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Telecoupling in the Food Supply Chain: Analysis of Trends and Gaps in the Literature

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Abstract

This study aims to shed light on gaps in research on telecoupling in the food supply chain. Both the Bibliographic Coupling and the Co-word analysis were applied to that end. Using broad search terms, we screened titles and abstracts in the Web of Science (WoS) and Scopus databases, categorising results by main topics. We synthesised relevant literature on each topic to provide a comprehensive overview. Key methodological steps included database selection, publication screening, exclusion criteria application, and a timeframe from 2013 to 2023. VOSviewer, bibliometric and scientometric analyses were conducted, revealing clusters of interconnected terms in co-word networks for each database. Results indicated recurring keywords across research areas. In co-citation analyses, WoS exhibited 35 references. Scopus showed limitations with only four co-cited references. The Bibliographic Coupling method highlighted shared theoretical bases among publications, emphasising common topics. Both databases offer distinct advantages, and the choice between them depends on the specific research focus. WoS provided a larger quantity of results for our topics. The Bibliographic Coupling method (co-cited references) resulted in eight papers. We identified significant research gaps in the literature on transportation flows within telecoupling in the food supply chain. Addressing these gaps could enhance the understanding of telecoupling dynamics and their impact on sustainability. The findings provide a foundation for future research and inform policy making in this area.

Keywords: systematic review, scientometric analysis, VOSViewer, telecoupling, supply chain

1. Introduction

The impacts of globalisation depend on trade relationships that emerge from increased integration among distant places that are connected to one another (Garrett et al., 2013; Liu et al., 2013). In an era marked by interconnected sustainability challenges such as feeding a growing population, addressing climate change and tackling pollution, there is a pressing need for a deeper understanding of the threads connecting distant places (Hull & Liu, 2018). This interconnectedness is exemplified by telecoupling, which involves linking local and regional social-ecological systems to large-scale, networked socioeconomic and environmental drivers operating at a distance (Liu, 2013; Zimmerer et al., 2018).

Telecoupling can be defined as the set of interactions among production, consumption and flows within natural systems, enabling the observation of economic, social, and environmental impacts of actors located at considerable distances but somehow interconnected (Liu, 2013). In an increasingly globalised world, studies and sustainability policies need to consider the socio-economic and environmental interactions between distant locations (Bruckner et al., 2015). This topic presents new challenges and opportunities regarding global environmental change (Carrasco et al., 2017). Currently, the consumption of provisioning ecosystem services is the main driver causing soil degradation and involving increasingly more food products produced in distant regions (Chotte & Orr, 2021). Despite significant conservation efforts, the natural environment continues to decline under the weight of continuous consumption (Díaz et al., 2019; Wang et al., 2022). Thus, the telecoupling framework can widen the perception of consumption's hidden impacts on the environment (Liu et al., 2013).

Nowadays, industry and consumers want to know where food comes from and who produces it. Consequently,

there is a will to restore the link between food and its geographic and cultural origins. This objective is evident in the global surge of certification schemes and fair-trade regulations (Hull & Liu, 2018). Moreover, smallholders play a crucial role in resource management and food production, addressing issues related to food and nutritional security (Eakin et al., 2017; Zimmerer et al., 2018).

On the other hand, global demand for commodities such as soybean, maize, wheat, and other farm products, has increased. When processed, these grains produce both oil and feed or other ingredients that are then incorporated into cooking oils, biofuels, livestock feeds, and numerous processed food products (Garrett et al., 2013).

Considering the Food Supply Chain, the telecoupling framework is a valuable opportunity to advance sustainability goals (Manning et al., 2023). That is because the Telecoupling framework, comprising systems, flows, agents, causes, and effects (Liu et al., 2013; Liu, Mooney et al., 2015). implies taking into account ecological footprints, including those related to greenhouse gas emissions and energy consumption in transportation. Furthermore, the assessment of telecoupled systems can be beneficial in improving food security (McCord et al., 2018).

Investigating the environmental impacts related to the trade of food demands the identification of suitable assessment and analysis tools (Millington et al., 2017; Schierhorn et al., 2019). In recent years, a growing body of research has quantified the flows of food crops, with a significant portion of these studies concentrating on the investigation of commodity flows at the international level among countries, overlooking, however, the subnational scale (Fridman & Kissinger, 2019).

