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Sustainable Management of Challenges in the Agri-Food Supply Chain: the Case of Upcountry Vegetable Farmers in Nuwara Eliya District, Sri Lanka

Abstract. This study aimed to identify the challenges associated with the sustainable management of the agri-food supply chain, with a particular focus on the upcountry vegetable sector. Additionally, it sought to develop strategies to address these challenges and establish mechanisms to further enhance sustainable supply chain management. A sample of 300 vegetable farmers from the Nuwara Eliya district was selected using a simple random sampling method. Data collection was undertaken between July and October 2024 through a field survey and two focus group discussions. Descriptive statistics and Garrett's Ranking technique were applied to analyse the quantitative data obtained from the survey. The qualitative data from the focus group discussions were analysed using thematic analysis. The findings revealed several key social challenges to sustainable development in agri-food supply chains, including limited access to agricultural inputs, insufficient awareness about managing these supply chains and low adoption of modern technologies. Major economic challenges identified included high production costs, inadequate financial support, difficulties for small-scale farmers in competing in both domestic and international markets, and poor knowledge of using ICT for market information. As the environmental challenges included long-distance transportation of products, limited product diversification capabilities and threats to entering export markets through maintaining the product quality. Hence, the study suggests providing concessional financial support for purchasing agricultural inputs, conducting awareness programmes to improve knowledge and experience in managing supply chains, introducing modern technologies to encourage the adoption of best practices, implementing strategies to reduce production costs, developing market information systems with better ICT access and improving transportation and opportunities for producing diversified agri-food products.

Keywords: agri-food, challenges, sustainable development, Sri Lanka, supply chains

JEL Codes: Q13, Q56

Introduction

The agri-food industry is one of the major manufacturing sectors in both developed and developing countries. This sector often consumes significant natural resources during the manufacturing process of agri-foods. Consequently, constraints within agri-food supply chains (AFSCs) hinder sustainable development in many developing countries (Jayalath et al., 2021). While developed countries pay greater attention to the sustainable management of AFSCs for community development, developing countries face numerous socio-economic issues due to the mismanagement of agri-food supply chain activities (United Nations [UN], 2020). Moreover, the AFSC is central to ensuring food security and supporting sustainable agricultural practices globally (Rejeb et al., 2021). However, increasing challenges such as

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climate change, resource depletion, and the need for economic equity are intensifying the pressure on AFSCs to adopt more sustainable practices (Annappa et al., 2023). Sustainable AFSC management integrates environmental, economic and social dimensions to create more resilient and equitable supply chains (Wang et al., 2024). Thus, sustainable management of AFSCs has the potential to foster development in rural areas of developing countries (Nchanji and Lutomia, 2021).

Given that Sri Lanka is a developing country, it is crucial to explore how the management of agri-food supply chains can be effectively utilised to address and mitigate the current challenges faced by AFSCs in Sri Lanka. This study specifically focuses on the upcountry vegetable sector in the Nuwara Eliya district, examining how AFSC management can be applied to overcome the challenges faced by smallholder farmers in this region.

In particular, farming requires an adequate amount of resources and a wide variety of services to optimise productivity. Resource deficiencies lead to lower productivity and reduced efficiency in agri-food supply chains (Lezoche et al., 2020; Food and Agriculture Organisation [FAO], 2018). In the context of developing nations, key challenges within their AFSCs include resource scarcity for farming, poor post-harvest practices, global climate change, environmental degradation and increasing food demand (De Boni et al., 2022).

This research aims to investigate the existing agri-food supply chain practices among upcountry vegetable farmers in Nuwara Eliya and to identify opportunities for improving sustainability through targeted interventions in supply chain management. The study seeks to understand the key constraints faced by the farmers and propose sustainable strategies involving technology adoption, policy reform, collaboration among stakeholders and capacity-building initiatives.

By focusing on a context-specific case in Sri Lanka, this research contributes to the broader literature on sustainable AFSC management in developing countries. It fills a critical gap by offering localised insights and practical recommendations that can be applied in similar rural and resource-constrained environments. Furthermore, it underscores the importance of integrating sustainability into every stage of the supply chain to promote both environmental stewardship and rural economic development.

Literature review

What are agri-food supply chains?

Agri-food supply chains (AFSCs) involve the sequential processes of transforming agricultural inputs into distributed and marketed agri-foods through production and processing (Borsellino et al., 2020; Lezoche et al., 2020). AFSCs are characterised by strong linkages between farmers, food processors or traders and retailers (Djekic et al., 2021; Aday and Aday, 2020). A typical agri-food supply chain is illustrated in Figure 1.

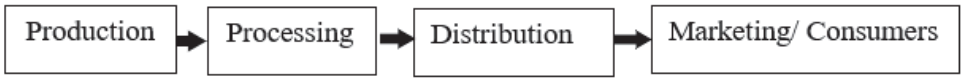

Fig. 1. Typical agri-food supply chain

Source: United States Department of Agriculture [USDA], 2022.

Moreover, during the processing stage, various processed products are created from farm products and are then delivered to consumers through transportation, storage and retailing (FAO, 2022; Vroegindewey and Hodbod, 2018).

Conceptualising Sustainable AFSC Management

Sustainable AFSC management encompasses various approaches, including resource optimisation, waste reduction, fair trade and ethical labour practices (Awais, 2024). According to Gyarmati (2024), the sustainability of AFSCs is typically evaluated through three pillars: environmental sustainability, economic sustainability and social sustainability. The environmental dimension involves reducing the carbon footprint, minimising waste and promoting biodiversity. Economic sustainability ensures profitability and long-term viability, while social sustainability focuses on labour rights, community welfare and equity in food distribution (Rosli et al., 2024). Pereira et al. (2020) highlight that sustainability in AFSCs requires a systemic approach, incorporating the entire supply chain from production to consumption. The adoption of circular economy principles, such as resource reuse and waste valorisation, has been emphasised in recent studies as a way to improve the sustainability performance of AFSCs (Bakker et al., 2023).

Importance of managing agri-food supply chains

AFSC management plays a significant role in enhancing sustainability in the agriculture sector, including reductions in labour requirements and costs (Hidayati et al., 2021). Managed AFSCs typically have lower labour requirements due to strong linkages between each step of the supply chain and a high degree of mechanisation. Consequently, labour needs are reduced, and expenses associated with labour wages are minimised within AFSCs (Bhat and Jõudu, 2019). Additionally, as the efficiency of AFSCs increases, the transparency of the production process improves, supporting better production practices in agribusinesses (FAO, 2022). Well-managed AFSCs also feature strong linkages between each component of the supply chain, which enhances communication throughout the process (Kim, 2018). Effective management of AFSCs involves the formulation and implementation of timely and significant legislation to enhance their efficiency and effectiveness (FAO, 2018; International Labor Organization [ILO], 2016). Sustainably managed AFSCs produce high-quality end products that meet consumer preferences, thereby enhancing competitive advantage (Barua and Rahman, 2021; Reklitis et al., 2021). Furthermore, properly managed AFSCs facilitate access to export markets by expanding global trade in agri-foods (Dissanayaka and Thibbotuwana, 2021). Overall, well-managed AFSCs contribute to the sustainability of the agricultural sector by minimising negative externalities and supporting sustainable development (Borsellino et al., 2020). However, consider the environmental sustainability, economic sustainability and social sustainability in AFSCs as follows:

Environmental Sustainability in AFSCs

Environmental sustainability is a primary concern in AFSCs. Sustainable sourcing and eco-efficient logistics are essential to reducing environmental impacts (Wang et al., 2024; Tasca et al., 2017). Innovations such as precision farming, organic farming and regenerative agriculture are becoming increasingly prominent (Konfo et al., 2024; Rempelos et al., 2023). Technologies such as sensor-based systems and drones allow farmers to optimise inputs like water and fertilisers, reducing environmental pollution (Ranjan et al., 2024). Additionally,

the use of renewable energy in processing and sustainable packaging is key to reducing the environmental footprint of AFSCs (Cossu et al., 2024).

