



Review

# Inventory Models in a Sustainable Supply Chain: A Bibliometric Analysis

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**Abstract:** This paper presents a bibliometric analysis of inventory models in a sustainable supply chain. The methodology contains reviewing previous research with a performance evaluation, network analysis, and science mapping to identify the applications, trends, and future research topics. Scientific mapping examines the periods and volumes of publications, authors, journals, countries, regions, organizations, subject areas, and citation analyses. The dataset was obtained with the Scopus database and analyzed using MS Excel and VOSviewer. The search equation identified 335 research papers, which resulted in 131 significant manuscripts on the subject after being screened and filtered. The most notable countries in developing research were Iran, India, China, the United States, Canada, Taiwan, France, the United Arab Emirates, Turkey, and Denmark. Saha, S., Ajay, S.Y., and Baboli, A. were the most cited authors. The journals that publish the most research were *Sustainability*, the *Journal of Cleaner Production*, and the *International Journal of Production Economics*. Some research focuses on reducing carbon emissions and polluting agents applied in different industries in China, Brazil, India, and others. The main findings were the number of industry sectors researching this topic, increasing the number of publications, and promoting the proper use of resources within a sustainable supply chain. There are many investigations of theoretical models that have applications in real-life cases. There is also evidence of the high importance of promoting sustainable development. The emissions regulations in a green supply chain applied to agricultural products have allowed for more actions to achieve responsible production and consumption, as seen in applied research in the pulp and paper industry.

**Keywords:** sustainable supply chain; inventory model; green supply chain; sustainable logistic



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## 1. Introduction

The bibliometric analysis applied statistical methods to overview scientific production related to a subject area, research fields, applications, and research opportunities [1,2]. Technology and increased customer expectations and demands have led to developing solutions from inventory approaches to ensure customer responses. Some studies have examined inventory models, which have allowed better results when executing the different processes in organizations [3]. The new technological era requires more significant dynamics in inventory management to identify the timely and adequate availability of goods and products. Additionally, the support of industries for green routes, sustainability, reuse, and awareness of caring for the environment has increased, thus generating research on inventory models aimed at Sustainable Supply Chains (SSC) [4]. Inventory models applied in SSC allow for optimizing costs, improving marketing or production, making good use of available resources, and considering sustainability and the environmental impact [5].

Inventory models contribute to the complete decision-making process within a supply chain [6]. The supply chain integrates manufacturers, distributors, and retailers working together to achieve greater efficiency. Furthermore, the supply chain is crucial for the arrival of goods to society, and it has significant implications for the use of energy and other resources [7]. A sustainable supply chain combines environmental management and supply chain management, which aims to reduce and mitigate the deterioration of nature, the consumption of natural resources, waste, and pollution, with solutions that consider the rational impact on the environment [8]. Inventory models contribute to the appropriate use of resources in a supply chain. They consider volumes, the availability to respond on time to consumers/customers, reducing costs, storage, and the dispatch of goods and products.

Some authors have studied the sustainable supply chain applied to different processes. Brandenburg et al. [9] presented a review of sustainable supply chain management modeling, considering model types, solution techniques, the industry focus, and sustainability dimensions. Ansari and Kant [4] developed a review of the sustainability approach in the supply chain. This study identified risk management, information transparency, and green inventories as the most influential framework in sustainable supply chains. Nikolopoulou and Ierapetritou [8] studied the effect of sustainable goals on the chemical process, including energy efficiency, environmental management, water, reverse logistics, inventories, and waste disposal.

Pahl and Voß [10] examined the effect of the deterioration process on inventory models, considering planning functions such as replenishment, aggregate production, inventory reflow, disposal, and recycling. This research proposed to include deterioration and perishable items into a multi-level supply chain to analyze the effect on the business process. Duque-Urbe et al. [11] developed a systematic review for a sustainable supply chain in hospitals, analyzing the strategy, processes (supply, purchase, warehouse, inventory, and transport), information, resources management (energy, water, and food), and others hospital practices. The research analyzed the economic, environmental, and social performance of hospitals.

Wen et al. [12] developed a bibliometric analysis of the evolution of supplier management, including sustainability, social responsibility, and knowledge management. This study indicated that inventory control and a vendor-managed inventory (VMI) strategy is essential for supplier management. Tang et al. [13] studied the effect of carbon emission (price/taxes, trades, and cap) in a transportation and inventory model considering the multiplayer dynamic game. Moreover, Ghosh et al. [14] analyzed the effect of carbon emission in production-inventory models for a sustainable supply chain. Consequently, Becerra et al. [15] developed a systematic review of quantitative models for sustainable supply chains and classified the articles based on the supply chain configuration, mathematical models, simulation, and algorithms. Pattnaik et al. [16] developed a literature review related to the greenhouse gas emissions consideration in inventory management publications. This research showed the relevant contributions related to the type of inventory model, GHG emission, and findings.

Supply chain sustainability has been considered in many studies in recent years. An important area that links logistics and sustainability is the management of green supply chains. This area provides a strategic approach to the environmental impact, resource efficiency, and operational processes [17,18]. This approach considers the flows of materials, information, and services that keep the environment sustainable [19]. The green supply chain generally generates strategies that affect decision-making with gas emissions, storage, deteriorating products, and remanufacturing processes.

Chung and Wee [20] and Wee et al. [21] investigated a production inventory problem, including green product design and the remanufacturing process, to reduce the adverse effects of the short life cycle of perishable products. Lin and Lin [22] and Widyadana and Wee [23] developed an inventory model to minimize the total supply chain costs, considering defective items and remanufacturing processes. Karimi et al. [24] studied the traveling agent problem in a green supply chain. The authors considered gas emissions, storage,

and supplier selection. Khatua et al. [25] developed a production-inventory model for a three-layer green supply chain considering uncertain holding costs and deteriorating items.

Bai et al. [26] studied a sustainable supply chain with deteriorating items, carbon policies, time-varying demand, and promotional effort considerations. Yang et al. [27] proposed a green supply chain for perishable food, including resources and energy reduction. Saxena et al. [28] examined a vendor–buyer problem with remanufactured items and the allowable delay of payments as a green supply chain strategy. Moreover, Taleizadeh et al. [29] included coordination contracts and the price-dependent demand to reduce carbon emissions in a green supply chain. Rani et al. [30] and Panja and Mondal [19] developed a fuzzy inventory model including the carbon-dependent demand, recycling, reverse logistics, remanufacturing, and credit period.

Inventory control improves environmental performance and reduces greenhouse gas emissions [31]. Most inventory models developed in sustainable supply chains have considered carbon emission reduction strategies. Martí et al. [32] proposed an inventory model including decisions with carbon footprints, the market, and taxes to improve procurement, production, transport, and storage processes. Sepehri and Sazvar [33] developed an inventory model for deteriorating products and greenhouse emissions under uncertain demand, backorders, sustainability criteria, different vehicles, and paths for transportation.

Kang et al. [34] included a shipment policy to reduce emissions, and Gautam et al. [35] incorporated an imperfect production system, carbon emissions, backorders, and defect management techniques. Lu et al. [36], Mokhtari and Rezvan [37], and Bazan et al. [38] examined a vendor-managed inventory (VMI) model with a greenhouse gas emission factor. Halat and Hafezalkotob [39] analyzed the inverse relationship between inventory costs and carbon emission. Moreover, Pan et al. [40] included carbon emission reduction policies, delivery, and technology in a production-inventory model to maximize the profits of a supply chain. Taleizadeh et al. [41] considered carbon emission policies related to inventory, delivery, storage, and the environmental impact.