Telecouplings studies focused on the urban scale are still notably limited (Schmitz et al., 2023). Outstanding among them is the study by Yang et al. (2016), which addresses water management challenges for sustainability. The work of Jordan and Gadda (2020) explores the impacts of urban telecouplings in certified organic fruits. Authors Schmitz et al. (2023) evaluate the urban telecoupling and associated environmental impacts of organic food, including energy consumption, Greenhouse Gas (GG) emissions, and carbon and energy footprints.

To encourage nations to increase food production and biodiversity conservation, and to pursue sustainable cities aligns with the Sustainable Development Goals (SDGs). A key issue is to understand how to spatially reconcile these potentially competing SDGs (Zhang et al., 2021). The impacts of globalization on land use and the increasing demand for food rely on the trade relationships that emerge among producers, traders, and consumers. There is a limited understanding as to how quality preferences in telecouplings influence trade patterns and supply chains (Garrett et al., 2013). Gaps persist regarding the attributes of distant interactions that remain unknown in relation to telecoupling (Liu, 2013; Liu, Mooney, et al., 2015). Thus, the aim of this research proposal is to identify some of these gaps.

Our study seeks to map the articles on telecoupling in the food supply chain. To address this issue, we conducted a systematic review, and employed scientometric analysis, guided by VOS Viewer. We first used broad search terms to obtain relevant articles, screened the titles and abstracts, and separated the results from each approach into their main topics. Then, we synthesized the most relevant literature on each topic. This research is essential for advancing the understanding of the role of telecoupling in global food systems, and our contribution provides a comprehensive synthesis that will serve as a foundation for future research and inform policymaking in this area.

2. Method

This study explores how researchers are addressing transportation flows in telecoupling related to the food supply chain. We first iteratively narrowed our search terms in order to find the most accurate ones. The literature review and screening process are summarized in Figure 1.

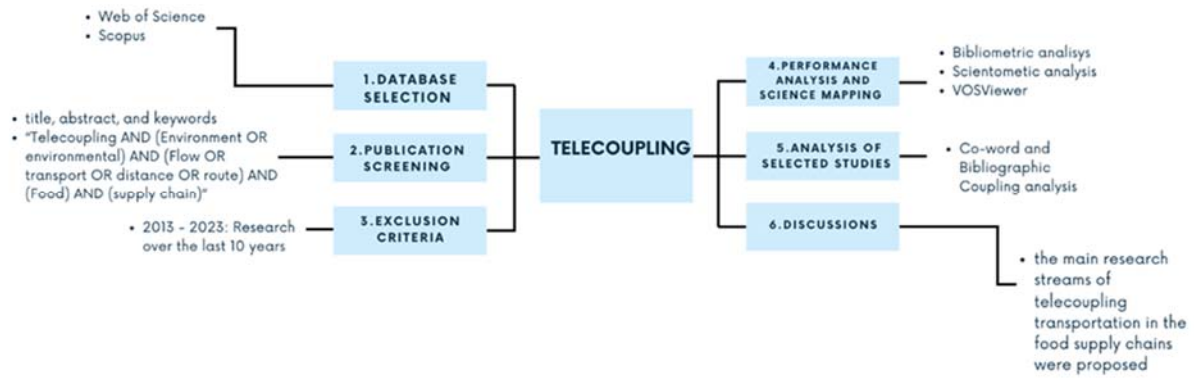


Figure 1. Workflow of research review

Secondly, we performed a scientometric analysis and a bibliometric literature review, which counted on keyword searching and removing irrelevant papers to screen out the sample articles with the highest degree of relevance to telecoupling in the food supply chain.

2.1 Exploration and Analysis Steps

The bibliometric literature review with respect to telecouplings in the food supply chain was conducted on Web of Science and Scopus databases, which are widely adopted in bibliometric research (Falagas et al., 2008).

A systematic literature review was used to identify the state of the art. The primary aim of a systematic review is to synthesize and critically evaluate the available evidence in a specific thematic area, relying on pre-selected and meticulously analysed studies (Manning et al., 2023). On the other hand, the scientometric analysis focuses on quantitative and statistical methods to measure and analyse patterns and trends in scientific production, including the number of publications, citations, and collaborations, among other factors (Baker et al., 2021). These methods served as primary tools to support the search for scientific papers and were outlined based on key steps, namely:

(1) Database selection—the search for peer-reviewed scientific articles was delimited to the Web of Science and Scopus databases.

