

Review

# Synergistic Interactions of SDGs in Food Supply Chains: A Review of Responsible Consumption and Production

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**Abstract:** In light of the significance of Food Supply Chains (FSCs) in attaining the United Nations' 17 Sustainable Development Goals (SDGs), a greater focus on synergistic interactions between these SDGs is called for. Although there is research within this area, the impact on the interactions of responsible consumption and production for supply chains is either fragmented or inconclusive. Implementing supply chain solutions to achieve one goal could potentially support or inhibit progress in other goals; thus, before implementing such solutions, a better understanding of the interrelationships between SDGs is required. A systematic review is conducted to evidence the current nature of the understanding of these interrelationships within the food supply chain context by focusing on Responsible Consumption and Production, which refers to SDG number 12. This review is conducted through a filtering process, where 171 peer-reviewed articles addressing different SDGs were analysed and synthesized. In addition to a detailed summary of the recent literature on the SDGs and their interrelationships, as addressed in the literature, this paper establishes the limitations in the existing literature and research challenges surrounding the SDGs. This article contributes a conceptual framework that identifies stakeholder and consumer pressures as enablers of synergistic interactions between SDGs, thus directing managerial and regulatory interventions through a holistic perspective of SDGs. Finally, the review discusses contradictory findings on SDGs and provides future research avenues.

**Keywords:** synergy; sustainable development goals; food supply chain; SDG 12; SDG 2; zero hunger; responsible consumption; production



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## 1. Introduction

In the Anthropocene Epoch, the planetary capacity to support humanity has reached a tipping point, thereby necessitating a change to more sustainable food systems to feed an ever-growing population. Food consumption patterns have been altered globally and the production of cereal grains, for example, should increase significantly while minimizing food wastage to ensure that all members of the society have equitable access to food [1]. Stewart and Lal [2] illustrate the congruity between population and food production as a significant issue in sustainability, thereby mandating a fundamental change in global food systems. The United Nations proposed the 2030 agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) and 169 targets, which is a blueprint for a plan of action for people, the planet, and prosperity (UN, 2015), potentially impacting sustainable access to food and nutrition (Table 1). This is further evidenced in Spiker et al. [3], who suggest that nutrition is interrelated to all 17 SDGs and their targets, thereby implying the importance of the food industry in attaining SDGs. Consequently, the food supply chain, as a pivotal element of the food industry, can significantly influence multiple SDGs [4–7]. Govindan [6] illustrates that the consumption and production patterns with respect to

natural ecosystems and societal responsibilities can directly influence the achievement of SDG 12. In essence, improvisation in the current food supply chain can improve food quality and food security [4,6], thereby evidencing the interrelationship between SDG 12 (Responsible Consumption and Production) and SDG 2 (Zero Hunger). By focusing on food waste, Principato et al. [8] opine that reducing food waste through better consumption and production systems can contribute to the achievement of the UN's SDGs, thereby suggesting a potential synergy between the availability of nutrition (addressed in SDGs 2 and 3) and sustainable production and consumption patterns (addressed in SDG 12).

**Table 1.** The UN's SDGs.

GOAL 1: No Poverty	GOAL 9: Industry, Innovation and Infrastructure
GOAL 2: Zero Hunger	GOAL 10: Reduced Inequality
GOAL 3: Good Health and Well-being	GOAL 11: Sustainable Cities and Communities
GOAL 4: Quality Education	GOAL 12: Responsible Consumption and Production
GOAL 5: Gender Equality	GOAL 13: Climate Action
GOAL 6: Clean Water and Sanitation	GOAL 14: Life Below Water
GOAL 7: Affordable and Clean Energy	GOAL 15: Life on Land
GOAL 8: Decent Work and Economic Growth	GOAL 16: Peace and Justice Strong Institutions
GOAL 17: Partnerships to achieve the Goal	

### *Synergy*

The term synergy, derived from the Greek word 'Synergos', literally translates into 'co-operate' or working together, and is associated with Aristotle's cliché of "the whole is greater than the sum of its parts" [9]. Strategies aimed at achieving the SDGs rarely act in isolation; in contrast, they interact with other SDGs in complex ways, thereby evidencing synergies, trade-offs, and contradictions between SDGs [10,11]. Kroll, Warchold, and Pradhan [10] define these interactions between SDGs as 'synergies' if the progress in one goal supports progress in other goals and 'trade-offs' when progress in one goal hinders progress in others. Numerous studies explore these interrelationships between SDGs and evidence synergies and trade-offs between multiple SDGs [9,10,12]. However, the state of research addressing these interrelationships and synergistic interactions between multiple SDGs remains underexplored in the literature, and due to the pivotal role of food systems on all the SDGs [13], it is important to understand how the interrelationships between various SDGs are explored in the current literature on FSCs. Against this backdrop, this study aims to address this gap in the literature and present a systematic review of the literature that evidences the state of research on SDGs and their synergistic interactions.

The contributions of our paper are threefold. First, we objectively report on the current SDGs addressed in the FSC literature. Second, we provide a historical overview of the application of SDGs and the synergistic interrelationships between the SDGs within FSCs through a qualitative assessment of the literature about SDGs. Lastly, we provide a platform for information for researchers that will enable them to identify, justify, and refine the strategic approaches concerning synergies between SDGs and Responsible Consumption and Production.

## **2. Background**

Food scarcity contributes to hunger and malnutrition, and due to its complexity and vicious nature, this results in a trap from which people cannot easily escape, thereby further complicating sustainable development. To address these issues, SDG 2 aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. As a logical solution, increases in agricultural production could mitigate hunger and food insecurity by

improving the availability of food [14]. However, due to limitations associated with arable land and issues associated with increased production of food using scientific conventional methods, increasing food production as opposed to addressing food waste might result in adversely affecting sustainable development. This necessitates more sustainable methods of food production and consumption, as addressed in SDG 12.

SDG 12 is “about doing more and better with less”, and from a food management context pertains to minimizing food loss and food waste, which is addressed in SDG target 12.3 [15]. Target 12.3 aims to “halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains by 2030”, thereby ensuing greater availability of food [16]. Govindan [6] explored this in an FSC context by defining consumption in terms of respect for sustainable patterns of food utilization and production, which, in turn, respects natural ecosystems. This can be considered as a precursor to SDG 12, which addresses sustainable consumption and production, and suggests a synergistic interrelationship between SDG 2 and 12 as responsible production systems can improve food security. However, these synergistic interactions are underexplored in the current FSC literature, thereby necessitating a review of the current literature to identify how researchers address this synergy in an FSC context.

Although supply chain inefficiencies contributing to food waste are more pronounced in the developing world [17], it can also impact residents in the developed world, wherein the consumption stage is the key contributor to food waste [17–19]. Residents in high-income developed countries are more prone to wasting food [20], but this can also negatively impact the achievement of SDGs. For example, non-sustainable consumption patterns can result in a decrease in the availability of healthier food options in developed nations, thereby negating efforts to achieving the SDGs associated with better health. This suggests that strategies aimed at more sustainable production and consumption systems (addressed in SDG 12) can potentially improve the availability of food and healthier alternatives, thereby implying synergies between target 12.3, SDG 2, and SDG 3, as the progress in one goal (SDG 12) favours progress in others (SDG 2 and 3).