Some authors have included information sharing as a strategy to reduce supply chain costs. Khan et al. [42] proposed an inventory model for a single-vendor and single-buyer supply chain integrating environmental and social considerations about profits, shortages, quality, health, and safety. Cui et al. [43] considered radio frequency identification (RFID) to improve the information sharing between the supply chain members.

This research was developed to analyze the academic and scientific literature related to sustainable supply chains and inventory models. This study seeks to answer the following questions: (i) What are the most representative articles, authors, and journals in inventory models for sustainable supply chains? (ii) What organizations, countries, and institutions generate more contributions related to sustainable supply chains? (iii) What are the main research clusters? (iv) How is a sustainable supply chain affected by inventory control? (v) How can the remanufacturing process, greenhouse gas policies, and information sharing improve inventory management in sustainable supply chains? (vi) What are the top strategies and future research lines in sustainable supply chains?

This bibliometric analysis allows for determining how the trends of the publications are related to the global sustainable development goals and global policies. The contributions of this paper that distinguish it from other research are as follows: (1) This study contributes to the literature on inventory models because it allows for analyzing the performance and scope of inventory control in sustainable supply chains. (2) The implementation of greenhouse gas policies, carbon emission regulations, sharing information, remanufacturing, and deterioration processes were analyzed to improve the performance of sustainable inventory management. (3) This research presents the applications of inventory models in different industries, showing their importance and improving the logistics processes.

The manuscript is organized as follows: Section 2 presents the search and analysis methodology. Section 3 presents the results of the bibliometric analysis and science mapping. The analysis includes the most representative scientific production, journals, authors, countries, institutions, and organizations. The science mapping shows the citation analysis

by articles, authors, and terms. Section 4 includes a discussion of the relevant aspects of the research, findings, analysis, and implications of the scientific research on inventory models for sustainable supply chains. Section 5 provides the conclusions, limitations, and future research.

## 2. Materials and Methods

The proposed bibliometric analysis examines publications related to inventory models applied in the sustainable supply chain. This approach includes performance and networking analysis applied to the dataset obtained by the Scopus database to identify the collaboration between authors, organizations, and countries. This study has developed the search by documents related to inventory models in sustainable supply chains to identify research corresponding to the topic. The search strategy was defined according to the research developed by Ospina-Mateus et al. [44], Reyes et al. [45], Meza-Peralta et al. [46], Khan, et al. [47], and Martínez et al. [48]. The search terms were based on the inventory model and sustainable supply chain, as shown in Table 1. The search strategy is considered the SCOPUS database, as it is a prestigious and significant repository for high-impact and globally relevant studies.

**Table 1.** List of keywords used for the literature search.

Groups	Search Items
Inventory models	"Inventory model" or "inventory" or "EPQ model" or "EOQ model" or "emission inventory" or "inventory control" or "stock control" or "stock" or "stock accuracy"
Sustainable supply chain	"Sustainable supply chain" or "green supply chain" or "green supplier" or "sustainable performance" or "sustainable logistics" or "Sustainable Supply Chain Management"
Search equation	TITLE-ABS-KEY ("inventory model" or "inventory" or "EPQ model" or "EOQ model" or "emission inventory" or "inventory control" or "stock control" or "stock" or "stock accuracy") and TITLE-ABS-KEY ("sustainable supply chain" or "green supply chain" or "green supplier" or "sustainable performance" or "sustainable logistics" or "Sustainable Supply Chain Management")) and (exclude (pubyear, 2021))

Three hundred and thirty-five (335) articles were obtained with the Scopus database. The first article was published in 1998, and the following ones from 2003 considered inventory control in reverse logistics networks. For this study, four filters were applied, as shown in Figure 1. The first filter was developed with only published articles in the last ten (10) years. The period of the search was from 2010 until 6 January 2021. The previous ten years were considered to determine the impact on public policies of the sustainable development objectives of the last decade. Finally, 324 manuscripts were obtained with this filter.

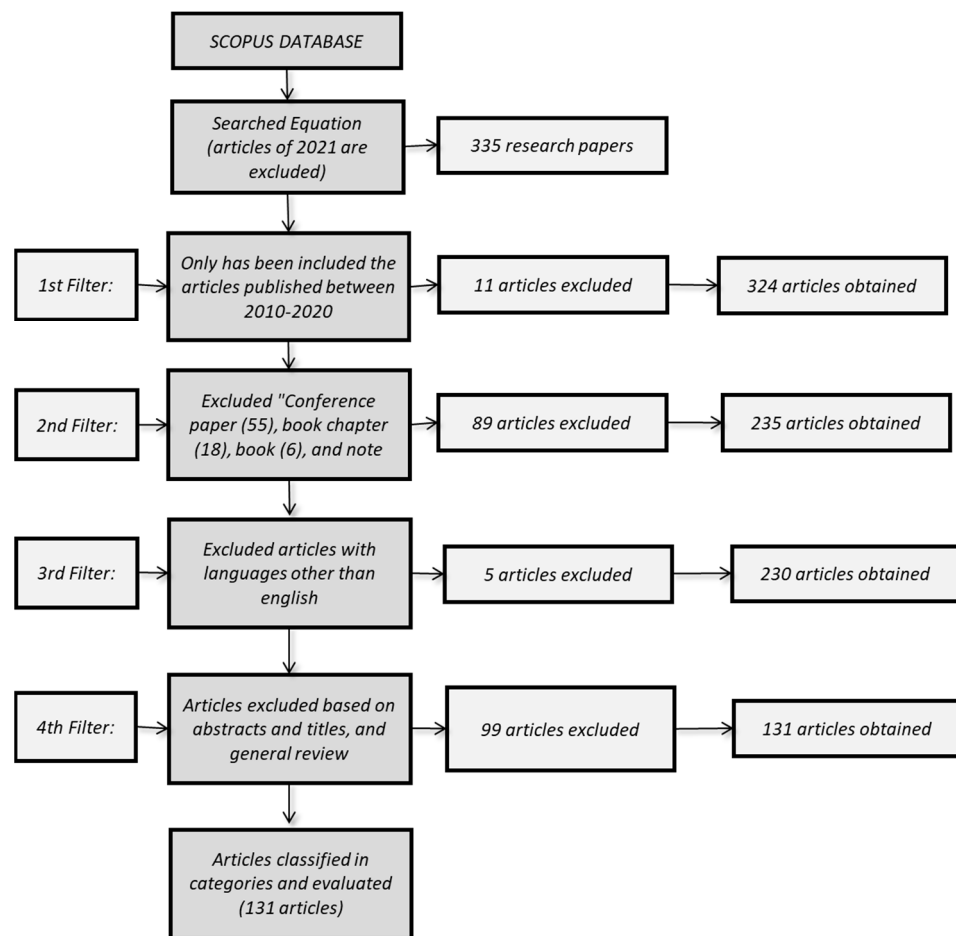


Figure 1. Research methodology.

Studies related to conference papers, book chapters, books, and notes were excluded with the second filter. Eighty-nine articles were excluded with this filter, and 235 documents were obtained. The third filter excluded three articles written in Chinese, one in Russian, and one in Croatian, leaving only 230 articles in English. With the fourth filter, titles and abstracts were reviewed, excluding 99 items that did not correspond to inventory models in SSC. Finally, 131 manuscripts were obtained. The 131 documents correspond to five literature reviews, 29 were full articles related to planning models, and 97 were full articles related to inventory models.