(2) Publication screening—search terms were applied using combinations, string-searching algorithms, and Boolean Operators for words found in the title, abstract, and keywords of the documents.

(3) Exclusion criteria/removing irrelevant papers—after reviewing the abstracts and titles, we excluded those that did not specifically address the topic under investigation. The search was constrained by parameters and combinations and was conducted within a 10-year time frame, from 2013 to 2023.

(4) Performance Analysis and Science Mapping—bibliometric and scientometric analysis were conducted using VOSviewer, a network visualization software. VOSviewer was chosen from among other visualization software since it is open source and free to access.

(5) Analysis of selected studies—the content of the articles was examined, and a review was developed.

(6) Discussion—Based on the scientometric analysis and literature review, the main research streams and gaps of telecoupling transportation in the food supply chains were suggested.

2.1.1 Step 1: Database Selection

For the bibliometric data collection, a search algorithm was defined to be employed in the Web of Science and Scopus databases. The selection of two distinct publication platforms aimed to encompass a broader range of articles

Scopus is a multidisciplinary citation-indexed database launched in 2004, providing various metrics for its materials. Currently, it encompasses more than 25,800 peer-reviewed journals, with 27% of these falling within the field of "physical sciences". Web of Science dates back to 1973, comprising three subdivisions and offering a wide array of tools for result manipulation (Norris & Oppenheim, 2007; Scopus, 2024).

2.1.2 Step 2: Publication Screening

In the review process, we identified search terms utilized in articles published over the last 10 years (until November 2023). The selected terms were chosen to simultaneously include the largest number of relevant articles.

We conducted several combinations of searches using potentially relevant terms found in either the title, abstract, or keywords. Subsequently, we delimited our investigation by combining the main themes of telecoupling in the food supply chain. The search algorithms employed in the Web of Science and Scopus databases are presented in Table 1.

Table 1. Search Algorithms Employed in Web of Science and Scopus (until Nov. 2023)

Id.	Terms	Publications number	
		WoS	Scopus
1	Telecoupling	229	254
2	Telecoupling AND (Environment OR environmental) AND (Flow OR transport OR distance) AND (Food)	34	21
3	Telecoupling AND (Environment OR environmental) AND (Flow OR transport OR distance OR route) AND (Food) AND (supply chain)	4	2

2.1.3 Step 3: Exclusion Criteria/Removing Irrelevant Papers

We identified 229 articles in WoS, and 254 in the Scopus database. Those articles were used in the scientometric analysis in VOSviewer. Refining the search with Boolean operators and string searching algorithm resulted in 4 articles in WoS and 2 in Scopus. However, to achieve a greater breadth of data, we employed the first set of strings (Table 1), that is, “telecoupling”. Bibliographic Coupling was the standard analysis for selecting the most influential articles.

2.1.4 Step 4: Performance Analysis and Science Mapping

After obtaining the articles through the algorithm, they were submitted to evaluation and treatment (identifying possible duplicates and/or those outside the scope of the research). All articles were then exported into the VOSviewer system. This software generates network maps from bibliometric data, connecting authors, citations, and common words, among other criteria, enabling the visualization of correlations among all identified papers. It also offers three presentation formats for its final product: networks, overlay, and density (Jan van Eck & Waltman, 2023).

In general, the program uses two measures: number and strength of connections. These measures indicate the magnitude or importance with which two topics are connected. For instance, the number of papers in which two keywords are used together, in the case of the co-word correlation method. Strength, on the other hand, is represented by the size of the “nodes” and the number of connections or citations (Baker et al., 2021). For example, in the map created by VOSviewer, the nodes can represent the most frequent keywords or authors (where a larger icon indicates higher frequency) and those that are cited together (as shown by the connecting networks).

2.1.5 Step 5: Analysis of Selected Studies

One selected method for this study was the co-word correlation technique, in which VOSviewer identifies and connects keywords that recur across different articles. The co-word correlation system was chosen for its ability to provide a better understanding of the content in each publication, indicating both past and current trends, as well as potential future trends. A minimum occurrence of ten co-word repetitions was established for inclusion in the map.

The other technique, bibliographic coupling, groups common references among different publications. By doing so, it organises the map in clusters. We used this technique to present the most influential and widely studied articles (Donthu et al., 2021), as well as to understand future trends.

