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Review

Key Performance Indicators for Food Supply Chain: A Bibliometric and Systematic Literature Review

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Abstract: Key Performance Indicators (KPIs) are rates, percentages, or averages that convey information depending on their application field. In the Food Supply Chain (FSC), a comprehensive study is lacking. This paper fills the gap through a systematic literature review of 125 documents on FSC performance measurement. Bibliometric analysis shows a growing publication trend, with common keywords being KPIs, supply chain management, performance, and sustainability. Content analysis identifies nine FSC product types, with agricultural, dairy, and meat products being the most common categories. Similarly, three FSC areas (supply, production, distribution) are outlined, with production receiving the greatest attention. Finally, KPIs are classified into economic, environmental, and social sustainability categories, to highlight their relationships with the triple bottom line. A framework including the most common KPIs for each stage of the FSC is also proposed, together with the specific KPIs for the different product types.

Keywords: key performance indicator (KPI); food supply chain; systematic literature review; performance measurement; bibliometric analysis

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1. Introduction

Key performance indicators (KPIs) are quantifiable measures used to evaluate an organization's performance against its strategic and operational goals, focusing on improvement [1]. Normally, they stand as a quantifiable measure of performance over time for a given objective. From finance and human resources to marketing and sales, KPIs help every area of the business move forward at the strategic level. Measuring something and consequently evaluating the related performance is extremely important for managers, since these results and trends may constitute the basis for relevant decision making. Indeed, the role of KPIs is that of allowing for evaluating an activity, in order to determine the extent to which the related goals have been achieved [2] or for assessing the convenience of a potential investment (e.g., through Return on Investment), thus permitting to weigh up strategies and behaviors that managers should set. Moreover, another characteristic that makes KPIs so powerful is that their behavior and trend over time can be graphed: by quickly looking at histograms or scatter plots, their interpretation is immediate, clear, and objective.

In recent years, performance measurement based on KPIs has literally grown, as supported by [2]. At the time of writing the present manuscript, namely, the first bimester of the year 2025, the Scopus database already proposes 19 new documents published in 2025, all focusing on specific KPIs in precise fields (the research key was "key performance

indicator*" in the Article Title; the overall outcome is 247 documents with the temporal constraint related to the publishing year). For the interest of readers, worth-of-note examples of documents, allowing a better understanding of the very different implementation fields, are KPIs for port terminal management [3]; KPIs for the pharmaceutical supply chain [4]; KPIs for assessing urban security and safety smartness [5]; KPIs for mechanical tests [6]; KPIs for business success [7]; KPIs for humanitarian logistics [8]; KPIs for higher education and sport programs [9,10], and for predicting the enterprise gross margin in livestock farms [11]; again, for sport analytics [12]; KPIs for monitoring the prostate cancer screening [13], KPIs for warehouse systems [14], and many other could be mentioned, demonstrating that KPIs can be involved everywhere including, for instance, the tertiary sector.

In line with the purpose of this paper, we focused on those studies that presented and evaluated KPIs for the food supply chain (FSC in the following). Among them, Vlachos [15] determined the extent to which the implementation of Radio Frequency Identification (RFID) can improve supply chain performance in agri-FSCs. To this end, the author developed a case study on a fruit cooperative using semi-structured interviews and other sources of evidence. Baba et al. [16] have mapped the available sustainability perspectives and indicators, focusing on the Malaysian FSC. These indicators were divided into the three facets of sustainability (economic, environmental, and social), and simultaneously cascaded into three hierarchies (tactical, operational, and strategic). Sharma [17] has highlighted various Industry 4.0 technologies and their practices in agri-FSCs. To be more precise, the author recognized 10 KPIs that will benefit decision-making in a digital, data-centered environment. Kumar and Choubey [18] identified 30 sustainability indicators from various studies in the perishable FSC and sorted them with the help of academic experts. The authors then applied an interpretive structural modeling approach to detect the interrelationship among the indicators.

KPIs are very common in literature and several reviews have been published about them, exploring the field from various perspectives. To be more precise, some reviews have evaluated specific application areas of the FSC. In chronological order, the first review of KPIs for FSC was by Manning and Soon [19], who analyzed how a pre-requisite program and KPIs for food safety can be developed for the production of fresh produce, in both low-input and high-input supply chains. Aivazidou et al. [20] provided a critical literature summary concerning the assessment of product water footprint, to map the state-of-the-art research related to freshwater consumption and pollution in the agricultural and industrial sectors. Moreover, the authors proposed a first-effort hierarchical decision-making framework that includes water footprint mitigation policies for agri-FSCs in order to support all stakeholders in developing a comprehensive water stewardship strategy. The review developed by [21] aimed at emphasizing the benefits of implementing Industry 4.0 in the agri-FSC. In particular, the authors presented how technologies enhance agri-FSC development, and then, they identified and highlighted the most common challenges that Industry 4.0 implementation faces in the agri-food environment. Finally, Zhao et al. [22] realized a comprehensive understanding of different social innovation measures adopted for decreasing food waste, utilizing a systematic literature review (SLR). The authors concluded that social innovation activities such as food rescue hubs, digital food-sharing platforms, solidarity stores, and social supermarkets are widely deployed in different food waste reduction processes.

However, to the best of the authors' knowledge, a review covering all the key aspects of performance measurement in the FSC is still missing, and this was the original gap intended to be filled by the present study. This work, in fact, originates from a previous one [23], in which a gap was highlighted, namely that of KPIs for the FSC. In the manuscript at hand, accordingly, the authors propose an update of the literature and of the previous

taxonomy, aimed at integrating the results presented in [23], by analyzing a wider stream of research. In more detail, this research focuses on the following research questions (RQs):

- **RQ1. How is the research on KPIs for the FSC characterized?**

This question aims to discuss the statistical trend of research related to the targeted topic, in terms of temporal evolution and publication type; research methodology; source (i.e., journals publishing the document in question); geography of the documents (i.e., where the study was carried out); top cited papers; and most prolific authors.

- **RQ2. What are the most frequent and persistent topics over time, and how do they relate to main research themes?**

This question aims to map the research topics; that goal is obtained by analyzing the papers' keywords with respect to their frequency and persistence. To be more effective, the timespan of analysis is divided into four periods; with respect to the same periods, an analysis of the evolution of the main topics is also conducted. Keyword co-occurrence is finally used to look at the relationships between the research topics identified.

- **RQ3. How can KPIs for the FSC be classified? Which different products have been predominantly studied? What FSC processes and activities are covered by KPIs?**

This question, overall, is intended to provide an exhaustive mapping of the literature about KPIs in the FSC. More precisely, the question concerns the different products treated in the FSC (and their trend in time), the distribution of KPIs and papers by FSC processes and activities, and the trend of publications by KPI categories. A final framework is also proposed for addressing this RQ, so as to let emerge the most common KPIs for each stage of the FSC, including a classification depending on the nature of the final products managed.

The remainder of the paper is structured as follows: Section 2 (Review methodology) details the procedure followed in the study; Section 3 presents the results, including an updated bibliometric and contents analysis; a discussion of the findings is proposed in Section 4, including the developed framework. Conclusions and future directions are finally presented in Section 5.

2. Review Methodology

2.1. Sample Creation

The research methodology selected for this study is the SLR. To ensure a comprehensive coverage of the relevant literature, the Scopus database (https://www.elsevier.com/products/scopus, accessed on 31 December 2024) was used for the search, which concentrates on pertinent and leading papers. Indeed, even if other databases could have a wider coverage, Scopus is generally recognized to cover nearly all studies in the engineering area (which also includes supply chain and logistics-related studies) [24], and its usage in SLR is confirmed even in recent studies [25,26].

The article selection process followed the main (and applicable) steps of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, recommended for SLRs [27]. The search protocol shown in Table 1 outlines the definition of the research strategy, including search strings, publication types, and languages not considered. In addition, the process of relevance screening is shown in a flow chart depicted in Figure 1. As can be seen from Table 1, the starting point was a search query on the Scopus database with the general keywords "food supply chain", "key performance indicator", "agriculture supply chain", "food" and "agriculture". The search, which was carried out in its final version between February and March 2024, returned, as a first result, a total of 395 papers. The exclusion criteria were clearly specified, with the purpose of correctly selecting the

research papers to be reviewed. To this end, in the present review the following documents were excluded:

- Documents different from journal articles, reviews, and conference papers as document types (Exclusion criterium #1)
- Studies not in English language (Exclusion criterium #2)

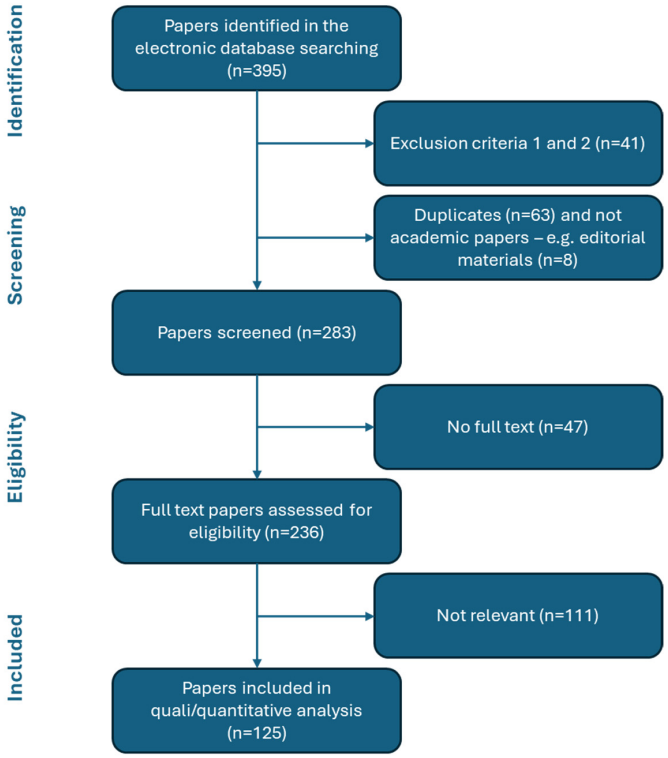

Figure 1. Flow diagram of the sample selection.

Table 1. Research strategy.