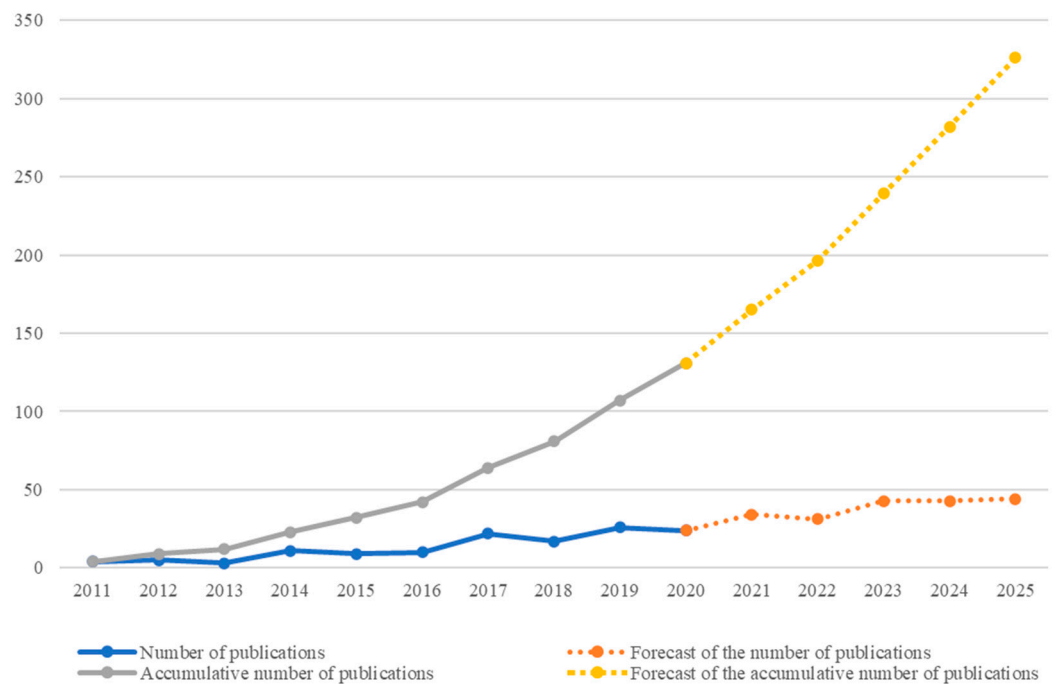
The dataset obtained contains information on the authors, title, year, sources, bibliographic information, affiliations, abstract, keywords, fundings details, sponsors, publishers, type of publication, publication stage, and others. The dataset was managed in MS Excel, and the network visualization was developed in VOSviewer software. The bibliometric mapping allows one to visualize and identify relations between articles, authors, organizations, countries, citations, and keywords [49]. Furthermore, VOSviewer software offers a visualization tool for the co-occurrence analysis of keywords analyzed by colors, sizes, and distance.

### 3. Results

#### 3.1. Publications by Year

This research considers the articles published in the last ten years, from 2010 to 2020. The documents per year is shown in Figure 2. Publications began to increase in 2013, and the highest peak was in 2019, with 26 articles. The ARIMA model was used to predict the volume of documents and analyze publication trends. The publications forecast for the following years (from 2021 to 2025) is 34, 31, 43, 43, and 44. An increase

in cumulative publications indicates exponential growth in future inventory models in sustainable supply chains.



**Figure 2.** Number of publications and cumulative by year with forecast to the year 2025.

### 3.2. Journals

A total of 69 journals published 131 papers. This indicates a growing interest in publications related to sustainability policies applied to inventory control for supply chains. Of the 69 journals, 81.2% published a single paper, 11.6% published between two and five papers, and only 7.2% published more than five articles.

Furthermore, the top 10 journals were established considering the number of articles published related to the inventory model applied in sustainable supply chains. Table 2 presents the top 10 most productive journals, including the publisher and indexing information such as the number of publications, the Scimago Journal Rank indicator-SJR 2020 [50], and the H-index 2020. These top journals have published 51.1% of the total publications. The journal *Sustainability* has published 15 articles concerning inventory models in the sustainable supply chain, followed by *the Journal of Cleaner Production* (13 articles), *the International Journal of Production Economics* (11 articles), *Computers and Industrial Engineering* (7 articles), and *the European Journal of Operational Research* (6 articles).

The subject categories in SJR are Management Science and Operations Research (Q1), Industrial and Manufacturing Engineering (Q1), Environmental Science (miscellaneous) (Q2), Renewable Energy, Sustainability, and the Environment (Q2), and Strategy and Management (Q1). These subject categories have a citation indicator greater than the mean of citable documents, indicating that the articles published in the journals have a high impact indicator and are often cited [50].

*Sustainability* is an open-access international journal that belongs to the Multidisciplinary Digital Publishing Institute (MDPI). This journal provides advanced research related to sustainability with an environmental, cultural, economic, and social focus. In recent years, this journal has published studies related to applying mathematical models to sustainable supply chains considering replenishment, transport, production decisions, and carbon emission reduction policies [51–53].

**Table 2.** Top 10 most productive journals in inventory models for sustainable supply chains.

No.	Journal	Publisher	No. of Publications	SJR-2020	H-Index 2020	Subject Area and Category
1	Sustainability	Multidisciplinary Digital Publishing Institute (MDPI)	15	0.612	85	Energy Engineering and Power Technology (Q2), Renewable Energy, Sustainability, and the Environment (Q2), Environmental Science (miscellaneous) (Q2), Management, Monitoring, Policy and Law (Q2), Geography, Planning and Development (Q1).
2	Journal of Cleaner Production	Elsevier	13	1.937	200	Environmental Science (miscellaneous) (Q1), Industrial and Manufacturing Engineering (Q1), Renewable Energy, Sustainability, and the Environment (Q1), Strategy and Management (Q1).
3	International Journal of Production Economics	Elsevier	11	2.406	185	Business, Management, and Accounting (miscellaneous) (Q1), Economics and Econometrics (Q1), Industrial and Manufacturing Engineering (Q1), Management Science and Operations Research (Q1).
4	Computers and Industrial Engineering	Elsevier	7	1.315	128	Computer Science (miscellaneous) (Q1), Engineering (miscellaneous) (Q1).
5	European Journal of Operational Research	Elsevier	6	2.161	260	Computer Science (miscellaneous) (Q1), Information Systems and Management (Q1), Management Science and Operations Research (Q1), Modeling and Simulation (Q1).
6	IFAC-Papers Online	IFAC Secretariat	4	0.308	72	Control and Systems Engineering (Q3).
7	Advances in Mathematics Scientific Journal	Researchpublication	3	0.060	5	Mathematics (miscellaneous) (NO Q).
8	International Journal of Production Research	Taylor & Francis	3	1.909	142	Strategy and Management (Q1), Management Science and Operations Research (Q1), Industrial and Manufacturing Engineering (Q1).
9	Transportation Research Part E Logistics and Transportation Review	Elsevier	3	2.042	110	Business and International Management (Q1), Management Science and Operations Research (Q1), Civil and Structural Engineering (Q1), Transportation (Q1).
10	Flexible Services and Manufacturing Journal	Springer Nature	2	0.934	46	Management Science and Operations Research (Q1), Industrial and Manufacturing Engineering (Q1).

*The Journal of Cleaner Production* is an academic journal that publishes cleaner production, sustainability, and environmental research applied to corporations, institutions, regions, and societies. This journal presents studies on energy, water, resources, and human capital efficiencies.

