Exploring the Drivers and the Interventions towards Sustainable Food Security in the Food Supply Chain

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Abstract: The sustainability of food security is a global concern, and one of the priorities related to it is the ability to identify effective efforts that can protect food security along the food supply chain (FSC). The present study demystifies the relation of sustainability and food security and structurally identifies the sustainable drivers, and the pragmatic interventions that can critically contribute to the sustainability of food security within each stage of the FSC. A systematic review of articles from six databases was implemented. Thematic analysis was engaged to detect the sustainable drivers and interventions practised at each stage in the FSC for food security purposes. Six main themes of the drivers and interventions were derived from the analysis: food security governance involvement, input resource management, output management, information sharing, income, and technology. The result identifies the potential that quality management has on the mediating effect towards sustainable food security, through which a conceptual model for sustainable food security in the FSC was thus developed. It is deduced that mapping and categorizing the drivers and intervention of sustainable food securities could help deepen the understanding of effective and innovative practices towards food security in the FSC.

Keywords: food security; sustainability; food supply chain; quality management; drivers; interventions

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1. Introduction

Global intention to fight hunger and malnutrition at the outset of the food security concept was first introduced in the World Food Conference in 1974. However, at that point in time, the idea was substantially focused on the national and international level, to secure the stability of basic food stock prices [1]. The development of the food security concept then moved its focal point to the individual level when the Food and Agriculture Organization (FAO) alerted the importance of equal food availability in 1983. After that, the concept took more enormous strides, with the official declaration of the World Food Security concept in the Rome Declaration on World Food Security in 1996 [2]. Subsequent development during the 2009 World Summit on Food Security has led to the recognition of "four pillars" of food security, namely: stability, availability, accessibility, and utilization [3–5]

Conventionally, food security embodies the person-focused concept. Nevertheless, further discussion has discerned that the sustainability concept is very relevant to food security [6].

The concept of sustainability had a stake on the international round table in 1974 when the World Commission on Environment and Development precisely defined it as the continual development of the international economy that meets present needs. Under any circumstances, sustainability should not compromise future generations' ability to meet their own needs. Since then, there has been intense debate among experts in addressing the drawback of sustainability concepts, which had focused mainly on economics [6]. Later, the triple bottom line (TBL) encompassing economic prosperity, environmental quality, and social justice concepts, was introduced. This helped to shed light on the controversy of sustainability concept viewed previously [7]. Merchants are aware that a product's quality uptrend is expected to focus on the economical, ecological, and social impact, which in turn are associated with the products' lifecycle. As a result, the concept of sustainability has become the centre of attention in products and services in the supply chain, across various industries. This is in stark contrast with convention food security that only focuses on food agendas [8].

In its State of Food Security and Nutrition in the World report, the FAO recognized that the major drivers of food security include economic downturn, climate vulnerability, and conflicts [9–11]. It then recommended several approaches that food security governance can adopt for the development of food security. The report indicated that these drivers showed a close resemblance to the sustainable development drivers. This means that sustainability is a participatory concept of food security and that food security synergy is linked to sustainable drivers [7,12]. A considerable number of existing studies have discussed the potential synergy and the development trend of sustainability concepts in the food security notion [4–6,13].

Concerning sustainable food security drivers, about 64% of the published articles relating to food security governance addressed food security at the global level, i.e., in FAO, the Committee on World Food Security, the G20, and national government centre [14]. The private sector has a significant role in food security in the food supply chain (FSC), but their contributions in the body of knowledge are still comparatively vague. Previous studies only focused on drivers, such as greenhouse gas (GHG) emissions and food waste generation [15,16]. No extensive review on other drivers; moreover, there is a lack of systematical analysis of the type of interventions in the context of sustainable development being used in the FSC for the betterment of food security [15,16]. There is limited knowledge about variations across value chains, information that would improve overall target (value chain)-based interventions and strategies. Therefore, this study aims to address the gap and answer the key question: "What are the sustainable drivers that match the food security and pragmatic interventions (practical activities, events, or actions that entail effect) being implemented at each sector of the FSC that could lead to the betterment of food security?"

2. Materials and Methods

Systematic literature review (SLR) is an approach of making sense of large bodies of information in a systematic way to provide convincing evidence to address some compelling issues. It is also a way of mapping out areas of uncertainty, and a way of identifying areas with little or no research done to detect if new input or research is required [17]. The SLR approach engaged in this study was adapted from previous scholars, such as Mohamed Shaffril et al. [18], Halim Lim et al. [19], and Tranfield et al. [20]. The SLR approach used in this study encompasses three main stages: (i) resource searching, (ii) review processing, and (iii) data abstraction and analysis.

2.1. Resource Searching

The approach of the SLR is characterized as a systematic review of literature that is inexhaustive in nature, but this approach focuses on the usage of multiple databases because it is crucial to increase the tendency of attaining articles in the targeted topic to avoid the risk of missing any critical materials [21]. This study utilized several databases to locate the resources needed for this review. Scopus served as the

main database, in accompaniment with other slightly smaller resources, such as Science Direct (n = 32), Wiley Online Library (n = 50), Emerald (n = 40), Springer (n = 10), and SAGE (n = 45). Scopus was chosen because it is one of the leading databases, with more than 75 million records, including 24,600 active titles and 5000 publishers. The other databases were also beneficial in other ways; for instance, Science Direct is one of the leading platforms for peer-reviewed literature. It has more than 2500 technical, health, and scientific journals, spanning 24 major scientific disciplines. The *Recommendation* featured in Science Direct also provides more efficient snowballing search for articles by suggesting relevant articles based on current reading.

2.2. Systematic Review Process

2.2.1. Tracking and Retrieve

Systematic review process encompasses tracking the right articles, and this step began with the development of keywords that had been suggested by the authors. These were based on similar contexts and terms, and then adopted for the search [6,12,22–24]. For the current study, the search string was developed in September 2019 to locate the relevant articles in Scopus. An extremely large volume of articles (4950 document results) was located by using the TITLE-ABS-KEY ("food security" OR "food insecurit*" AND "sustainab*" OR "sustainab* development"), AND TITLE-ABS-KEY ("agricultur*" OR "manufactur*" OR "producer" OR "retail" OR "restaurant" OR "logistic" OR "delivery" OR "supply chain" OR "value chain"). However, due to the consequence of tracking bias and variance, a large population of the articles located also included irrelevant articles. To eliminate these redundancies, the search string was readjusted to TITLE ("food security" OR "food insecurit*" AND "sustainab*" OR "sustainab* development) AND TITLE-ABS-KEY ("agricultur*" OR "manufactur*" OR "producer" OR "retail" OR "restaurant" OR "logistic" OR "delivery" OR "supply chain" OR "value chain"). Consequently, a total of 229 articles were successfully identified in Scopus. Manual searching was also performed using similar keywords on other databases. This resulted in another 177 articles. Thus, in total, there were 405 articles that were successfully retrieved.

2.2.2. Screening

The identified articles (n = 405) were then screened based on inclusion and exclusion criteria, as illustrated in Table 1. Only articles with primary data and explicit discussion of relationship, drivers, and intervention between food security and sustainable system under the FSC were accepted. Articles from agriculture, manufacturing, logistics, retail, and restaurants were included in the review process, but only those from peer-reviewed sources were selected. Others, like literature review, book chapters, and articles from conference proceedings, were excluded so as to ensure the quality of the articles selected. Only English articles published between 2009 to 2019 were selected to reflect a decade of publication on the issue and to avoid the possibility of translation error variance and obsolete information. The screening process resulted in the exclusion of 341 journal articles, and 64 articles identified as relevant for review.