# Query	Search		Exclusion Criteria		# Papers Identified After Exclusion Criteria
	Terms in "Title, Abstract, Keywords"	# Papers Identified Before Exclusion Criteria	# Criteria and Description	# Papers Removed	
1	"food supply chain" AND "key performance indicator"	**35**	#1: book chapter	4	**30**
			#2: Chinese	1	
2	"agriculture supply chain" AND "key performance indicator"	**1**	-	-	**1**
3	Food AND "key performance indicator"	**252**	#1: book chapter; Note; Editorial; Short survey; Letter; Data paper; Book	16; 2; 2; 1; 1; 1; 1	**224**
			#2: Chinese; Ukrainian; Russian; German; French	2; 1; 1; 1; 1	
4	Agriculture AND "key performance indicator"	**107**	#1: Book chapter	5	**99**
			#2: Chinese; German	2; 1	
Papers identified in the electronic database searching					**354**

The application of those criteria reduced the original sample to 354 papers. As shown in Figure 1, these 354 articles were further reduced to 283 after having merged the results from the four queries and excluded duplicates and non-academic papers. In the

final step, these publications were checked for their availability as full texts (47 papers removed) and thematic focus on the research questions (111 papers not considered). Finally, 125 documents were selected for the SLR.

All the 125 papers included were fully reviewed and read; their bibliometric data were extracted from Scopus and imported as comma-separated values (CSV) format on Microsoft Excel™. The main data extracted from the reviewed publications were classified in categories as displayed in Table 2 below.

Table 2. Classification categories of articles reviewed.

Categories	Description
Year	Year of publication
Paper classification	**Type of document**
Journal	Research and review paper published in international journal
Conference paper	Research paper published in conference proceedings
Methodology	**Methodology used by the authors to carry out the research**
Empirical	Any research where conclusions of the study are strictly drawn from concrete empirical evidence and data, and therefore originates from verifiable evidence
Analytic/model	Research that provides an analytical model to quantify some KPIs in the FSC
Case study	Study that presents one or more applications to real contexts
Conceptual	Paper that discusses some specific KPIs in FSC, without any direct application (i.e., mostly theoretical)
Source title	**Journal/conference in which the document was published**
Geography	**Country of the first author**
Citations	**Number of citations received** (at the time of data extraction)
Author	**Who has contributed to the study**
Author keywords	**Main topics of a research paper** [28]
Types of SC Agricultural; Meat; Fish; Dairy; Bread; Animal and plant production; Alcohol-free drinks; Food production; Fruit	FSC classification based on the type of products studied
Stage of SC Supply Production Distribution	FSC classification according to its different stages [23]
KPIs measured	**Dimension of its performance over time**
Economic	How the FSC interacts with the economic impacts
Environmental	How the FSC interacts with environmental emissions
Social	How the FSC interacts with the local community and society as a whole

2.2. Procedure for Analyzing the Papers

2.2.1. Statistical Analyses

The documents in the final sample were subject to various analyses, including statistical trends and bibliometric analyses, performed using Microsoft Excel™. To be more precise, in terms of statistical trends, the following aspects were investigated:

(i) The temporal evolution of the papers by publication year;
(ii) The papers' distribution by publication type and research methodology, according to the classes in Table 2;
(iii) The most productive journals;
(iv) A geographic mapping of the publications according to the author's nationality;
(v) The top-cited papers;
(vi) The outstanding authors, as a function of the number of documents written.

2.2.2. Keyword Analysis

As far as the bibliometric tools, a detailed keyword analysis was made. Keywords are essentially used by authors to express the main topics of their paper; as such, in scientometrics, the analysis of the authors' keywords is recognized as an effective tool to trace the topics covered in a scientific field and their trend [29]. In this study, keywords were mapped with respect to their frequency and persistence. By frequency, we mean the number of occurrences of a keyword in the sample of papers reviewed; persistence, instead, refers to the number of years of its presence, computed considering the year of its first appearance and the year of the last one [30]. By combining these two pieces of information, interesting considerations about the research trends can be observed. In particular, after setting appropriate boundaries for frequency and persistency, keywords can be classified into the following:

- Low-persistence and low-frequency: emerging/phantom concepts. These topics could be relatively new to the research field or could describe themes that have progressively disappeared.
- Low-persistence and high-frequency: trendy concepts. These topics are relatively new but have already attracted the attention of numerous researchers in the field.
- High-persistence and low-frequency: intermittent concepts. Terms in this category denote themes that have been known for many years, but have been studied with low continuity.
- High-persistence and high-frequency: well-established (core) concepts. Relating terms are expected to denote themes that have long been studied by many authors in the field.

The same analysis and classification were made by dividing the timespan of the papers into 4 periods (period 1: 2003–2008; period 2: 2009–2013; period 3: 2014–2018; period 4: 2019–2023), so as to highlight the changes in time of the topics treated in research, namely, increased/decreased interest, newly emerged topics, or disappeared ones. Again, appropriate (new) boundaries were set for the keyword classes. Sankey diagrams were used to graphically show the change in time of the keywords' classes. On the basis of the classification made, the evolution of the macro-themes across the four periods was also explored.

Keyword co-occurrence analysis was finally used to support the results, and in particular to map the connections between the research topics identified. Co-occurrence analysis is a text-mining technique that checks the presence of pairs of keywords in the documents reviewed; common pairs of keywords are assumed to identify relationships between sci-

entific topics [31]. VOSviewer version 1.6.20 (https://www.vosviewer.com/, accessed on 31 December 2024) is used to support the mapping of the research topics.

2.2.3. Content Analysis

In addition to bibliometric analyses, a series of analyses was carried out by carefully looking into the papers' content:

(i) The time distribution of papers for the different products treated in the FSC;
(ii) The papers' distribution by FSC areas;
(iii) The trend of publications by KPI categories.

3. Results

In this Section, results from the statistical, keyword, and content evaluation are offered. The subsections that follow reproduce this subdivision.

3.1. Outcomes of the Statistical Analyses

It is useful to point out that, for completeness, the final sample of papers (125) is fully reported in Table A1 (Appendix A), together with their classification by research methodologies. From the appendix, it is possible to note that empirical studies emerged as the most frequent type of research (68 publications), followed by case studies (43) and analytical models (39). Note that in the same paper, more methodologies could be involved; for instance, an analytical model could be developed and then implemented in a case study. In this case, both categories were assigned to the paper. Moreover, it is interesting to note that empirical studies have appeared in literature with good continuity, with the only exceptions being the years 2003, 2009, and 2010, in which there were no empirical papers. This result is in line with the topic investigated: empirical research normally deals with data collected from real contexts, and KPIs are normally built on data and numbers.

This Section is intended as a general overview of the state of the literature that focuses on measuring the performance of FSC by means of KPIs. In Figure 2, the evolution of the yearly number of papers inside the present sample is reported, specifying the type of publications by year.

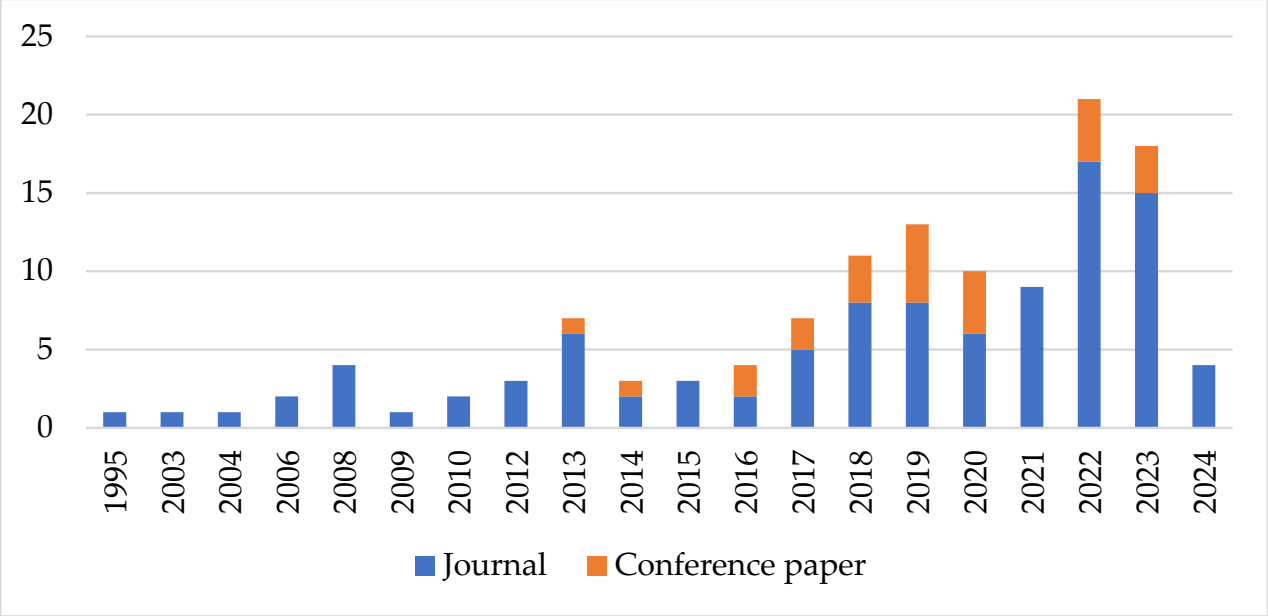

Figure 2. Distribution of publications by year and publication type.

The column chart corresponding to the year 2024 is significantly lower if compared to the values reached in the latest years, because the available literature includes papers published before March only (reflecting the time of the query). Nonetheless, as can be seen from the figure above, the general trend observed is that the number of publications is growing. Overall, the statistical data indicate that publication and research in the area of KPIs in FSC increased in the years 2018–2023 (82 papers out of 125, 65.6% of the sample). It should be noted, however, that in general an increase in scientific publications is recorded in almost all the fields related to supply chain issues, above all, after the recent pandemic. Indeed, FSCs have been adversely affected by COVID-19 under different perspectives [32], and thus, numerous studies relating to COVID-19 have precisely targeted the FSC. The sales volume was one of the typical aspects investigated: at the beginning of the pandemic, COVID-19 caused demand and supply uncertainty, with an initial decrease in demand because of the consumers' less frequent store visits and restrictions/limitations to people movements [33,34]. An opposite effect, instead, was observed later, when the early lockdown measures changed people's purchasing behavior, leading to "panic" buying and thus an increase in demand. The perishability of the items, a typical challenge of the FSC, was another typical field of research, because of the additional risk perishability involved in pandemic periods [35].

As can be deduced from the figure above, the sample consists of 100 articles in international journals, including 90 research papers and 10 reviews, and 25 papers published in international conferences. In addition, it is interesting to point out that the first review, dealing with quantitative models for sustainable food logistics management, was published in 2012 [36], while the first conference paper was in the following year [37]. The fact that literature reviews were mostly published in the last years (i.e., two reviews published in 2018; one review per year published in 2019, 2020, 2021, and 2022; two reviews published in 2023) is in line with the fact that literature reviews, to be defined as such, need a certain number of documents on which to focus, meaning that previously a huge number of documents was produced.