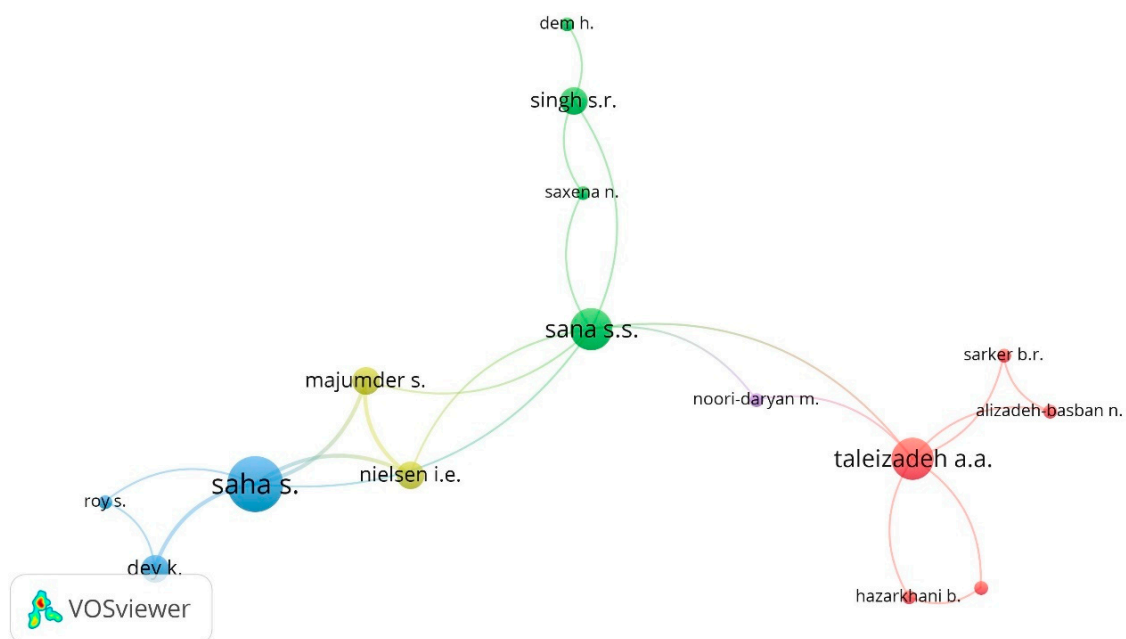
### 3.3. Authors

The top ten most productive authors with the record of publications, citations, and publications as the first author are presented in Table 3. In first place is Subrata Saha with four publications concerning inventory models in SSC, but none has any of them as the first author. This is followed by Ajay Singh Yadav, Armand Baboli, Mohamad Jaber, Pamela Nolz, Shib Sankar Sana, Zeinab Sazvar, Ata Allah Taleizadeh, and Huiming Moses Wee with three publications each, and Nabil Absi with two publications, of which neither lists them as the first author. The authors who appear as the first authors in their publications are Ajay Singh Yadav, Pamela Nolz, Zeinab Sazvar, Ata Allah Taleizadeh, and Huiming Moses Wee. They only represent 50% of the top 10 who appear as first authors in their publications. The others do not appear as the first authors in the articles published regarding the topic. In the same way, it was possible to identify the countries of origin of each author and the number of citations that each author has had (See Table 3).

**Table 3.** Top 10 most productive authors in inventory models for sustainable supply chains.

No.	Name of Author	Country of Author	Number of Publications	Number of Publications as the First Author
1	Saha, S.	Denmark	4	0
2	Ajay, S.Y.	India	3	3
3	Baboli, A.	France	3	0
4	Jaber, M.Y.	Canada	3	0
5	Nolz, P.C.	Austria	3	2
6	Sana, S.S.	India	3	0
7	Sazvar, Z.	Iran	3	2
8	Taleizadeh, A.A.	Iran	3	3
9	Wee, H.M.	Taiwan	3	1
10	Absi, N.	France	2	0

Figure 3 presents the analysis of co-authorship by documents obtained with VOSviewer. It shows a correlation between the different authors, where the authors with the highest correlation are Subrata Saha, Shib Sankar Sana, and Ata Allah Taleizadeh. Four clusters are identified and represent the main groups correlated with their respective colors, led by the authors, presented in Table 3.