Economic Sustainability and Resilience

Economic sustainability in AFSCs revolves around long-term profitability and the resilience of supply chains to external shocks, including geopolitical instability and climate change (Oriekhoe et al., 2024). Research highlights the importance of risk management, supply chain diversification and digital technologies for enhancing supply chain resilience (Olutimehin et al., 2024). Additionally, addressing food waste, particularly during storage, transport and retail, is essential for improving economic and environmental sustainability (Todd and Faour-Klingbeil, 2024).

Social Sustainability and Fair-Trade Practices

Social sustainability is concerned with labour rights, fair wages and food security (United Nations, 2020). Ethical supply chain practices, including fair trade certifications, have gained attention for improving the livelihoods of farmers in developing countries (El Din and Masengu, 2024). Furthermore, food access and equity remain significant challenges, as small-scale farmers often face barriers to market participation and large retailers dominate the food distribution system (Dhillon and Moncur, 2023).

Digitalisation and Technology in Sustainable AFSCs

Technological advancements such as IoT, artificial intelligence (AI) and big data analytics are transforming AFSCs (Konfo et al., 2023). These technologies are being applied to optimise resource use, reduce waste and improve decision-making (Misra et al., 2020). AI-driven predictive analytics helps farmers improve production schedules, while IoT devices monitor factors like soil health and weather patterns, enabling more efficient farming (Burak, 2024).

Sustainable management of the agri-food supply chain in Sri Lankan scenario

According to Wątróbski (2019), sustainable management can be defined as the formulation, implementation and evaluation of decisions and actions related to both environmental and socio-economic sustainability. Thus, sustainable management of the agri-food supply chain is increasingly recognised as essential for promoting environmental health, economic stability and social fairness. This is particularly true in regions that are both ecologically sensitive and economically dependent on agriculture (Çakmakçı et al., 2023). The Nuwara Eliya District in Sri Lanka, known for its upcountry vegetable cultivation, exemplifies the complexities involved in managing a sustainable agri-food supply chain, given its high altitude, diverse crops and reliance on small-scale farming (Aiome et al., 2022).

Sustainable management in this context involves a range of practices aimed at reducing environmental impact, optimising resource use and strengthening the resilience of farming systems (Çakmakçı et al., 2023). In Sri Lanka, proper management strategies for AFSCs have not yet been well formalised or implemented in the agricultural sector (Dissanayaka and Thibbotuwana, 2021). When AFSC activities are isolated, it leads to various issues within the agriculture sector. As a result, Sri Lanka loses approximately 270,000 metric tons of fruit and vegetable production due to inefficiencies in the supply chain (Dissanayaka and

Thibbotuwana, 2021). This situation underscores the importance of sustainably managing AFSCs within Sri Lanka's agri-food sector.

Recently, the management of AFSCs has received attention from researchers and practitioners. However, the literature suggests that the potential benefits of sustainability in AFSCs are not yet fully explored, especially regarding enhancing the sustainability of the agricultural sector and developing Sri Lanka's economy (Jayalath et al., 2021). In Nuwara Eliya, vegetable farmers face significant challenges such as resource management, market access and climate change impacts (Gunathilaka and Samarakoon, 2022).

Methodology

The concept of managing agri-food supply chains (AFSCs) is well established in Sri Lanka. Both developed and developing countries have increasingly embraced AFSC management as a crucial strategy to promote sustainability within the agricultural sector (Çakmakçı et al., 2023). Recently, AFSC management has been recognised as a vital approach for achieving sustainable development in many developing nations, including Sri Lanka (Bandara and Amarasekara, 2023). This study aimed to identify the challenges associated with sustainable AFSC management in Sri Lanka's upcountry vegetable sector and to propose strategies to address these issues. Furthermore, the study sought to develop mechanisms to enhance the overall sustainability of AFSC management. In the Nuwara Eliya District, approximately 66,148 vegetable farmers operate within this sector. Using Krejcie and Morgan's (1970) sample size determination table, a sample size of 300 farmers was selected as appropriate for this population. A simple random sampling method, utilising a random number generator, ensured that all participants had an equal chance of selection. This sample size is widely accepted as sufficient to provide reliable and accurate results while balancing practical constraints, particularly with a 95% confidence level. Data collection took place from July to October 2024, employing a pre-tested, self-administered questionnaire complemented by two focus group discussions, each involving ten participants. The questionnaire survey examined the current status of AFSC management and identified challenges to sustainable practices. The focus group discussions offered in-depth insights into the obstacles faced and helped formulate timely and practical strategies to overcome them. For data analysis, descriptive statistics profiled the socio-economic characteristics of respondents, while Garrett's Ranking technique was applied to prioritise the key challenges encountered in the sustainable management of AFSCs in Sri Lanka.

Results and Discussion

Socio-demographic profile of the respondents

Descriptive statistics were used to analyse the selected socio-demographic profile of the selected respondents. The results are presented in Table 1.

Table 1. Socio-demographic profile of the respondents

Factor	Category	Number	Percentage (%)
Age (Years)	20-39	60	20.0
	40-59	195	65.0
	60-79	45	15.0
Gender	Male	257	85.7
	Female	43	14.3
Marital status	Single	10	3.3
	Married	290	96.7
	Other	00	00.0
Educational level	No primary education	05	01.7
	Primary education	20	06.7
	Junior secondary education (O/L)	243	81.0
	Senior secondary education (A/L)	32	10.7
Monthly income (LKR)	Less than 20,000	27	09.0
	20,001 - 40,000	263	87.7
	40,001 - 60,000	10	3.3
Number of family members	less than 4	57	19.0
	4-5	223	74.3
	more than 5	20	6.7
Cultivated land size (Acres)	0.0-0.5	30	10.0
	0.5-1.0	63	21.0
	1.0-1.5	197	64.3
	1.5-2.0	10	3.3
Farming experience (Years)	0-5	55	18.3
	5-10	92	30.7
	10-15	133	44.3
	15-20	20	6.7

Source: Field survey July - October 2024.

According to the findings of Table 1, the majority of the respondents (65.0%) were in the age category of 40-59 years. Additionally, among the respondents, 85.7% were male and

only 14.3% were female. Furthermore, in this study, 96.7% of farmers were married, and the majority of them (81.0%) had studied up to junior secondary education (GCE Ordinary Level). However, only 10.7% of the respondents had senior secondary education. According to FAO (2018), if farmers have a considerable level of education, there is potential for access to the adoption of modern farming technologies, access to necessary credit facilities and also agricultural information needs and accessibility. Nevertheless, most of the respondents reported that they had 4-5 members in their families. Moreover, their average farm size was 0.84 acres, and the average level of farming experience was 13 years. While 87.7% of them received LKR 20,001–40,000 as their monthly income, 9.0% received only LKR 20,000 as their monthly income.