As far as the journal analysis is concerned, the sample under investigation comes from 100 different sources; among these, 85 (68%) published one paper only. Figure 3 below presents the sources that published at least two papers reviewed in this study.

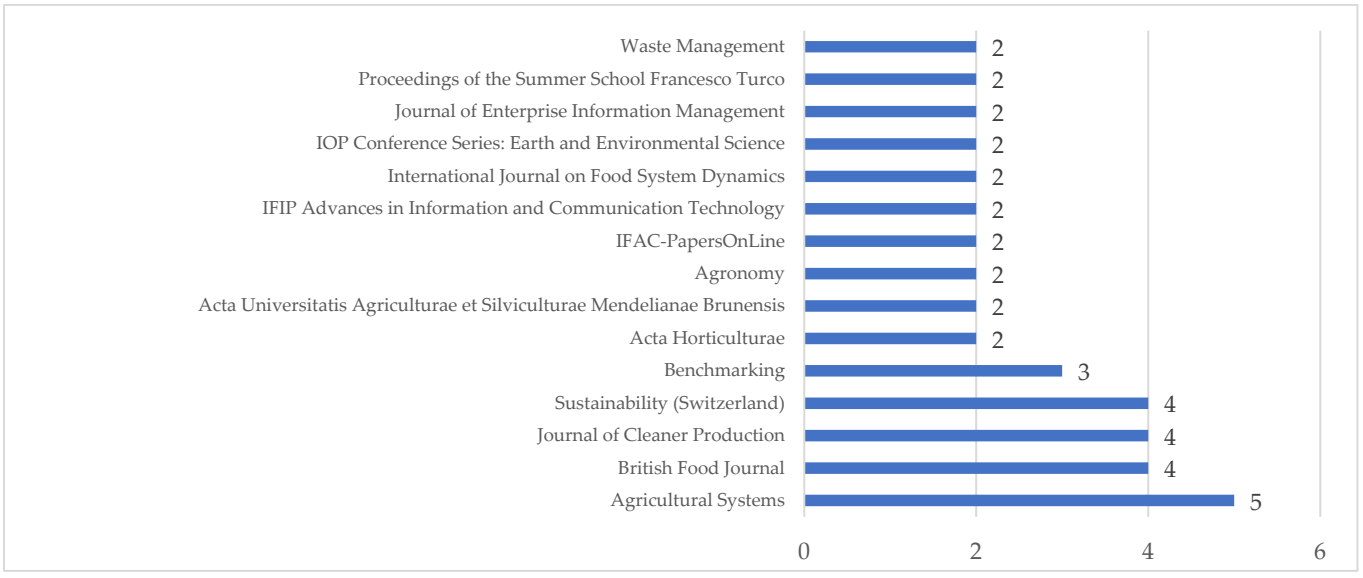

Figure 3. Distribution of papers by source (Note: sources with >2 papers are displayed).

The above figure reveals that out of the 15 sources with the highest number of publications, *Agricultural Systems* stands at the top (5 papers out of 125; [38–42]), followed by *British Food Journal* [19,43–45], *Journal of Cleaner Production* [20,46–48] and *Sustainability* [49–52], with 4 documents each. It is interesting to note that these mentioned journals specifically deal with food (as expected) or sustainability issues; the latter stresses one of the main research areas when managing FSC.

Regarding the geographical distribution, the mapping of the studies was carried out by providing the nationality (on the basis of the affiliation) of the first author. The figure below (Figure 4) shows the main results, limited to countries with at least four publications.

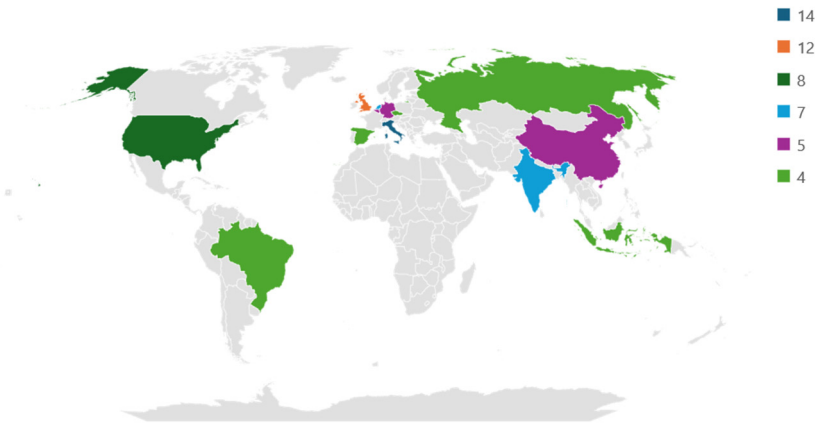

Figure 4. Map of the publications according to the first author's nationality.

The majority of the selected papers are from Italy (14 papers out of 125, 11.2% of the sample), the United Kingdom (12), and the United States (8). This is in line with the fact that in Italy the agriculture and food sector greatly impacts economic gains and jobs, contributing to about 4% of gross domestic product (GDP), with the largest contribution attributable to the primary sector [53]; in the United States as well, it contributes to the 5.6% of the GDP [54]. As can be seen from the figure above, no countries in Africa have more than four contributions on the topic of KPIs in the FSC, despite their huge problems in terms of food scarcity or food security.

Citation analysis has become particularly popular in review studies because of its ability to accurately identify influential papers on a given topic [55]. The table below (Table 3) shows the most cited papers: the upper part of the table presents the 10 most cited papers overall, while the lower part organizes the publications in descending order of the number of citations per year. The right part of the table shows the topics covered and the approaches/techniques adopted for the most cited papers.

Thirty-three publications received more than twenty-five citations on Scopus at the time of writing, and twelve with even more than fifty citations.

As shown in the table above, the paper with the highest number of citations (developed by [56], with 206 citations) is a document in which a chance-constrained model for the multi-supplier inventory routing problem is proposed; it is then followed by [57] and [58], with 196 and 97 citations, respectively. In the first document, food security with reference to a specific family of bacteria was investigated, while in the second, a literature review is proposed on life cycle costing studies related to food waste; this topic is somehow a foretaste of common trends of research: the economic issue and the sustainability one (in this case, in terms of food waste). It is interesting to note that the top two positions are the same for both rankings, while the third and fourth positions are reversed. Overall, five publications appear in both rankings [56–60].

Table 3. Top-cited publications.

#	Paper	Year	Citations	Topic Covered	Approach/Technique Adopted
1	[56]	2018	206	Perishability	Inventory Routing Problem
2	[57]	2014	196	Food security	Literature review
3	[58]	2018	97	Food waste	Literature review
4	[59]	2019	89	Food delivery services	Web mining techniques
5	[36]	2012	85	Sustainable food logistics management	Literature review
6	[60]	2019	80	Traceability	Blockchain technology
7	[44]	2006	76	Sustainable food procurement	Focus group
8	[20]	2016	75	Water footprint	Critical literature synthesis; hierarchical decision-making framework
9	[61]	2009	72	Carbon footprint of perishable goods	Sensor information
10	[43]	2003	69	Food safety and animal welfare policies	Case study discussion
#	**Paper**	**Year**	**Citations per Year**	**Topic Covered**	**Approach/Technique Adopted**
1	[56]	2018	29.42	Perishability	Inventory Routing Problem
2	[57]	2014	17.82	Food security	Literature review
3	[59]	2019	14.83	Food delivery services	Web mining techniques
4	[58]	2018	13.86	Food waste	Literature review
5	[62]	2022	13.67	Bioprocess technologies needed for cell-based meat production	Literature review
6	[60]	2019	13.33	Traceability	Blockchain technology
7	[47]	2021	11.25	Agrivoltaic systems	Optimization model
8	[63]	2021	10	Precision agriculture	Multidisciplinary architecture: AgriFusion
9	[64]	2020	9.2	Agriculture supply chain	Framework for supply chain performance measurement based on IoT
10	[20]	2016	8.33	Water footprint	Critical literature synthesis; hierarchical decision-making framework

Table 4 presents the most prominent authors.

Table 4. Top authors.

Author	No. of Papers	References	Citations
Van der Vorst J.G.A.J.	4	[36]	85
		[65]	36
		[56]	206
		[66]	8
Manning L.	3	[45]	26
		[67]	32
		[19]	8
Bottani E.	3	[68]	2
		[69]	0
		[23]	0
Trenz O.	3	[70]	22
		[37]	3
		[71]	7

As Table 4 shows, four authors only published more than three papers on KPIs in the FSC within the sample. It is interesting to note that the table did not show any particular collaboration among the most prominent authors. In addition, two of Van der Vorst's contributions [36,56] also appear among the most cited publications. This is an indication that Van der Vorst is an author who has contributed to research on the topic both quantitatively and qualitatively. As far as their research topic is concerned, for Trenz, it is possible to see that his three documents specifically deal with reporting, while Manning mainly focused on the meat supply chain; Van der Vorst, instead, worked on the logistics issue. For Bottani, no connections among her three publications can be derived.

3.2. Outcomes of the Keyword Analysis

As far as the keywords analysis is concerned, firstly note that 11 publications lacked the author's keywords and were obviously excluded from this elaboration. The keywords retrieved from the remaining 114 papers initially returned 576 different terms. After having adjusted synonyms, acronyms, and spelling, the final list includes 343 terms. According to [72] and as anticipated earlier, keywords were classified according to two different parameters, i.e., frequency and persistence, describing the number of occurrences of a concept over time and its continuity in time. Table 5 shows the distribution of the keywords according to those parameters; from that table, it is immediate to note that most of the keywords (250, 72.8%) were used only once by authors, and thus are expected to describe very specific (niche) concepts. In aggregated analyses, these terms will be excluded, for a more effective representation of the outcomes.

By mapping those terms having frequency $\geq$4, 20 keywords were recorded, whose distribution in time is shown in Figure 5.

The representation above indicates that "Key Performance Indicators" is the most frequent keyword (33 papers). This result is confirmed by the fact that this general term was used to run all the queries and was, therefore, expected to be among the keywords most frequently observed. "Supply chain management" and "Performance" take the second and third positions with frequency of 17 and 14, respectively—which again could be expected. Sustainability emerges (with 13 occurrences), suggesting that quite often KPIs could be involved in measuring sustainability-related parameters, in line with what has been observed for the journal analysis; for "Energy efficiency" (5) and "Food waste" (5, again) similar considerations can be made.

Table 5. Number of keywords by frequency and persistency.