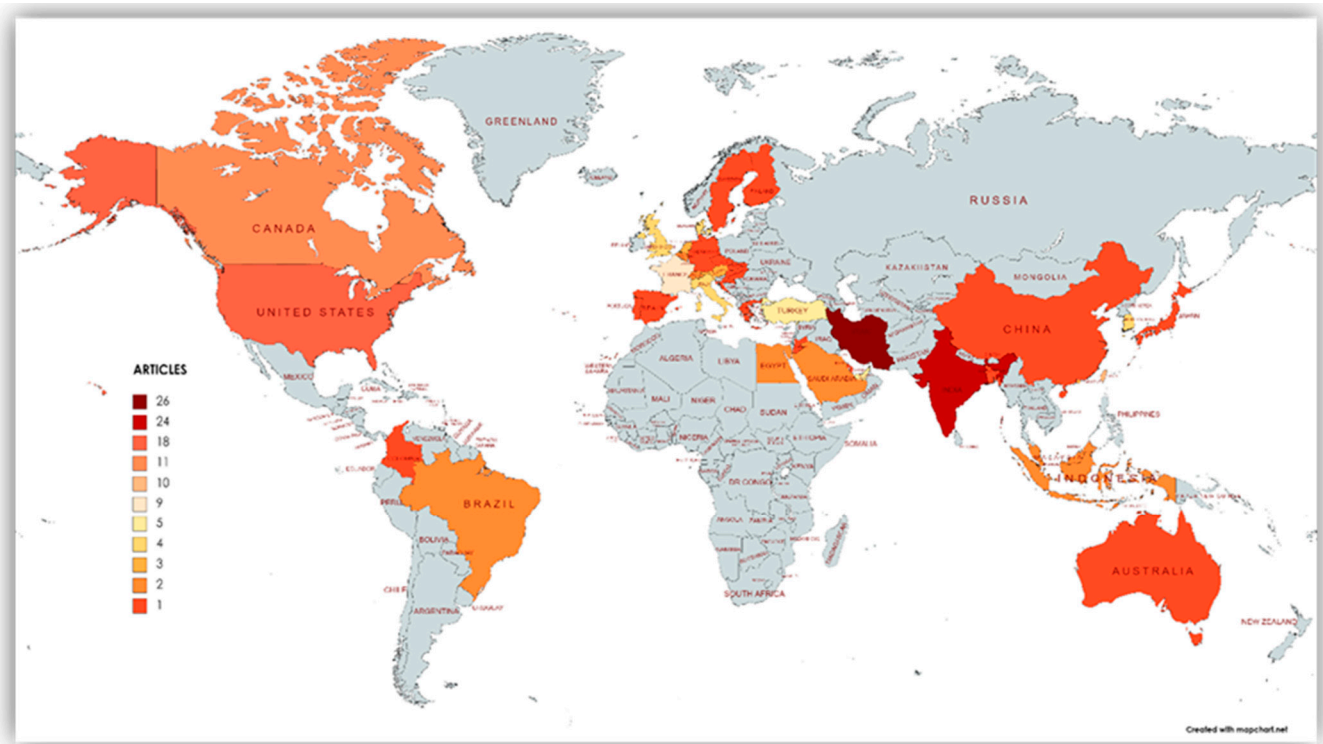


**Figure 3.** Author cooperation network in inventory models in a sustainable supply chain.



### 3.4. Countries, Institutions, Organizations

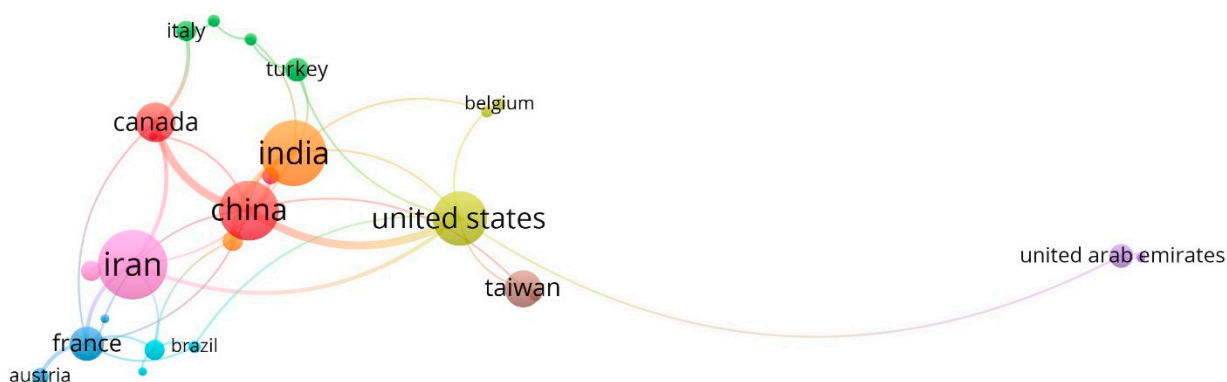
The number of publications concerning inventory models applied to SSC by country was established according to the Scopus database (See Figure 4). The regions in the world that publish the most on SSC were identified. The country with the most publications was the Republic of Iran, which, with 26 publications, represents 13.9% of the total articles published. Furthermore, 19.55% of the publications in this country are in the top 10. The second country is India with 12.83%, followed by China with 11.23%, the United States with 9.62%, and Canada with 5.88%. The top 10 countries correspond to 68.43% of the total publications, and the rest represent 31.57% of the total publications worldwide concerning inventory models in SSC.



**Figure 4.** Author cooperation network in inventory models in a sustainable supply chain.

In addition, Figure 5 presents nine correlative groups that show the correlation between the different countries mentioned above. Iran, India, China, and the United States represent the clusters with the highest correlation due to the joint work between these countries' publications.

The institutions or universities with the largest publication of articles are based in Iran. The University of Tehran, with eight articles published, ranks first in the Top 5 (See Table 4). Islamic Azad University and the Sharif University of Technology are in second and third place with five publications, followed by Wirtschaftsuniversität Wien and the Indian Institute of Technology Kharagpur with three publications each. The number of articles published by universities and institutions in the Top 5 represents 11% of the total articles published by all institutions worldwide. The remaining 89% were publications with between one and three articles per institution.



**Figure 5.** Cooperation network between countries in the research of inventory models in a sustainable supply chain.

**Table 4.** Top 5 most productive institutions in inventory models in a sustainable supply chain.

No.	Institutions	Country	Number of Publications
1	University of Tehran	Iran	8
2	Islamic Azad University, Qazvin Branch	Iran	5
3	Sharif University of Technology	Iran	5
4	Wirtschaftsuniversität Wien	Austria	3
5	Indian Institute of Technology Kharagpur	India	3

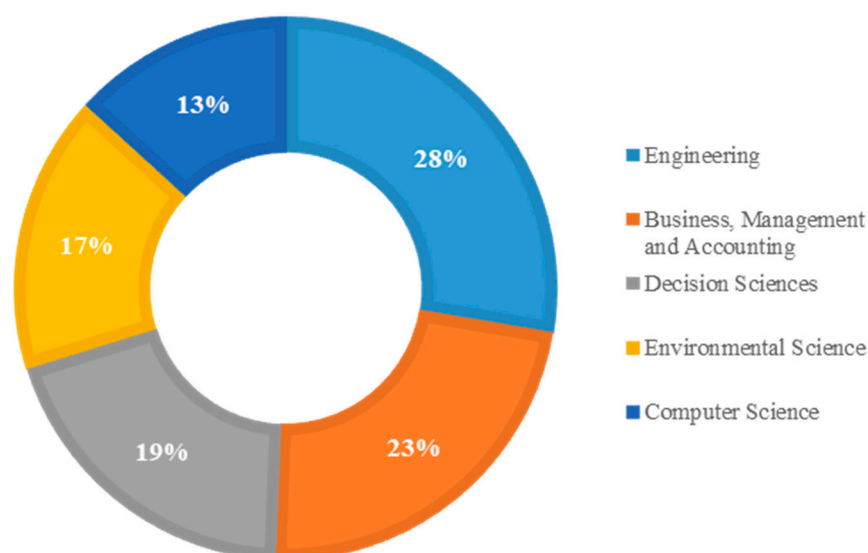
The top 10 sources of funding with the highest number of sponsored articles concerning inventory models in SSC are presented in Table 5. The principal funding sponsor is the National Natural Science Foundation of China, with 15 financed articles, corresponding to 23.07% of all articles supported by different sponsors worldwide. The countries with the most institutions sponsoring research related to inventory models in sustainable supply chains are China with six institutions, the United States, the United Kingdom, and Brazil with three institutions each.

**Table 5.** Distribution of articles by funding entities.

No.	Funding	Country	Articles
1	National Natural Science Foundation of China	China	15
2	Natural Sciences and Engineering Research Council of Canada	Canada	5
3	European Commission	Belgium	3
4	Fundamental Research Funds for the Central Universities	China	2
5	Ministry of Human Resource Development	Saudi Arabia	2
6	Ministry of Science and Technology, Taiwan	Taiwan	2
7	National Office for Philosophy and Social Sciences	China	2
8	National Research Foundation of Korea	South Korea	2
9	Seventh Framework Programme	United Kingdom	2
10	University of Tehran	Tehran	2

### 3.5. Analysis of Subject Categories

The Top 5 main subject areas in inventory models in SSC were identified. Results show that the Engineering area includes 65 articles representing 28% of the publications analyzed. This was followed by Business, Management, and Accounting with 54 articles (23% of publications), Decision Sciences with 46 (19% of publications), Environmental Science with 17%, and Computer Science with 13% of articles. According to this information, the Top 5 were determined, as shown in Figure 6.



**Figure 6.** Subject categories most frequently published in the inventory model in a sustainable supply chain.

### 3.6. Analysis of Citations

The most cited articles are presented in Table 6, with their respective countries, subject areas, categories, journals, and institutions or universities. Bouchery et al. [54] developed the most cited article on the subject. This study contains a review of the classic inventory methods related to sustainability. This research reformulates the classical EOQ model as a multi-objective problem called the sustainable order quantity model. This study has 209 citations, corresponding to 19.35% of the total citations in the Top 10. Hoen, Tan, Fransoo, and van Houtum [55] developed an inventory model considering the carbon footprint and different emission regulations. This publication obtained 14.01% of citations. Zhang and Liu [17] applied game theory in a three-level green supply chain, considering a Stackelberg approach, the Shapley value method, and asymmetric Nash negotiation to promote cooperation. The number of citations in this study corresponded to 11.02%. Chung and Wee [20] developed an inventory model considering green product designs, remanufacturing efforts, and short life cycles. This publication presented 9.81% of total citations. Finally, Bazan, Jaber, and Zanoni [38] presented an inventory model in a two-layer supply chain, including remanufacturing items, the energy used in the production processes, the GHG emissions from production and transport activities, and the number of times remanufacturing (recovery). This research contained 9.72% of the citations.