From a generic research (non-supply chain) context, several studies illustrate synergistic interactions and trade-offs between SDGs [9–11]. However, these synergies in SDGs can be dependent on other variables, as evidenced by Mainali, Luukkanen, Silveira, and Kaivo-Oja [9], who suggest differences in synergies based on location. In the context of responsible consumption and production, food loss and waste is a significant issue that has economic, environmental, and social consequences within the associated supply chain in developing countries [21]. Even though this has been explored in the literature through the three dimensions of sustainability, there is still the issue of the interconnections between SDGs and food production and, due to its impact on hunger and malnourishment [22], these problems do not appear to be mitigated further. One of the likely rationales could be the differing stakeholder goals [23] and given that sustainable food production and consumption can contribute positively towards multiple SDGs [4], it raises specific perspectives that have never been investigated systematically. To our knowledge, there has not been a systematic compilation of these SDGs within the context of FSCs; therefore, this study aims to identify and ascertain the impact of these relationships between SDGs. We address the primary research question, “How are 16 SDGs inextricably interrelated with SDG 12 in the context of an FSC?”. Using current literature studying the impact of the FSC on SDGs, this research question explores the synergies between SDGs as evidenced in the current literature and, thereby, proposes a conceptual framework to achieve synergistic interactions between SDG 12 and SDG 2. Given that the scope of this study is limited to the FSC, the synergistic interactions will be explored by focusing on SDG 12 (Sustainable consumption and production) as this SDG is strongly associated with production and consumption systems [6,24].

### 3. Theoretical Foundation

To achieve the SDGs, a coordinated approach involving multiple stakeholder collaboration is necessary [25,26], thereby implying the pivotal role of stakeholders in achieving SDGs. Stakeholder theory posits that both internal and external groups will influence organizational practices as they have a “stake” in the organization and this easily extends to the supply chain as supply chain actors will influence the supply chain [6,27]. Freeman and McVea [27] define stakeholders as “any group or individual that can affect or is affected by the achievement of an organization’s objectives” and several academic papers use Stakeholder Theory as a theoretical lens to explore the influence of stakeholders on SDGs [6,25,28,29]. Within the FSC, several stakeholders influence the achievement of SDGs, including farmers, producers, processors, certification agencies, traders, retailers, distributors, and final consumers [30]. As these stakeholders (supply chain actors) influence the supply chain’s ability to achieve SDGs, stakeholder theory is an ideal theoretical lens in this study and using this theoretical perspective, this section delves into the roles and responsibilities of multiple stakeholders in minimizing food waste in the supply chain.

Although consumer pressures for sustainability can positively influence the entire supply chain [31], non-sustainable consumption habits, especially in high-income countries, is a significant contributor to food waste, thereby suggesting the influence of the consumer as a stakeholder. The policymaker is another significant stakeholder wielding a direct impact on food waste [32], as evidenced by the French government’s policy on donating unsold foods to retailers, thereby directly minimizing food waste [33]. However, a non-holistic perspective of stakeholder’s actions when designing and implementing policies and regulations can negatively influence SDGs.

As evidenced in the Indian and Chinese contexts, supply chain actors have a major influence on food waste, especially within the developing world [17,19]. Although more pronounced in low-income countries due to ineffective supply chains, food waste is not limited to low-income countries but can occur at any stage of the supply chain [34,35]. Within the foodservice sector, food service employees, including managers, can impact consumption habits, thereby contributing to food waste [36].

Conspicuous consumption habits, especially among the rich urban residents, are significant contributors to food waste [37,38]. However, in comparison to previous decades, this is evidenced in traditionally low-income countries as well due to an increase in wealth among the urban elite in traditionally low-income countries, thereby posing as a barrier to SDG 12.3 [38,39]. An exploratory study on the amount of food waste generated in Lhasa HORECA (HOTels, REstaurants, and CAFés) evidenced an increasing trend in food waste. These conspicuous consumption habits can be due to dining culture, as evidenced by Wang et al. [40], describing the principle of ‘mianzi’ in Chinese culture, which considers over-ordering as a kind of hospitality. Liao et al. [41] attribute this to the influence of Confucian culture on face-saving and group conformity. Such studies evidence the pivotal role of consumers and their actions in achieving SDG 12, 12.3, and SDG 2. This shows the various stakeholders’ influence on the supply chain’s sustainability orientation, and as an extension, the ability to achieve certain SDGs.

Although not from a supply chain context, multiple studies address synergies and trade-offs between SDGs [10,12,42,43]. Kroll, Warchold, and Pradhan [10] illustrate synergistic interrelationships between SDGs 1, 3, 7, 8, and 9 and Mainali, Luukkanen, Silveira, and Kaivo-Oja [9] illustrate synergistic interactions between SDG 2 and SDGs 1, 6, and 7. Mainali, Luukkanen, Silveira, and Kaivo-Oja [9] illustrate synergistic interactions by citing the importance of ending hunger and guaranteeing food security in developing economies. This suggests a relationship between SDG 2 and the availability of water. In a similar vein, Pradhan, Costa, Rybski, Lucht, and Kropp [12] suggest SDG 12 (Responsible consumption and production) is most often associated with trade-offs with other SDGs.

However, a key limitation of these studies is the generic focus of these studies exploring the interactions between the SDGs, which mandates further research that explores the interactions of the SDGs within a specific research context. Due to increasing global trade,



the food supply chain has a significant impact on SDGs, but current research does not explore the impact of food supply chains on SDGs. Although literature reviews address the current nature of the knowledge on SDGs [44,45], far too little attention has been paid to the synergies between the SDGs and food supply chain. The focus of this study intends to address this gap in the current literature by analysing the impact of food supply chain operations conducted to evidence the current nature of understanding of these interrelationships within the food supply chain context by focusing on responsible consumption, and Production (SDG 12).

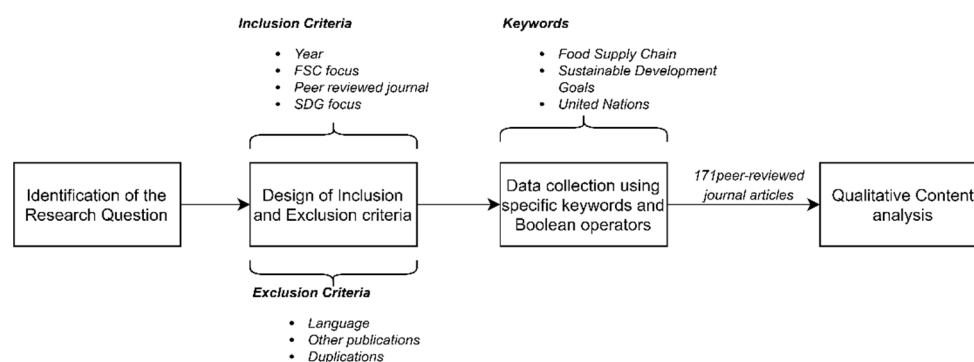
#### 4. Materials and Methods

This study aims to identify the interrelationships between the SDGs from an academic context through a comprehensive review of the SDGs in an FSC context. For this, we employed a structured literature review using the process explicated in recent studies of the supply chain [26,46] (See Figure 1).