Frequency Count	N° of Keywords	Persistency Count	N° of Keywords
1	250	1	9
2	57	2	47
3	16	3	65
4	6	4	23
5	5	5	17
6	1	6	25
7	2	7	28
9	2	8	17
13	1	9	14
14	1	10	5
17	1	11	14
33	1	12	23
-	-	13	17
-	-	15	7
-	-	16	4
-	-	17	14
-	-	19	8
-	-	22	6
Total	343	Total	343

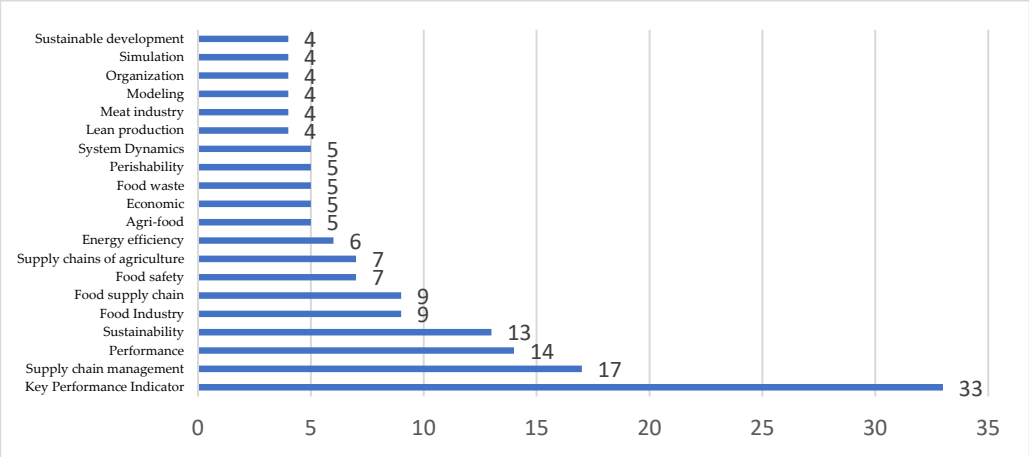

Figure 5. Most frequently used keywords.

Using the detailed data of frequency and persistence for the whole timespan of analysis, the keywords were classified into the four groups mentioned in Section 2.2.2, after setting the following boundaries:

- Persistence: half of the timespan covered by the 114 studies, i.e.,

$$\text{Persistence} = (2024 - 2003)/2 = 10.50 \quad (1)$$

- Frequency: median value of the observations, i.e.,

$$\text{Frequency} = 3.51 \quad (2)$$

The results of the classification are detailed in Table 6; for a more effective representation, the outcomes are limited to those keywords with frequency ≥2 (88 selected terms).

Table 6. Overall classification of the keywords (frequency ≥ 2).

Class	List of Keywords
Well-established topics (19 terms)	Key Performance Indicator; Supply chain management; Performance; Sustainability; Food Industry; Food supply chain; Food safety; Supply chains of agriculture; Energy efficiency; Agri-food; Economic; Food waste; Perishability; Lean production; Meat industry; Modeling; Organization; Simulation; Sustainable development
Trendy topics (6 terms)	Energy efficiency; Agri-food; Food waste; System Dynamics; Organization; Sustainable development
Emerging/phantom topics (51 terms)	Automated Warehouse; Case study; Cold supply chain; Decision making; Food integrity; Food processing industry; Industry 4.0; Internet of Things; Life cycle assessment (LCA); Logistics; Manufacture; Agent-based modeling; Analytic Hierarchy Process; Balanced scorecard; Biomanufacturing; bread; Business process reengineering; Circularity; Climate change; Commercial agriculture; Data analytics; Demand-side management; Discrete simulation Distribution centers; Efficiency; Enterprise agility; Financial performance; Fuzzy TOPSIS; Green economy; Horizontal logistics collaboration; House of quality; ICT; Imports; Industrial dryers; Irrigation; Machine learning; Management; Multi criteria analysis; Online food delivery; Quality function deployment; Renewable energy; Risk analysis; Scenario analysis; School canteen; Skills strategy; Smart agriculture; Smart industry; Stochastic programming; Sustainable intensification; Urban agriculture; Yield gap
Intermittent topics (12 terms)	Literature review; Nutrition; Production; Sensors; Benchmarking; Catering food production; Dairy business; Environmental performance; Food distribution; Plant factory; Public sector organizations; Quantitative models

As can be seen from the table above, most of the core concepts, as again expected, reflect those shown earlier in Figure 5, and include, among others, "Key performance indicator", "Supply chain management", and "Performance". "Corporate reporting", "Literature review", "Nutrition", and other terms were instead classified as intermittent research topics. Among the emerging concepts, we found numerous keywords (51), depicting various themes, including "Automated warehouse", "Case study", "Cold supply chain", "Decision making", and others; this demonstrates the diversity of the contexts in which KPIs can be involved and the various purposes for which they can be computed. In the quarter

with high frequency and low persistency, corresponding to the trendy topics, in contrast, we found six concepts only, some of which interestingly related to sustainability issues ("Energy efficiency", "Agri-food", "Food waste", "System Dynamics", "Organization", and "Sustainable development").

The same analysis, made by dividing the timespan of the papers into the four periods previously mentioned, returned the results shown in Table 7. The boundaries used to classify the keywords were again set at half the timespan (i.e., the duration of each period) for the persistency, and to the median value of occurrences for the frequency. Because of the analysis of more periods, it is always possible that the same keyword is observed at various moments in time, resulting in a total number of terms that differs from the overall value previously stated. Outcomes in Table 7 highlight, first of all, that the number of keywords has progressively increased in time, obviously in line with the increase in the number of papers. Well-established topics are in general few in number, while most of the topics observed in any period express emerging/phantom concepts, which could be expected to either gain importance in time or to disappear. Again, these findings further confirm the variety of research topics in the field under examination.

Table 7. Keywords' classification by period.

Keyword Class	Period 1 (2003–2008)	Period 2 (2009–2013)	Period 3 (2014–2018)	Period 4 (2019–2023)
Well established	1	0	0	4
Trendy	0	1	1	0
Intermittent	8	9	25	62
Emerging/phantom	11	26	45	109
Total keywords	20	36	71	175
Number of papers	7	13	26	68

A detailed mapping of the changes observed in the keyword classes is proposed in Table 8 and Figure 6; Figure 7 shows instead the evolution of the macro-themes across the four periods of analysis, on the basis of the same classification.

Table 8. Trend of the keywords' classification by period.

		period 2				
	period 1 -> period 2	well established	trendy	intermittent	emerging/ phantom	*disappeared*
period 1	well established					*1*
	trendy					
	intermittent				2	*6*
	emerging/phantom					*11*
	new		*1*	*9*	*24*	
		period 3				
	period 2 -> period 3	well established	trendy	intermittent	emerging/ phantom	*disappeared*
period 2	well established					
	trendy					1
	intermittent					9
	emerging/phantom			1	4	21
	new		*1*	*24*	*41*	

Table 8. *Cont.*

	period 3 -> period 4	*period 4* well established	trendy	intermittent	emerging/phantom	*disappeared*
period 3	well established					*1*
	trendy					*23*
	intermittent	1		1		*39*
	emerging/phantom	1		2	3	
	new	*2*		*59*	*106*	

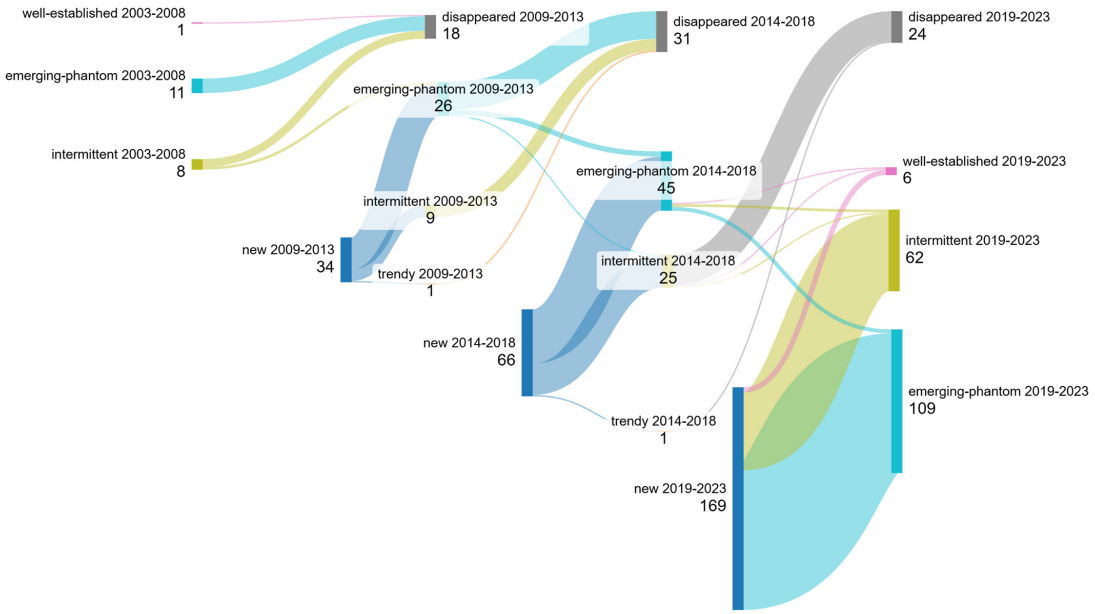

Figure 6. Trend of the keywords' classification by period.

This mapping clearly shows that for each period, numerous "new" terms were introduced by researchers; these terms typically appeared as emerging/phantom concepts, which is consistent with their first occurrence in time. The quota of "disappeared" terms is also relevant; this suggests that numerous topics were treated for a limited time, and in particular, in one period only, and then disappeared in the next period. Again, these considerations substantiate the previous findings about the variety of topics covered in performance measurement in the FSC.

Nonetheless, at the same time, some macro-themes appear to have been studied in various periods (cf. Figure 7), and in particular, some of them moved from less studied (e.g., intermittent or emerging) to more studied (e.g., well established), thus showing an increased interest in these topics. To be more precise, from period 2 to period 3, the term "simulation" moved from emerging/phantom to intermittent, thus showing an increased popularity of the topic. This is confirmed by the fact that a similar macro-theme also appears in the last period, either as "agent-based simulation" (emerging/phantom) or as "discrete event simulation" (intermittent). Similarly, from period 3 to period 4, various terms have moved from emerging/phantom to different classes; specifically, "energy efficiency" and "food industry" have become core concepts of the last period of analysis, while "Supply chain management" and related themes appear as intermittent topics. These outcomes indicate the progressive attention paid to specific topics, and, in particular, to sustainability-related issues in FSC, and the decreasing importance of more general concepts (e.g., "supply chain management").