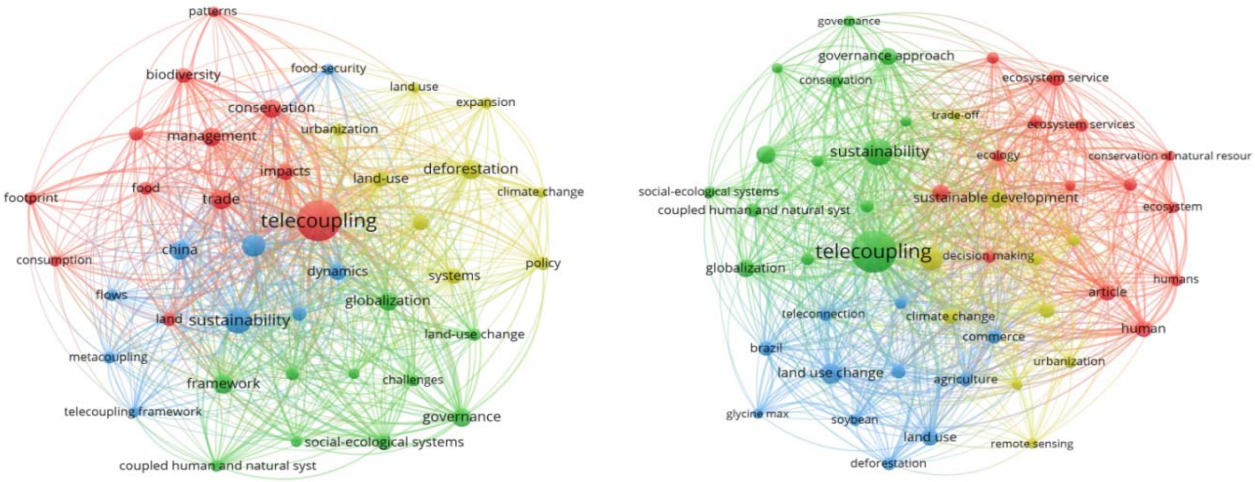
2.1.6 Step 6: Discussions: Trend Analysis

The development unfolded through surveys and reflections on the topic, incorporating conceptual reviews and insights into transportation dynamics. The literature review focused on internationally selected papers, specifically assessing works related to distances associated with telecoupling, particularly in the context of the food supply chain.

3. Results and Discussions

3.1 Potential Trends: Co-word Analysis

The maps presented in Figure 2 illustrate the networks and the overlap of topics within selected publications based on WoS and Scopus databases, respectively.



WoS Scopus

Figure 2. Co-occurrence - all keywords

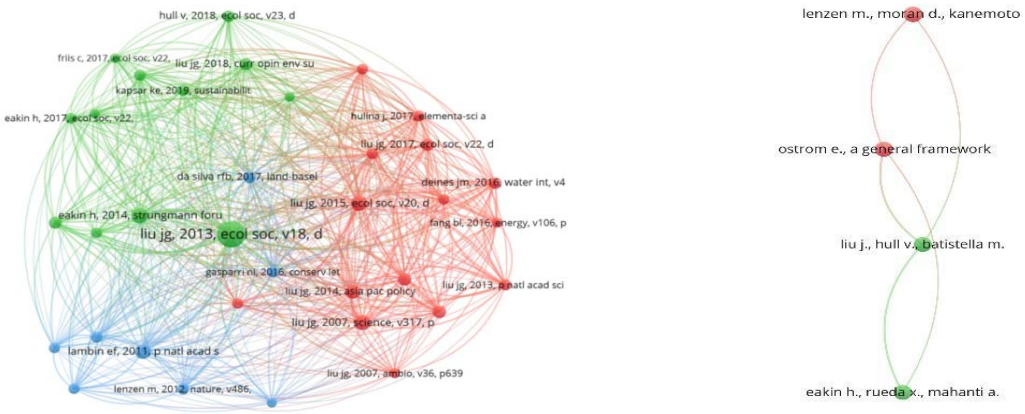
WoS offers 229 articles with regard to telecoupling. Among the 40 terms provided, “telecoupling” is the most employed (141 occurrences). The result was the division into four interconnected clusters. All references with more than 10 common citations were considered, resulting in 1385 keywords, of which only 40 were interconnected. On WoS, Cluster 1 (red) includes terms such as biodiversity, conservation, consumption, food, footprint, impacts, international trade, land, management, patterns, and trade. In addition, Cluster 2 (green) represents the application of governance, globalisation, challenges, and other keywords related to governance studies. Cluster 3 (blue) represents papers on sustainability, flows, and metacoupling, as well as telecoupling framework. Cluster 4 (yellow) shows keywords in policy area, land use, urbanization, deforestation, and expansion.

