ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-294X (Online)
ISSN: 2521-2931 (Print)
CODEN: MJSAEJ

Malaysian Journal of Sustainable Agriculture (MJSA)

DOI: http://doi.org/10.26480/mjsa.01.2026.62.70

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RESEARCH ARTICLE

SUSTAINABILITY IMPACT ASSESSMENT CRITERIA OF ORGANIC FOOD SUPPLY CHAINS IN SRI LANKA

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ARTICLE DETAILS

Article History:

Received 27 January 2026
Revised 20 February 2026
Accepted 19 March 2026
Available online 19 April 2026

ABSTRACT

The inspiration of this study pertains to the problem of identifying and prioritizing sustainability impact assessment criteria of local organic food supply chains. Scoring models are often regarded as the most promising method of handling this increasingly important sector, but the literature on sustainability assessment concepts is only emerging. Multi-Criteria Decision Analysis based techniques such as Fuzzy Analytic Hierarchy Process (FAHP) appear practically appealing, as a way to develop commercially viable arrangements to develop sustainability assessment decision models. The first phase of our study identifies sustainability assessment criteria for organic food supply chains through literature review and expert panel interviews. Literature identifies environmental sustainability, economic sustainability and societal sustainability as the main criteria and a set of sub-criteria under each main criterion. The second phase develops a FAHP survey questionnaire for criteria analysis and weighting. Sub criteria such as Reduction of Food Waste, Reduction of Impact from Transportation and Emissions and Transparency and Traceability receive highest weights under economic, environmental and social criteria. Our research provides a structured decision-making framework which can be a valuable tool for strategic planning, enabling targeted interventions to improve farmers' resilience and support the growth of the organic sector in Sri Lanka.

KEYWORDS

Sustainability Impact Assessment, Organic Food Supply Chains, Multi-Criteria Decision Analysis, Fuzzy Delphi Method (FDM), Fuzzy Analytic Hierarchy Process (FAHP)

1. INTRODUCTION

Food is an essential human survival requirement and a life-blood of livelihoods of billions of people globally (Manning et al., 2006; Fritz and Schiefer, 2008). It is necessary to have an efficient supply chain management of food (FSCM) that can guarantee its availability, safety, and nutritional quality, monitor the flow of products between farm and fork, and ensure standards (Beske et al., 2014; Pannila et al., 2022). A food supply chain (FSC) is a complicated chain of interrelated processes that include agricultural production, processing, distribution and retailing. All these have their own challenges and opportunities (Broekmeulen and Fransoo, 2006). Good coordination among these stages is essential towards providing safe, nutritious, and quality food to the consumers. In addition, well-organized FSCs are crucial in enhancing sustainable agriculture through maximization of resources and minimization of wastes in addition to fair trade practices (Okorie et al., 2022). Therefore, ensuring that FSCs are well managed is not only vital in ensuring food security but also in promotion of environmental and socio-economic sustainability in the global food systems.

The agricultural background of Sri Lanka is very high and a large percentage of the population is involved in agriculture. These traditional farming methods that are largely dependent on the use of synthetic fertiltizers and pesticides have however resulted in environmental degradation, health issues and economic insecurity among farmers.

The organic movement in Sri Lanka started to gather force in the 1980s (Lanka Organic Agriculture Movement, n.d.) but received official recognition in the early 2000s with the creation of certification organizations like National Organic Control Unit (NOCU) in 2014. Organic farming has grown despite the barriers such as accessibility to markets, costs of certification, and consumer awareness especially on export oriented products such as tea, spices, coconut kernel products among others (NOCU - Sri Lanka, n.d.). The domestic market is equally expanding due to the health conscious urban consumer and government efforts supporting organic farming.

Nevertheless, the industry has structural difficulties such as fragmented supply chains, poor infrastructure, and poor policy backing. With the introduction of a strong sustainability assessment framework, it is possible to identify the most critical criteria that the policymakers and other stakeholders are more focused on, so that the incentives and the resources can be redirected to the areas where they will make the biggest difference. This focus strategy will help get better interventions that will promote economic sustainability, environmental responsibility, and social equity in the supply chains of organic food in Sri Lanka.