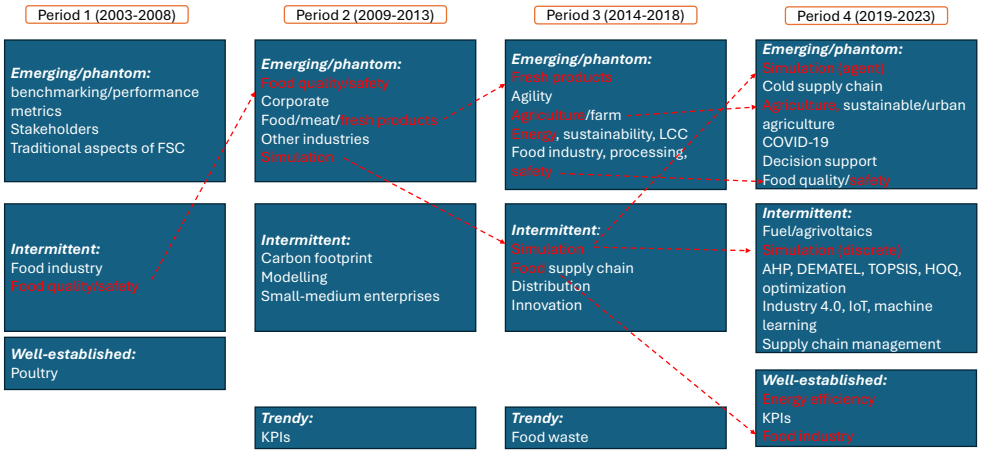

Figure 7. Trend of the macro-themes by period.

The final analysis, i.e., the keywords co-occurrence (Figure 8), built by setting a minimum number of five connections between terms, confirms that, overall, the most recurring topics in the sample of papers reviewed are "key performance indicators", "supply chain management", and "food industry", which are all listed as core topics of this stream of research. In addition, strong relationships between these topics are clearly highlighted in the figure. Moreover, Figure 8 shows, among others, the following relationships:

- Simulation, performance management, and supply chain management (orange cluster): this suggests that simulation-based techniques have been exploited by authors as effective tools for performance measurement and management.
- Food industry, agriculture, energy consumption, and energy efficiency (green cluster). This outcome indicates an increasingly important role of energy-related issues in the agri-FSC.
- KPIs, productivity, climate change, circular economy (violet cluster): possibly, these relationships suggest that KPIs have been used for measuring efficiency, but at the same time, are increasingly being used for measuring environmental-related aspects (in line with the presence of "sustainable development" among the core topics).

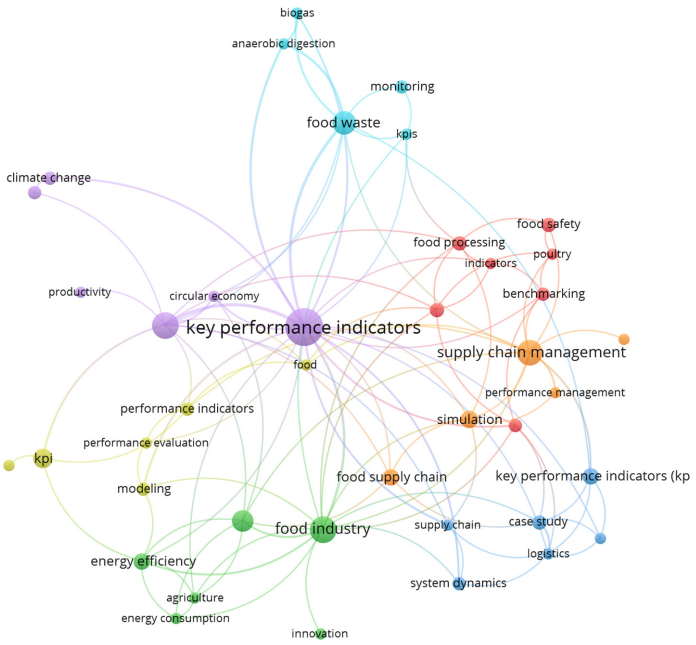

Figure 8. Keywords co-occurrence.

3.3. Outcomes of the Content Analysis

In this Section, the results of the analysis carried out on the contents of the 125 selected documents are proposed.

Figure 9 shows the first aspect investigated, namely, the time distribution of papers for the different products covered in the FSC in question. Specifically, nine categories of products can be found: agricultural products, meat, fish, dairy products, bread, animal and plant production, alcohol-free drinks, food production (in general), and fruit. Moreover, on the basis of the results, two additional groups were added: the "Combination", which means that more products are referred to in the document in question, and "Not specified" in cases where the searched information was not found.

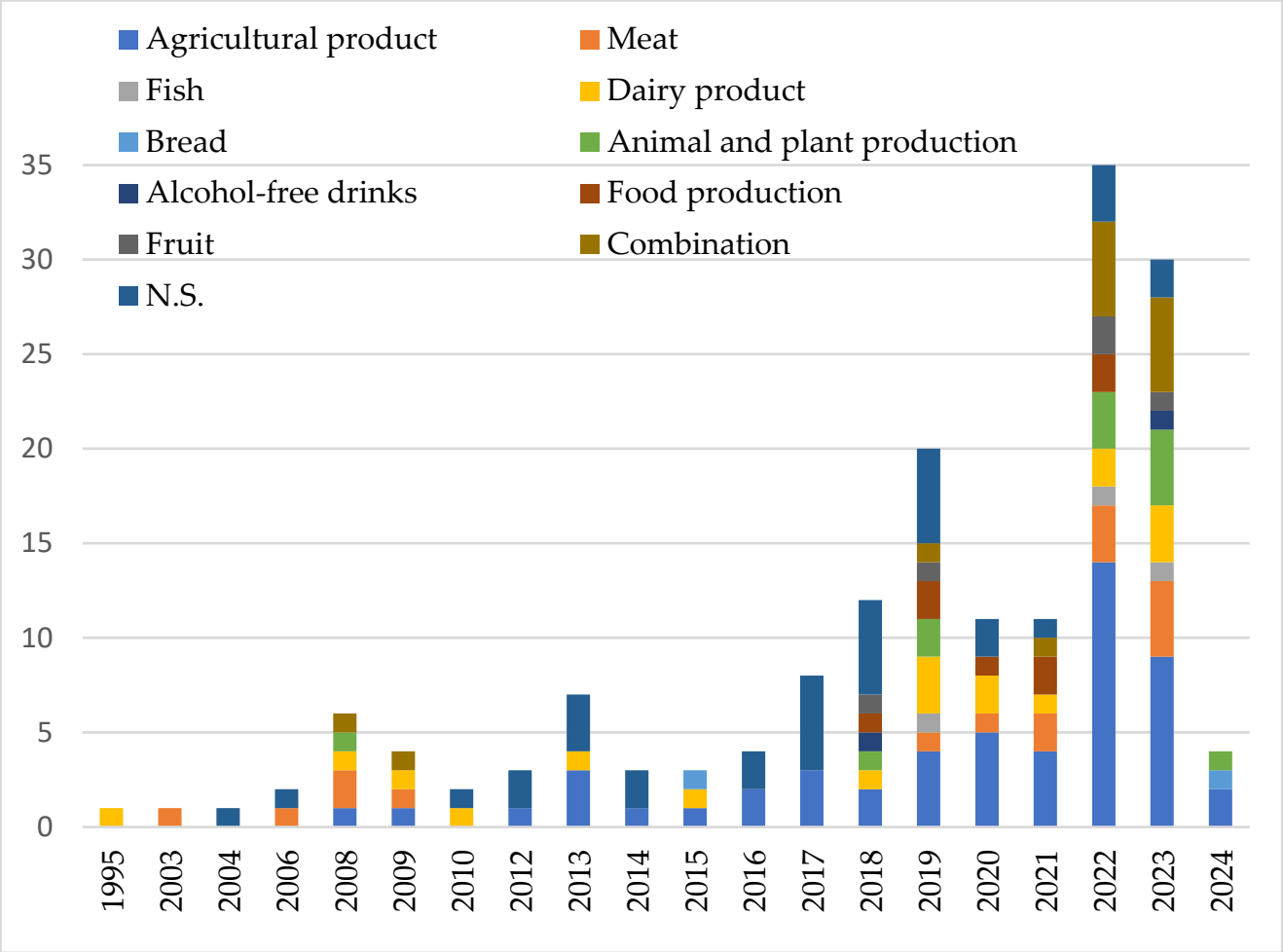

Figure 9. Paper distribution by-products.

As can be seen from the figure above, in 35 studies, the product type of the FSC studied is not specified, while in 14 papers, more than one type of product (combination) is treated. Moreover, agricultural products are the most popular in the analyzed sample (53 out of 125 studies—42.4%), followed by papers dealing with dairy (18 papers) and meat (16 studies) products. These results are in line with the journal analysis and the keywords one, since agricultural issues have already emerged. For completeness, instead, the numbers of the remaining food categories are the following: 12 (animal and plant production); 8 (general food production); 5 (fruit); 3 (fish); and 2 (bread and alcohol-free drinks).

Following the classification proposed by Tebaldi et al. [73], FSCs were categorized into three different areas: supply, production, and distribution. By "supply", a phase is meant in which the product is treated as a raw material, including activities such as cultivation

or farming; the remaining two stages instead deal with industrial transformation and subsequent distribution of the final product.

The results are shown in Figure 10. In this case as well, in addition to the three mentioned phases, the "Combination" and "Not specified" (N.S.) groups were added; when a combination is recalled, it could be referred to as a FSC intended as a whole.