2.2.3. Eligibility

The primary purpose of the eligibility step was to identify further the articles which contain the intended information that can answer the research question and to exclude those that do not. The eligibility process is illustrated according to PRISMA 2009 (Figure 1). Sixty-four articles were further screened for eligibility through the title, abstract, and main contents. A further exclusion was carried out for articles that do not contain explicit discussions of the relationship, drivers, and intervention between food security and sustainability under the context of the food supply chain, and also articles without primary data. Consequently, 24 articles were excluded, leaving only 40 eligible articles to be used for further analysis.

Table 1. Inclusion and exclusion criteria to assess and organize articles.

Criterion	Inclusion	Exclusion	Justification
Context	Food supply chain (FSC)/value chain including manufacturer, logistic, retail, and restaurant	Other than food supply chain Experimental Laboratory	Only include articles with explicit discussion on sustainable food security in the context of the FSC that could answer the research question.
Intervention	Food security Sustainability	Environment (laboratory) Scientific experimentation	Only articles with primary data and explicit discussion on sustainable practices towards food security state.
Mechanism	Implementation	Readiness Barriers Scientific experimentations	
Output	Drivers Pragmatist intervention Relationship Quality management		Articles with primary data and explicit discussion on relationship between sustainability and food security, drivers, and intervention between food security and sustainable system under food supply/value chain, i.e., agriculture, manufacturing, logistic, retail, and restaurant.
Literature type	Journal (research articles)	Any articles without primary data, for example, but not limited to literature review, book chapter, conference proceedings	Only include articles with primary data to avoid synthesis error variance in secondary sources.
Language	English	Other than English	To avoid translation error variance.
Timeline	2009–2019	<2009	To review latest development (in the last decade) in food security and sustainable system.

2.3. Data Analysis

Using the thematic analysis, this study synthesized the sustainable drivers together with the pragmatic interventions that affect the state of food security. The term drivers in this study refers to the factors that directly or indirectly influence the food security state [25,26], while pragmatic interventions refer to any practices that directly or indirectly influence the food security states [27,28]. First, a database was established to collect, extract, store, and categorize the information for descriptive analysis. Next, the articles were analyzed based on categories which include publication year, research country (if not specified, then primary author's country of origin), application sectors (i.e., agriculture, manufacturing, logistics, retail and restaurant, supply chain), research approach, and designs [12]. Following this, thematic analysis was performed by extracting the statements or data that helped to answer the research question. Subsequently, the comments were grouped into relevant themes which then led to the creation of concepts or ideas [29].

Main themes and subthemes were developed for each category so as to collect the relevant information of the sustainability drivers and pragmatic interventions. For instance, an article statement that elicited the effect of agricultural yield on food security state would be grouped under the sustainable drivers of the "output management" theme, and the subtheme of "yield", alongside the type of pragmatic interventions that facilitate the drivers. Each theme's definition was standardized among the authors. ISO 9000: 2015 was used for the theme definition and the food security governance definition was adopted from Termeer et al. [30]. The formal and informal interactions across scales between public and/or private entities were ultimately aiming at the realization of food availability, food access, and food utilization, and their stability over time.

Next, the data analysis process through thematic analysis began with a set of a priori codes; however, the codes were flexible as the analysis progressed [31]. The drivers were cross-referenced to related sustainable domains and food security pillars [6,32]. The codes were then stored and defined in a codebook and compared with the terms used in the key articles to address any inconsistency that occurred during the process of theme development. Consultations and consensus among the authors were acquired for the agreement of the themes to minimize cognitive bias [31].
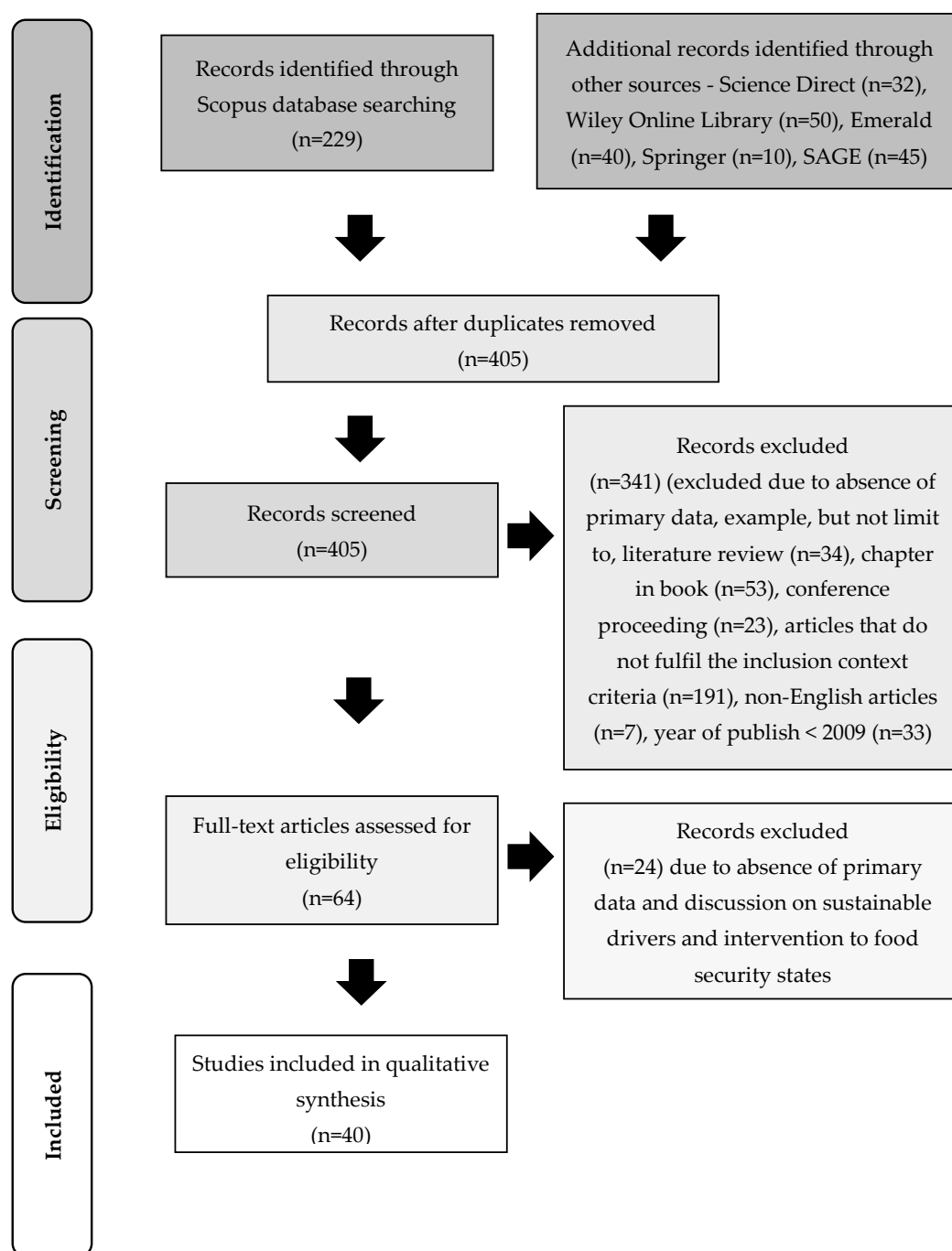
Figure 1. Systematic review-process flow figure (PRISMA).