Papers published from 2015 to 2020 were collected through four databases to identify the interrelationships between the SDGs through a comprehensive review of academic journal articles to interpret, understand, and explore concepts within the current literature in FSCs. Due to the academic and managerial value of this field of research, this paper goes beyond a summarization of what is currently written about SDGs by modelling the synergistic interrelationships between the SDGs and creating a conceptual model that contributes to the synergistic interactions between SDG 12 and SDG 2.

This SLR involved four steps, which included:

- Identification of research questions;
- Designing of inclusion and exclusion criteria;
- Conducting the review through the selection of relevant databases, collecting of academic studies using specific search strings;
- Quality analysis and synthesizing the data.



**Figure 1.** Structured literature review process.

##### Steps 1 and 2—Research question identification and criteria design

Although the overarching research question pertains to the interrelationships between multiple SDGs, there were multiple gaps this study attempts to address, which include:

- Publication timeline, geographic scope, and methodologies used in academic journal articles;
- Interrelationships between multiple SDGs as evidenced in academic journal articles;
- Contribution of academic articles in FSC on achieving the goals and synergistic relationships between key SDGs (SDG 12 and SDG 2).

Multiple inclusion criteria were employed to identify studies that focused on SDGs proposed by the United Nations, and these include:

- Year—the United Nations published the SDGs in 2015 and previous studies on SDGs might not address the specific SDGs formulated in the United Nations’ 2030 SDGs;

- FSC relevance;
- Scholarly peer-reviewed journal articles;
- Studies addressing SDGs.

The exclusion criteria aimed to disqualify journal articles based on the following criteria:

- Language—studies published in other languages were excluded;
- Journal articles—books, book reviews, conference papers, and other academic publications were excluded from the review process;
- Duplications.

Four databases—Elsevier, ProQuest, Emerald, and WSI—were used to identify scholarly peer-reviewed articles addressing SDGs using specific keywords. Multiple searches were conducted based on article titles to ensure the most relevant studies were identified in this review, thereby resulting in specific keywords that were employed. These keywords included “Food Supply Chain”, “Sustainable Development Goals”, and “United Nations”, which ensured that only studies addressing The United Nations’ SDGs within the context of the FSC were retrieved by the researchers. After eliminating duplicates, 171 full-text articles were sourced for further data synthesis and a classification framework using Microsoft Excel was designed by extracting and recording the following:

- Authors;
- Year of Publication;
- Journal title;
- Title of the article;
- Methodology;
- Geographical scope;
- Keywords;
- SDGs addressed.

Due to the nature of the databases, only credible, high-quality academic publications were retrieved and analysed. In addition to the impact factor, the purpose of the study, and the relevance to SDGs, one of the criteria employed in the classification framework involved recording the SDGs addressed in every study that we reviewed. However, SDGs were not evidenced explicitly in some studies as several studies do not specifically use numbers to dictate which SDG or target is explored. This necessitated the principal researcher to manually quantify the non-numerical targets/SDGs into the numerical SDGs or targets.

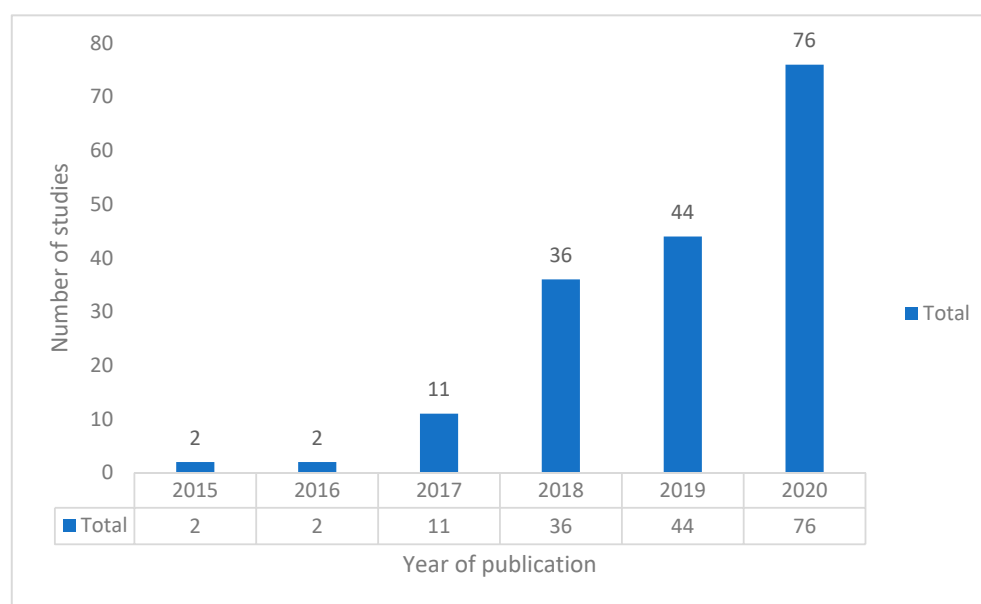
A qualitative content analysis using NVIVO was performed on the 171 peer-reviewed journal articles that were retrieved in Step 2. This mode of analysis is useful for answering the “why” questions and the findings are relevant to resolving a specific problem, thereby making it ideal in this research context [47]. An inductive content analysis led to a process of clustering abstractions based on the relevance and the implication of addressing SDGs in an academic research. This technique of content analysis develops themes by relying on inductive reasoning and the themes emerged from the raw data (selected academic studies) through repeated examination and comparison of the studies. Additionally, multiple authors reviewed the content of the studies that met the eligibility criteria to minimize conflicts that could have occurred during the review process. This methodology of qualitative content analysis, double coded by the fourth author, resulted in a conceptualization of synergistic interrelationships of SDGs in academic FSC research, thereby building a model enabling synergistic interactions between SDG 12 and SDG 2.

## 5. Results

Sustainable FSC practices have a significant impact on SDGs, as evidenced in the current literature [4,46], and the following sections describe this in further detail.

### 5.1. Descriptive Findings

This section briefly describes the characteristics of the studies included in this study of the literature on SDGs in FSCs published between 2015 and 2020. The trends in publications illustrate an increase in academic interest in addressing SDGs (Figure 2). A total of 171 studies were analysed, of which 71 were empirical studies, followed by 47 literature reviews or conceptual papers, 27 mathematical modelling papers, and 26 quantitative secondary data analyses usually involving food consumption and waste data.