Sustainability assessments offer a methodological scheme to determine the environmental, economic and social effects of agricultural systems. Compared to the traditional assessment methods that make use of a single dimension of assessment (e.g., yield or profit), sustainability assessment can be improved by incorporating multi-criteria decision analysis (MCDA) approach, which concomitantly evaluates several and, frequently, conflicting aspects to establish the most balanced and sustainable options.

Fuzzy Analytic Hierarchy Process (FAHP), which is a method of MCDA, comes in very handy in the context of organic food supply chains. FAHP provides the hierarchical organization of major criteria and sub criteria reflecting the uncertainties that appear as the result of subjective expert judgments by quantifying the preferences in the language and creates a

Quick Response Code	Access this article online	
	Website: www.mjsa.com.my	**DOI:** 10.26480/mjsa.01.2026.6270

scoring-based decision model to allow the policymakers to understand which factors should be considered as urgent. This research aims at coming up with a systematic sustainability evaluation framework of the Sri Lankan organic food supply chains. As a part of a systematic literature review and consultations with the expertise, this paper will seek to identify the most important environmental, economic, and social criteria in the context of organic food supply chains in Sri Lanka. This measure will see the framework record the context particular aspects like soil health, fair trade, and supply chain transparency. The Fuzzy Analytic Hierarchy Process (FAHP) will provide the relative weight of each selected criterion by the use of the pair-wise comparisons defining which aspects of sustainability (e.g., food waste reduction, carbon footprint, etc.) require urgent consideration. The completed criteria and their weights will be incorporated into an effective system to use by stakeholders, farmers, policymakers, and businesses, to assess and enhance performance in terms of sustainability. Such a tool will facilitate specific interventions, e.g. the logistic optimization to reduce emissions or the improvement of traceability systems to promote social equity.

2. Literature Review

This section consists of two sections. Section 2.1 performs systematic literature review to identify and contextualize sustainability impact assessment criteria for organic food supply chains. Section 2.2 is about the literature on application of Multi-Criteria Decision Analysis (MCDA) methods to assess the above criteria.

2.1 Sustainability impact assessment criteria for organic food supply chains

The framework utilized to develop this review is grounded in three dimensions of sustainability, including environmental, economic, and social dimensions as identified and subsequently, adjusted to the context of Sri Lanka by Hansika and Wijerathna (2021; Schmutz et al., 2017). These two works were used as background references since offered a global model to assess sustainability in the field of food supply chains, whereas applied the model specific to their research, specifically to short organic food supply chains in Sri Lanka (Schmutz et al. (2017; Hansika and Wijerathna, 2021).

Based on this common framework, more peer-reviewed articles and government reports and sector-specific case studies were subjected to thematic analysis in order to identify and narrow down on recurring criteria and sub-criteria. The smart indicators indicate theoretical and practical realities of the organic farming industry in Sri Lanka. The sections below examine the major literature and how each study played a part towards the formulation of the sub-criteria applied in this research.

To provides the basic framework on which one can assess the sustainability effects of short food supply chains (SFSCs) (Schmutz et al., 2017). Their work suggests three primary dimensions such as environmental, economic and social dimensions all of which have certain assessment areas. With regard to environmental sustainability, they evaluate the eco-efficiency in utilizing abiotic resources including land, water, and nutrients. They further highlight the importance of SFSCs in the enhancement of biodiversity and ecological habitats since such systems usually entail a variety of crops and livestock, encompassing conventional species. This paper acknowledges the capability of SFSCs to lower transportation distances and emissions, which is vital to low-carbon supply chains. Furthermore, Schmutz et al. assess stable packaging and recycling systems by determining food chains that decrease the packaging waste and reuse the materials.

Economically, the research evaluates financial sustainability in terms of revenue generation and excess reinvestment, and also the minimization of food waste in the chain of production to consumption. Job creation and self-employment opportunities on the food chain are used to measure livelihood development. Their food safety and quality standards, such as the lack of pollutants and the adherence to the legal health standards, represent social sustainability. They consider food security in food access and transparency and traceability as well, looking at the visibility of stages in the supply chain, and the transparency in recording and communicating it to consumers.