Measurement of constructs

The challenges associated with AFSCs can be broadly categorised into three main constructs: social, economic and environmental. 'Social challenges' refer to barriers related to awareness, access, institutional support and socio-cultural issues that hinder effective participation in the development of AFSCs. These include limited accessibility to agricultural inputs such as: fertilisers, seeds and agrochemicals; a lack of research and development supporting small-scale agri-food production; farmers' limited awareness of grassroots-level AFSC management; gender-based barriers to access; underutilisation of modern farming technologies; the absence of clear policies and regulations for AFSC governance at the farmer level; weak collaboration between public and private institutions.

'Economic challenges' encompass financial and market-related constraints affecting the sustainability of AFSCs. These challenges include high production costs, insufficient financial support for AFSC activities, limited agribusiness expansion based on the 3Rs (Reduce, Reuse, Recycle) concept, small-scale farmers' difficulty in competing in local and international markets, poor economic conditions among farmers and AFSC stakeholders and inadequate knowledge of ICT tools for accessing market information.

'Environmental challenges' highlight environmental and logistical difficulties influencing AFSC performance and competitiveness. These challenges include adverse climatic conditions causing significant yield losses, the burden of long-distance transportation of agricultural goods, concerns over maintaining product quality for export markets, limited capacity for product diversification and high levels of competition among AFSC participants. To assess these challenges, a survey instrument can be used where respondents indicate their level of agreement with each statement on a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) in a quantitative manner.

Farmer characteristics reflecting two focus group discussions

The characteristics of the farmer, reflecting two focus group discussions, are presented in Table 2.

Table 2. Characteristics of the farmer reflecting two focus group discussions

Focus Group	Farmer ID	Type of Farmer	Age	Farming System	Key Focus Area	Theme(s)	Code(s)	Insights / Remarks
1	1	Carrot Farmer	45	Highland root crop farming	Limited input access	Social Challenge	Limited input access	Access to quality seeds and organic fertilisers is limited and costly.
	2	Leek Farmer	39	Small-scale vegetable farming	Market competitiveness challenge	Economic Challenge	Market competitiveness challenge	Struggles to compete with low-cost imports and local bulk producers.
	3	Cabbage Farmer	61	Mono-crop hill farming	Poor institutional coordination	Social Challenge	Poor institutional coordination	Weak support from agri-extension services hinders market connections.
	4	Bean Farmer	43	Intensive vegetable farming	Awareness gap in AFSC management	Social Challenge	Awareness gap in AFSC management	Limited understanding of supply chain efficiency and market linkages.
	5	Tomato Farmer	56	Mid-elevation vegetable belt	Underuse of modern farming tech	Social Challenge	Underuse of modern farming tech	Slow adoption of tech like poly tunnels or drip systems in hilly terrain.
	6	Potato Farmer	51	Highland monocropping	Financial constraints	Economic Challenge	Financial constraints	Needs capital for cold storage and market expansion.
	7	Bell Pepper Farmer	48	Greenhouse farming	Export quality compliance issues	Environmental Challenge	Export quality compliance issues	Post-harvest losses and lack of standardisation hinder exports.
	8	Cucumber Farmer	60	Tunnel farming	ICT illiteracy in market access	Economic Challenge	ICT illiteracy in market access	Limited ability to use digital tools for price discovery or buyer outreach.
	9	Lettuce Farmer	42	Organic leafy greens	Lack of product diversification	Environmental Challenge	Lack of product diversification	Focused only on fresh sales; no value-added processing or packaging.
	10	Radish Farmer	55	Upland seasonal farming	High agri-production cost	Economic Challenge	High agri-production cost	Rising costs of land prep, labour and transport strain profits.
2	1	Cauliflower Farmer	44	Cool-climate cultivation	Climate-related yield loss	Environmental Challenge	Climate-related yield loss	Irregular rainfall and frost damage affect yields.
	2	Broccoli Farmer	49	Export-oriented farming	Climate-related yield loss	Environmental Challenge	Climate-related yield loss	Export targets unmet due to unseasonal rains.
	3	Chilli Farmer	46	Mixed crop with spices	Low economic resilience	Economic Challenge	Low economic resilience	Fluctuating prices make income unstable.
	4	Female Carrot Farmer	41	Family-based diversified plot	Gender inequality in AFSC access	Social Challenge	Gender inequality in AFSC access	Faces barriers in accessing credit, inputs and training compared to male farmers.
	5	Small-Scale Eggplant Farmer	59	Off-season vegetable grower	Policy and regulatory vacuum	Social Challenge	Policy and regulatory vacuum	Lacks policy support to stabilise off-season production.
	6	Organic Herb Farmer	38	Mixed herb and vegetable farm	Weak adoption of sustainable practices	Economic Challenge	Weak adoption of sustainable practices	Limited composting, rainwater harvesting or residue reuse.
	7	Goat-integrated Tomato Farmer	47	Vegetable-livestock integrated	Logistical/transportation burden	Environmental Challenge	Logistical/transportation burden	Difficult terrain and poor roads increase transport costs and spoilage.
	8	Community Veg Farmer	36	Collective farming effort	Poor institutional coordination	Social Challenge	Poor institutional coordination	Group faces weak links with institutional buyers or cooperatives.
	9	Export-oriented Cabbage Farmer	52	Certified export production	Export quality compliance issues	Environmental Challenge	Export quality compliance issues	Certification adds cost but buyers still demand more quality assurance.
	10	Climbing Bean Farmer	50	GAP-certified system	Lack of product diversification	Environmental Challenge	Lack of product diversification	Focused only on fresh beans; lacks investment in dried/processed formats.

Source: Authors' research.

Primary codes assigned for the focus group discussion findings

Primary codes were assigned for the focus group discussion, and the findings are presented in Table 3.

Table 3. Primary codes assigned for the identified challenges

Item	Challenge	Primary Code
	Social Challenges	
1	Lower accessibility to agricultural inputs	Limited input access
2	Inadequate research & development for small-scale production	Lack of R&D support
3	Lack of awareness on managing AFSCs at the grassroots level	Awareness gap in AFSC management
4	Gender-based access barriers	Gender inequality in AFSC access
5	Low use of modern farming technologies	Underuse of modern farming tech
6	No policies/regulations for farmer-level AFSC management	Policy and regulatory vacuum
7	Weak public-private institutional collaboration	Poor institutional coordination
	Economic Challenges	
1	High production costs	High agri-production cost
2	Inadequate financial support for AFSC development	Financial constraints
3	Limited agribusiness expansion via the 3Rs	Weak adoption of sustainable practices
4	Small-scale farmers can't compete in markets	Market competitiveness challenge
5	Poor economic conditions of farmers and stakeholders	Low economic resilience
6	Poor ICT knowledge for market info sharing	ICT illiteracy in market access
	Environmental Challenges	
1	Yield losses from adverse climate	Climate-related yield loss
2	Long transport distances for agri-products	Logistical/transportation burden
3	Export market entry challenges due to quality standards	Export quality compliance issues
4	Limited capacity for product diversification	Lack of product diversification
5	High competition in AFSCs	Market saturation/competition pressure

Source: Authors' research.