3. Results

3.1. Trends of the Publications

The frequency distribution of the articles, according to the sectors in the FSC, is illustrated in Figure 2. It was observed that 43% of the articles focused on agriculture agendas. This sector certainly evoked the interests of researchers in the sustainable food security system. Next in line were 23% of the articles that comprise research in the manufacturing industry sector, while discussion on retail and logistics lagged far behind with 5% and 8%, respectively.
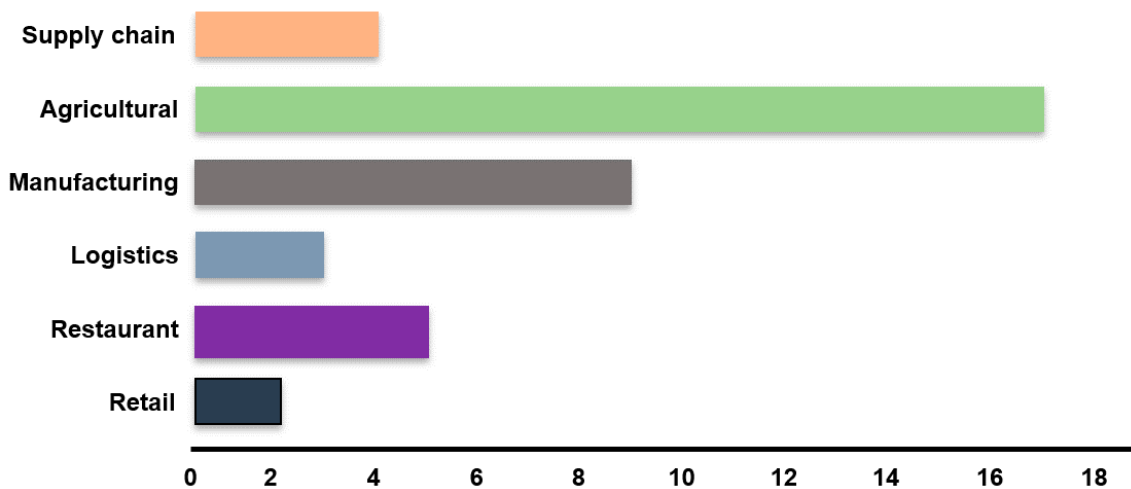
Figure 2. The distribution of articles according to the FSC sector.

The year of publication frequency is illustrated in a Pareto chart (Figure 3). The *y*-axis on the left represents the number of papers published. The bar chart is arranged in the order of the highest number of articles to the lowest number of articles, based on the Pareto chart principle. The right-axis and the line represent the cumulative percentage of the published articles, whereas the *x*-axis represents the year that the articles were published. The line chart is a visual subtool used to depict cumulative percentage to directly spot whether a certain set of data follows the 80/20 rule, moving from left to right across the analysis, to a total of 100%. It was observed that 80% of the articles were published only in recent years (between 2015 to 2019). Thus, it suffices to say that the broach on the sustainable food security system in the FSC is still in its infancy.
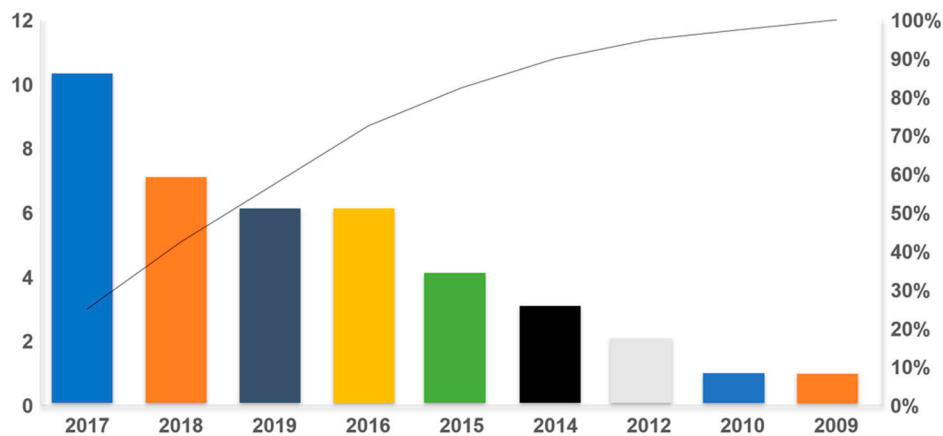
Figure 3. Pareto diagram of articles based on the year of publication.

Figure 4 depicts that the interest and proposition of sustainable food security within the FSC was distributed across the globe, including Asia, Europe, North and South America, and Africa. The highest number of our analyzed articles (23%) come from the world's largest economic countries, like China and the United States of America. Nonetheless, the focus of the studies between these two leading countries was different. Studies from China focused primarily on agricultural agenda, whereas those from the United States of America prioritized on issues about sustainability on food manufacturing, restaurants, and FSC. It is relatively straightforward to envisage that China, as the most populous country in the world, has its focal point on sustainable agricultural agenda as the country itself has more than 1.4 billion people to feed daily. Its population is anticipated to grow continuously, year-by-year [33].
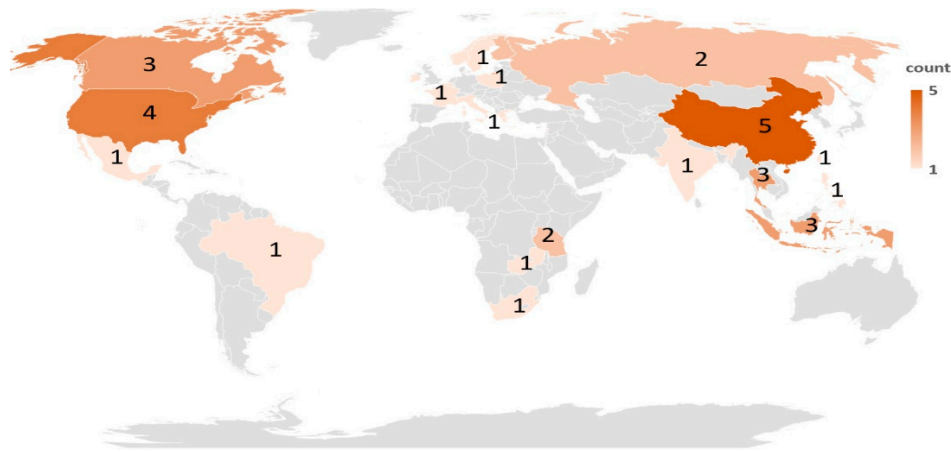
Figure 4. Geographical distribution of the studies.

Meanwhile, the United States of America's Global Food Security Strategy from 2017–2021 aimed at strengthening sustainable food security in the entire food and agriculture system. This may help to explain why the country was prioritizing issues of sustainability in food manufacturing, restaurants, and FSC [34].

Apart from the United States and China, the global commitments to resolve food insecurities and hunger are demonstrated through the participation of sustainable development resolution [35]. For instance, the African Development Bank (AfDB) actively promotes food chain sustainable developments by offering various funding options for African investors [36]. The European Commission has also striven to reduce 50% of food waste by the year 2025 by deploying various food security strategies and policies [37]. As importantly, the review of Mottet et al. [38] illustrated the challenges and strategies, including policies, regulations, research, and development of the sustainable domestic herbivore production in Latin America and South Asia.