Scopus provided 254 articles with regard to telecoupling. Among the included terms, “telecoupling” is the most employed (166 occurrences). The result was the division into 4 interconnected clusters. All references with more than 10 common citations were considered, resulting in 1923 keywords, of which 49 were interconnected. Cluster 1 (green) includes terms such as biodiversity, conservation of nature, decision-making, ecology, ecosystem, ecosystem service, environmental management, environmental policy, and environmental protection. Cluster 2 (red) encompasses the terms anthropocene, conservation, coupled human and natural system, globalisation, governance, governance approach, metacoupling, nature-society relations, social-ecological system, spill-over effect, sustainability, and telecoupling. Cluster 3 (blue) themes are related to agriculture, commerce, deforestation, environmental economics, land use, international trade, soybean, and teleconnection. Cluster 4 (yellow) shows keywords on climate change, economic and social effects, environmental impact, remote sensing, spatiotemporal analysis, sustainable development, trade-offs, and urbanisation.

In general, the selected publications use the same keyword across research areas in both databases.

3.2 Bibliographic Coupling

The maps presented in Figure 3 display the most cited authors with their connections determining which articles are co-cited. We considered the most influential publications among the most relevant authors in each cluster.



WoS Scopus

Figure 3. Co-citation/cited reference

In the analysis of the co-citation of references from the 229 articles provided by WoS, only 35 references were co-cited. The minimum number of constraints, set at 20 references with common citations, resulted in a total of 13,506 references, of which only 40 were interconnected. WoS's results allow us to examine the most influential and relevant publications today. These documents tend to serve as a foundation for the development of studies, and citing them adds significant credibility to articles. The maps in Figure 3 also reinforce the longstanding notion that the Web of Science is a highly reliable database with technical excellence in terms of references and bibliometric data collection. Its direct compatibility with the bibliometric analysis software VOSViewer, makes it possible to read and present data more clearly, providing only the first author and the publication year. This format provides a quick and effective way for a subsequent qualitative analysis.

The analysis of the co-citation of references from the 254 articles provided by Scopus resulted in four references that were co-cited. The minimum number of constraints, set at 20 references with common citations, resulted in a total of 18,499 references, of which only 4 were interconnected. This shows that Scopus exhibits limitations in its effectiveness for collecting references and bibliometric data related to telecoupling. Moreover, there is a notable scarcity of co-citation, indicating fewer connections in publications among authors

In addition to the map networks, VOSviewer creates a list of the most relevant publications (co-cited references) which is presented in Table 2. The number of times an article was cited is the essential metric for bibliographic coupling.

Table 2. Co-citation analysis and the five most influential publications (until Nov 2023)

Database	Cited reference	Citations	Total link strength
WoS	(Liu et al., 2013)	161	898
	(Eakin et al., 2014)	56	447
	(Liu, Hull, et al., 2015)	54	465
	(Liu et al., 2007)	52	388
	(Lambin & Meyfroidt, 2011)	48	288
Scopus	(Lenzen et al., 2012b)	16	2
	(Eakin et al., 2017)	15	3
	(Liu et al., 2013)	15	5
	(Ostrom, 2009)	15	4

Among the articles listed by WoS, Liu et al. (2013) stand out with 161 citations, presenting a study on framing sustainability in a telecoupled world. This paper presents a framework using two examples of distant interactions associated with the trade of agricultural commodities and invasive species. It also highlights the implications of the framework and discusses research needs and approaches to advance research on telecoupling. This publication has broad applicability as it permeates the entire field of telecoupling. In the case of Scopus, after analysing co-

citation, the number of citations was fewer than in WoS, indicating a relatively lower link strength.

As for the articles included in Scopus, Lenzen et al. (2012a) were cited 16 times, presenting a study on how international trade contributes to biodiversity threats in developing nations. This research explores critical aspects, revealing that a significant number of species face threats due to international trade along intricate routes. Notably, the study underscores that consumers in developed countries contribute to threats against species by demanding commodities ultimately produced in developing nations. The article emphasizes the importance of examining biodiversity loss as a global systemic phenomenon rather than isolating the analysis to degrading or polluting producers. Furthermore, these findings contribute to enhanced regulatory measures, the establishment of sustainable supply-chain certifications, and improved consumer product labelling.