As per the information in Table 3, each of these challenges identified from the focus group discussion is assigned a simplified primary code for easier identification and thematic analysis, providing a clear framework for understanding the multifaceted issues facing sustainable AFSC management in Sri Lanka.

Challenges encountered in sustainably managing agri-food supply chains

Management of agri-food supply chains (AFSCs) is not novel to Sri Lanka. However, its application remains at a considerably lower level (Vidanapathirana et al., 2018). Thus, the current status of AFSC management is timely and important for identifying the challenges of sustainably managing AFSCs in the country.

A field survey and focus group discussions were conducted to identify the key challenges in the sustainable management of AFSCs in Sri Lanka. These challenges were studied under three categories: social challenges, economic challenges and environmental challenges. The findings are presented in Table 4.

Table 4. Challenges of sustainably managing AFSCs in the study area

No	Challenges	SD	D	M	A	SA	Mean	SD	Decision
	Social challenges								
1	Lower accessibility to agricultural inputs such as fertiliser, seeds and agrochemicals.	07	17	19	21	56	3.85	3.56	Agree
2	Inadequate research & development activities for improving small-scale agri-food production activities.	06	13	24	43	34	3.72	3.37	Undecided
3	Lack of awareness regarding the way of managing AFSCs activities at grassroots level.	04	09	17	22	68	4.18	3.81	Agree
4	Poor accessibility to the AFSCs due to gender-oriented issues.	21	18	37	34	10	2.95	2.69	Undecided
5	A lower level of utilising modern farming technologies within the AFSCs.	03	05	16	19	77	4.35	3.95	Agree
6	Unavailability of policies and regulations to manage the AFSCs at the farmer level.	37	44	05	22	12	2.40	2.28	Disagree
7	Poor level of public and private institutional collaboration for the management of AFSCs-based activities.	02	17	28	34	39	3.76	3.40	Agree
	Economic challenges								
1	Higher production costs associated with agri-foods.	00	02	00	47	71	4.56	4.07	Agree
2	Unavailability of adequate financial facilities for the development of AFSCs based activities.	01	08	21	28	62	4.18	3.78	Agree
3	Expand agribusiness activities based on the 3Rs concept.	08	29	44	23	16	3.08	2.77	Disagree
4	Small-scale farmers are inability to compete with higher capturing shares of domestic markets and international markets.	00	12	38	21	49	3.89	3.52	Agree
5	The poor economic status of the farmers and other AFSC components.	33	18	32	28	11	2.77	2.56	Undecided
6	Poor knowledge regarding the utilisation of ICTs for sharing market information.	02	11	26	36	45	3.93	3.55	Agree
	Environmental challenges								
1	Yield losses due to adverse climatic conditions.	26	64	28	24	38	4.37	3.30	Agree
2	Long-distance transportation of agricultural products.	01	04	25	37	53	4.14	3.72	Agree
3	Threats to entering into export markets through maintaining the product quality.	00	21	24	28	47	3.84	3.49	Agree
4	Product diversification capability	02	04	19	41	54	4.18	3.76	Agree
5	A large number of competitors around the AFSCs.	19	24	22	38	17	3.08	2.85	Undecided

Note: 1.00-1.49 = strongly disagree, 1.50-2.49 = disagree, 2.50-3.49 = undecided, 3.50-4.49 = agree, 4.50-5.00 = strongly agree

Source: Field survey July-October 2024.

According to the findings of Table 4, social challenges that need to be overcome for sustainably managing AFSCs include lower accessibility to agricultural inputs such as fertiliser, seeds and agro-chemicals, a lack of awareness regarding the management of AFSC activities at the grassroots level, a low level of utilisation of modern farming technologies within the AFSCs and poor public and private institutional collaboration for the management of AFSC-based activities. However, respondents disagreed with the notion that there is an unavailability of policies and regulations to manage AFSCs at the farmer level. Even though policies are formulated and implemented to manage the AFSCs, their activation is considerably lower.

As for the economic challenges, higher production costs associated with agri-foods, unavailability of adequate financial facilities for the development of AFSC-based activities, small-scale farmers' inability to compete with higher capturing shares of domestic and international markets and poor knowledge regarding the utilisation of ICTs for sharing market information were identified. Additionally, respondents disagreed regarding the expansion of agribusiness activities based on the 3Rs concept. In this study, identified environmental challenges included yield losses due to adverse climatic conditions, long-distance transportation of agricultural products, threats to entering export markets while maintaining product quality and product diversification capability.

Challenges that are highly affecting the sustainable management of AFSCs

Challenges affecting the sustainable management of AFSCs were ranked from the most important factor to the least important factor according to the farmers' perspective. Garrett's Ranking technique was used to rank the challenges to identify the adverse impact on the sustainable management of AFSCs. According to Garrett's Ranking technique, the findings are presented in Table 5.

Table 5. Percept position and Garrett's value

No	Likert-scale grading	$\frac{100\ (Rij–0.5)}{Nj}$	Percept position	Garrett's value
1	SD	$\frac{100(1 - 0.5)}{5}$	10	75
2	D	$\frac{100(2 - 0.5)}{5}$	30	60
3	M	$\frac{100(3 - 0.5)}{5}$	50	50
4	A	$\frac{100(4 - 0.5)}{5}$	70	40
5	SA	$\frac{100(5 - 0.5)}{5}$	90	25

Source: Authors' research.

Validation of ranking results;

Null Hypothesis (H_0): There is no significant difference between the ranks of the responses.

Alternative Hypothesis (H_1): At least one response differs significantly from the others.

Calculate the Friedman Test Statistic for the validation process using the formula:

$$1560(\chi^2 F) = \frac{12}{(5 \cdot 5 \cdot (5+1)} + [5^2 + 10^2 + 15^2 + 20^2 + 25^2] - 3 \cdot 5 \cdot (5 + 1)$$

$$(\chi^2 F) = 1560$$

The calculated test statistic value (p-value) is greater than 0.05; there is no significant difference in the rankings across responses.

Hence, Garrett's Ranking technique was used to rank the challenges to identify the adverse impact on the sustainable management of AFSCs. Results are presented in Table 6.

Table 6. Challenges of sustainable management of AFSCs in the study area

	Challenges	SD	D	M	A	SA	Total	Avg	Score	Rank
	Social challenges									
1	Lower accessibility to agricultural inputs such as fertiliser, seeds, and agro-chemicals	525	1020	950	840	1400	4735	39.46	56	3
2	Inadequate research & development activities for improving small-scale agri-food production activities	450	780	1200	1720	850	5000	41.67	54	5
3	Lack of awareness regarding the way of managing AFSCs activities at the grassroots level	300	540	850	880	1700	4270	35.58	58	2
4	Poor accessibility to the AFSCs due to gender oriented issues	1575	1080	1850	1360	250	6115	50.96	50	6
5	Lower level of utilising modern farming technologies within the AFSCs	225	300	800	760	1925	4010	33.42	59	1
6	Unavailability of policies and regulations to manage the AFSCs at the farmers' level	2775	2640	250	880	300	6845	57.04	47	7
7	Poor level of public and private institutional collaboration for the management of AFSC-based activities	150	1020	1400	1360	975	4905	40.88	55	4
	Economic challenges									
1	Higher production costs associated with agri-foods	0	120	0	1880	1775	3775	31.46	60	1
2	Unavailability of adequate financial facilities for the development of AFSC based activities	75	480	1050	1120	1550	4275	35.63	58	2
3	Expand agribusiness activities based on the 3Rs concept.	600	1740	2200	920	400	5860	48.83	51	5
4	Small-scale farmers are unable to compete with higher capturing shares of domestic markets and international markets	0	720	1900	840	1225	4685	39.04	57	3
5	Poor economic status of the farmers and other AFSC components	2475	1080	1600	1120	275	6550	54.58	48	6
6	Poor knowledge regarding the utilisation of ICTs for sharing market information	150	660	1300	1440	1125	4675	38.96	56	4
	Environmental challenges									
1	Yield losses due to adverse climatic conditions	1950	3840	1400	960	950	9100	75.83	37	5
2	Long-distance transportation of agricultural products	75	240	1250	1480	1325	4370	36.42	57	1
3	Threats to entering into export markets through maintaining the product quality	0	1260	1200	1120	1175	4755	39.63	55	3
4	Product diversification capability	150	240	950	1640	1350	4330	36.08	56	2
5	A large number of competitors around the AFSCs	1425	1440	1100	1520	425	5910	49.25	50	4