The sustainability assessment tool in this study was designed based on the direct information provided by (Schmutz et al. (2017). The broad categorization they do in terms of sustainability was the structural basis of classifying the sub-criteria that fell under the three broad dimensions of sustainability. Their study identified specific indicators which were modified into ten major sub-criteria, namely, Efficient Use of Natural Resources, Promotion of Biodiversity and Ecological Habitats, Reduced Impact of Transportation and Emissions, Sustainable Packaging and Recycling, Financial Viability and Profitability, Livelihood Development, Reduction of Food Waste, Food Safety and Quality, Food Security, and Transparency and Traceability.

Analysis add to most of these dimensions with their research of organic farmers in Nepal with special focus on the economic viability (Banjara and Poudel, 2015). According to their results, organic agriculture will be able to improve the socio-economic position of farmers, as it is cheaper due to the elimination of the costs of synthetic fertilizers and pesticides and has greater access to a better price on the market. The paper also brushes on the livelihood development where farmers were in a better position than those, who were engaged in manual labor, economically. Although they point out the efficient utilization of natural resources in organic agriculture, they also indicate difficulties in accessing land particularly in the peri-urban regions and the problems associated with pollution on the roadside plots, which impacts the quality of crops as well as their marketability. They also use the authority of to promote bio diversity in such systems (Pradhan et al., 2015).

This paper confirms the relevance of the framework proposed by Schmutz et al. to a South Asian setting, providing the examples of possible analogy with the situation in Sri Lanka. It promotes the use of Efficient Use of Natural Resources, Financial Viability and Profitability, and Livelihood Development as the major sub-criteria. Further, it also puts emphasis on the problems encountered in reality, such as poor access to land, and thus puts into context the application of these criteria in Sri Lanka.

In a study discuss organic vegetable farming as a means of alternative livelihood. Their article has good arguments to prove financial feasibility; as several farmers are reporting higher monthly earnings as a result of high prices and decreased production expenses (Pradhan et al., 2015). The production of organic vegetables was a major source of income to the family and was spent on basic essentials such as food, education and medical services. They also mention the full market accessibility, which is provided through cooperatives and local NGOs, which regularly buy products. The study promotes conservation of biodiversity through organic farming that does not use synthetic inputs and improves the balance of the ecosystem, which is environmentally friendly.

The results of Pradhan et al. support the role of Financial Viability and Profitability, Promotion of Biodiversity and Ecological Habitats, and Market Accessibility as being pertinent sub-criteria. The success of the cooperative-supported market-access in Nepal which is documented provides useful information on analyzing the distribution systems of local organic produce in Sri Lanka.

The analysis concentrates on the contribution of organic farming towards creation of coherent livelihood in India, which can provide multiple applicable knowledge to Sri Lanka (Udin, 2014). He underlines that organic farming increases the resilience of climatic conditions because the local varieties of crops are less sensitive to drought and floods, as well as the pests that do not affect them due to the improved quality of soil structure. Another benefit of the study is livelihood gain to the smallholder farmers who can work sustainably even in presence of low external labor or capital. Udin concludes that organic farming could lead to a decrease in yield but high prices and reduced costs compensate this, which increases the economic viability of farming. He also emphasizes on the issue of diversification of farms whereby families produce vegetables, fruits, and spices both as a source of food and income. The other area of the study that can be noted is the application of natural pest and weed control mechanisms which generate little impact on the environment.

The study by Udin has justified Climate Resilience in Organic Agriculture, Diversification in Organic Farming, Financial Viability and Profitability, Livelihood Development, and Pest and Weed Control as part of the evaluation model. Such observations are in tandem with the facts of the smallholder organic farmers in Sri Lanka, particularly those engaged in mixed farming and having access to a small number of external inputs.

That study contributes a methodological framework for prioritizing sustainability criteria under uncertainty using Delphi and Fuzzy AHP (Gupta et al., 2023). Their study emphasizes two key social sustainability factors that are relevant to the context of our study which are access to agricultural knowledge and support, and transparency and traceability. They argue that small-scale farmers must receive timely technical information, training, and institutional support to respond flexibly to consumer demands and supply chain changes. Their findings stress the importance of stakeholder collaboration, data sharing, and digital record-keeping for effective supply chain transparency.