From the research approach and design (Figure 5), 70% of the studies used a quantitative approach, with quantitative survey appearing to be the dominant method used in the nonexperimental design, as compared to other research methods, since the food security state tends to stem from generalizing the individuals' experiences, household, national, regional, and global level [14]. Meanwhile, 15% of the studies implemented the qualitative approach, predominantly using the case study method. This is because the method allows an in-depth investigation into the implementation of the pragmatic interventions towards the betterment of food security states.
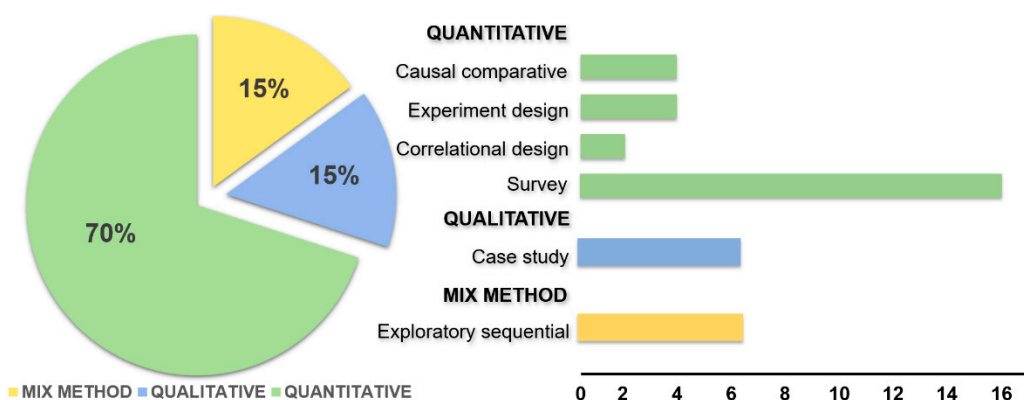
Figure 5. Research approach and design.

The remaining 15% of the studies belonged to the mixed-method approach, largely based on exploratory sequential (quan-qual) method, with the primary intention to explore the individuals' perception and experiences of food security.

3.2. The Domain of Sustainable Food Security

The sustainable drivers that have relation with food security states were articulated by Schindler et al. [32], Hassini et al. [39], Petit et al. [40], and Kummu et al. [41]. The list consists of nine sustainability drivers that related to food security:

1. Balanced and diversified diet
2. Community support program
3. Employees' health, safety, and welfare
4. Agronomic education
5. Sufficient food
6. Fair income and freedom to trade
7. Soil fertility
8. Positive water supply for agricultural activities
9. Agrodiversity

The SLR shows that the "Sustainability" and "Supply Chain Sustainability" maturity models do not require a network perspective following the TBL approach [7]. Sustainability drivers were then mapped and categorized based on the food security and sustainability dimensions proposed by Schindler et al. [32], since they had concluded that the potential of food security in smallholder agrifood systems, and local foods, largely depended on the socioeconomic and environmental criteria.

Similarly, labor welfare, investment, and waste and loss rate related to the social domain; finished products' quality was related to the social and economic domain; costing (including labor and finance) was related to the economics domain; and finally, water, land, air usage, and toxicity were related to the environmental field of sustainability [40]. Nevertheless, the study does not further map the food security domain. Siddh et al. [42], based on grounded theory, showed that the internal quality of perishables had a positive impact on the social, economic, and environmental output of perishables in the FSC. In a study looking at the implications of food waste on sustainability development, Kummu et al. [41] concluded that food waste reduction was affected by economic, political, and social factors, and these would eventually improve the state of food security.

Figure 6 shows the categorization of the sustainability attributes derived from previous studies. These categorizations include employees' health, safety, and welfare [32], and labor welfare [40]. They were then grouped under the "health, safety, and welfare" category. Other categorizations include agrodiversity [32], finished product quality [40], and internal quality. They were grouped under the "product quality and diversity" category [42]. This visual effect ascribed the challenges of delineating each attribute to the respective triple bottom line domain. Nevertheless, every sustainable domain eventually contributed to the food security state.

3.3. Sustainable Food Security Drivers and Pragmatic Interventions in the Agriculture Sector

The literature indicated the most common driver of sustainable food security is the food security governance decisions [43–48], which subsidy and assistance programs are the most implemented interventions globally. The state of government policy, transformation programs, and subsidies, positively leaned towards attaining the "availability" domain in food security [47]. Nonetheless, such policies have obscured the environmental impact, resulting in a higher environmental cost per unit of rice output, but with approximately twice the level of fertilizer and pesticide input. It was recommended that the policy development should consider various scales of farm households and cropping patterns that were consistent with farmland grain-planting suitability.
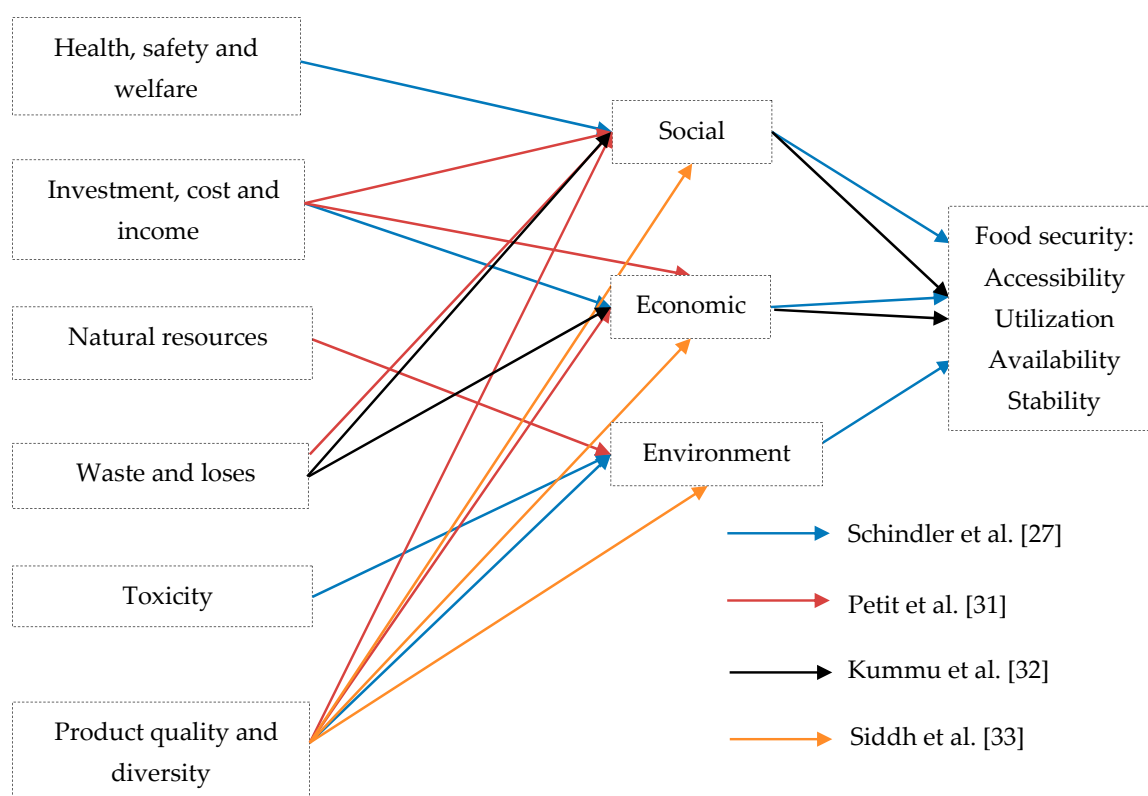
Figure 6. Mapping triple bottom line (sustainability) to the food security concept and its attributes.

Most of the interventions implemented in agriculture were meant to improve yield and to lower the environmental costs, with better economic gains across land and water [32,43,47,49–53]. Consequently, better resource efficiency with less costly input is in tandem with the market's participation. This caused the self-determination of prices to increase the net income of farmers and laborers, hence improving household food security states [32,54]. Salary, food prices, and accessibility to food markets all influence food purchases and should be considered as part of the food security drivers.