Source: Authors' research.

As per the results of Table 4 and Table 6, the main social challenges for the sustainable management of AFSCs are a lower level of utilisation of modern farming technologies within the AFSCs, a lack of awareness regarding the management of AFSC activities at the grassroots level and lower accessibility to agricultural inputs such as fertiliser, seeds and agro-chemicals. According to the findings from the focus group discussions, the social

challenges faced by upcountry vegetable farmers in Sri Lanka include a lower utilisation of modern farming technologies. Tomato farmers (FG1, ID 5) report that difficult terrain and a lack of technical support hinder the adoption of innovations like poly tunnels and drip irrigation, aligning with the quantitative findings of low technology use. Organic herb farmers (FG2, ID 6) similarly reveal weak uptake of sustainable practices such as composting and rainwater harvesting, indicating gaps in awareness and practical training. ICT illiteracy among cucumber farmers (FG1, ID 8) further limits the adoption of digital tools, constraining market access and farm management efficiency. Additionally, a lack of awareness regarding AFSC management is evident, with bean farmers (FG1, ID 4) expressing limited understanding of supply chain dynamics and market linkages, signalling a need for grassroots capacity building. Community vegetable farmers (FG2, ID 8) also face poor institutional coordination, weakening their connections to cooperatives and institutional buyers, reflecting systemic weaknesses in AFSC management. Accessibility to agricultural inputs is another key issue; carrot farmers (FG1, ID 1) struggle with costly and scarce quality seeds and fertilisers, while female carrot farmers (FG2, ID 4) confront gender-based barriers to credit and input access, exacerbating inequalities.

In addition to that, the economic challenges for sustainable management of the AFSCs are higher production costs associated with agri-foods, the unavailability of adequate financial facilities for the development of AFSC-based activities and the inability of small-scale farmers to compete with larger shares of domestic and international markets. Based on the focus group discussion findings, economic challenges are highlighted by rising production costs reported by radish farmers (FG1, ID 10), including expenses for land preparation, labour and transport that erode profitability, as well as capital shortages faced by potato farmers (FG1, ID 6) for essential infrastructure such as cold storage, which hinders scaling operations. The unavailability of adequate financial facilities limits farmers' capacity to buffer income fluctuations or compete effectively; leek farmers (FG1, ID 2) and chilli farmers (FG2, ID 3) point to this gap, as do goat-integrated tomato farmers (FG2, ID 7), who are unable to invest in better logistics. Small-scale farmers, such as leek growers, face scale disadvantages in competing with imports and bulk producers, while export-oriented cabbage farmers (FG2, ID 9) bear high certification costs yet still encounter stringent buyer quality demands, highlighting a cost-reward imbalance that threatens market competitiveness.

Moreover, identified environmental challenges for the sustainable management of AFSCs are the long-distance transportation of agricultural products, product diversification capability and threats to entering export markets while maintaining product quality. The focus group discussion findings revealed that the environmental challenges include long-distance transportation difficulties, with goat-integrated tomato farmers (FG2, ID 7) citing poor roads and rugged terrain that increase transport time and spoilage, an issue also shared by potato and cabbage farmers in remote highland areas. Product diversification remains limited, as lettuce (FG1, ID 9) and climbing bean farmers (FG2, ID 10) rely heavily on fresh produce sales without value addition, making them vulnerable to market price fluctuations and wastage. Furthermore, bell pepper farmers (FG1, ID 7) and export-oriented cabbage growers (FG2, ID 9) face significant post-harvest losses, lack of standardisation and stringent export quality requirements, exemplifying environmental challenges in maintaining export competitiveness amid infrastructural and resource constraints.

This integrated interpretation demonstrates how statistical trends manifest as complex, lived realities for farmers, underscoring the urgent need for targeted interventions including technology transfer, gender-sensitive input support, financial inclusion and infrastructural

improvements to foster more sustainable and resilient agri-food supply chains in Sri Lanka's upcountry vegetable sector.

Strategies to overcome the challenges associated with managing agri-food supply chains in Sri Lanka

Based on the findings of this study, the following strategies can be highlighted:

- Empowering farmers by facilitating financial facilities at concessionary rates to purchase required agricultural inputs such as fertiliser, seeds and agro-chemicals.
- Encouraging research and development activities for improving small-scale agri-food production activities.
- Conducting awareness programmes to disseminate knowledge and improve experiences for the AFSCs at the grassroots level.
- Organising extension programmes to enhance farmers' adoption of sustainable development of AFSCs.
- Facilitating foreign training opportunities to gain the latest information about sustainably developed AFSCs, as well as outsourcing foreign experts to provide timely, updated information from other countries.
- Introducing mechanised farming practices to overcome the labour shortage issues arising from labour-intensive activities in farming.
- Introducing modern technologies to enhance farmers' adoption of AFSCs-based practices.
- Policies and strategies need to be updated promptly for managing the AFSCs at the farmer level.
- Enhancing collaboration among relevant public institutions to formulate and implement the management of AFSCs-based practices within AFSCs.
- Formulating and implementing timely strategies for reducing the high production costs associated with agri-foods.
- Developing market information systems by increasing the availability of ICTs to access market information.
- Encouraging small-scale farmers to capture considerably higher market shares in domestic and international markets.
- Persuading farmers to cultivate resilient agri-food crop varieties in adverse climatic conditions.
- Expanding facilities for storing agri-food products and enhancing the accessibility of proper transportation.
- Persuading farmers to use Good Agricultural Practices (GAP) while performing their farming activities to maintain the final agri-food quality.
- Facilitating more opportunities to produce diversified agri-food products.

Scope of managing agri-food supply chains for sustainable agriculture in Sri Lanka

Correct application of the AFSC approach facilitates sustainable development in the agriculture sector in Sri Lanka. According to the literature review, proper management of AFSCs ensures the achievement of six Sustainable Development Goals (SDGs) out of the 17 SDGs set by the UN for developing countries (Pietrzyck et al., 2021; Djekic et al., 2021).

Over the past decades, the concept of managing AFSCs has received considerable attention as a solution to mitigate social, environmental and economic challenges in the agri-food industry (Naik and Suresh, 2018). Thus, agri-food supply chain management plays a

significant role in supporting sustainable development in the agriculture sector in Sri Lanka (Dissanayaka and Thibbotuwana, 2021).