Gupta et al.'s analytical approach and identified social indicators justify the inclusion of Access to Agricultural Knowledge and Support and Transparency and Traceability as key social sub-criteria. Their emphasis on digital data systems and institutional coordination provides a useful benchmark for evaluating governance structures in Sri Lanka's organic supply chains.

The researchers apply Schmutz et al.'s framework to Sri Lanka, specifically assessing short organic food supply chains via a direct farmer' market in central part of Sri Lanka (Hansika and Wijerathna, 2021). Their study demonstrates measurable reductions in GHG emissions (from 1.2093 to 0.7624 $kgCO_2/kg$) due to shorter transportation distances and reduced chemical input use. It also documents strong institutional support for farmers, including training on Good Agricultural Practices (GAP), financial assistance, and marketing support.

Hansika and Wijerathna's work was critical in localizing the international framework. Their findings validated the practical relevance of Reduced Impact from Transportation and Emissions and Access to Agricultural Knowledge and Support within the Sri Lankan context. Their empirical data strengthened the environmental and social sustainability components of this study's evaluation model.

Analysis to provide a broader view of organic agriculture's environmental and social impacts in developing countries (Zanoli et al., 2007). The study supports the role of organic farming in preserving biodiversity through reduced chemical use and enhanced soil fertility. It also discusses the role of organic supply chains in improving food safety and nutritional quality, highlighting reduced exposure to harmful substances as a public health benefit. Moreover, the study addresses sustainable packaging, noting that organic chains often use methods that reduce environmental costs and improve food quality. Finally, Zanoli et al. emphasize the multifunctionality of organic farming, beyond food production, it contributes to landscape preservation, animal welfare, and broader ecological benefits.

This research support several sub-criteria central to this study, including Promotion of Biodiversity and Ecological Habitats, Sustainable Packaging and Recycling, and Food Safety and Quality (Zanoli et al., 2007). Their macro-level perspective reinforces the broader sustainability potential of organic agriculture in developing regions like Sri Lanka, aligning well with this study's focus on environmental and social impact assessment.

Table 1: Main and sub criteria used for the assessment

Main criteria	Sub criteria
Economic	Reduction of Food Waste
	Livelihood Development
	Market Accessibility for Organic Produce
	Diversification in Organic Farming
	Financial Viability and Profitability
Environmental	Reduced Impact from Transportation & Emissions
	Sustainable Packaging and Recycling
	Efficient Use of Natural Resources
	Promotion of Biodiversity and Ecological Habitats
	Climate Resilience in Organic Agriculture
	Natural / Organic Pest and Weed Control
Social	Transparency and Traceability
	Food Safety and Quality
	Food Security
	Access to Agricultural Knowledge and Support

By synthesizing insights from with regional and local evidence from Banjara and, this study constructs a robust and context-sensitive framework for assessing sustainability in Sri Lanka's organic food supply chains (Schmutz et al., 2017; Poudel, 2015; Pradhan et al., 2015; Udin, 2014; Gupta et al., 2023; Hansika and Wijerathna, 2021; Zanoli et al., 2007). Each sub-criterion ranging from resource efficiency and emissions reduction to market access, resilience, and consumer transparency is directly anchored in peer-reviewed research. The final framework thus balances methodological rigor with contextual relevance, serving as both a practical assessment tool and a strategic guide for improving the sustainability performance of organic food systems in Sri Lanka.

2.2 Role of Multi-Criteria Decision Analysis (MCDA) in Supply Chain Sustainability Assessment

To effectively address the growing complexity and uncertainty of global food systems, the Multi-Criteria Decision Analysis (MCDA) techniques, especially the Analytic Hierarchy Process (AHP) and its fuzzy variant (FAHP), have become an adequate means of assessing and improving the sustainability of food supply chains. In this case, it is applied to the organic agriculture sector in Sri Lanka, where FAHP is used to identify priorities in the sustainability criteria and offers a formal and empirical framework of decision-making. The validity of this methodological selection can be explained by an increasing body of literature that proves the flexibility and applicability of AHP-based methods in different food supply chain settings.