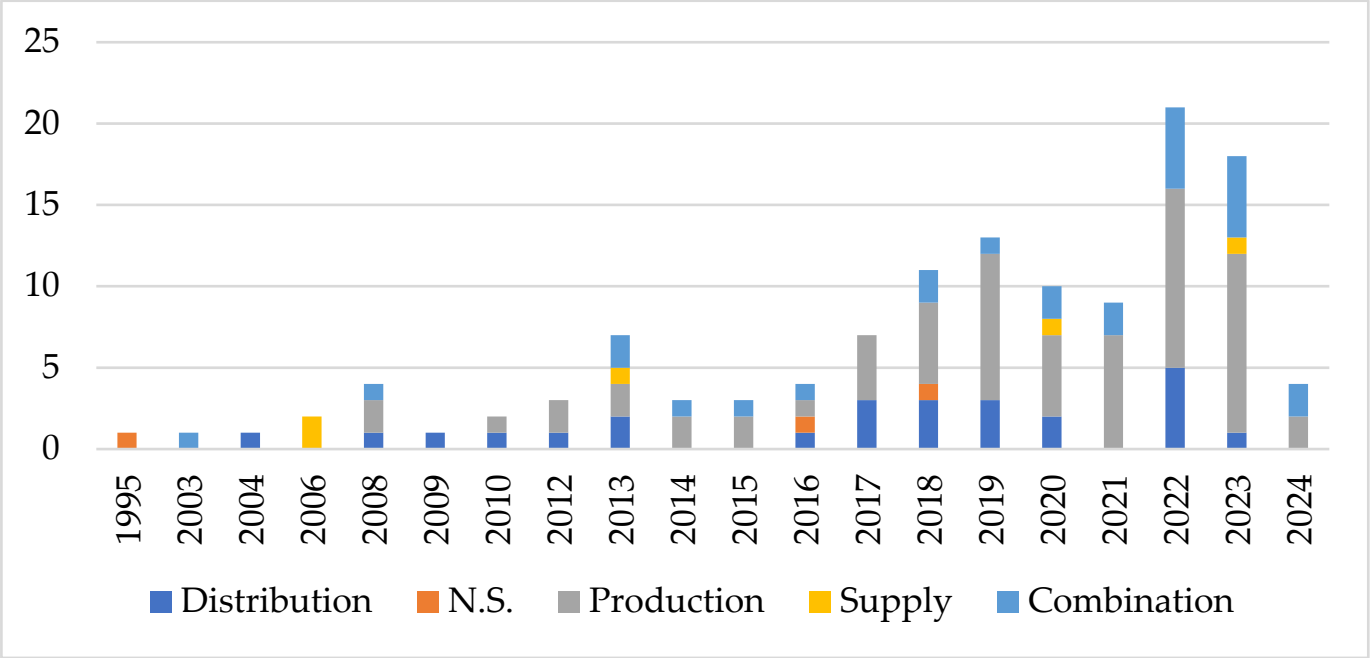

Figure 10. Paper distribution by FSC areas.

As shown in Figure 10, the area with the highest number of contributions is production (with 66 papers—52.8%), followed by combination and distribution, with 26 and 25 studies, respectively. Note that in contrast with the previous results, the supply stage was scarcely involved (five documents only); this could be due to the fact that agricultural products can be considered raw materials for industrial processes. Moreover, it could also be expected that KPIs are mostly involved in industries rather than in agricultural contexts.

Going into the detail of the FSC stages, the three figures that follow show the distribution of the studies by type of activity for each of the areas, proposed in their logical order. Figure 11 presents the classification for supply. It can immediately be seen that a total of 20 studies have dealt with supply. It should be specified, however, that out of these 20 studies, 5 are classified as supply only, while the remaining 15 are classified as a combination of multiple areas. Specifically, 10 supply + production, and in this case, the product of the supply stage can be considered as the raw material of the production processes; 4 supply + production + distribution, considering a whole FSC; 1 supply + distribution; in this last case, we deal with products of the supply stage that are directly sold without any industrial process. The activities recognized in the 20 documents dealing with the supply stage are the growing, the procurement, the raw material selection and also the combination of these. In other words, this means that KPIs are involved in measuring aspects related to these activities, and this holds true also for the following activities referring to the other SC stages.

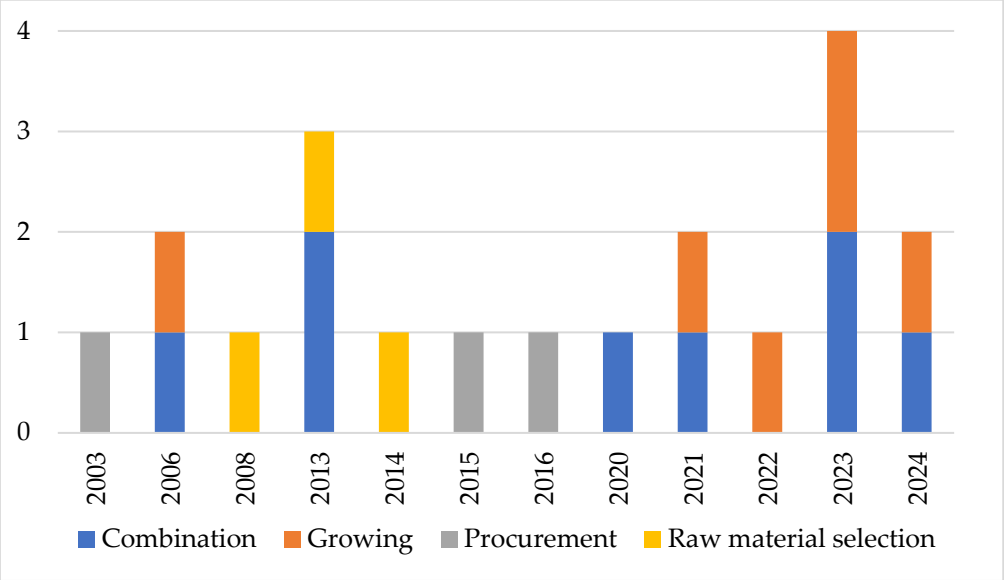

Figure 11. Distribution of reviewed papers by supply activities.

With respect to the supply activity, as can be seen from the figure above, the combination of multiple activities appears to be the most investigated with reference to the use of KPIs, with 8 out of 20 contributions, followed by the growing activity (6 papers).

Figure 12, instead, shows the classification for production, i.e., the industrial level. There are 91 studies for this area, 66 of which focus on the area of production alone, while the others study production along with other areas (25 papers). Specifically, production and supply with 10 studies, production and distribution with 11 papers, and production with supply and distribution with 4 contributions, with the same meanings provided for the supply stage. In this case, four activities can be found, plus the combination option: performance evaluation, planting, processing, and harvest.

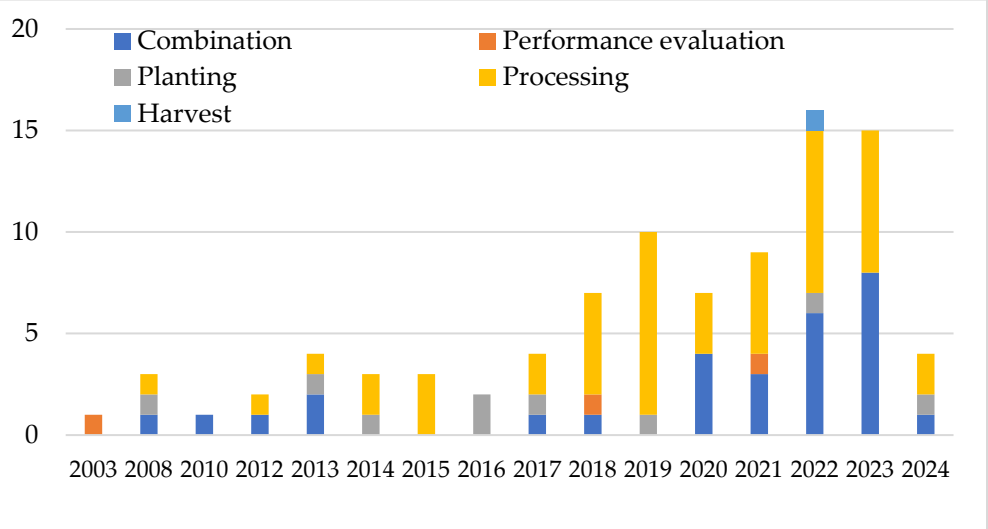

Figure 12. Distribution of reviewed papers by production activities.

As depicted in the figure above, processing is the main activity in the production area (49 studies), followed by combinations of several activities within the same paper (29 publications). Interestingly, only one study focused on harvesting activity.

Figure 13, finally, reports the classification for the distribution. There are 41 papers on this area, 25 of which focus on the area of distribution alone, while the others focus on the

distribution along with other areas (16 papers): distribution with supply and production (4 studies), distribution and supply (1 study), and distribution with production (11 papers).

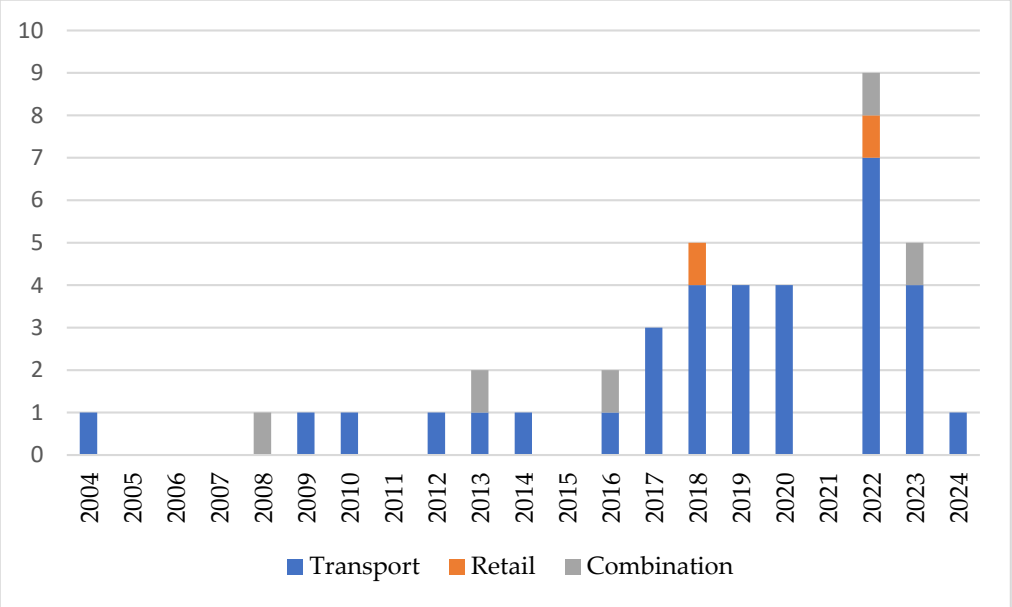

Figure 13. Distribution of reviewed papers by distribution activities.

Distribution in the FSC is mainly characterized by two activities: transport (34 papers) and retail (2 studies). In addition, it can be seen from the figure that there are five studies that combine these two activities together. This result is definitely in line with the sustainability issue; indeed, transport is one of the most impactful activities in terms of harmful emissions toward the environment, and several companies are starting to measure their emissions and to monitor their transport activities [74]. Therefore, it is not surprising that several studies have their focus on that.

As already mentioned in Table 2, the KPIs were classified into three categories of sustainability, including economic, environmental, and social aspects. Figure 14 shows the time distribution of KPIs classified into the three categories, again including the combination and the documents in which this information is not detectable.