Hence, correct management of AFSCs supports the reduction of hunger within the nations of the globe by increasing the accessibility of food for them (UN, 2020). Moreover, proper management of AFSCs helps enhance the economy within the farming community as well as the other components of the AFSCs. Thus, this leads to enhanced economic growth within the nations (Lezoche et al., 2020; FAO, 2018). In addition, sustainably managed AFSCs lead to optimised responsible consumption and production of agri-foods (Kumar et al., 2022; Pietrzyck et al., 2021). Considering the farmers' perspective, well-managed AFSCs can help protect life on land when practising their farming activities: GAP certification (Bamunuarachchi et al., 2019; Naik and Suresh, 2018). Hence, farmers perform necessary climate actions to minimise hazards to the surrounding environment, leading to reduced environmental pollution (Djekic et al., 2021). Additionally, public and private collaboration builds strong partnerships to achieve the goals for sustainable management of AFSCs (Trang et al., 2022; Pancino et al., 2019)

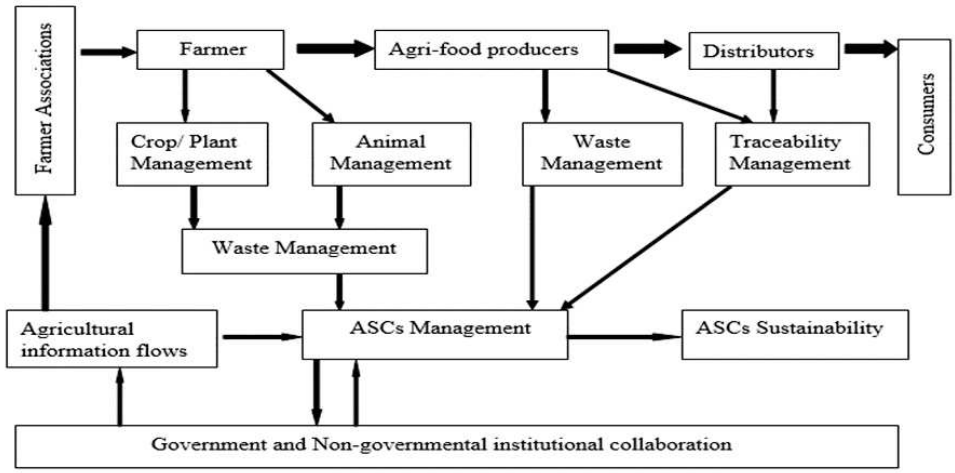

Fig. 2. Sustainable management of AFSCs in Sri Lanka

Source: Adapted from Rejeb et al., 2021; Florea et al., 2019.

Sustainable management of agri-food supply chains for the future

Nowadays, AFSCs require major transformations aimed at promoting sustainability by reducing and recycling waste for the reuse of AFSC activities (Agnusdei and Coluccia, 2022). Hence, Figure 2 illustrates the importance of crop/plant management, animal management, waste management and traceability management for the sustainable management of AFSCs to enhance their collaborative demand (Rejeb et al., 2021; Florea et al., 2019).

Figure 2 shows the adapted form of Rejeb et al. (2021) and Florea et al. (2019). The study of Rejeb et al. (2021), summarising the framework of the potentials of big data for AFSC sustainability, describes that crop/plant management, animal management, waste management and traceability management lead to sustainable AFSC management. Moreover, the general representation of an agri-food supply chain elaborates on the farmer associations,

farmers, food industries, distributors and consumers (Florea et al., 2019). According to Figure 2, agri-food supply chain components are interconnected with all the representatives: farmers, agri-food producers, distributors and consumers. The literature review indicates that sustainable AFSC management consists of crop/plant management, animal management, waste management and traceability management. Thus, farmers engage in crop/plant and animal management or integrated farming systems management through the management of waste/residuals to build sustainable AFSCs. In addition, governmental and non-governmental institutional collaboration supports the dissemination of agricultural information to farmers' associations as well as individual farmers. Regarding agri-food producers, they transform agricultural production into agri-foods while managing their waste materials based on the 3R approach. Moreover, agri-food producers and distributors maintain traceability management practices by planning, organising and coordinating all tasks interconnected with traceability.

Conclusions

As per the findings of the study, the majority of the farmers are middle-aged, married and have studied up to junior secondary education. The challenges encountered in the sustainable management of AFSCs fall into three categories: social, economic and environmental. The key social challenges include lower accessibility to agricultural inputs, limited awareness regarding the management of AFSCs and a lower level of utilisation of modern technologies within AFSCs. The main economic challenges are higher production costs associated with agri-foods, inadequate financial facilities, small-scale farmers' inability to compete with larger shares of domestic and international markets and poor knowledge regarding the use of ICTs for sharing market information. Furthermore, the primary environmental challenges for the sustainable management of AFSCs are the long-distance transportation of agricultural products and limited product diversification capability. Therefore, to address these challenges, the following strategies are recommended: providing financial facilities at concessionary rates for purchasing necessary agricultural inputs; conducting awareness programmes to disseminate knowledge and improve farmers' experiences with AFSCs; introducing modern technologies to increase farmers' adoption of AFSCs-based practices; formulating and implementing timely strategies to reduce high production costs associated with agri-food; developing market information systems by increasing ICT availability; enhancing transportation accessibility; facilitating more opportunities to produce diversified agri-food products. These strategies are identified as essential for the sustainable management of AFSCs in the upcountry vegetable sector in Sri Lanka. Hence, sustainable management of AFSCs is enhanced through collaboration with local agricultural extension services to address the specific challenges faced by farmers in the upcountry vegetable sector, offering government incentives or subsidies for farmers using modern technology, implementing credit access for small-scale farmers, promoting product branding and marketing strategies to help farmers compete in both domestic and international markets, introducing user-friendly mobile apps to share market information with farmers, and encouraging the use of refrigerated vehicles for transporting perishable goods.

Implications

Policy-makers' perspective: According to the findings, focusing on improving infrastructure, reducing post-harvest losses and ensuring fair market access for upcountry farmers leads to the development of policies that enhance the resilience of the vegetable supply chain in Sri Lanka. However, sustainable practices and government support in technology adoption, farmer training and market linkages could be crucial for enhancing the sustainable development of AFSCs.

Non-government organisations' perspective: They support leveraging the research to design targeted interventions that address specific challenges faced by farmers in the region, such as improving farming techniques, supporting organic farming and facilitating market connections. They also promote environmental sustainability and food security initiatives within the AFSCs.

Farmers' perspective: The study can offer insights into best practices for sustainable farming, help reduce dependency on harmful chemicals and suggest ways to adapt to climate change. Moreover, the findings elaborate on the strategies for better marketing, reducing costs, increasing income and improving the overall efficiency of the vegetable supply chain.

References

Aday, S., Aday, M.S. (2020). Impact of COVID-19 on the food supply chain. *Food Quality and Safety*, 4(4), 167-180. doi: https://doi.org/10.1093/fqsafe/fyaa024.

Agnusdei, G., Coluccia, B. (2022). Sustainable agrifood supply chains: Bibliometric, network and content analyses. *Science of The Total Environment*, 824, 153704.