From the perspective of land usage, it was found to be equivalent to water and energy footprints [32,51,55]. The status of the tenure and ownership of the lands determined the fate of the land usage (households with customary land tenure had a 17.4% lower probability of adopting crop diversification). Crop diversification was observed to be an intervention that exhibited a strong impact on the household food security state [51]. Several interventions were implemented to improve water efficiency, including (i) terracing, (ii) area closure, (iii) planting fodder grasses, (iv) planting legumes and trees, (v) soil bund construction, (vi) crop rotation, (vii) stop free grazing, (viii) waterways, (ix) manure, (x) inorganic fertilizer, (xi) dams inspection, and (xii) cut off drains [32,45].

The household food security state was also greatly influenced by the farmers' and laborers' competency level [32,45,50,54,56]. The effort to systematically improve the farmers' technical knowledge (in labor technical productivity change) in the agricultural production process would contribute to the betterment of the agricultural industry [54]. This study suggested that agroecological projects, workshops, seminars, and training events should be conducted continuously. This would provide the opportunity for farmers and workers to increase their knowledge, thus encouraging them to gradually adopt more advantageous agripractices for sustainability and improved food security [56].

However, it should be noted that poorly developed countries can lack incentives that cause growth and agricultural efficiency. It should be stressed that, apart from assistance at the national level, alleviating the global problem of hunger requires the participation of the international community [57].

A summary of the sustainability drivers and pragmatic interventions associated with agriculture, including livestock agendas, is illustrated in Table 2.

3.4. Sustainable Food Security Drivers and Pragmatic Interventions in the Manufacturing Sector

Manufacturing is the most substantial contributor to the environmental impact categories, including water, energy, land usage, acidified air emission, ozone depletion, global warming potential, and waste generation [59].

A striking result shown in Table 3 is the relevance of both recycling and quality improvement as the interventions within input and output resource management. The closed-loop supply chain model is a novel intervention used to intigate the realization of sustainable operations that positively affected profitability (15-year operation lifetime that breaks even in a maximum 10-year payback time), the energy self-sufficiency indicator (cogeneration plant is completely self-sufficient in electric energy), and the employment possibilities [60]. Postfarm gate recycling processes and the optimization of the performance of packaging utilizations are among the pragmatic interventions, which can reduce the environmental impact [59–62].

Another form of recycling process was located, which is by investigating the potential of reusing reconditioned water to reduce wastes and save costs [61,62]. For example, water was successfully recovered in the dairy industry via a combination of ultrafiltration and reverse osmosis processes.

From the perspective of managing the manufacturing practices in the context of sustainable food security, Ocampo [63] identified seven sustainable manufacturing practices. These were ranked in the following order: total quality management, resource efficiency, material efficiency, just-in-time, green manufacturing, waste elimination at source, and ecoefficiency. In the food industry, quality management and innovation have shown a significant impact on green performance [64]. Ocampo [63] suggested that total quality management was the most suitable intervention as it focuses on meeting customer expectations of integrating sustainability considerations in finished food products.

The trends in literature show that food waste produced from manufacturing can come from unavoidable waste (e.g., animal fat, slaughter waste) and have no-value final products [59]. The results postulated that major drivers and interventions are based on the input resource management, where product waste was cited the most. In the recent advances of integrated systems, quality management approach has become more a conventional intervention in the manufacturing sector in addressing the waste issues [65,66].

The conventional purpose of a quality improvement program in the food industry is to improve product quality and to reduce production costs by minimizing variations and reducing wastes [67]. Nevertheless, the purpose was revolutionalized to support the effort for green food production, primarily by reducing wastes effectively [65,66,68]. Powell et al. [65] demonstrated the success of lowering milk loss and subsequently, reducing wastewater. Food waste (environmental impact) reduction was implemented through the use of basic quality tools, such as brainstorming, process flow, project charter, key performance indicators, measurement system analysis, material balance analysis, critical-to-quality, cause and effect figure, design of experiment, Pareto chart, control chart, mistake proofing, lean tools such as value stream mapping (VSM), and the six sigma tools, such as statistical process control (SPC) through define, measure, analyze, improve, and control (DMAIC) [65,68].

Table 2. Summary of sustainable food security drivers and pragmatic interventions in the agricultural sector.

Sustainable Food Security Drivers	Food Security Domain	Sustainability Domain	n	Pragmatic Intervention	Reference
Output Management					
Yield optimization	Accessibility Utilization Availability	Economic Social Environmental	8	System of Rice Intensification	Mishra et al. [50]
				Double/intercropping	Nkomoki et al. [51] Qi and Dang [47] Qi et al. [53]
				Agroforestry Upgrading strategies	Nkomoki et al. [51] Schindler et al. [32]
				Proper seed selection according to climate and region	Frimawaty et al. [43]
				Sustainable agricultural intensification practices	Western [52]
Food Security Governance Involvement					
Policy towards food security	Accessibility Utilization Availability	Economic, social and environment	5	Subsidy and assistance programs	Qi and Dang [47] Rosdiana et al. [44] Frimawaty et al. [43] Mulema et al. [45] Yuan et al. [46]
Evidence base decision			1	Field study of environmental performance and sustainability of agricultural production	Skaf et al. [48]
Information sharing	Accessibility Utilization	Social	6	Training	Schindler et al. [32] Elisante et al. [56] Zhang et al. [54,54] Mulema et al. [36] Mishra et al. [41] Western [52]

<div align="center">**Table 2.** *Cont.*</div>

Sustainable Food Security Drivers	Food Security Domain	Sustainability Domain	n	Pragmatic Intervention	Reference
Income Improvement					
Fair trade	Stability	EconomicSocial	1 2	Market participation Self-determination of price	Schindler et al. [32] Zhang et al. [54] Galipeau [49]
Livestock management	Stability		1	Hen vaccination, use of hybrid layer hens, and layer hens housing facilities	Dumas et al. [28]
Land status	Availability		3	Provide land ownership and tenure agreement terms	Charoenratana et al. [55] Nkomoki et al. [51] Schindler et al. [32]
InputResource Management					
Materials	Availability	Environment	2	Use of organic pesticide	Elisante et al. [56] Frimawaty et al. [43]
			1	Use of organic fertilizer	Frimawaty et al. [43]
Water management	Availability	Environment	1 1	Rainwater harvesting Rainwater management (RWM) practices	Schindler et al. [32] Mulema et al. [36]
Technology	Accessibility Utilization	Economi cSocial	1	Internet of things (IoT)	Kaur [58]

Table 3. Summary of sustainable food security drivers and pragmatic intervention associated with the food manufacturing sector.

Sustainable Food Security Drivers	Food Security Domain	Sustainability Domain	n	Pragmatic Intervention	Reference
Input Resource Management					
Energy	Availability	Environment	1	Biogas Cogeneration plant	Sgarbossa and Russo [60]
Water	Availability	Environment	4	Biogas Ultrafiltration Reverse osmosis system	Asem-Hiablie et al. [59] Meneses and Flores [62] Nugroho Soebandrija [61]
Material	Availability	Economic Environment	1	Packaging material optimization/usage reduction	Asem-Hiablie et al. [59]
Costing	Accessibility Availability	Economic Environment	1	Recycling	Asem-Hiablie et al. [59]
Product quality and waste	Accessibility Availability	Economic Environment	2	Quality Management	Pipatprapa et al. [64] Cotrim et al. [68]
		Economic Environment	2	Lean Six Sigma	Powell et al. [65] Dora and Gellynck et al. [66]
Output Management					
Production waste	Accessibility Availability Utilization	Economic Environment	2	Nonstandard product inspection machine Recycling	Nugroho Soebandrija [61] Asem-Hiablie et al. [59]
Information sharing	Accessibility Utilization	Social	2	Lean Six Sigma Brainstorming	Powell et al. [65] Dora and Gellynck et al. [66]

In principle, Lean Six Sigma (LSS) has a positive effect on sustainable food sustainability, incorporating two solid Lean and Six Sigma as quality [65,66]. The LSS can promote process capability, employee's engagement, empowerment, and educate employees on the consequences of waste [32,45,50,52,54,66,69–71].

