are mined. The colors range from dark blue to yellow to refer to old and new topics, respectively. Colors ranging from blue to dark green correspond to older topics. Words represented from light green to yellow represent new terms. The older the term, the closer to blue it is. As shown in Fig. 7, the newest terms include food waste, food loss, carbon footprint, contract, blockchain, IOT, resilience, short food supply chain, cold chain and sustainable supply chain. Some of these words were also identified in the word network for keywords used by authors, presented previously. However, some of them require further discussion.

Blockchain technology (BCT) emerged in 2008 as a core component of the bitcoin cryptocurrency. Blockchains provide transactional, distributed ledger functionality that can operate without a centralized trusted authority (Galvez et al., 2018). It is viewed as one of the most important technology trends influencing businesses (Behnke and Janssen, 2020). Blockchains introduced serious disruptions to the traditional business processes because applications and transactions needed centralized architectures or trusted third parties to verify them. With BCT they can operate in a decentralized way with the same level of certainty (Casino et al., 2019). A blockchain is a concatenation of data, which is combined into individual blocks and stored on all of the users' computers. This sequence of data into blocks results in a sequence that reflects the course of transactions in the form of a chain. The data blocks are protected against subsequent changes with cryptographic methods (Tönnissen and Teuteberg, 2020).

Blockchain can be used in the supply chain to store and share data, like those related to location, time, temperature, and humidity levels, with other parties and to compare the data received with other node data, or outside data, for verification (Bumblauskas et al., 2020). The AFSC can benefit from the blockchain concept because it brings transparency, efficiency, security and safety (Galvez et al., 2018). Safety is guaranteed since sensor networks verify most of the information being uploaded, so it becomes much more difficult for a party to be dishonest about where the product is coming from (Bumblauskas et al., 2020). For final customers, BCT provides more detailed information of agri-food products from farm to their homes (Zhao et al., 2019). Despite its increasing use and benefits, BCT adoption in AFSCs faces some challenges such as the need of data standardization, governance mechanisms, enhancement of the technology to deal with large amounts of data and privacy mechanisms to protect users (Pearson et al., 2019).

BCT enables instant traceability of data. Traceability is one of the keywords considered as new research topics, depicted in Fig. 6. Different technologies have been used over time for tracking products through the supply chain. The major traditional food traceability technologies include Radio Frequency Identification Devices (RFID), Barcode readers, isotopic technologies, and firm specific traceability mechanisms (George et al., 2019). Considering food traceability as part of logistics management emphasizes the fact that food safety and quality are concerns strongly dependent on logistics operations (Behnke and Janssen, 2020).

Resilience was identified as one of the new research streams. Supply chain risks and resilience are a consolidated research stream in the area of SCM. Since there are so many disruption risks that may threaten supply chain operations, being able to develop resilience may be a real

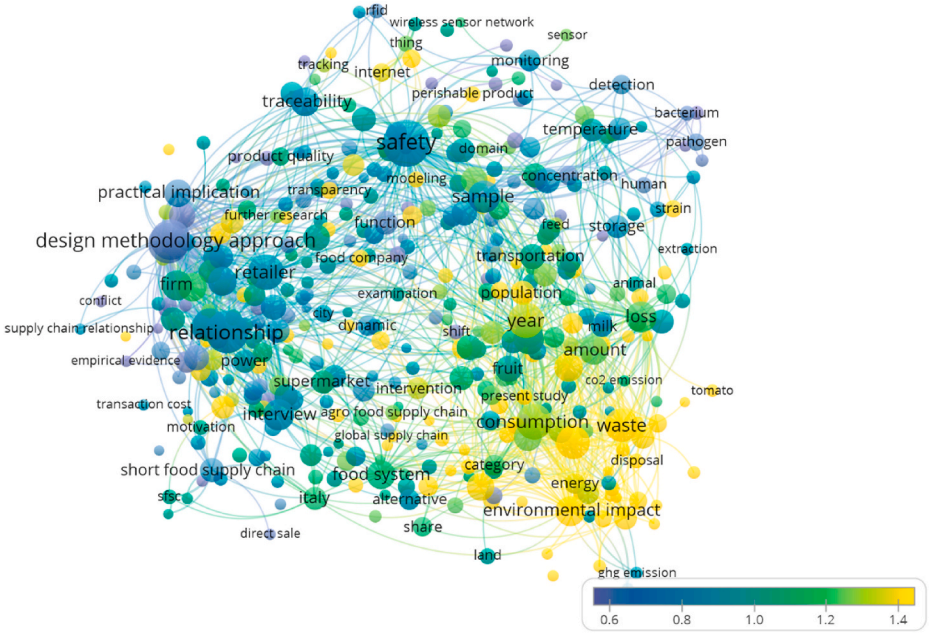

Fig. 8. Hot research topics.

competitive advantage. In this context, companies are stimulated to dedicate effort and resources in business continuity plans to face economic and environmental turbulences (Bottani et al., 2019). This is especially true in the context of AFSC since these chains are among the most vulnerable and fragile since such risks could have terrible consequences on health and safety aspects affecting final customers (Bottani et al., 2019). In an AFSC, risks are mostly related to weather, biological/environment, logistical/infrastructure, market, policy/-regulation, financial, and operational/managerial factors (Zhao et al., 2020).