MCDA approaches provide the opportunity to integrate a variety of sustainability aspects including economic, environmental and social into a single assessment process despite the fact that the aspects may be qualitative or competing. This is especially relevant in organic food systems where the decision making process very often has tradeoffs among productivity, ecological impact, and social equity. Recent studies like those have justified the ability of MCDA to address these multidimensional tradeoffs (or tradeoffs), which proves that the tool is suitable to the food chain sustainability analysis (Mohseni et al, 2022). It focuses on the use of hierarchies, expert-driven pairwise comparisons, and consistency (Mohseni et al., 2022). Their use of the AHP and hybrid AHP models to their various food products lends credence to the methodological direction they have taken in this study.

In addition, the fuzzy AHP type employed in the present paper gives an opportunity to introduce the expert opinion in a subtle way, especially in the context of the Sri Lanka situation when an subjective evaluation is extremely important because of insufficient data. Another study conducted on the Brazilian meat supply chain assesses the sustainability performance of suppliers through safety, quality, and compliance criteria, which may be the same issues as those discussed in this paper, including food safety, transparency, and market access (Ramos et al., 2020). It is also through the use of fuzzy logic in the processing of the linguistic expert inputs by the Brazilian study that the correctness of the methodology framework used in the current study is further confirmed.

Hybrid MCDA models have been very effective in the performance analysis of the food supply chain. As an example, the hybrid AHP-DEMATEL-TOPSIS model created serves to research pork suppliers in Colombia by (Ortiz-Barrios et al., 2020). Weights were derived with the help of AHP, assessed with the help of DEMATEL, and ranked the alternatives with the help of TOPSIS. Their findings prioritized the service quality and monetary soundness of the suppliers, which also showed similar results with this study wherein economic predictors, including market access and food waste diminution received the utmost rank among Sri Lankan stakeholders.

Continuing to support this method, measured the performance of food supply chain by the hybrid approach based on fuzzy DEMATEL and DANP with the focus on interdependencing between the performance indicators of customer satisfaction, logistics efficiency, and quality (Sufiyan et al., 2019). Their conclusion that the performance of FSC depends on the collaboration and coordination of decisions makes is in line with participatory structure of the FAHP approach that was used in the present research.

The applicability of FAHP to sustainability models is also proven analysis prioritized the risks in the Halal food supply chain with the help of AHP (Khan et al., 2022). The analysis has identified the strength of AHP in its ability to convert the qualitative data (e.g., trust, reputation) into the structured rankings. This is especially applicable to the fact that this study incorporates such criteria as transparency, institutional support, and food safety. The fact that they used the Saaty 1-9 scale, consistency checks ($CR < 0.1$) reflects the methodological rigor used in the present study and, hence, becomes the cross-validation of reliability.

As a study designed a fuzzy AHP-TOPSIS framework to decrease subjectivity in assessing perishable produce, and the fuzzy logic proves to be effective in managing uncertainty in supply chain decisions (Leung et al., 2021). The speed and its reliability in decision making was enhanced and it showed the benefits of structured and quantitative approach over manual or subjective assessments. This is in tandem with the fact that the current study has made use of FAHP in the representation of the stakeholder judgment in the organic supply chains of Sri Lanka, which supports the validity and effectiveness of the suggested scoring system.

The researchers note that even though most MCDA application in sustainable supply chain risk analysis is based on a single approach or dual-method, future applications are integrated and hybrid-based (Moktadir et al., 2024). Their analysis of more than 100 papers leads to the fact that there is an increasing necessity to integrate MCDA with optimization or simulation-based methods. Although the paper will use a pure FAHP strategy, the model can easily be extended to include other operating instruments in the future to complement the scenario analysis and risk mitigation planning in organic food supply chains in Sri Lanka.