The soft benefits of the quality improvement techniques include being able to educate the employees on the consequence of waste, and how to minimize wastes as quality improvement programs that promote employee involvement in the process [32,45,50,52,54] The sustainability drivers and the pragmatic interventions associated with manufacturing are summarized in Table 3.

3.5. Sustainable Food Security Drivers and Pragmatic Interventions in the Food Logistics Sector

The result postulated that the logistics affected mostly on the accessibility category of food security principles driven by input, output resource management, and food security governance involvement. Transportation costs and greenhouse gas (GHG) emissions are the dominant paradigm in the food logistics and distribution process [72–74]. Effective food distribution for business today not only considers the operation base, shelf-time, organoleptic and biophysical characteristics, but also must be economically efficient and environmentally friendly. The intervention that enables minimization of carbon dioxide emissions and distribution costs is through reassessment of distribution [73]. Evidently, the feature that makes food supply chains unique and more daunting than perishability is the intense heterogeneity of the industry, with hundreds of thousands of small producers supplying tens of thousands of middle players serving thousands of sale points, and hundreds of retailers each operating a distribution chain [75].

The impact of logistics performance on food security varies according to region [76–78]. In South Africa, the delivery infrastructure impaired rural food security due to poor road conditions, which threatened personnel safety and security. As a result, food shelf-life in retail was shortened due to late delivery or even no distribution at all to some remote counties [72]. Complications from such problems often lead to higher food prices, and the lack of nutrient diversification at retail levels. In order to meet the challenges, food policy intervention at different levels, including infrastructural development, support of entrepreneurship, adaptive production, land reformation, and skill-building needs to be brought to the forefront so as to achieve better food security states [75,79–81]. The sustainability drivers and interventions associated with food logistics are summarized in Table 4.

Table 4. Summary of sustainable food security drivers and intervention associated with the food logistics sector.

Sustainable Food Security Drivers	Food Security Domain	Sustainability Domain	n	Pragmatic Intervention	Reference
Input Resource Management					
Costing	Accessibility	Economic and social	1	Distribution route improvement design	Vorotnikov et al. [74]
Output Management					
Greenhouse gaseous emission	Availability	Environment	1	Distribution route improvement design	Validi et al. [73]
Food Security Governance Involvement					
Financial assistance	Accessibility Utilization	Social	1	Incentives Grants Subsidy and assistance programs	Pereira et al. [72]

3.6. Sustainable Drivers and Pragmatic Interventions in the Retail and Restaurant Sector

In the retail and restaurant sector, food loss/waste, locations, and food prices critically affect food security through high food waste volume [82–84].

"Take back" agreement at the retail level is deemed to be the culprit of food waste generation, particularly bakery items [82]. In business terms, suppliers often agree to take back products that are of unsatisfactory quality or approaching expiry. Meanwhile, at the restaurant level, food waste generation is invariably due to low-quality products, e.g., overripe and underripe produce from suppliers. An innovative approach to avoid the rejected food from becoming food wastes, the function of the food is often changed to animal feed, and the source of biogas [85].

It was observed that poor green practices in the restaurant are believed to be the main cause of food wastes [84,85]. First-in-first-out (FIFO) policy is a highly recommended practice to avoid wilted and spoilt food, especially salad and steak, that are usually prepared at the earliest stage of food preparation [84]. The lack of communication with the customers in informing them about the size or portions also led to food waste generation [84]. According to Pulkkinen et al. [83], consumers are willing to choose low carbon footprint meals if they were informed and given an option. The lack of green practices information was also found to disappoint consumers, thereby highlighting the importance of communication as an intervention to avoid food wastes [85].

Schubert et al. [85] ranked the important green practices or interventions at the restaurants from the consumer's perspective. Reducing energy usage and wastes, using biodegradable or recycled products, serving locally grown food, and using organic products are the top four practices expected by consumers. The least mentioned interventions were donations to environmental projects and paying fees to reduce their ecological footprints.

Food insecurity also affects the different groups of the population, e.g., low-income and senior citizens, who may be affected by limited food choices, financial aids program availability, location of restaurants, and retail and food prices [86]. Thus, a subsidy program such as Nutrition North Canada was introduced to reduce the burden of the cost of nutritious food for residents living in remote areas. Nonetheless, [87] emphasized that the success of such subsidy programs depended on the managers and retailers who were responsible for the full accountability of such programs, such as claims accuracy, transparent fiscal reporting, retail competitions, and prohibitive freight costs. The summary of these sustainability drivers and interventions associated with manufacturing is illustrated in Table 5.

Table 5. Summary of sustainable food security drivers and intervention in the food retail and restaurant sector.

Sustainable Food Security Drivers	Food Security Domain	Sustainability Domain	n	Pragmatic Intervention	Reference
Input resource management					
Materials	Availability	Environment	1	Use of biodegradable or recycled products	Schubert et al. [85]
	Accessibility	Environment	1 1	Use of organic products Serve locally grown food	Cheng et al. [88] Schubert et al. [85]
	Utilization	Social	1	First-in-first-out	Charlebois et al. [84]
Energy	Availability	Environment	1	Installation of energy-saving facilities	Cheng et al. [88]
Output Management					
Food lost/wastages	Availability	Economic Environment	1	Standard operating procedure compliance	Charlebois et al. [84]
			1	"Take back" agreement terms	Eriksson et al. [82]
Healthy and balance diet meal	Accessibility Utilization	Social	1	Provision of variety and healthy meals	Cheng et al. [88]
Information sharing	Accessibility Utilization	Social	3	Public awareness and education program	Galloway [87] Charlebois et al. [84] Pulkkinen et al. [83]
Food Security Governance Involvement					
Assistance	Accessibility Utilization Accessibility	Economic Social Environment	2	Subsidy and assistance programs	Galloway [87] Oemichen and Smith [86]

4. Discussion

This research focuses on the sustainable food security drivers in their practical interventions in the context of FSC, and further suggests mediator intervention to improve the state of sustainable food security.