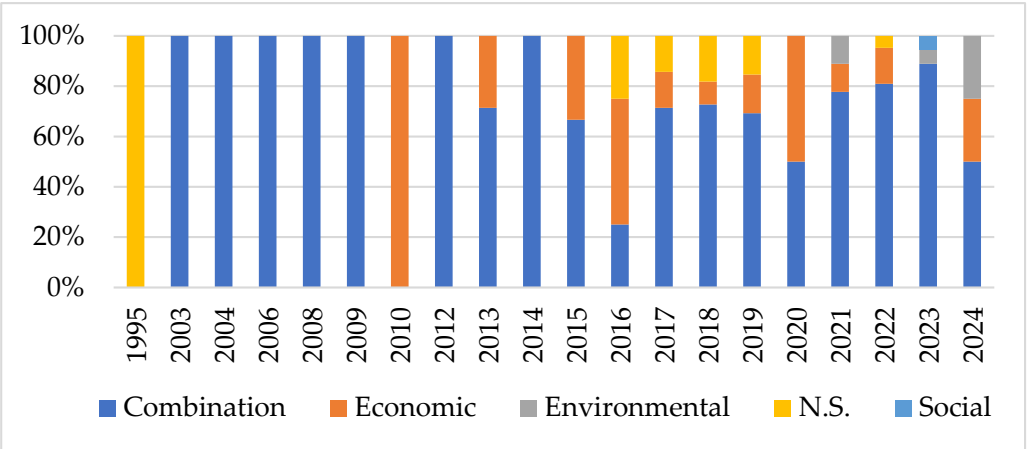

Figure 14. Trend of publications by KPI categories.

As can be seen from the figure above, the combination of more than one category of KPIs prevails (92 out of 125 studies—73.6%), followed by the economic perspective with

21 papers, 8 papers for which the information was not available, 2 documents in which KPIs for measuring the environmental perspective are mentioned, and only 1 including the social dimension. Indeed, the most investigated FSC stage was production, and according to this, economic KPIs are closer to the industrial context. Moreover, it is once again demonstrated that quite often social perspective is neglected since it is difficult to be quantified and measured [74].

Among the economic KPIs, we found Return on assets [71,75], Gross margin [76], Return on sale [68], Economic farm surplus [38], and Sharpe ratio [77]. Among the environmental KPIs, we identified Water footprint [76], pH levels [78], CO_2 emissions [21,51,56], Global Warming Potential [79], and Soil fertility [38]. Finally, among those classified with the social dimension were Labor relations [37], Human equity [80], and Accessibility of basic services [38].

Given the high quantity of studies with KPIs combinations, Figure 15 details the different groupings. As shown in this figure, the combination of all three types of KPIs (Economic, Environmental, and Social) is the most studied in the literature (56 out of 92 studies), reflecting the Triple Bottom Line approach, which corresponds to the most complete level of analysis of an activity or of a process. In line with the fact that quite often the Social aspect is neglected both in the literature and in real cases, the combination of Economic and Environmental KPIs follows, with 22 papers. Conversely, Social and Environmental is the least studied combination, with one contribution only; also, this result was expected if noting again that the production stage is the most widely investigated.

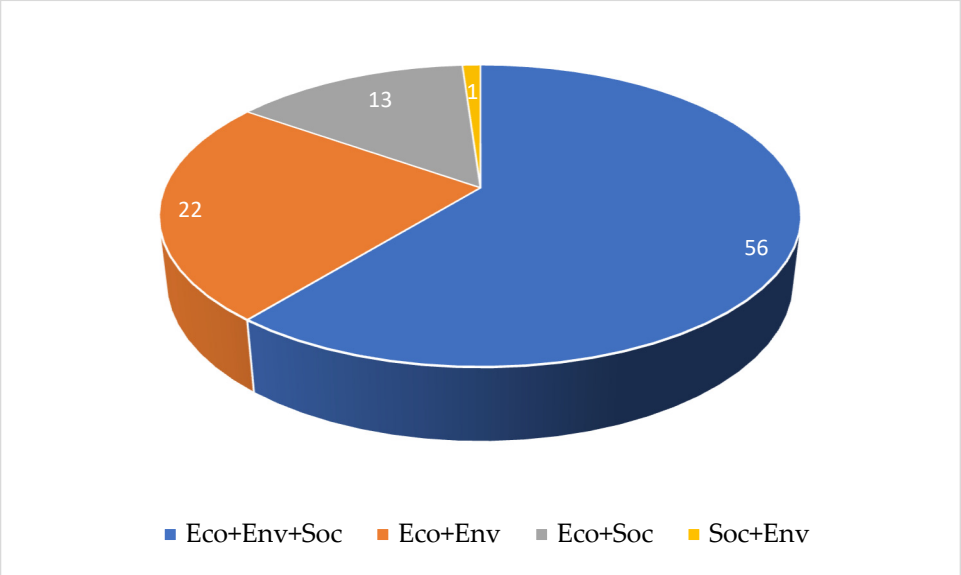

Figure 15. Combinations of sustainability KPIs.

4. Discussion

4.1. Theoretical Implications

From a scientific point of view, the present study provides a comprehensive bibliometric analysis of performance metrics in the FSC, highlighting the key trends and contributing to some gaps in the literature, and ultimately, laying the groundwork for future research aimed at improving the efficiency and sustainability of this vital sector.

On the basis of the set of analyses made in the previous Section, an answer to the RQs can be delineated. As regards the RQ1 ("How is the research on KPIs for FSC characterized?"), it can be observed that the general trend in time of the publications is growing, with a relevant quota of empirical studies (68 publications), followed by case studies (43)

and analytical models (39). The paper with the highest number of citations is a study describing a chance-constrained model for the multi-supplier inventory routing problem, with 206 citations at the time of writing, followed by [57,58], with 196 and 97 citations, respectively. This suggests that the topic of performance measurement in the FSC is increasingly being studied taking real data from the field. The source with the highest publication numbers is *Agricultural Systems* with five documents. The majority of papers reviewed are from Italy and the United Kingdom, with 14 and 12 papers, respectively, in line with the importance of agri-food industries in those countries. With respect to the authors, only four researchers published more than three papers on KPIs in the FSC within the sample. It is interesting to note that the analysis did not show any particular collaboration among these prominent authors.

Regarding the RQ2 ("What are the most frequent and persistent topics over time, and how do they relate to main research themes?"), the most common keywords in the sample of papers turned out to be key performance indicators, supply chain management, performance, and sustainability, as expected since they correspond to the terms used for the queries. In addition, outcomes highlight that the number of keywords has progressively increased in time, obviously in line with the increase in the number of papers. Trend of the keywords' classification by period confirms the increased importance of performance measurement in the FSC, as well as the progressive attention to sustainability issues in that context. Other topics whose importance has progressively increased in time refer to simulation-based techniques and energy-related issues. Strong relationships between these topics and those relating to performance measurement, supply chain management, and their FSCs were also highlighted.

From the results of the content analysis (RQ3), nine main types of products treated in the FSC were identified. Specifically, agricultural products are the most spread in the sample analyzed, followed by papers dealing with dairy and meat products. In an FSC, three different areas can be identified, i.e., supply, production, and distribution [23]. The FSC phase with the highest number of contributions is production, in contrast to the above finding (66 papers), followed by the combination of more phases and the distribution process, with 26 and 25 studies, respectively. Looking at the supply process, the combination of multiple activities appears to be the most developed, followed by growing, while processing is the most analyzed activity in the production area, followed by combinations of several activities within the same paper. Finally, transportation and retail are the two activities that characterize distribution. The KPIs were classified into three macro categories, namely, economic, environmental, and social, and the combination of more than one category of KPIs prevails, followed by the economic perspective, confirming the involvement of the industrial level.

4.2. Practical Implications

From a practical perspective, this study highlights the importance of analyzing KPIs in different sectors and stages of the FSC. In particular, it is clear that some specific areas or activities of the FSC are poorly studied from the point of view of the social, environmental, and economic KPIs; examples of these areas are supply, raw material selection, and procurement. Similarly, the production stage exhibits a small percentage of studies that analyze performance and KPIs in the planting and harvesting phase. The distribution phase of food products is also little analyzed in terms of KPIs. The outcomes of this study, therefore, suggest a deeper investigation of these areas and phases of the supply chain by conducting specific analyses (e.g., in the form of case studies) and defining specific KPIs to be monitored, consequently obtaining greater benefits for the entire food value chain.

On the basis of the contents developed, the framework proposed in Figure 16 was built. In detail, for each previously identified stage of the FSC (i.e., supply, production, and distribution), the framework summarizes the most common KPIs that can be effectively used for performance measuring and monitoring. Note that most of the KPIs are in common for all three stages (as partially expected), and that the three different Venn diagrams refer to each of the three sustainability dimensions (i.e., social—red, environmental—green, and blue—economic).

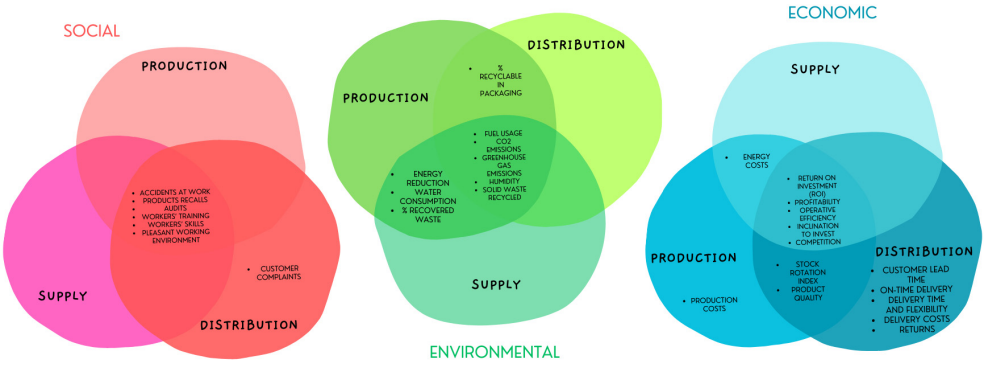

Figure 16. Most common KPIs for each stage of the supply chain.

Moreover, for completeness, the list of the specific KPIs found for each of the identified products is also provided; in this case, some KPIs are very specific and are clearly related to the FSC to which they refer. Table 9 resumes the findings.

Table 9. KPIs for the different FSC products.