Aiome, G.N., Fernando, S.P., Dissanayake, A.K., De Silva, P.C., Samarakoon, S.M. (2022). Shoring up the Upcountry Vegetable Farmers. Hector Kobbekaduwa Agrarian Research and Training Institute, 114, Wijerama Mawatha, Colombo 07, Sri Lanka. Retrieved from: http://harti.gov.lk/images/download/reasearch_report/new/rf_250.pdf.

Annappa, N.N., Bhavya , N., Kasturappa, G., Uday Kumar, S.N., Krishna Murthy, R. (2023). Climate Change's Threat to Agriculture: Impacts, Challenges and Strategies for a Sustainable Future. [In:] S. Kushwaha, V. Kamalvanshi, Climate change in Agriculture. AkiNik Publications® New Delhi. doi:10.22271/ed.book.2395.

Awais, M. (2024). Sustainable Practices in Agriculture Supply Chain Management: A Global Perspective. *International Research Journal of Engineering and Technology* (IRJET), 11(02), 282-288. Retrieved from: https://www.irjet.net/archives/V11/i2/IRJET-V11I246.pdf.

Bakker, E., Hassink, J., Veluw, K. (2023). The 'inner' dimension of Dutch farmers' trajectories of change: drivers, triggers and turning points for sustained agroecological practices. *Agroecology and Sustainable Food Systems*, 47(5), 687-717. doi: 10.1080/21683565.2023.2180563.

Bamunuarachchi, B.D., Hitihamu, S., Lurdu, M.S. (2019). Good Agricultural Practices (GAP) in Sri Lanka: Status, Challenges and Policy Interventions. Hector Kobbekaduwa Agrarian Research and Training Institute, 114, Wijerama Mawatha, Colombo 7, 62.

Bandara, T., Amarasekara, N. (2023, April 16). Contemporary Issues in Agri-Food Supply Chain in Sri Lanka. Retrieved from: https://www.advocata.org/commentary-archives/2023/04/16/contemporary-issues-in-agri-food-supply-chain-in-sri-lanka.

Barua, P., Rahman, S.H. (2021). Sustainable management of the agricultural products value chain in response to climate change for the South-Eastern coast of Bangladesh. *Modern Supply Chain Research*, 3(2), 88-125. doi:10.1108/MSCRA-07-2020-0020.

Bhat, R., Jõudu, I. (2019). Chapter 2 - Emerging issues and challenges in agri-food supply chain. Sustainable Food Supply Chains: Planning, Design, and Control through Interdisciplinary Methodologies, 23-37.

Borsellino, V., Schimmenti, E., Bilali, H.E. (2020). Agri-Food Markets towards Sustainable Patterns. *Sustainability*, 12(6), 2193. doi:https://doi.org/10.3390/su12062193.

Burak, A. (2024, September 5). AI in Agriculture: Smarter Solutions for Modern Farms. Retrieved from: https://relevant.software/blog/ai-in-agriculture/.

Çakmakçı, R., Salık, M.A., Çakmakçı, S. (2023). Assessment and Principles of Environmentally Sustainable Food and Agriculture Systems. *Agriculture*, 13(5), 1073. doi: https://doi.org/10.3390/agriculture13051073.

Cossu, D., Zanchi, L., Maranghi, S., Zamagni, A., Gaias , G., Duce, P., Vagnoni, E. (2024). Ecolabelling for improving sustainability of agri-food supply chain: An experimental implementation of the Made Green in Italy scheme on the hard sheep milk cheese. *Cleaner Environmental Systems*, 12, 100153. doi:https://doi.org/10.1016/j.cesys.2023.100153.

De Boni, A., Palmisano, G.O., De Angelis, M., Minervini, F. (2022). Challenges for a Sustainable Food Supply Chain: A Review on Food Losses and Waste. *Sustainability*, 14(24), 16764. doi:https://doi.org/10.3390/su142416764.

Dhillon, R., Moncur, Q. (2023). Small-Scale Farming: A Review of Challenges and Potential Opportunities Offered by Technological Advancements. *Sustainability*, 15(21), 15478. doi:10.3390/su152115478.

Dissanayaka, N., Thibbotuwana, M. (2021). Sri Lanka's agri-food trade: Structure, opportunities, challenges and impact of COVID-19. Feed the future, Research paper 6.

Djekic, I., Batlle-Bayer, L., Bala, A., Fullana-i-Palmer, P., Jambrak, A.R. (2021). Role of the Food Supply Chain Stakeholders in Achieving UN SDGs. *Sustainability*, 13, 9095. doi: https://doi.org/10.3390/su13169095.

El Din, M.S., Masengu, R. (2024). Fair Trade and Ethical Sourcing in Agriculture: Paving the Way for Sustainable Supply Chains. [In:] O.T. Chiwaridzo, R. Masengu, J. Garwi, Sustainable Practices for Agriculture and Marketing Convergence. IGI Global. doi:10.4018/979-8-3693-2011-2.ch004.

Florea, A.-M., Capatina, A., Radu, R. I., Serban, C., Boboc, M. G., Stoica, C., . . . Stanciu, S. (2019). Limiting Factors that Influence the Formation of Producer Groups in the South-East Region of Romania: A Fuzzy Set Qualitative Comparative Analysis (fsQCA). *Sustainability*, 11(6), 1614. doi: https://doi.org/10.3390/su11061614.

Food and Agriculture Organisation (FAO). (2022). Agrifood chains.

Food and Agriculture Organisation (FAO). (2018). The future of food and agriculture – Trends and challenges.

Gunathilaka, R.D., Samarakoon, P.K. (2022). Adaptation to Climate Change. [In:] A. Haque, P. Mukhopadhyay, M. Nepal, M.R. Shammin, Climate Change and Community Resilience (pp. 415-430). Springer, Singapore. doi: https://doi.org/10.1007/978-981-16-0680-927.

Gyarmati, G. (2024). Transformation of the Three Pillars of Agri-Food Sustainability around the COVID-19 Crisis—A Literature Review. *Sustainability*, 16(13), 5616. doi: https://doi.org/10.3390/su16135616.

Hidayati, D.R., Garnevska, E., Childerhouse, P. (2021). Sustainable Agrifood Value Chain—Transformation in Developing Countries. *Sustainability*, 13(22), 12358. doi: https://doi.org/10.3390/su132212358.

International Labor Organisation [ILO]. (2016). Value Chain Development for Decent Work: How to create an improvement in working conditions in targeted sectors.

Jayalath, M., Thibbotuwawa, A., Perera, N. (2021). Towards a Sustainable Agri-Food Supply Chain. *Bolgoda Plains*, 1(2). doi:10.31705/BPRM.v2.2021.12.

Kim, B. (2018). Agricultural Value Creation through Effective Supply Chain Management. Operations Strategy and Management Science, KAIST Business School, Korea, 2(2). Retrieved from: https://lupinepublishers.com/agriculture-journal/fulltext/agricultural-value-creation-through-effective-supply-chain-management.ID.000132.php.

Konfo, T.R., Chabi, A.B., Gero, A.A., Lagnika, C., Avlessi, F., Biaou, G., Sohounhloue , C.K. (2024). Recent climateRecent climate-smart innovations in agrifood to enhance producer incomes through sustainable solutions. *Journal of Agriculture and Food Research*, 15, 100985. doi: https://doi.org/10.1016/j.jafr.2024.100985.

Krejcie, R.V., Morgan, D.W. (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement*, 30, 607-610.