4.1. Sustainable Food Security Drivers in the FSC

The inextricable relation of food security and sustainability with the drivers in the sustainable food security system is summarized in Figure 7, and these drivers are consistent with several significant studies on sustainable food security [27,89,90]. Past literature has shown the interrelationships between the food security pillars and sustainability domain, and mapped by Berry [6], i.e., environmental domain is interrelated with the availability pillar, economy domain is interrelated with the accessibility pillar, whereas social domain is interrelated with the accessibility and utilization pillars. However, further mapping of drivers into these pillars and domains remains a challenge, as particular drivers may relate to the various pillars of food security, as discussed in Section 3.2. Thus, FSC should be flexible in categorizing the drivers and implement suitable pragmatic interventions that may contribute to multiple food security pillars [26,91].
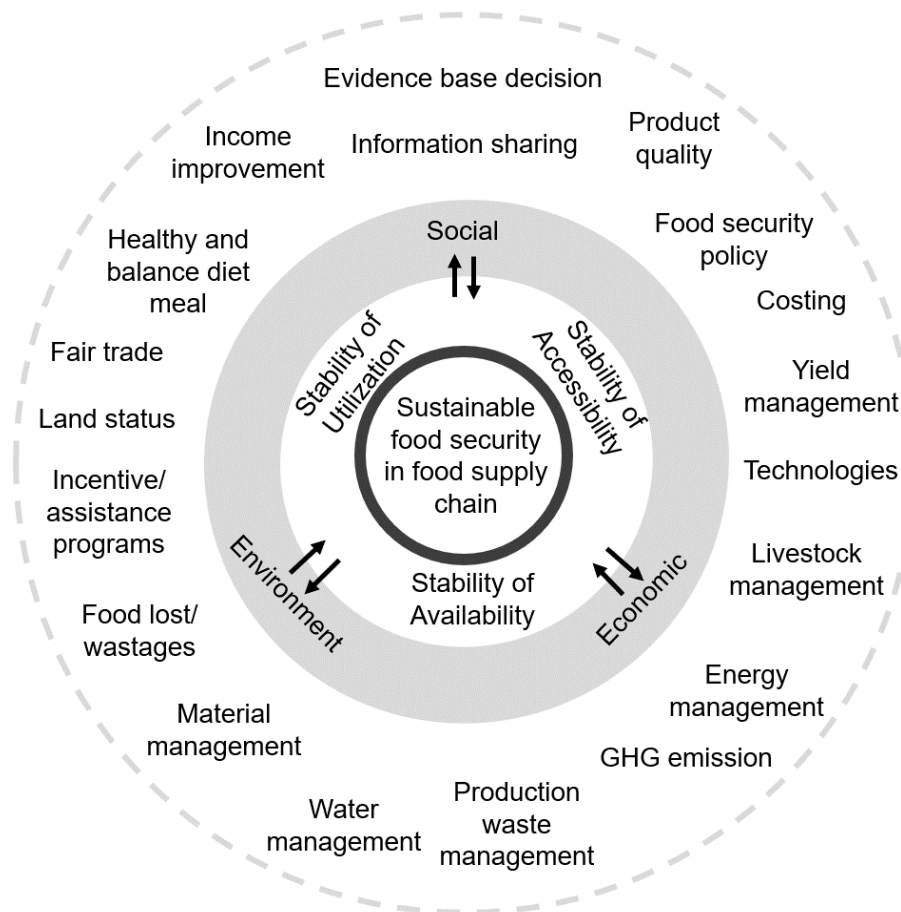
Figure 7. Drivers of the sustainable food security system with the association of food security and sustainability concept.

Further analyzing the commonality of food security drivers themes between each FSC sector (see Table 6), this study identified that the trends of food security in FSC are affected by sustainable food security drivers: (i) food security governance involvement, (ii) input resource management, (iii) output management, and (iv) information sharing.

Table 6. Common sustainable food security drivers at every sector in FSC.

	FSC sector			
	Agriculture/Livestock	Manufacturing	Logistics	Retail and Restaurant
Food security governance involvement	✔	X	✔	✔
Input resource management	✔	✔	✔	✔
Output management	✔	✔	✔	✔
Information sharing	✔	✔	X	✔

The first driver for sustainable food security illustrated the importance of food security governance involvement in ensuring the proper allocation of resources, and that the decisions were made based on clear evidence. The notion of food security governances can be referred to formal and informal rules and processes through public and private actors articulating their interests, and decisions for achieving food and nutrition security (at local, national, and global level) are made and implemented [30,92]. The involvement of food security governance exhibits its potent effects on the success of a sustainable food security system within the FSC through established policy, assistance programs, and facilities resources, e.g., subsidy, grant, and incentive. Food security governance must portray several leadership criteria, including (i) accountability, (ii) making evidence-based decisions, (iii) resource management, and (iv) readiness to collaborate and cooperate with relevant interested parties [14,87,92–95].

Information sharing, likewise, is significantly addressed in the agriculture, manufacturing, and restaurant and retail sectors, but not in the logistics sector (Table 4). Hence, effective information sharing is deemed as one of the sustainable variables in the achievement of food security targets [96]. For instance, without sufficient information-sharing with relevant parties, the distribution route improvement design by Vorotnikov et al. [74] and Validi et al. [73] would have failed. Information should be shared and received by internal and external interested parties, and stakeholders including, but not limited to, suppliers, workers, and internal/external customers (ISO 9000:2015). Various effective information-sharing platforms, e.g., electronic websites, signboards, training, seminars, workshops, and marketing point-of-purchase displays should be fully utilized to ensure that each organization is capable of demonstrating utmost sustainable food security performance.

Input resource management and output management are commensal variables, which postulate involvement in every sector within the FSC. Input resources, be it renewable, nonrenewable, or costing, should be utilized most effectively and efficiently [97]. In this context, effectiveness is defined as the extent to which customer requirements or intended objectives are met. At the same time, efficiency is the measurement of how the organization's resources and efforts are economically utilized when meeting customer satisfaction or intended goals [98,99]. Waste output, be it food waste or processing waste, shall be minimized through innovative approaches, including reusing, regenerating, recycling, reducing, or substituting with less harmful alternatives, while maintaining optimum yield and quality (including food safety and nutrition) in fulfilling food security goals [100,101].

Intervention variables could be hypothesized as mediators in the relationship between the exogenous variables and food security states with the reason of intervention. This explains how such exogenous variables could affect the dependent variables (food security state) [102]. Costs (input resource) would have an impact on food security states in areas that have difficulties in self-sufficiency meat (independent meat source) [74]. Redesigning the distribution route is one of the interventions in which minimizing the usage of fuel could lower the price of food, while maximizing the delivery volume could increase the volume of food with affordable prices that can be purchased by remote villages. This helps to improve the food security states. In addition, managing restaurant food losses (exogenous variable) is vital for the betterment of food security (dependent variable) [41,84]. Compliance to standard operating procedures in restaurants, e.g., following the first-in-first-out (FIFO)

method could prevent food wastage and resource depletion. This intervention explains how the independent variable is exerting its effect on the dependent variable.

It was identified that across the four stages of FSC, several drivers are customized for the specific stage of the food chain. Quality management that was categorized under both output and input drivers, however, is the most common driver towards achieving sustainable food security at all stages of FSC, with reducing waste as the focal point. Therefore, this study proposes quality management practices that have an impact on food security state.

4.2. Role of Quality Management (QM) Intervention in Sustainable Food Security

It was identified that food waste, quality, and costing are common issues of food securities across the supply chain. Reducing cost and waste are able to be achieved with the implementation of quality management approaches. Quality management is, therefore, an appropriate strategy that could be introduced in the FSC, because quality management is underpinned by four key variables: information management, input processing, output management, and participation of top management [63,64,68,103]. As a matter of fact, these variables have been identified as part of the total quality management (TQM) success criteria, alongside employee competency, the voice of the customer, organization identity, engagement and empowerment, relationship management, performance evaluation, and analysis and infrastructure [104] (see Figure 8). In addition, this conceptual model with QM proposed as the mediator aligns with the systematic review of Siva et al. [105], who illustrated that daily sustainability management, including an environmental management system (EMS) with satisfying stakeholder requirements, are facilitated by the QM implementation. Even so, this paper only discussed the contribution of QM towards sustainability without a food security context. In another study, Maistry et al. [103] concluded that by using structural equation modelling (SEM) where the TQM has the highest total effect on organization sustainable performance also contributes towards organization strategy via employee engagement and empowerment.