The study also made another contribution by introducing a benchmarking framework (MCDA) of supply chain sustainability (Yakovleva et al., 2012). Their efforts highlight the role of AHP to promote stakeholder engagement, open distribution of weight, and creation of composite performance indices. Such a participative and open process does not only lead to increased credibility of findings, but also promotes uptake of the policy by the stakeholders and alignment of stakeholders.

To sum up, the literature is a strong indication of the choice of FAHP to assess sustainability criteria in organic food supply chains in Sri Lanka. FAHP and other MCDA approaches offer the required degree of flexibility, rigor, and clarity in terms of supporting strategic decision-making with participation through benchmarking and supplier performance and risk prioritization (Khan et al., 2022; Ortiz-Barrios et al., 2020; Yakovleva et al., 2012). The current study will be based on these methodological foundations but will be adapted to the socio-economic and institutional realities of Sri Lanka and will contribute to the overall discussion by providing a context-specific decision support framework of sustainability assessment of organic agriculture.

3. Materials and Methods

The research paper is a proposal of a decision making framework which will be used to identify and classify the significant criteria and sub- criteria that can be applied in assessing the sustainability effects of the organic food supply chain in Sri Lanka. It also entails the provision of relative weightings to these elements with a view of showing their weight. The aim is to provide a balanced and functional instrument to the stakeholders to evaluate the sustainability performance.

Multi Criteria Decision Making (MCDM) is a methodology that is used to evaluate and choose between options that includes a number of, and in many cases conflicting, criteria. It provides a systematic approach of ranking and comparing options both quantitatively and qualitatively (Taherdoost and Madanchian, 2023). There are different methods of tackling MCDM problems. The most popular ones include the Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting (SAW), Multi Attributes Utility Theory (MAUT) and Elimination and Choice Expressing Reality (ELECTRE). The analysis introduced AHP which subdivides the problem into a hierarchy and uses pairwise comparisons to determine the weights and calculate the score of the alternatives (Sayegh Saaty, 1980).

The AHP would be a good fit to the study as it enables the decomposition of the intricate sustainability assessment issues into a hierarchical picture of primary, and sub-criteria. It also allows in-depth pairwise comparisons, which is beneficial in terms of establishing the relative significance of every factor in a more accurate manner. The benefit of AHP is that it allows both qualitative and quantitative data and, therefore, it can be utilized to measure multiple dimensions of sustainability. Besides, the technique has a consistency check to confirm the reliability of the comparisons thus enhancing the overall soundness of the evaluation process (Saaty, 1980). APH implementation in this regard enables a constructive and open evaluation of the sustainability factors, such that the resulting framework has been representative of the interests of different stakeholders in the organic food supply chain. The summary of solution approach used in this study is illustrated in figure 1.

Fuzzy AHP is an improvement on traditional AHP in that it uses some fuzzy logic in managing uncertainty and subjectivity of expert judgments. It can better represent ambiguity through the use of fuzzy numbers in pairwise comparisons and is thus suited to complex ones such as sustainability assessment with vague or multiple criteria (Van Laarhoven and Pedrycz, 1983; Klir and Yuan, 1995).

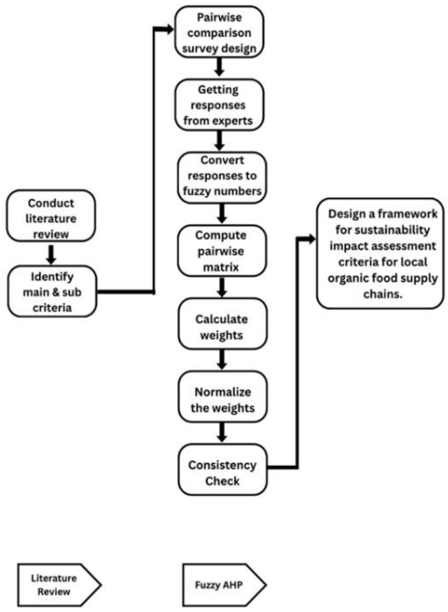

Figure 1: Visual representation of the solution approach

Step 1: Structuring the Hierarchy

The initial step entails the compilation of pertinent sustainability criteria and sub criteria with the help of a systematic literature review. These aspects are then arranged into hierarchical model which indicates the evaluation framework. The first is the overall goal, which is to choose the most sustainable organic supply food chain in Sri Lanka, and then the three major criteria, which are the environmental, economic, and social criteria. Every primary criterion is further subdivided into sub-criteria that are used to reflect certain aspects of sustainability. This is a hierarchical framework that allows a thorough and well-organized study of the multifaceted variables that affect sustainability (Saaty, 2008; Ishizaka and Labib, 2011).