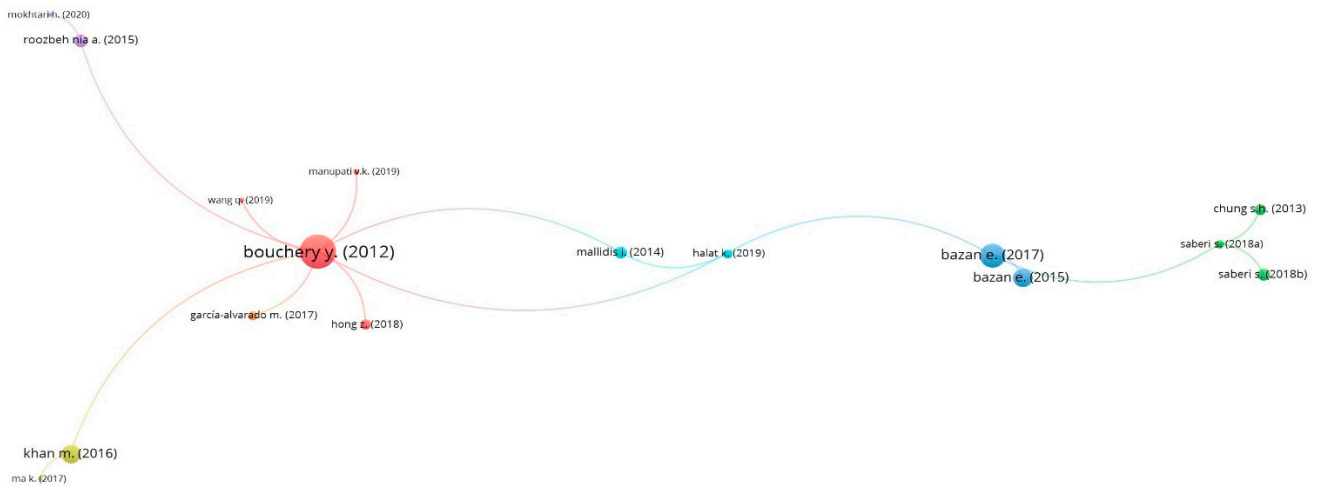
**Table 6.** Top 10 publications with most citations in inventory model in a sustainable supply chain.

No.	Citation	Title	Times Cited	Average Citations per Year	Institution	Journal	SJR-2020	Country (1st Author)	Main Topic (Subject Area and Category)
1	Bouchery, Ghaffari, Jemai and Dallery [54]	Including sustainability criteria into inventory models.	209	26.13	Ecole Centrale Paris	European Journal of Operational Research	2.161	France	Mathematics: Modeling and Simulation, Decision Sciences: Management Science and Operations Research, Computer Science: General Computer Science, Decision Sciences: Information Systems and Management.
2	Hoehn, Tan, Fransoo and van Houtum [55]	Effect of carbon emission regulations on transport mode selection under stochastic demand.	150	18.75	Eindhoven University of Technology	Flexible Services and Manufacturing Journal	0.934	Netherlands	Engineering: Industrial and Manufacturing Engineering, Decision Sciences: Management Science and Operations Research.
3	Zhang and Liu [17]	Research on coordination mechanism in three-level green supply chain under non-cooperative game.	118	14.75	Anhui Agricultural University	Applied Mathematical Modelling	1.011	China	Mathematics: Applied Mathematics, Mathematics: Modeling and Simulation.
4	Chung and Wee [20]	Short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system.	105	0.00	Chung Yuan Christian University	International Journal of Production Economics	2.406	Taiwan	Economics, Econometrics, and Finance: Economics and Econometrics, Decision Sciences: Management Science and Operations Research, Business, Management, and Accounting: General Business, Management, and Accounting, Engineering: Industrial and Manufacturing Engineering.
5	Bazan, Jaber and Zanoni [38]	Carbon emissions and energy effects on a two-level manufacturer retailer closed-loop supply chain model with remanufacturing subject to different coordination mechanisms.	104	26.00	Ryerson University	International Journal of Production Economics	2.406	Canada	Economics, Econometrics, and Finance: Economics and Econometrics, Decision Sciences: Management Science and Operations Research, Business, Management, and Accounting: General Business, Management, and Accounting, Engineering: Industrial and Manufacturing Engineering.

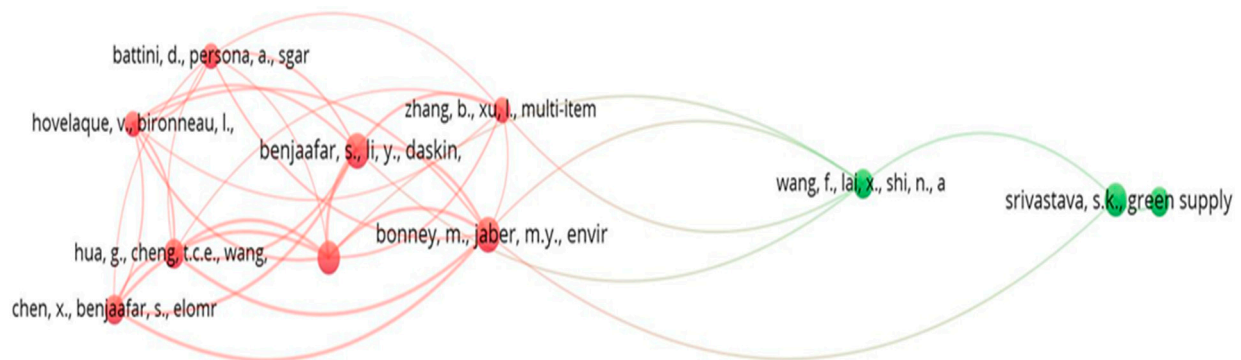
Table 6. Cont.

No.	Citation	Title	Times Cited	Average Citations per Year	Institution	Journal	SJR-2020	Country (1st Author)	Main Topic (Subject Area and Category)
6	Abdallah et al. [56]	Sustainable supply chain design: a closed-loop formulation and sensitivity analysis.	95	11.88	Masdar Institute of Science and Technology	Production Planning and Control	1.331	United Arab Emirates	Business, Management and Accounting: Strategy and Management, Decision Sciences: Management Science and Operations Research, Engineering: Industrial and Manufacturing Engineering, Computer Science: Computer Science Applications.
7	Pahl and Voß [10]	Integrating deterioration and lifetime constraints in production and supply chain planning: a survey.	79	11.29	University of Hamburg	European Journal of Operational Research	2.161	Germany	Mathematics: Modeling and Simulation, Decision Sciences: Management Science and Operations Research, Computer Science: General Computer Science, Decision Sciences: Information Systems and Management.
8	Bai, Chen and Xu [26]	Revenue and promotional cost-sharing contract versus two-part tariff contract in coordinating sustainable supply chain systems with deteriorating items.	75	18.75	Concordia University	International Journal of Production Economics	2.406	Canada	Economics, Econometrics and Finance: Economics and Econometrics, Decision Sciences: Management Science and Operations Research, Business, Management and Accounting: General Business, Management and Accounting, Engineering: Industrial and Manufacturing Engineering.
9	Bazan et al. [57]	Carbon emissions and energy effects on manufacturing–remanufacturing inventory models.	68	11.33	Ryerson University	Computers and Industrial Engineering	1.315	Canada	Engineering: General Engineering, Computer Science: General Computer Science.
10	Nikolopoulou and Ierapetritou [8]	Optimal design of sustainable chemical processes and supply chains: A review.	67	7.44	Rutgers University	Computers and Chemical Engineering	1.017	United States	Chemical Engineering: General Chemical Engineering, Computer Science: Computer Science Applications.

The analysis of citations by document was developed in VOSviewer. The research developed by Bouchery, Ghaffari, Jemai, and Dallery [54] occupies first place in the top 10 most cited articles, as shown in Figure 7. The citation analysis shows six clusters derived mainly from the author mentioned above, showing the articles' relationships and citations. Furthermore, the correlation of citations by cited references is presented in Figure 8.



**Figure 7.** Analysis of most frequent co-citations in inventory models in a sustainable supply chain.



**Figure 8.** Citation analysis by cited references in inventory models in a sustainable supply chain.

### 3.7. Term Analysis

An analysis of the terms used in the titles and abstracts of the manuscripts helps identify research trends on the subject. Figure 9 shows the co-occurrence analysis by all keywords in articles obtained in VOSviewer. In the analysis, three clusters were identified. The main keywords used in the articles selected were Supply Chain Management and derivatives such as remanufacturing, optimization, decision making, logistics, and numerical model, focused on engineering and supply chains. A second cluster included sustainability, integer programming, and stochastic systems. Finally, the third cluster evidenced terms related to sustainable development focused on cost–benefit analysis, inventory management, commerce, and sales.