Since the nine final articles resulting from the Bibliographic Coupling research technique were duplicated in the databases, there was a need for their exclusion.

Based on the obtained results, WoS presents a relatively positive disparity in terms of the number of articles and co-citations. Not only did it provide keywords directly related to telecoupling, but it also brought the widest range of articles from the original algorithm and represented co-citations.

Moreover, the bibliographic coupling method revealed a common theoretical base shared by the majority of publications across the considered databases. It highlighted papers that address common and fundamental issues in telecoupling research, as well as more specific and trending topics such as food, footprint, environment, governance, policy, and networks.

3.3 Gaps in Research on Telecoupling in the Food Supply Chain

The intricate interplay of the telecoupling framework involving its essential elements (the sending system, spillover system, and receiving system (Liu et al., 2013), represents the food supply chain. The analysis of bibliometric data and examination of relevant articles support the identification of potential research gaps, offering guidance for future investigations into transportation flows within telecouplings of the food supply chain.

Liu et al. (2013) asserted that spillover systems can significantly impact local-to-global sustainability by disseminating the effects of telecouplings across space. In addition, cross-sectoral connections among coupled systems remain a largely uninvestigated area of research. Examples presented by Liu et al. (2013) include food-feed-fuel exchanges in the agricultural sector and, more broadly, agriculture-energy-finance linkages among sending, receiving, and spillover systems, such as the relation between biofuels, financial investments, and land commodities. On the other hand, the authors did not discuss the food supply chain in depth, having only addressed commodities and food-feed-fuel and proposed an integrated framework base, which is an umbrella concept that refers to socioeconomic and environmental interactions over distances.

In contrast, Eakin et al. (2014) provided insights into the divergent values among social actors impacted by telecoupling effects, exemplified through the concept of "food miles." This unintended consequence underscores the potential for misleading information in telecouplings, demanding robust tools for tracking indirect interactions and identifying critical thresholds for change. They state that despite uncertainties in operationalizing telecoupling, its global significance influences researchers to engage with fundamental concepts and analytical tools, potentially fostering the development of a transdisciplinary science with profound implications for methodology and reporting.

Liu, Hull, et al. (2015) applied the integrated framework to uncover the significant unknowns within spillover systems. They found complex relationships among different telecouplings—e.g., amplification, offsetting, spatial overlaps—which cannot be detected by traditional separate studies. Such an integrated study leads to a more comprehensive understanding of distant human-environment interactions and has significant implications for global sustainability and human well-being. In some cases, it is not even clear where the spillover systems are. Furthermore, many other environmental and socioeconomic effects across the telecoupled systems are not measured quantitatively. Feedback and relations among multiple telecouplings require further quantification. The telecoupling framework emphasizes temporal dynamics, not just in the past and in the present, but also into the future.

A comparative examination of six studies reveals crucial insights into diverse complex characteristics that cannot be observed in a single study. Legacy effects persist over varying durations, ranging from decades to centuries. Future research on coupled systems must encompass separate site-specific studies and long-term comparative projects across multiple sites. Additionally, there is a need to move beyond existing approaches and develop comprehensive portfolios for studying coupled systems, establishing an international network for interdisciplinary research (Liu et al., 2007).

Lambin and Meyfroidt (2011) argued that sound policies and innovations can reconcile forest preservation with

food production leveraging globalization to increase land use efficiency. To do so, land systems should be understood and modelled as open systems with large flows of goods, people, and capital that connect local land use with global-scale factors. However, their study lacks an in-depth exploration of the food supply chain and its correlation with telecoupling.

Lenzen et al. (2012b) demonstrated that international trade along complex routes threatens a significant number of species, with consumers in developed countries contributing to species threats through their demand for commodities from developing countries. The authors recommend enhancing regulatory frameworks, sustainable supply-chain certification processes, and product labelling for effective tracking.

In utilizing telecoupling as a holistic analysis of food systems, Eakin et al. (2017) illustrated diverse mechanisms that drive changes within the food system. Their findings led to the conclusion that interconnections in food systems extend beyond economic considerations and are rooted in knowledge, ideology, finance, culture, consumer preferences, and ways of life. It is worth noting, however, that their emphasis was more on the governance aspect rather than the food supply chain.