Products	Economic KPIs	Social KPIs	Environmental KPIs
Agricultural products; Fruits; Animal and plant production	Farm profit per hectare Weight of the fruit/vegetable Volume and dimensions of the fruit/vegetable Crops distance Crops yield Net/Gross economic irrigation water productivity (NEWP–GEWP) Agronomic productivity Farmers income Dried product quality % of permanent grassland and pasture areas % of the area for biological agriculture Weight of parturient sheep Value of sheep bodies at slaughter	Employment in agriculture Number of agri-tourists Agricultural food safety Foodborne diseases Flavor of the product Rural community participation Landowner independence in decision making	Soil fertility Plant growth and well-being Water quality indicators Water footprint Pesticide usage Soil Ph Weed Coverage Rate
Meat	Number of livestock	Animal well-being Meat consumption rate	Reducing meat waste
Dairy products	Young versus adult cows % of self-produced food Animal density Calf births	-	-
Bread	Wheat level in silos	-	-

Given their common characteristics, agricultural products, fruits, and animal and plant production were evaluated together; indeed, they share most of the KPIs found. It is interesting to note that most of the KPIs refer to economic issues, as the nature itself of businesses tends to the prioritization of these aspects. Environmental KPIs were found for these FSCs only; this does not surprise us at all, since this category includes environmentally related activities such as cultivation of livestock, above all, in the supply stage. For fish and alcohol-free drinks, no specific indicator was detected, and this is the reason for their exclusion from this table; the KPIs involved for these products were the ones in common with other FSCs referring to more general aspects.

5. Conclusions

With the aim of mapping, analyzing, and classifying the main KPIs related to the FSC, this study presents a detailed analysis of a sample of 125 articles in this context, using mainly bibliometric tools. The studies constituting the sample were classified into articles (90), reviews (10), and conference papers (25). The whole sample of papers reviewed was analyzed through bibliometric statistics, using Microsoft Excel™. The studies were cataloged on the basis of various characteristics, namely, publication year, research methodologies, most productive journals, geographic origin of the study, citation, influential authors, and keywords. Then, a content analysis was carried out to delineate the main topics covered according to the different products presented in the FSC, relating areas, KPI categories, and types of KPIs combination.

Despite the scientific and practical contributions, the authors are obviously aware of some limitations of this paper, e.g., the fact that the search results were obtained by considering only the Scopus database, while other databases (such as Web of Science—WoS, and GoogleScholar) were not included in the review. Thus, as a further research direction, it is suggested that additional various databases be used. It is necessary to specify, however, that for these topics, compared to Scopus, WoS does not typically add content; we have checked this aspect by making some queries on WoS and this is confirmed from the results obtained. As far as Google Scholar or Openalex, these tools typically return a wide range of results, but their usage in systematic reviews is not common, as it is almost unfeasible to set filters when making queries (e.g., limit the search to abstract, title or keyword, or publication year). Similarly, the framework built from the set of analyses shows some limitations, as it was derived from the sample of documents reviewed in this study, and as such, it could not be assumed to be fully exhaustive. Rather, it could not be excluded that more KPIs could be involved for measuring performances of the listed products. In line with this consideration, as an ongoing research activity, the authors are working on a second step of the present work, with the purpose of increasing the level of detail of the performance metrics, e.g., by providing the detailed formulae or definitions of each KPI depending on the context. The expected outcome of this activity would be the development of a useful tool for practitioners who want to monitor different parameters of their business.

Author Contributions: Conceptualization, E.B., L.T., G.C. and C.M.; methodology, G.C. and L.T.; software, G.C.; validation, E.B., C.M. and L.T.; formal analysis, G.C.; investigation, L.T.; resources, L.T.; data curation, G.C.; writing—original draft preparation, L.T. and G.C.; writing—review and editing, E.B. and C.M.; visualization, L.T. and G.C.; supervision, E.B. and C.M.; project administration, E.B. and C.M.; funding acquisition, E.B. and C.M. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Full list of documents constituting the final sample, listed in chronological order.

References	Year	Research Methodologies			
		Analytic/Model	Empirical	Case Study	Conceptual
Reinemann & Mein [81]	1995	X	X		
Lindgreen & Hingley [43]	2003			X	
McKinnon & Ge [82]	2004		X		
Manning, Baines & Chadd [45]	2006				X
Rimmington, Smith & Hawkins [44]	2006		X		
Dodd et al. [38]	2008			X	
Gellynck, Molnár & Aramyan [83]	2008		X		
Manning, Baines & Chadd [67]	2008	X	X		
Trevisani & Rosmini [84]	2008				X
Ilic, Staake & Fleisch [61]	2009			X	
Beukes et al. [85]	2010	X			
Shokri, Nabhani & Hodgson [86]	2010			X	
Hřebíček et al. [70]	2012	X			X
Soysal et al. [36]	2012		X		
Wauters et al. [87]	2012	X	X	X	
Flipse et al. [88]	2013		X		
Manning & Soon [19]	2013				X
Popelka et al. [37]	2013				X
Sigl et al. [89]	2013		X		
Torkko et al. [90]	2013		X		
Vlachos [15]	2013		X	X	
Vlajic et al. [65]	2013	X	X	X	
Chen & Yu [91]	2014		X	X	
Flipse, van der Sanden & Osseweijer [92]	2014		X	X	

Table A1. *Cont.*

References	Year	Research Methodologies			
		Analytic/Model	Empirical	Case Study	Conceptual
Woodford et al. [57]	2014	X			X
Corsini et al. [93]	2015	X	X		
De Marco et al. [94]	2015		X		
Sharma, Chandana & Bhardwaj [95]	2015	X	X		
Aivazidou et al. [20]	2016		X	X	
Fortuin & Omta [96]	2016		X		
Jimenez, Mediavilla & Temponi [97]	2016	X		X	
Van Der Waal et al. [98]	2016		X	X	
Crandall et al. [99]	2017		X		
Derqui & Fernandez [100]	2017		X		
Fisseler, Kemeny & Reiners [101]	2017	X			X
Kassem et al. [71]	2017		X		
Reynoso [102]	2017	X	X		
Sel, Soysal, Çimen [46]	2017	X			
Siriwatthanaphan, Jansuwan & Chen [103]	2017	X		X	
Alamar et al. [104]	2018				X
Barabanova et al. [105]	2018	X			X
Biswal & Jenamani [106]	2018		X		
Bottani, Rinaldi & Solari [68]	2018	X			
De menna et al. [58]	2018		X		
Demartini et al. [49]	2018			X	
Immawan, Asmarawati & Cahyo [107]	2018			X	
Kuznetsov et al. [108]	2018	X			X
Lambin & Corpart [109]	2018				X
Nejatian et al. [75]	2018		X	X	
Soysal et al. [56]	2018	X			
Baba et al. [16]	2019				X
Bastos, Scarpin & Pecora [110]	2019		X	X	
Blažková & Dvouletý [111]	2019		X		
Casino et al. [60]	2019	X		X	
Correa et al. [59]	2019		X		
Gardas et al. [112]	2019	X			

Table A1. *Cont.*

References	Year	Research Methodologies			
		Analytic/Model	Empirical	Case Study	Conceptual
Guido et al. [113]	2019			X	
Kataike et al. [114]	2019		X	X	
Klychova et al. [115]	2019				X
Kubo & Okoso [116]	2019				X
Nejatian et al. [117]	2019		X		
Nozari et al. [118]	2019	X			
Pradella et al. [119]	2019		X		
Assa & Wang [77]	2020	X			X
Chen & Voigt [120]	2020		X		X
Chichenkov & Faizullin [121]	2020				X
Kurnianto et al. [122]	2020		X		
Kusrini, Safitri & Fole [123]	2020		X		X
Lagarda-Leyva et al. [124]	2020	X		X	
Nuseir [125]	2020			X	
Ojo et al. [126]	2020		X	X	
Tadić et al. [127]	2020		X		
Yadav, Garg & Luthra [64]	2020		X	X	
Campana et al. [47]	2021	X	X		
Devkota et al. [39]	2021		X		
Iten, Fernandes & Oliveira [128]	2021			X	
Jones et al. [129]	2021		X	X	
Morella et al. [21]	2021		X		X
Salah & Mustafa [130]	2021			X	
Singh, Berkvens & Weyn [63]	2021				X
Talukder et al. [80]	2021	X			
Walkiewicz, Lay-Kumar & Herzig [131]	2021			X	
Abeysiriwardana & Jayasinghe-Mudalige [132]	2022		X		X
Abeysiriwardana, Jayasinghe-Mudalige & Seneviratne [133]	2022				X
Al Akasheh, Eleyan & Ertek [134]	2022		X		

Table A1. *Cont.*

References	Year	Research Methodologies			
		Analytic/Model	Empirical	Case Study	Conceptual
Alrobaish et al. [135]	2022		X		
Badraoui, Boulaksil & Van der Vorst [66]	2022		X	X	X
Battarra et al. [136]	2022	X			
Bayir et al. [137]	2022			X	
Bottani et al. [69]	2022			X	
Chen et al. [62]	2022	X			X
Diaz et al. [79]	2022	X			
Giedelmann, Guerrero & Solano-Charris [138]	2022		X	X	
Guan et al. [139]	2022	X	X		
Hong et al. [50]	2022			X	
Kumar et al. [48]	2022	X	X		
Martínez-López et al. [76]	2022		X	X	
Onwude et al. [140]	2022	X	X		
Rahman, Nguyen & Lu [40]	2022	X			
Rajmis et al. [141]	2022		X		
Saint-Ges et al. [142]	2022		X	X	
Trienekens et al. [143]	2022		X		
Wohlenberg et al. [144]	2022				X
Bojar et al. [145]	2023		X		
Bottani et al. [23]	2023	X	X		
Cagliano et al. [146]	2023			X	
Darbyshire et al. [147]	2023	X	X		
Firman et al. [148]	2023		X		
Gilligan, Moran & McDermott [149]	2023			X	
Gómez-Ramos & Rico Gonzalez [150]	2023			X	
Iranshahi et al. [151]	2023	X	X		
Kumar, Tyagi & Sachdeva [152]	2023	X			
Loemba, Kichonge & Kivevele [153]	2023		X		
Martin, Elnour & Siñol [154]	2023			X	
Meitz et al. [51]	2023		X		
Mohamed, Mogili & Kasup [155]	2023			X	
Obe et al. [156]	2023		X		

Table A1. *Cont.*

References	Year	Research Methodologies			
		Analytic/Model	Empirical	Case Study	Conceptual
Ros et al. [157]	2023		X		
Shen et al. [78]	2023		X		X
Wang et al. [42]	2023	X	X	X	
Wei et al. [41]	2023	X			
Dyson et al. [158]	2024		X		
Kasztelan & Nowak [159]	2024	X	X		
Marrucci, Daddi & Iraldo [160]	2024			X	
Mostafa et al. [52]	2024			X	

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