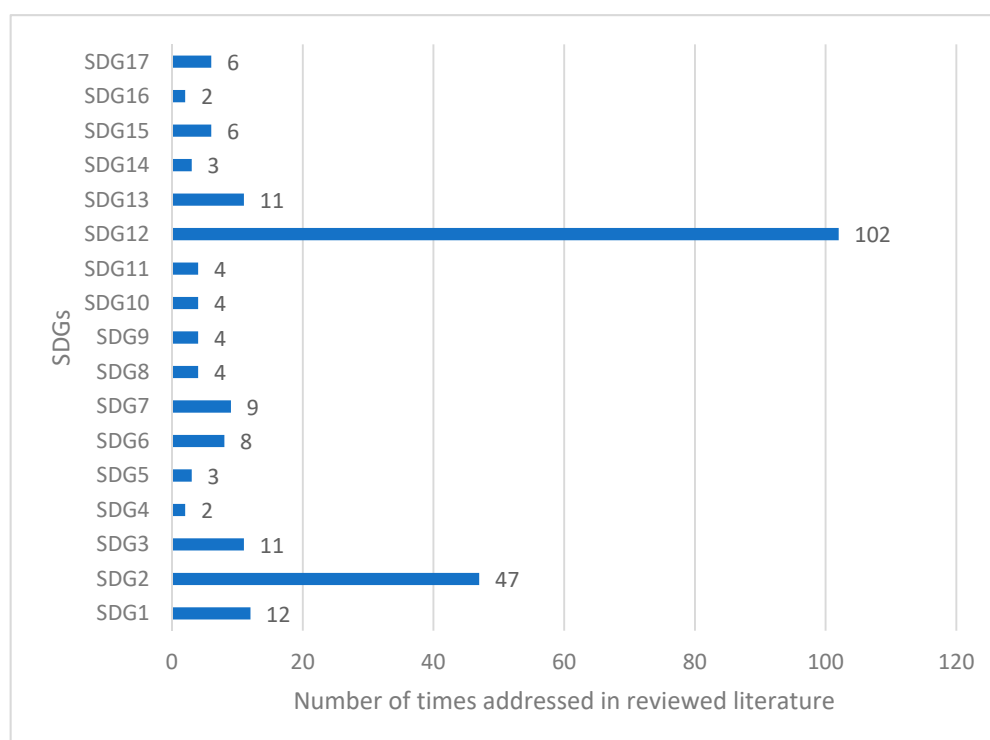


**Figure 2.** Number of papers published yearly.

As illustrated in Figure 3, SDG 12 is the most widely cited SDG within academic research on food supply chains and SDGs and this could be due to the direct impact of sustainable supply chain management practices on sustainable production and consumption (SDG 12). Several studies evidence the impact of inefficiencies within supply chains as a key barrier to the achievement of sustainable production and consumption, thereby hampering the achievement of SDG 12 [6,17,21]. As evidenced in the literature, these barriers are not specific to any single tier within the supply chain and can be due to the focal company [28]; food retailers, including restaurateurs [38,48]; post harvesting, storage, or marketing stages [49]; and processing and production [8]. Lemaire and Limbourg’s review addressing SDG 12 evidence supply chain-based solutions, including business process redesign, as well as integration of the supply chain models, redistribution, recovery, and disposal as solutions to the systemic challenges within FSCs [50]. Similarly, Diaz-Ruiz et al. [51] proposed preventative solutions, including diet valuations, awareness, and redistribution methods that address supply chain inefficiencies. This suggests that improvements in the FSCs that address inefficiencies within the supply chain can contribute to achieving SDG 12. Sustainable operations within the FSC can directly contribute to achieving SDG 12 and this is evidenced through the number of papers addressing the interrelationships between SDG 12 and the operations of the FSC.

In addition to SDG 12, 47 studies identified the impact of the FSC on SDG 2, thereby suggesting that SDG 2 is also widely addressed in the current academic literature. The impact of FSC operations on food security and food availability is evidenced in the literature [34,52,53] and several studies focused on the triple bottom line impact of the FSC and its impact on SDG 2, thereby providing tangible solutions to achieving SDG 2 [54]. These solutions include effective stakeholder partnerships [55], policy improvement [55,56], improved agricultural systems [2,54], and sustainable supply chain operations [28,57]. Although SDG 3 and SDG 13, addressing good health and well-being, and climate change,

were addressed 11 times in the reviewed literature, due to the relevance of SDG 12 and SDG 2, the rest of the paper will focus on these SDGs in contrast to other SDGs.



**Figure 3.** SDGs addressed in the reviewed literature.

Analysing the geographic scope of the studies showed that most studies were conducted in developed economies: 60 papers were conducted within a single developed country, followed by 48 papers that either did not focus on any specific geographic region or had a global focus, and 30 papers focused on developing regions. Other studies focused on multiple developed economies (17 articles), multiple developing economies (10 articles), and, finally, six studies focused on both developed and developing economies (Table 2).

**Table 2.** Number of studies based on geographic scope.

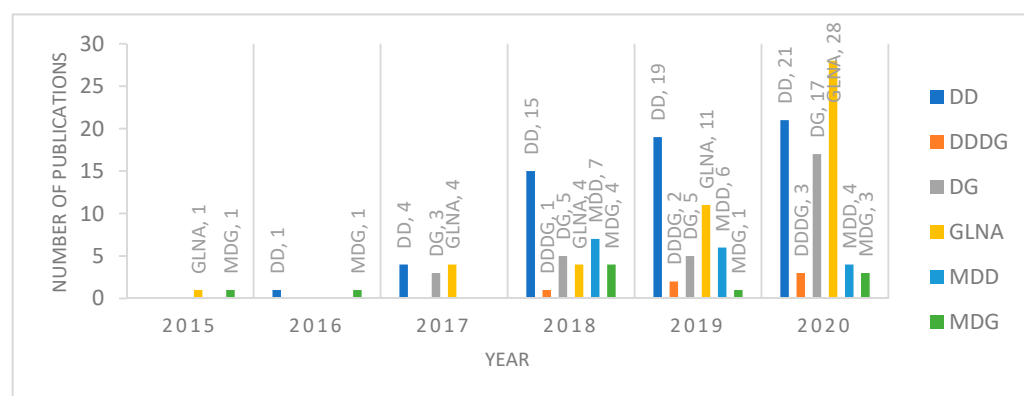
Region	Number of Publications
Developed economies (DD)	60
Developed and Developing (DDDG)	6
Developing (DG)	30
Global or No Region (GLNA)	48
Multiple Developed (MDD)	17
Multiple Developing (MDG)	10
Grand Total	171

After analysing the geographic scope of the papers reviewed, it is evident that most papers focus on high-income developed countries, which can be considered a significant limitation due to the global nature of the FSC. Since this review considered papers over a 6-year period, to ascertain any potential changes to this limitation in the current research, the trends in the geographic scope of the publications were analysed. This analysis shows that although there is an increasing trend in research in the developing world context, the emphasis of academic research exploring SDGs in FSCs is within the developed economies,

thereby suggesting a significant limitation to the current nature of the literature (Table 3 and Figure 4).