Ostrom (2009) provided a framework to identify subsystem variables influencing the likelihood of self-organization in achieving sustainable Social-Ecological Systems. This framework facilitates the design of data collection instruments and the analysis of findings. It also emphasises the need for quantitative and qualitative data across resource systems to develop and test theoretical models, ultimately leading to improved policies.

Based on our findings, we identified the following gaps in the research on telecoupling transportation in the food supply chain:

- investigate nonlinear dynamics in telecoupling, focusing on thresholds, reciprocal feedback loops, and time lags.
- explore the duration and impact of legacy effects from past couplings on present and future conditions.
- examine interactions within the sending, spillover, and receiving systems, treating telecoupling as a comprehensive supply chain.
- investigate spillover systems, focusing on their location, dynamics, and impact on local-to-global sustainability.
- explore cross-sectoral connections among coupled systems, especially in areas like food-feed-fuel exchanges and agriculture-energy-finance linkages.
- delve into the food supply chain, beyond commodities, to understand interactions among sending, receiving, and spillover systems;
- explore the potential for misleading information in telecoupling systems, particularly regarding “food miles”;
- develop robust tools for tracing indirect interactions and identifying critical thresholds for change in telecoupled systems;
- investigate the development of a transdisciplinary science to address uncertainties in operationalizing telecoupling, with implications for methodology and reporting.
- uncover unknowns within spillover systems, including their location and dynamics.
- quantitatively measure environmental and socioeconomic effects across telecoupled systems, especially in cases where measurements are lacking.
- explore temporal dynamics emphasized by the telecoupling framework, considering the past, present, and future.
- explore interactions among different coupled systems, considering increasing globalization and interactions across scales.
- in-depth exploration of the food supply chain, specifically examining its correlation with telecoupling and implications for forest preservation and food production.
- investigate threats to species resulting from international trade, with a focus on the role of consumers in developed countries.
- explore the effectiveness of enhancing regulatory frameworks, sustainable supply-chain certification processes, and consumer product labelling for tracking and mitigating threats to species.
- in-depth exploration of the governance aspect of telecouplings, considering a more detailed exploration of the food supply chain within the context of telecoupling as a holistic approach for food systems analysis.
- investigate subsystem variables affecting the likelihood of self-organization in achieving sustainable Social-Ecological Systems.

• develop and test theoretical models by designing effective data collection instruments for the core set of Social-Ecological Systems variables across resource systems.

This study proposes a number of research gaps for further investigation of telecoupling transportation within food supply chains. By investigating telecoupling dynamics, we may ameliorate our understanding of the ongoing complex and interconnected flows.

4. Conclusions and Recommendations

This study employed a systematic review and scientometric analysis to map articles addressing telecoupling in the food supply chain. Utilizing Web of Science (WoS) and Scopus databases, we conducted an examination of the literature and applied techniques such as co-word analysis and bibliographic coupling.

Our co-word analysis revealed trends in keyword patterns across research areas for each database. In WoS, four distinct clusters were classified, ranging from practical cases and governance studies to sustainable practices and policy considerations. Similarly, Scopus displayed clusters covering topics from biodiversity and conservation to agriculture, commerce, and climate change. This suggests a variety of research themes, which can potentially assist the understanding of telecoupling in the food supply chain.

The bibliographic coupling method exposed a shared theoretical base among publications, emphasizing common and fundamental topics in telecoupling research. Notably, influential articles identified through co-citation analysis served as a knowledge base, contributing to the credibility and development of subsequent studies.

This study uses the Web of Science and Scopus databases to shed light on the current research gaps. Web of Science stands out for its notable advantage in presenting more results. However, other databases, such as Scopus, can be useful, depending on the area under investigation. Our study led to the recommendation of a comprehensive list of potential research gaps. This approach could offer a foundation for future studies, aiming to contribute to a better understanding of telecoupling complexities within the food supply chain.

Some open research questions that could be explored in future studies on telecoupling in food supply chains include: the impact of telecoupling interactions on the environmental and social sustainability of supply chains, its influence on resilience in the face of global shocks, and the role of public policies and international regulations in these dynamics. Additionally, it would be valuable to investigate the economic and social implications for local producers, as well as the effects of emerging technologies, such as artificial intelligence and blockchain, in optimizing and enhancing the transparency of these supply chains.

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