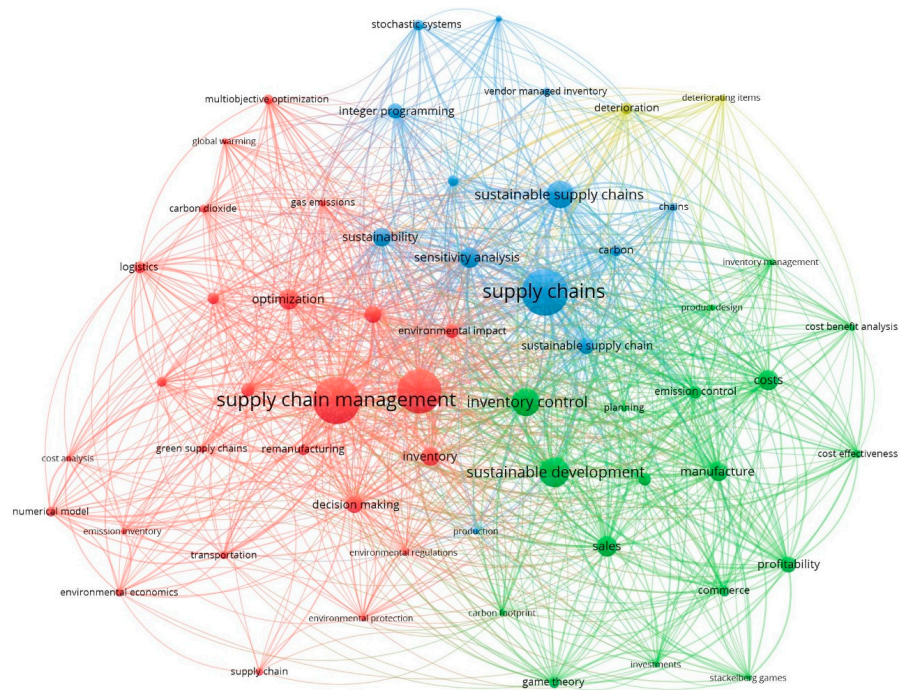


Figure 9. Terms of analysis on the subject.

Finally, Figure 10 the co-occurrence analysis by all keywords with an overlay visualization. For example, the most used keywords between 2017 and 2018 correspond to green and yellow, which are supply chain, management, salts, carbon, integer programming, numerical model, cost analysis, sustainable development, and game theory.

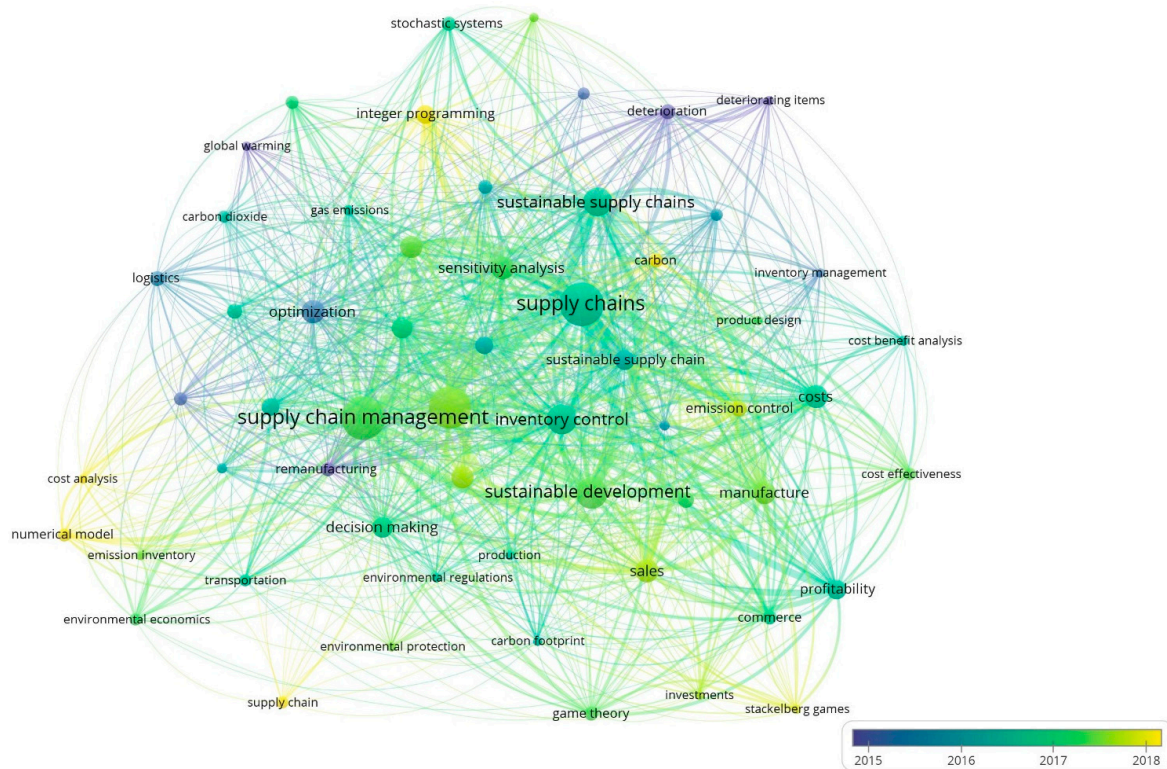


Figure 10. Analysis of representative terms on the subject over time.

#### 4. Discussion

The number of articles published concerning inventory models in SSC per year should increase from 24 articles published in 2020 to 44 published by 2025. This subject is increasingly essential for improving processes within a sustainable supply chain, thus increasing the number of studies each year. The most notable countries in developing research related to inventory models in sustainable supply chains were Iran, India, China, the United States, Canada, Taiwan, France, the United Arab Emirates, Turkey, and Denmark. According to the scope of the publications, six of the documents were related to literature reviews. Ninety-six of the articles were related to specific inventory models. Twenty-nine are linked to the production and planning model that considered inventory aspects. Furthermore, 79.38% of the studies were applications in real life. Lu, Shang, Wu, Hegde, Vargas, and Zhao [36] studied the excessive confidence of a green supplier to make optimal decisions in three types of supply chains. Zhao et al. [58], Taleizadeh, Alizadeh-Basban, and Sarker [29], Gautam, Kishore, Khanna, and Jaggi [35], and Nielsen et al. [59] considered game theory in the sale of a new product. Taleizadeh, Hazarkhani, and Moon [41] determined the amount of carbon dioxide emissions in a plant. Moreover, Bazan, Jaber, and Zaroni [38], Manupati et al. [60], Halat and Hafezalkotob [39], and Rout et al. [61] studied the carbon emission policies (carbon tax, strict carbon capping, carbon offset, and carbon cap-and-trade) for a production-distribution and inventory problem to generate policy markets.

Some authors include uncertain demand [62], stochastic demand [18,43,63], effort-dependent stochastic demand [36], deterministic non-stationary demand [64], carbon reduction, and price-dependent demand [29]. Other considerations incorporate a remanufacturing process for products [20,65], maintenance services [66], and emission penalty tax by remanufacturing gas emission [57].