**Table 3.** Number of studies based on geographic scope and year.

Year of Publication	DD	DDD	DG	GLNA	MDD	MDG	Total
2015				1		1	2
2016	1					1	2
2017	4		3	4			11
2018	15	1	5	4	7	4	36
2019	19	2	5	11	6	1	44
2020	21	3	17	28	4	3	76
Grand Total	60	6	30	48	17	10	171



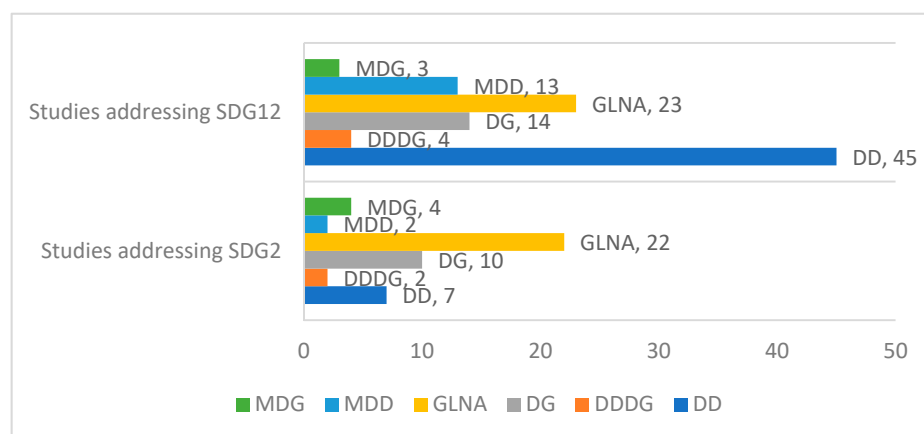
**Figure 4.** Number of studies based on geographic scope and year.

A total of 102 papers address SDG 12 and 47 studies addresses SDG 2, and due to this overemphasis of these two SDGs, studies citing these SDGs were analysed further in this study. Based on the analysis, it is evident that SDG 2 (Zero Hunger), addressing food security, is studied more in a developing world context compared to studies in the developed world (Table 4 and Figure 5). SDG 2 aims to eradicate hunger, as this could be a more significant problem in a developing world context [3]. However, the consumption habits of the inhabitants in the developed world can influence food security in developing economies, thereby suggesting the non-siloed nature of food waste and food security [58]. Moreover, SDG 12 is studied more in a developed world setting compared to studies focusing on a developing world context. The implications of this finding are further explicated in the direction for future studies section.

**Table 4.** Number of studies exploring SDG 2 and SDG 12.

Region of Study	Studies Addressing SDG2	Studies Addressing SDG12
Developed economies (DD)	7	45
Developed and Developing (DDD)	2	4
Developing (DG)	10	14
Global or No Region (GLNA)	22	23
Multiple Developed (MDD)	2	13
Multiple Developing (MDG)	4	3





**Figure 5.** Number of studies exploring SDG 2 and SDG 12.

The study reviewed 171 articles focusing on SDGs and FSCs and 102 of these articles addressed SDG 12, of which 83 papers specifically addressed target 12.3. The strongest relationship between the SDGs based on the number of publications was evidenced between SDG 12 and SDG 2 (19 papers address both SDG2 and SDG 12). Specifically, eight academic studies addressed both target 12.3 and SDG 2 and four of these studies specifically addressed target 2.4.

### 5.2. Responsible Consumption and Production (SDG 12) and Other SDGs

Several studies address the interrelationships between Sustainable Production and Consumption (SDG 12) and other SDGs [28,53,59]. Pohlmann's [28] study on poultry supply chains evidence interrelationships between SDG 12 and SDGs 1, 2, 3, 4, 5, 7, 8, 9, 10, 15, and 17. The sustainable production systems in poultry supply chains contribute to creating new jobs, thereby impacting poverty levels (SDG 1) and, as an extension, results in the lower cost of poultry meat and increased availability of protein in underdeveloped countries (contributing to SDGs 2 and 3) [28,34]. Asian, Hafezalkotob, and John [4] illustrate the impact of a sharing economy-based model in agricultural supply chains in achieving SDG 12 and other SDGs, including SDG2 and SDG3, due to improved accessibility and availability of healthier food products in developing economies. These studies illustrate a synergistic interaction between SDG12 and other SDGs, and the current nature of the literature on these interactions is illustrated in Table 5 and Figure 6.

**Table 5.** The SDGs and targets in the reviewed studies addressing SDG 12.

SDG	SDG1	SDG2	2.1	2.2	2.3	2.4	2.5	2.a	2.b
Studies	6	19	1	2	2	4	1	1	1
SDG	SDG3	SDG4	SDG5	SDG6	SDG7	7.a	SDG8	8.2	8.4
Studies	10	2	2	5	4	1	4	1	1
SDG	SDG9	9.2	9.5	SDG10	SDG11	SDG12	12.1	12.2	12.3
Studies	3	1	1	1	3	102	2	3	81
SDG	12.4	12.5	12.6	12.7	12.8	12.a	12.b	12.c	SDG13
Studies	2	3	2	2	2	2	2	2	9
SDG	13.2	SDG14	SDG15	15.2	15.3	SDG16	SDG17		
Studies	1	3	6	2	1	1	3		

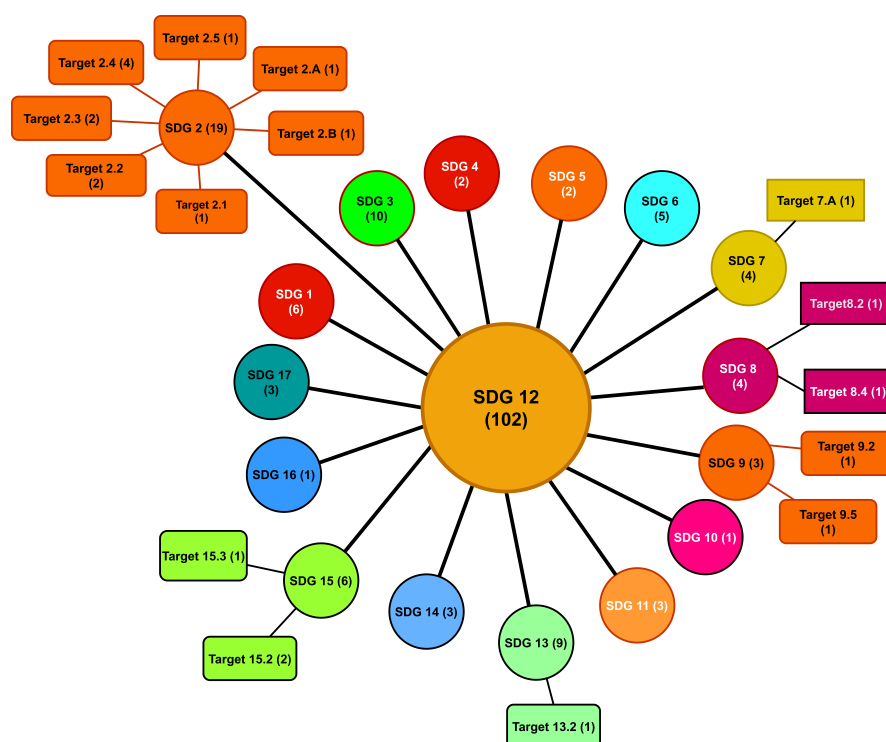


Figure 6. Interrelationships with SDG 12 identified in the literature.