Other new research topic, according to this study, is short food supply chains (SFSCs). Due to concerns with a loss of biodiversity, deforestation, soil and water pollution, AFSCs have led food producers to develop new initiatives (Aggestam et al., 2017) to cope with new customers and environmental demands. SFSCs are based on local cooperation between farmers and consumers and are considered as promising alternatives to conventional agri-food systems. These chains are food supply schemes in which farmers sell their products to consumers directly or with the intervention of only one extra node (Lioutas and Charatsari, 2020). The shorter distances within the chain aim at producing economic gains, as well as achieving social and cultural goals like health and environmental care, and strengthening of cultural bonds through a friendly and communitarian pattern of consumption (Sellitto et al., 2018). Products commercialized through these networks are also embedded with information, allowing consumers to understand how and where food is produced, enabling the formation of a stronger bond of trust between consumers and producers (Aggestam et al., 2017). We agree with Cappelli and Cini (2020) who state it is essential to develop and improve research to provide technical solutions for SFSCs and local productions. This is particularly true in the current context of international COVID-19 pandemic. SFSCs might feel less the effect of international restrictions and are closer to the consumers.

The identification of trend subjects in AFSC research also includes the identification of hot research topics. The concept of a hot topic is a research subject that is being analyzed and discussed in highly-cited articles. To develop a map of the hottest topics in AFSC, a citation-based overlay visualization mapping of all keywords was used, whose relatedness depends on the number of times they occur together in publications over the period of 2008 and 2019. To identify the hot topics, the citation score of a paper in which the term appears was matched with topic clusters. The citation score of the paper was normalized, and a score of 1.0 was derived when a document citation number was equal to the average of all documents published in the same year. The corrected citation scores of all documents from which the terms were mined are then averaged with the coldest topics colored in dark blue (score 0.6) and the hottest topics in yellow (score 1.4). This same procedure was adopted in previous studies (Ferramosca and Verona, 2020). Fig. 8 shows the network for hot topics. Among them, one can observe the words: food waste, loss, waste, LCA (life cycle assessment), environmental impact, packaging, water use, food waste prevention, food waste generation, carbon footprint, architecture and blockchain.

Since most of these terms have been discussed before, attention will be called to the subject of Life cycle assessment, which is considered to be a powerful tool for assessing the environmental effects of any product, unit process, or system of processes. Its application includes, but is not limited to impact assessment, uncertainty analysis, and sustainability investigation (Mahmud et al., 2020). Besides being an effective method to analyze environmental performance, LCA also provides important factors for technical and economic comparison and political decision making (X. Zhang et al., 2020b). The subject is gaining prominence in practice for addressing sustainability-related challenges in production and consumption (A. Zhang et al., 2020a). LCA has been recognized as a sophisticated approach to evaluate the overall impact of a process and related products through its life cycle from an environmental viewpoint. LCA is being performed in different sectors for an optimal evaluation and comparison purposes (Parra-Saldivar et al., 2020). Due to all these reasons, LCA is considered a hot topic in AFSC.

Table 5
SCM practices and dimensions.

SCM Dimension/Practice	# of occurrences	Reference
Distribution Management	2	APICS (2017)
Information Management	2	
Inventory Management	1	
Training	2	
Procurement	4	
Reverse Logistics	3	
Risk	11	
Sustainable Supply Chain Management	10	

4.6. SCM and SSCM practices

SCM is implemented through the execution of different SCM practices. Li et al. (2005) define SCM practices as the set of activities undertaken by an organization to promote effective management of its supply chain. Jabbour et al. (2011) observed that there is not a pattern in defining SCM practices. In general, SCM practices involve different types of relationships, best practices related to SCM processes, and the use or dependency of technology. Due to the vast variety of definitions regarding SCM practices, we have used the practices defined by the Supply Chain Operations Reference (SCOR) Model (APICS, 2017) as a reference. Some of these practices have been used as keywords in the set of articles studied. Table 5 shows the keywords considering SCM practices and dimensions identified, considering keywords provided by authors. Among the frequently used keywords, we can highlight the use of risk and SSCM. Procurement and reverse logistics were also used, but in fewer studies.