The concept of quality management in the food industry is covered in vast areas, and it involves several systems, with the term used to depict TQM, Lean, Six Sigma, ISO, and Quality Assurance [98]. Nevertheless, Luning and Marcelis [106] defined the overall food quality management concept model as consisting of five aspects:

1. Quality design, such as quality function development (QFD), failure mode, and effect analysis (FMEA), which formulates the standards in meeting customer, interested parties, or stakeholder requirements.
2. Quality control, such as statistical process control (SPC), which ensures output meets customer, interested parties, or stakeholder requirements.
3. Quality improvement, such as Sigma, Lean Six Sigma, and dashboard metrics, as a method to continually improve in every aspect to meet or exceed customer, interested parties, or stakeholder requirements.
4. Quality assurance, such as such as Hazard Analysis Critical Control Point (HACCP), ISO, British Retail Consortium (BRC), which ensures and verifies the processes capability in meeting customer, interested parties, or stakeholder requirements.
5. Quality policy and strategy, which define directions and internal responsibilities to achieve customer, interested parties or stakeholder requirements.

World-renowned ISO 9001 Quality Management System (QMS) demonstrated its ability to consistently provide quality products and services that meet customer and applicable statutory and regulatory requirements (ISO 9001:2015). Improving product quality tends to create added value in sustainability. For instance, improvement of economic benefits via sales increment, and social benefits via the fulfilment of public environmental concern needs [107]. Furthermore, the QMS is also considered as the starting point of Environment Management System ISO 14001, Social Accountability (SA 8000), and Occupational Health and Safety (ISO 45001) [68]. Wiengarten and Pagell [108] concluded

that higher performance in environmental management in terms of cost, flexibility, and delivery performance is achieved by organizations that practice quality management systems. In a study by Strotmann et al. [109], adapting PDCA (plan–do–check–act) is seen as a intervention developed via an implementation framework that assists the FSC's managers in reducing food wastes.
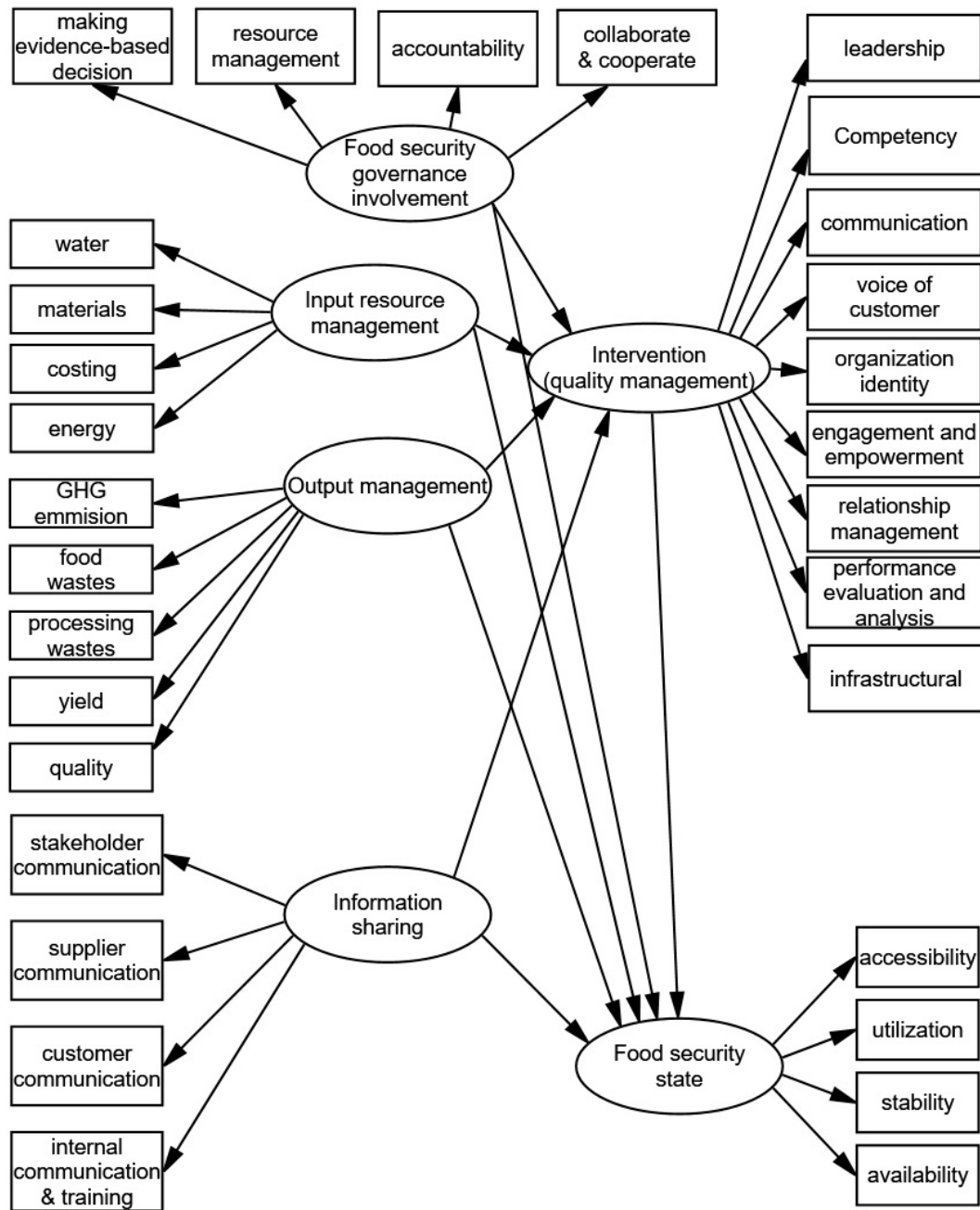
Figure 8. Conceptual model of sustainable food security system.

Started with TQM, Lean and Six Sigma are the renowned approaches to improving operational performance across industries, and now also serve environmental purposes [66]. The conventional Lean concept tackles seven wastes in an organization, and capable in facilitating cleaner and sustainable productions [71]. Likewise, Six Sigma, which is originally a disciplined, project-oriented, data-driven approach, can be used to reduce variations and defects in a process via the DMAIC methodology [110]. Such an application has evolved to implement innovative programs that simultaneously enhance

environmental performance and provides tremendous cost savings [111]. While Lean is known for its strength in waste elimination through the usage of TQM, value stream mapping (VSM) and just-in-time (JIT) in supply chain [94,112] waste elimination, and TQM demonstrated significant correlations on all three dimensions of sustainability. The Six Sigma method (DMAIC) and tools (cause-and-effect diagram) have been successfully adopted by Kandananond [113] to systematically reduce water footprints in the agricultural sector.

5. Conclusions

This paper sought to identify trends in publications in the direction of sustainable food security by examining its drivers that are critical for shaping food policy. Four main drivers were identified from this systematic review of 40 articles; these reflect the sustainability drivers and the interventions practiced by each sector in the FSC.

The first driver focused on the critical role of food security governance, especially for agriculture, logistics, retailers, and restaurants. The second driver explained the importance of effective management of the input resources, e.g., water, biosafety materials, and energy via various innovative interventions. The third theme highlighted output management, especially on food waste reduction and GHG reduction. The fourth theme was the labor income gained through fair trade, which directly impacts farm workers. Based on the analysis, quality management was also identified as a hypothetic generic intervention that could mediate the effect of these familiar drivers towards food security in the FSC.

In general, previous literature had postulated a conceptual model of sustainable food security drivers in the context of FSC. Further effort to improve the new developments is suggested to generalize the result through statistical analysis, e.g., structural equation modeling (SEM). In addition, the definition of sustainable food security in this study is "individual ability to acquire foods that satisfy human nutritional needs without compromising the human and environmental health at all times. The food supply chain can implement effective practices that would improve the state of sustainable food security, such as food security governance involvement, input resource management, output management, and information sharing." This definition is necessary because the existing food security definition does not proclaim the participatory role of the sustainability concept. This study provides a profound understanding of the sustainable drivers and interventions towards food security and further provides new innovative solutions to food security issues through the implementation of quality management practices.

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