The interrelationships between target 12.3, addressing food waste, and other SDGs were evidenced in multiple tiers of the FSC [8,28,32,53]. For example, a literature review by Carino et al. [60] identified food loss and waste as one of the most widely explored barriers to environmental sustainability within food services in the hospital and evidenced that effective food service management directly impacts the industry's ability to achieve SDGs 11, 12 (including 12.3), and 13. This suggests the implications of SDG 12.3 on SDGs 11, 12, and 13 and, as an extension, the environmental impact of food services in hospitals. Another study highlighted the impact of food sharing models as an alternative distribution system, thereby helping to achieve the poverty and food waste reduction goals of the United Nations (SDG 1 and target 12.3) [61]. These studies illustrate the potential synergies between multiple SDGs within the FSC, as illustrated in Figure 6.

### 5.3. Synergies between Sustainable Production and Consumption (SDG 12) and Zero Hunger (SDG 2)

A stronger link and potential synergistic interactions between SDG 2 and SDG 12 are evidenced by the number of papers focusing on both SDG 2 and SDG 12 (19 studies). More specifically, 9 papers addressed SDG 12.3 and SDG 2, thereby implying a relationship between food waste and hunger, addressed in target 12.3 and SDG 2.

Hunger and food waste are inextricably linked, as suggested by Ellis, Kwofie, and Ngadi [49], as wasting food results in food insecurity, thereby resulting in increased levels of poverty and hunger. Several studies depict the synergies between sustainable food production systems (SDG 12) and different SDGs [4,46,53], thereby contradicting Pradhan, Costa, Rybski, Lucht, and Kropp [12] on the trade-offs associated with SDG 12.

A direct relationship between food waste and food insecurity is evident as a higher level of food wastage increases food insecurity, especially in developing nations [21,49,52,55]. However, Ponis, Papanikolaou, Katimertzoglou, Ntalla, and Xenos [34] suggest the detrimental impact of food waste is evidenced in developed economies as well. For example, food waste leads to a decrease in availability and increase in the costs of healthier food, thereby contributing to increased consumption of cheaper ultra-processed food. This consumption pattern (of unhealthy products) results in health detriments including obesity, thereby evidencing strong interrelationships between SDGs 2, 3, 12, and target 12.3. Blesh,

Hoey, Jones, Friedmann, and Perfecto [52] conducted an integrated literature review on SDG 2 using a food systems lens and propose that adaptive, effective, and participatory solutions can be a pathway towards SDG 2. After comprehensively reviewing the existing literature and its impact on SDG 2, Blesh et al. [52] explicate the relationships between SDG 2 and other SDGs, including SDGs 1, 2, 3, 7, 11, 12 (specifically 12.3 on halving food waste), 13, and 15. Guidance on how to coordinate actions to achieve these goals is important and a siloed approach to achieving these goals individually might undermine current sustainability-based approaches [52]. These studies suggest a synergistic interrelationship between SDG 12 and SDG 2 and propose solutions addressing SDGs must account for these interrelationships as SDGs do not act in isolation and may have potential synergies or trade-offs.

#### Synergies between Target 12.3 and Target 2.4

Analysis of the interrelationships between multiple targets shows an interesting relationship between SDG target 12.3 and target 2.4. The most common target addressed in SDG 2 that addressed target 12.3 is target 2.4, and this was explored in four academic research papers [29,52,53,55]. Target 2.4 aims to ensure food production systems that maintain ecosystems while strengthening climate change adaptation capacity and improving land and soil quality, thereby suggesting a synergy with target 12.3, which focuses specifically on food waste management, as a precursor to sustainable production and consumption (SDG 12). A review by Teigiserova, Hamelin, and Thomsen [53] on contributors to food loss and waste in food residue biorefineries propose several guiding criteria that helped attain SDGs. Although the key targets accounted for in the study were 8.2, 9.5, and 12.3, the first guiding criteria that aim to preserve quality is coherent with both targets 2.4 and SDG 12.3, among others. Blesh et al. [52] suggest these targets, and the interactions between them, are not studied extensively in the literature, thereby necessitating further empirical research on the synergistic interrelationships between SDG target 12.3 and 2.4. Though underexplored in the literature, these studies suggest a synergistic interrelationship between SDG 12.3 and SDG 2.4 within the FSC context and warrant further empirical research identifying enablers to such synergistic interactions between targets 12.3 and 2.4.

#### 5.4. The Conceptual Model for Achieving Synergistic Interactions between SDG 2 and 12

Pradhan, Costa, Rybski, Lucht, and Kropp [12] identified non-synergistic trade-offs between SDG 12 and 2 and this review of the literature focusing on the FSC contradicts Pradhan et al.'s (2017) findings by illustrating synergistic relationships between SDG 12 and 2 in an FSC context. This section conceptualizes a synergistic framework based on the reviewed studies that addressed SDG 12 and SDG 2. This involves the identification of enablers of synergies explicated in the current literature (Table 6) and creating a conceptual model based on these enablers (Figure 8).

**Table 6.** Studies addressing SDG 12 and SDG 2 in the FSC literature.

Author	Unit of Study	Key Enabler Identified	Key Contribution to SDG Literature
Abdella et al. [62]	Various	Novel approaches to assess sustainability orientation	Modelled an approach to present the environmental impact of various supply chains.
Adenle, Azadi, and Manning [55]	Unspecified	Sustainable agriculture and policies	Reformulation of agricultural policies to ensure sustainable development
Asian, Hafezalkotob, and John [4]	Organic FSC	Technology underpinning the sharing economy	Peer to Peer sharing enable financial gains with improved sustainable development
Blesh, Hoey, Jones, Friedmann, and Perfecto [52]	Unspecified	Place-based, adaptive, participatory solutions for SDGs	Identified limitations in literature and mandate place-based, adaptive, participatory solutions addressing local institutional capacities, agroecosystem diversification and ecological management, and the quality of local diets.
Canadas et al. [63]	Food industry	Advancements in green chemistry	Neoteric solvents as a greener alternative to improve environmental, animal, and human health
Chen et al. [64]	Unspecified	Green Chemistry, Circular Economy, Policies, Cross Departmental Collaboration, Cleaner Production, Integrated Chemical Management Systems, Education, and Sustainable Business Models	Illustrate current issues in Green Chemistry and circular economy and propose integrated strategies for GCP implementation.
Galli et al. [65]	Agri-food systems	Agricultural and food-related policies	Identified and illustrated policy processes' contribution to sustainable food systems in Europe
Jonkman, Barbosa-Póvoa, and Bloemhof [57]	Sugar beet supply chain	Supply chain redesign	Mathematical Modelling of a redesigned sugar beet supply chain improve economic and environmental performance
Lillford and Hermansson [66]	Unspecified	Food Science and Technology (FS&T), continuing investment, and improved awareness	Improvements in FS&T and awareness improvement strategies can improve both production and consumption patterns globally and locally.
Nedelciu et al. [67]	Global phosphorus supply chain	Sustainability reporting	Improved sustainability reporting processes contribute to evaluation of sustainability commitments and sustainable development.
Pohlmann, Scavarda, Alves, and Korzenowski [28]	Poultry supply chain	Improved legislations, better business models, improved measurement of supply chain impacts, collaboration, stakeholder engagement, and improvement in awareness	The importance of revising environmental legislation to align with SDGs
Ponis, Papanikolaou, Katimertzoglou, Ntalla, and Xenos [34]	Household consumption patterns	Strategies to improve household purchasing and consumption and awareness improvement	Household behaviours of shopping and consuming food products contribute to food waste
Porter, Reay, Bomberg, and Higgins [32]	Fresh produce in EU	Improved policies, food loss mitigation systems, and improve alternative use of food	The negative impact of EU CAP withdrawal mechanisms on avoidable food losses.