Risk and SSCM were discussed previously because they were also considered frequent and new research streams. Reverse logistics is “the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal” (Govindan et al., 2014). In reverse logistics, the closing loop of supply chains provides a feedback flow from the point of consumption to the point of origin to return items after they served their original purpose (Taghikhah et al., 2019). Sufiyan et al. (2019) highlights the importance of reverse logistics in AFSCs by stating that its processes should be executed efficiently and effectively since food must be provided to the consumer on time, due to its short shelf life and sensory features like taste, odor, and appearances.

Procurement is discussed in the literature as a mechanism to implement and control collaborative relationships among supply chain partners (Sancha et al., 2016). In AFSCs, it has been argued that networks involving business actors, such as government support agencies and third level institutions, are critical to successful and sustainable rural development (McKitterick et al., 2019). As a key stakeholder in AFSCs, farmers typically experience limitations in business skills, so they need to recur to an integrated collaboration system (Dania et al., 2018). In order to participate in such collaborative networks, social components such as trust in and satisfaction with AFSC partners are necessary. Trustworthy and satisfied agri-food growers and market agents constantly add value by coordinating their supply chain activities (Akhtar et al., 2016). The word “contract”, a mechanism that can be used to govern such relationship has been previously identified as a new research topic, which corroborates the relevance of Procurement as a research topic in the area.

Although not recognized by the SCOR Model as a SCM practice, Collaboration is recognized by several authors as an important SCM practice (Jabbour et al., 2011). It is also considered in the literature as a SSCM practice, those that include enhancement of relationships between

Table 6
SSCM practices.

SSCM Practice	# of occurrences	References
Supply chain management	57	Beske et al. (2014)
Collaboration	3	
Risk management	10	
Productivity	4	Kamble et al. (2020)
Revenue sharing	1	
Food quality	12	
Food waste	69	
GHG emissions	11	
Water footprint	5	
Collaboration	3	
Transparency	6	

the partners, the flow of goods and information and issues of sustainability (Beske et al., 2014). Due to the importance sustainability has in the AFSC research field, this study extended the identification of SCM practices to SSCM practices as well. In order to identify keywords that represent SSCM practices, we have used two studies as references (Beske et al., 2014; Kamble et al., 2020). Table 6 shows the keywords related to SSCM practices and dimensions identified, considering keywords provided by authors. Among the frequently used keywords, we can observe food waste, SCM, food quality, greenhouse gas (GHG) emissions, and risk management.

5. Conclusions

This study carried out a bibliometric analysis using different techniques such as topic mapping, co-citation, co-authorship and overlay visualization of the AFSC research field. A set of 1236 articles from the Web of Science database was analyzed with the objective of characterizing the area as well as identifying research tendencies. This study has found out that USA researchers' studies have been more cited. China, India and Brazil have been recently incorporated to the co-authorship network. Frequently used keywords identified are food supply chain, food waste, sustainability, food safety, supply chain management, food industry, and food security. New research themes include contract, blockchain, internet of things, resilience, and short food supply chain. Some of the hot research topics identified are life cycle assessment, environmental impact, packaging, water use, food waste prevention, food waste generation, blockchain and carbon footprint. In terms of SCM practices identified, considering keywords provided by authors, this study observed that risk and SSCM are frequently used keywords. Procurement and reverse logistics were observed in fewer studies. SCM, food waste, food quality, GHG emissions and risk management are SSCM practices frequently observed.

No bibliometric review can provide a perfect picture of the development and current status of the field. This study's findings are limited in scope because the search approach used to create the corpus of literature on AFSC research might have excluded some relevant studies. Future studies might consider expanding the findings of this research by using alternative databases, for example, Scopus and including additional types of publication other than journal articles. Besides, in order to identify SCM and SSCM practices, this study relied only on keywords provided by authors. Although keywords represent central topics related to a paper, the absence of a word in a keyword list does not imply that the paper is not related to that word (or practice in this study). Articles' abstracts can also be analyzed with different text mining techniques such as Centring Resonance Analysis (CRA) (Barbosa et al., 2017; Baumeister et al., 2020) to characterize research topics. Anyway, in order to deeply understand and assess the SCM/SSCM practices adoption in AFSCs, a different research methodology would have to be used, like a systematic literature review. In spite of these limitations, we believe that this study provides a comprehensive analysis of the AFSC research community that offers interesting and useful insights about the development of the field and its current situation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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