Kumar, M., Sharma, M., Raut, R.D., Mangla, S.K., Choubey, V.K. (2022). Performance assessment of circular-driven sustainable agri-food supply chain towards achieving sustainable consumption and production. *Journal of Cleaner Production*, 372(20), 133698. doi:https://doi.org/10.1016/j.jclepro.2022.133698.

Lezoche, M., Hernandez, J.E., Diaz, M.D., Panetto, H., Kacprzyk, J. (2020). Agri-food 4.0: a survey of the supply chains and technologies for the future agriculture. *Computers in Industry*, doi:10.1016/j.compind.2020.103187ff. ffhal-02395411f.

Misra, N.N., Dixit, Y., Al-Mallahi, A., Bhullar, M.S., Upadhyay, R., Martynenko, A. (2020). IoT, Big Data, and Artificial Intelligence in Agriculture and Food Industry. *IEEE Internet of Things Journal*, 1(1), 99. doi: 10.1109/JIOT.2020.2998584.

Naik, G., Suresh, D. (2018). Challenges of creating sustainable agri-retail supply chains. *IIMB Management Review*, 30(3), 270-282.

Nchanji, E.B., Lutomia, C.K. (2021). Sustainability of the agri-food supply chain amidst the pandemic: Diversification, local input production, and consumer behavior. *Advances in Food Security and Sustainability*, 6, 221-229.

Olutimehin, D.O., Ofodile, O.C., Ejibe, I., Odunaiya, O.G., Soyombo, O.T. (2024). The role of technology in supply chain risk management: Innovations and challenges in logistics. *International Journal of Management & Entrepreneurship Research*, 6(3), 878-889. doi:10.51594/ijmer.v6i3.941.

Oriekhoe, O.I., Adisa, O., Ilugbusi, S. (2024). Climate Change and Food Supply Chain Economics: A Comprehensive Analysis of Impacts, Adaptations, and Sustainability. *International Journal of Applied Research in Social Sciences*, 6(3), 267-278. doi:10.51594/ijarss.v6i3.885.

Pancino, B., Blasi, E., Rappoldt, A., Pascucci, S., Ruini, L., Ronchi, C. (2019). Partnering for sustainability in agri-food supply chains: the case of Barilla Sustainable Farming in the Po Valley. *Agricultural and Food Economics*, 7(13). doi:https://doi.org/10.1186/s40100-019-0133-9.

Pereira, S.C., Scarpin, M.R., Neto, J.F. (2020). Agri-food risks and mitigations: a case study of the Brazilian mango. *Production Planning & Control*, 32(14), 1237-1247. doi: https://doi.org/10.1080/09537287.2020.1796134.

Pietrzyck, K., Jarzebowski, S., Petersen, B. (2021). Exploring Sustainable Aspects Regarding the Food Supply Chain, Agri-Food Quality Standards, and Global Trade: An Chain, Agri-Food Quality Standards, and Global Trade: An Empirical Study among Experts from the European Union and the United States. *Energies*, 14(18), 5987. doi: https://doi.org/10.3390/en14185987.

Ranjan, A., Singh, S., Pathak, S. (2024). Precision farming: Uses drones, satellite imagery, and other technologies to increase efficiency and resource utilisation. In Fields of Tomorrow: Advancement in Modern Agriculture (pp. 21-34). Astitva Prakashan 2024. Retrieved from: https://www.researchgate.net/publication/380847941._Precision_farming_Uses_drones_satellite_imagery_and_other_technologies_to_increase_efficiency_and_resource_utilisation.

Rejeb, A., Rejeb, K., Zailani, S. (2021). Big data for sustainable agri-food supply chains: a review and future research perspectives. *Journal of Data, Information and Management*, 3, 167-182. doi: https://doi.org/10.1007/s42488-021-00045-3.

Reklitis, P., Sakas, D.P., Trivellas, P., Tsoulfas, G.T. (2021). Performance Implications of Aligning Supply Chain Practices with Competitive Advantage: Empirical Evidence from the Agri-Food Sector. *Sustainability,* 13(16), 8734. doi: https://doi.org/10.3390/su13168734.

Rempelos, L., Kabourakis, E., Leifert, C. (2023). Innovative Organic and Regenerative Agricultural Production. *Agronomy*, 13(5), 1344. doi: https://doi.org/10.3390/agronomy13051344.

Rosli, M.N., Mutalib, M.A., Shamsuddin, A.S., Lani, M.N., Ariati, I., Tang, S.G. (2024). Navigating the environmental, economic and social impacts of sustainable agriculture and food systems: a review. *Frontiers of Agricultural Science and Engineering*, 1-21. doi:10.15302/J-FASE-2024550.

Tasca, A.L., Nessi, S., Rigamonti, L. (2017). Environmental sustainability of agri-food supply chains: An LCA comparison between two alternative forms of production and distribution of endive in northern Italy. *Journal of Cleaner Production*, 140(2), 725-741. doi: https://doi.org/10.1016/j.jclepro.2016.06.170.

Todd, E.C., Faour-Klingbeil, D. (2024). Impact of Food Waste on Society, Specifically at Retail and Foodservice Levels in Developed and Developing Countries. *Foods*, 13(13), 2098. doi: https://doi.org/10.3390/foods13132098.

Trang, N.T., Nguyen, T.-T., Pham, H.V., Cao, T.T., Thi, T.H., Shahreki, J. (2022). Impacts of Collaborative Partnership on the Performance of Cold Supply Chains of Agriculture and Foods: Literature Review. *Sustainability*, 14(11), 6462.

United Nations (2020). Maximising Agri-food supply chain opprtunities to redless to COVID 19 in developing countries. United Nations Conference on Trade and Development. Retrieved from: https://unctad.org/system/files/official-document/ditctabinf2020d9_en.pdf.

United States Department of Agriculture [USDA]. (2022, June 01). USDA Announces Framework for Shoring Up the Food Supply Chain and Transforming the Food System to Be Fairer, More Competitive, More Resilient. Retrieved from: https://www.usda.gov/media/press-releases/2022/06/01/usda-announces-framework-shoring-food-supply-chain-and-transforming.

Vidanapathirana, R., Champika, J., Rambukwella, R., Wijesooriya, N. (2018). Quality and Safety Issues in Fruit and Vegetable Supply Chains in Sri Lanka: A Review. Hector Kobbekaduwa Agrarian Research and Training Institute 114, Wijerama Mawatha, Colombo 7, Sri Lanka. Retrieved from: http://www.harti.gov.lk/images/download/reasearch_report/2018/217.pdf.

Vroegindewey, R., Hodbod, J. (2018). Resilience of Agricultural Value Chains in Developing Country Contexts: A Framework and Assessment Approach. *Sustainability*, 10(4), 916. doi: https://doi.org/10.3390/su10040916

Wang, G., Wang, Y., Li, S., Yi, Y., Li, C., Shin, C. (2024). Sustainability in Global Agri-Food Supply Chains: Insights from a Comprehensive Literature Review and the ABCDE Framework. *Foods*, 13(18), 2914. doi: https://doi.org/10.3390/foods13182914.

Wątróbski, J. (2019). Towards Knowledge Handling in Sustainable Management Domain. *Procedia Computer Science*, 159, 1591-1601. doi: 10.1016/j.procs.2019.09.330.

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