Table 6. Cont.

Author	Unit of Study	Key Enabler Identified	Key Contribution to SDG Literature
Sala et al. [68]	Unspecified	Life cycle thinking (LCT) and assessment (LCA), identification of hotspots, FSC optimization, technological improvements and behavioural changes	Present the impact of LCT and LCA approaches in identification of hotspots, FSC optimization, technological improvements and behavioural changes
Sharif and Irani [29]	Unspecified	Policy	Recommended a morphological grid of food security scenarios based on the VUCA framework.
Soussana et al. [69]	Global soil management	Soil management initiatives	The 4 per 1000 initiative can potentially achieve multiple SDGs
Teigiserova, Hamelin, and Thomsen [53]	Repurposed food waste using biorefineries	Innovative technology and methods	Highlighted the role of technological innovations in the valorisation of the studied feedstock
Thomé, Cappellesso, Ramos, and Duarte [46]	FSCs and Short FSCs	Interest convergence, value addition	Developed a coexistence conceptual framework based on the convergence of interests and value addition driven by sustainability pressures.
Tucho and Okoth [59]	University food and waste	Closed-loop nutrient circulations	Analysis of food consumption and waste generation in a university setting based on the food–energy–sanitation nexus.

Studies addressing both SDG 12 and SDG 2 indicate the importance of effective policy design for achieving SDGs, and a reformulation of existing policies can contribute to the achievement of SDGs [28,65,69]. For example, national dietary guidelines promote the consumption of ruminant meat for better protein intake; however, increased meat intake might have a negative environmental impact, thereby necessitating changes to such guidelines. In addition to policies, frameworks to implement these changes, effective stakeholder education and management, and supply chain integration are critical to achieving SDGs [69]. In some cases, this may involve a rework of ineffective and sometimes complementary policies, thereby suggesting effective policy as an enabler to synergistic interactions between SDGs [32]. Such policies aimed at consumption practices, as evidenced in the Chinese government's policies on 'Clean Plate' and 'Operation Empty Plate', can contribute to the minimization of food waste and, thereby, achieving SDG 12.3. Such initiatives can influence consumer psychology and, as an extension, the achievement of SDGs (Figure 7).

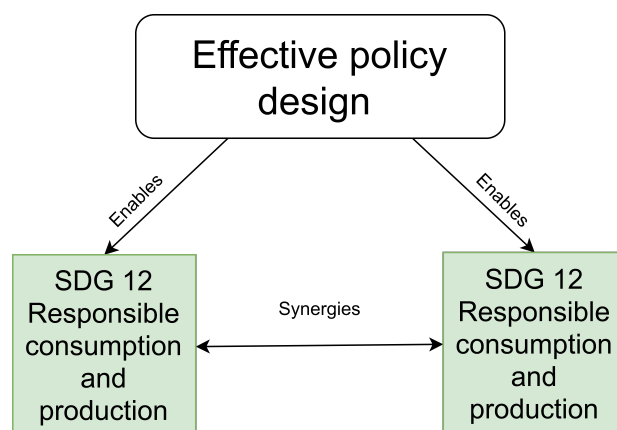


Figure 7. Example of policy as an enabler for SDGs.



Many studies address the influence of technology in achieving multiple SDGs, including 2 and 12 [4,53,66,68]. Lillford and Hermansson [66] explore the role of technology (specifically, Artificial Intelligence and Machine Learning) in addressing both SDG 2 and target 12.3 and suggested that using technology can influence SDG 12.3 and, as an extension, SDG 2. As Asian, Hafezalkotob, and John [4] illustrate, an improvement in operations using technologies that enhance the sharing economy can improve the availability of food through improved production systems, thereby suggesting a synergistic relationship between SDG 2 and 12. Even within a consumption context, technological innovations in neurogastronomy, gastrophysics, molecular gastronomy, the Internet of Things, and artificial intelligence can result in changes in food consumption habits and preferences, thereby resulting in healthier diets and potentially less wasteful behaviour [70].

Several studies address the importance of sustainable supply chain practices in achieving SDG 2 and 12 [64,68]. Studies suggest that redesigning FSCs to account for the environment can contribute to achieving SDG 2 and 12, thus suggesting sustainable supply chain design as an enabler [28,57]. The impact of collaboration on SDGs is evidenced in other articles [21] and the study by Adenle, Azadi, and Manning [55] exploring poverty and food insecurity within the African context demonstrates the influence of sustainable agriculture in mitigating poverty and food insecurity. This implies that sustainable agricultural practices can enable synergies between SDGs.

Exacerbated by ineffective supply chains, food insecurity can be a systemic problem in developing countries, thereby contributing to food insecurity [17,19]. As another enabler, Karki, Bennett, and Mishra [24] studied the impact of supply chain relationships in attaining SDG 12.3 and SDG 2 and propose that a coordinated effort between supply chain actors is a significant driver to these SDGs. In the context of stakeholder management, in addition to supply chain stakeholders, the consumers and their consumption habits can be significant barriers to SDGs [38,40]. Novel solutions to achieve sustainable food consumption practices by improving awareness through education can influence the lowering of food waste generation, thereby contributing to food security (achieving target 12.3 and SDG 2), and suggesting synergies between the two SDGs [34,62]. The impact of such awareness improvement strategies has been explored further [38], suggesting that nation-wide campaigns aiming to improve awareness of food waste and consumption patterns can improve perception towards food waste.

However, studies have shown the importance of a multi-stakeholder view whereby governments and the international community should be involved in strategies that mitigate food insecurity and poverty (SDGs 1, 2, and 3) [55]. Achieving SDGs requires the active participation of stakeholders and involves the engagement of multiple stakeholders, including the public and private sectors and the consumers [66]. A philosophical change in consumption patterns, through awareness management and other strategies, can be a significant pressure for sustainability, and such stakeholder pressures are a precursor to SDGs as illustrated in the conceptual model. As illustrated in Figure 8, sustainable FSC management through the implementation of responsible operations, as evidenced in the reviewed literature, can influence SDG 12 and SDG 2, thereby creating synergistic interactions between them.