Some authors have considered strategies to reduce carbon emissions in the supply chain. Bai, Chen, and Xu [26], Karimi, Niknamfar, and Pasandideh [24], and Baek and Kim [67] studied the benefits of cooperation between a manufacturer and retailers to reduce carbon emissions. Moreover, Manupati et al. [60], Halat and Hafezalkotob [39], and Bouchery et al. [54] suggested governments determine policies that regulate carbon emissions in supply chains. García-Alvarado et al. [31] included the benefit of complying with environmental legislation for a sustainable supply chain. Furthermore, Hoehn, Tan, Fransoo, and van Houtum [55] took real-life data to reconsider the mode of transport used and reduce emissions, and Zhang et al. [51] applied an algorithmic method in a real-world case that balances emissions reduction and business benefits. Ghosh, Jha, and Sarmah [14] evaluated companies with applied inventory models to reduce carbon emissions in supply chains.

Other authors have studied the perishable items' effect on the sustainable supply chain. Chung and Wee [20] and Wee et al. [21] studied an inventory model for a short life-cycle product in a reverse supply chain. Furthermore, Sadeghi Rad and Nahavandi [68] proposed a mathematical model for a multi-period, multi-product, and capacitated closed-loop green supply chain, where costs and environmental emissions and the maximization of customer satisfaction were minimized. Jabarzadeh et al. [69] proposed a closed-loop supply chain optimization problem for a perishable agricultural product to achieve three pillars of sustainability, including minimizing total network costs and carbon dioxide emissions from different network activities. Rout et al. [61] considered the deterioration of single-item and imperfect production to manage inventories in a sustainable supply chain.

Some applications have been applied in different industries. The study of García-Alvarado et al. [70] was applied in the pulp and paper industry. Tang et al. [71] presented a study case from the National Petroleum Corporation of China. Yang et al. [27] developed their study in the food industry. Li et al. [72] investigated the improvement of the environmental performance of supply chains, taking into account the delivery times. Treitl et al. [73] proposed an inventory routing model in the petrochemical industry in Southeastern Europe. Wanke et al. [74] developed a mathematical model that improves the planning of sustainable logistics networks in Brazil, reducing carbon emissions in different industries.



Furthermore, Zhao et al. [75] studied companies with high pollution and emissions, such as the pulp and paper forestry in Stora Enso, Guangxi, China.

Other articles correspond to research with a real-life application. Nolz, Absi, and Feillet [76] focus on the health sector in France. Moreover, Wang, Cai, and Florig [7], Zheng et al. [77], and Tang, Ji, and Jiang [71] developed studies in different industrial sectors in China and evaluated the correct use of energy and other resources through the modeling of inventories in SSC. Ali et al. [78] proposed a model of a reverse logistics network for the recovery of products in an Indian plant of a Saudi Arabian air conditioning organization. Shaik et al. [79] developed a data analysis of BSE telecom index companies and analyzed the impact of financial and sustainable performance on the stock performance of BSE Telecom index companies in India from 2008 to 2017. Niranjana et al. [80] developed a model considered for a leading kitchenware company in the southern part of India. Gholipour et al. [81] developed a model in a green supply chain network to minimize the total costs in a production chain for automotive parts in Iran. Haftor et al. [82] applied machine learning to analyze the reduction of negative adverse environmental factors in a truck supply chain.

Saha, S., Ajay, S.Y., and Baboli, A. were the most cited authors. The journals that publish the most research concerning inventory models in SSC are *Sustainability*, the *Journal of Cleaner Production*, and the *International Journal of Production Economics*. Thus, three articles where Saha, S. is co-author are published in the *Journal of Cleaner Production*. This journal is the second most productive in publications related to inventory models in SSC.

Furthermore, the leading journals identified in this top 10 belong mainly to the subject areas of Environmental Science, Industrial and Manufacturing Engineering, Renewable Energy, Sustainability and the Environment, and Management Science and Operations Research at Scopus. Table 6 shows that the most cited articles are developed by Bouchery et al. [54] but this does not correspond to the most cited author in the top 10. Finally, we can see the analysis of citations by document in Figure 7, where, clearly from VOSviewer, this article has the highest correlation. Subsequently, the most used keywords are Supply Chains, Supply Chain Management, Sustainable development, Sustainability, Optimization, Decision making, Carbon, Costs, and Sustainable Supply Chain (see Figure 9).

On the other hand, the top 10 leading institutions or universities (see Table 4) were in Iran. This country has the most significant amount of research related to inventory models in SSC. Of these institutions, 70% of them correspond to public universities, and only 30% of the institutions are private universities.

Finally, the Sustainable Development Goals (SDG) focus on the continuous work to increase clean and non-polluting energy, responsible consumption and production, climate action, and ecosystem maintenance [83]. This approach allows for determining how the trends of the publications are related to the global sustainable development goals or global policies. Firstly, some research focuses on reducing carbon emissions and polluting agents applied in different industries in China, Brazil, India, and others. These studies seek to preserve ecosystems and reduce carbon or pollution in the atmosphere. Similarly, the emissions regulations in a green supply chain applied to agricultural products have allowed for more actions to achieve responsible production and consumption, as seen in applied research in the pulp and paper industry mentioned above.

The research trends identified in this bibliometric analysis are related to working together to fulfill the sustainable development objectives and the policies to reduce polluting emissions worldwide. This approach promotes the production and creation of new supply chain systems that promote sustainability within companies through inventory models.

Within the benefits and potentialities in inventory management, comprehensive impacts can be promoted from the economic, environmental, and social aspects. Sustainability is a fundamental contribution that makes a difference because it improves the supply chain management system in the long term. In the transport and logistics services sector, protecting the environment is a vital criterion for obtaining competitive differences.

The disadvantage of promoting sustainable inventory management is that these go against profitability due to the restrictions that must be considered. However, this biblio-

metric review was able to show that some applied studies demonstrate that these aspects can be overcome with efficient supply chain management.

## 5. Conclusions

This research analyzed the Scopus database for research on inventory models in SSC globally from 2010 to 2020. These models can be applied in companies, organizations, and corporations to solve different problems within the supply chain, optimize different resources, and contribute to the maintenance of the environment. The main findings were the number of industry sectors researching this topic, increasing the number of publications, and promoting the proper use of resources within a sustainable supply chain. Many investigations of theoretical models have applications in real-life cases and evidence of high importance for promoting sustainable development.

This bibliometric review seeks implications of inventory models linked to sustainability. The results point out different aspects of making decisions when including inventory models to promote sustainable development. Additionally, when considering the carbon footprint's environmental impact, it is possible to determine the implications of inventory management to promote manufacturing industries with a green seal. Formulating inventory models with variables and parameters for environmental protection helps companies create a complex and solid inventory structure for sustainable development. In addition, the approach of the 2030 Agenda for Sustainable Development promotes this kind of research, seeking to make visible that it is possible to implement an optimization approach in the supply chain, and particularly in the management of inventories that contribute to the reduction of pollution and waste that affects social welfare.

The limitations found throughout this research are presented. Only the Scopus database was considered because the significant articles in the Web of Science are indexed in Scopus, which could cause the information to be duplicated when using the Web of Science. Another limitation is the number of years selected to develop the study in the different items corresponding to inventory models in SSC, since only the last ten years from 2010 to 2020 were considered.

Similarly, the bibliometric analysis and scientific mapping for sustainable supply chain inventory models identify future research lines. At first, a systematic review of selected items was identified to classify and identify the different areas of application of such research in the industry and how these represent a great help in improving and optimizing SSC. The requirements to improve the performance of SSC have been identified considering delivery times or deadlines, different retailers, product deterioration, and different recycling options to recover the materials. Similarly, the benefits of government incentives within the supply chain, stochastic demand, and the impact of uncertainty demand are considered. Other research extensions consider that developing heuristic and metaheuristic approaches can efficiently solve complex and significant cases concerning inventory models in SSC.

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