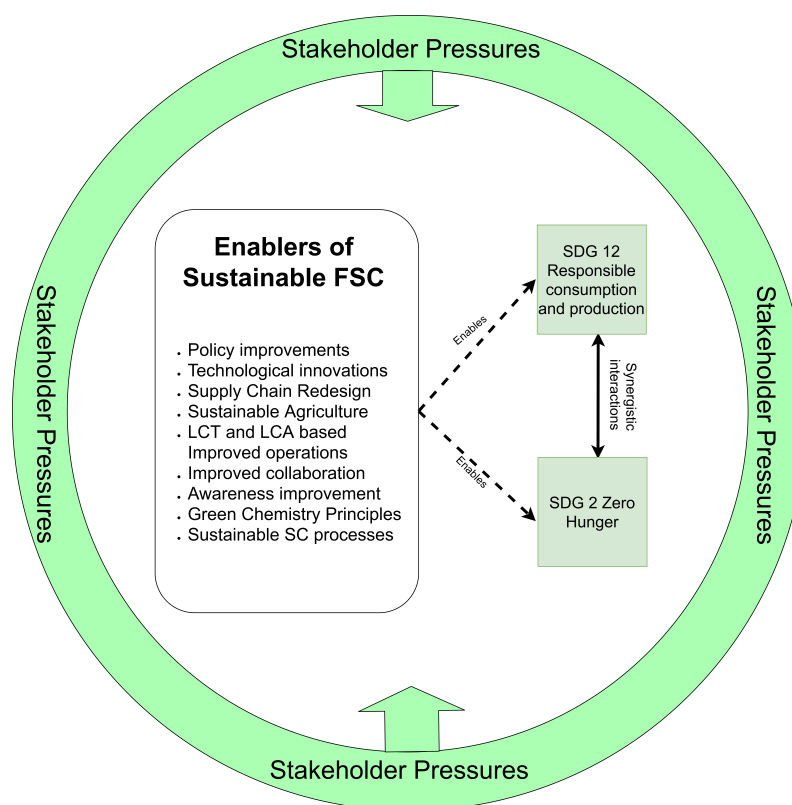


Figure 8. Conceptual model for achieving synergies between SDGs.

## 6. Implications and Future Research Directions

The key outputs of a systematic literature review are the production of research-based knowledge through the interpretation of research findings and the identification of gaps in the current literature [26]. We evidence this through the design of a conceptual model and identifying the gaps in current research, thereby guiding future studies exploring SDGs in FSCs, and this section explicates these gaps in the current literature.

As Porter, Reay, Bomberg, and Higgins [32] suggest, though there are synergistic interactions between the SDGs, some SDGs may be at odds with others due to competing trade-offs. Prior research has shown that regulatory policies can drive sustainability within supply chains [71,72] and, as an extension, creating legislation that addresses these synergies and trade-offs between SDGs is critical to the achievement of the SDGs. Policies that do not address these trade-offs can adversely affect the achievement of SDGs, as evidenced in the fresh produce sector in the EU [32]. For policy makers, this mandates the reformulation of agricultural policies to ensure sustainable development [55], and as Pohlmann, Scavarda, Alves, and Korzenowski [28] illustrate, revised legislation must align with the SDGs. Through this study, we propose that policymakers take it one step further and align legislation with multiple SDGs while being cognizant of their interrelationships, which may differ globally.

Trade-offs can be evidenced through the contradiction between the impact of the processing of food products on social and environmental perspectives. For example, increased processing of food products can prolong the shelf life, thereby minimizing the propensity to waste, but may also lower the nutritional value of the product, thereby suggesting a non-synergistic interaction (trade-offs) between target 12.3 and SDG 3 [56,65]. Such issues involving sustainability trade-offs are evidenced in terms of stakeholder prioritizations [32] but their impact on SDGs and other enablers is currently underexplored in an FSC context. Supply chain managers have to account for these synergies and design business models that emphasize greater collaboration and improved stakeholder engagement and awareness [28]. If aware of the synergies and trade-offs between SDGs, these business models can bolster the achievement of multiple SDGs, rather than creating fragmentary solutions

that achieve one SDG, albeit, at the expense of another. This necessitates further empirical research on the enablers of synergistic and non-synergistic interactions between SDGs from a consumption and production context.

Although some studies identify and suggest piecemeal consumption-based solutions for these issues, they have not focused on the non-synergistic interactions between SDGs from a holistic supply chain context [73,74]. Future research must explore both synergistic and non-synergistic interactions between multiple SDGs and create holistic solutions addressing the complex barriers impacting trade-offs between SDGs. Such studies could enrich the current state of the literature and provide practitioners with novel perspectives on the interrelationships between multiple SDGs in an FSC context. Improved knowledge of these synergistic and non-synergistic interactions can bolster managerial interventions to achieve these SDGs by accounting for multiple SDGs and their interactions.

We identified the synergies between food waste (target 12.3) and sustainable food production systems (target 2.4) but, as evidenced in the study, this relationship is currently underexplored in the supply chain literature. Future studies should further explore the relationship between SDG 12.3 and SDG 2.4 and identify drivers and barriers to achieving synergies between targets 12.3 and 2.4. Although institutional factors can be a significant barrier to SDGs [21], research on SDGs using institutional theory as a theoretical lens is limited even though there are significant institutional isomorphic pressures within this context. Therefore, future studies can use institutional theory as a theoretical lens to explore synergistic interactions between targets 12.3 and 2.4 and explore the implications of various institutional pressures in achieving these targets.

Food waste drivers in affluent economies can lower the economic access to food in non-affluent settings and the literature suggests increased globalization of the FSCs, as primary producers might be usually in low-income countries and consumers in high-income, developed countries [3,58]. However, studies that account for both developing and developed countries are significantly limited and this is a critical gap in the current literature. Although there may be difficulties in studying the impact of SDGs in multiple locations due to the interrelationships and complexities within the global FSC, there is a need for empirical studies addressing both developing and developed countries' contributions towards SDGs. Synergies between SDGs are dependent on location [9], and as the studies exploring the FSC's impact on SDGs are within a developed economic context, this is a significant limitation in the current research. Although some studies address this [17,75,76], future studies should focus on SDGs in both developing and developed region contexts. For this, we suggest further research into the dynamics between stakeholders in developing and developed economies and their impact on achieving SDGs.

## 7. Conclusions and Limitations

This structured systematic review explores the nature of the current literature exploring the United Nations' SDGs and the synergistic interactions between these SDGs. Within an FSC context, SDG 12, which focuses on sustainable production and consumption practices, is the most widely explored SDG, followed by SDG 2 aiming for Zero Hunger. The main contribution of this study is a snapshot of the existing gaps in the literature addressing SDGs in FSCs, which can guide future studies on the nature of the synergistic interactions between the SDGs to address future research. The conceptual model based on studies that addressed SDG 12 and SDG 2 show the impact of sustainable practices on the achievement of these two SDGs, as evidenced in the current literature. As with any study, this study has some limitations. Two of the key limitations of this study involved the use of only four databases and a limited focus of SDG research in FSCs. Future studies must account for studies on SDGs in the broader supply chain context and not limit the scope to a specific supply chain.

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