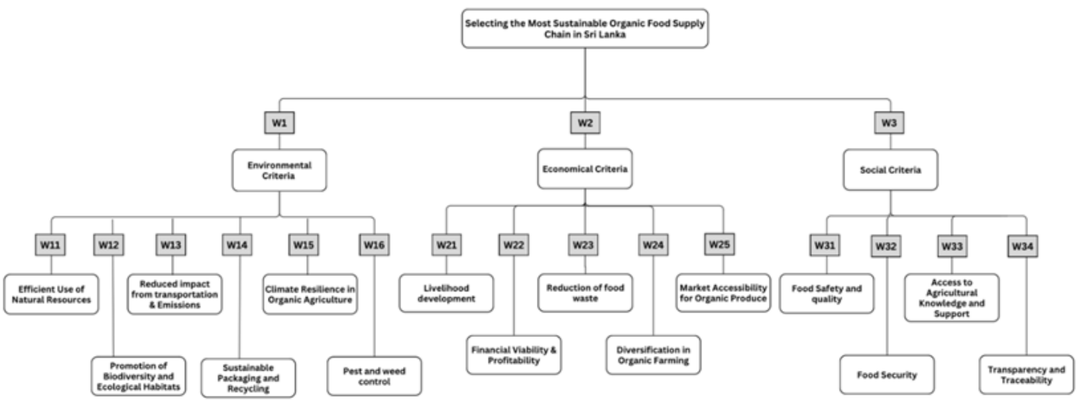

Figure 2: Hierarchical model with main and sub criteria

Step 2: Expert Input and Pairwise Comparisons

Through a pairwise comparison, interviews were conducted on experts to provide their views on the relative significance of the criteria.

Purposive sampling was done to carefully identify eight experts who would represent the entire organic food supply chain ecosystem in Sri Lanka. The criteria used were based on those with proven knowledge in the form of professional qualification, experience, and participation in sustainable agricultural programs. The selection of the experts was made on the three terms; the first is that he or she should have minimum of five years of professional experience in the field, be it in agriculture, sustainability, or supply chain management, the second is direct experience in the field on either of the three by engaging in the practice, consulting, or policy implementation, and lastly, proven track record working with the smallholder farmers or agricultural enterprises in Sri Lanka.

The professionals were strategically divided into three different areas in order to include various points of view and possible insularities in various work experiences. Sector 1: agricultural technology and innovation (experts 2, 5, 7) is a combination of agronomic and digital innovation skills with expertise in technological solutions and professionals with practical experience in farming. Sector 2 is the field of organic agriculture and sustainable practices (experts 3, 4) as well as specialists directly involved in organic certification procedures and regenerative agriculture transformation, who will introduce significant expertise specific to the sector. Sector 3 is the sustainability strategy and supply chain development (experts 1, 6, 8) where professionals experienced in corporate sustainability and supply chain management unit expertise will be found to provide strategic and systems level views.

Table 2: Notable biases identified within sectors of experts

Sector	Experts	Notable Biases Identified
Agricultural Technology & Innovation	3	Environmental Criteria
Organic Agriculture & Sustainable Practices	2	Environmental Criteria
Sustainability Strategy & Supply Chain Development	3	Economic Criteria

The sector categorization, it is important to note that they were biased against professional backgrounds with the sector 1 and 2 experts being more likely to support environmental criteria since they are directly exposed to the ecological practice of farming and the experts in sector 3 were more likely to endorse economic criteria given their experiences in the field of corporate and strategic planning. This bias identification aided by a system made the framework valid in that all three dimensions of sustainability were represented at equal rates and that the alignment of the natural preference of the profession and domain was taken into account.

These comparisons were conducted using a nine-point Likert scale that was proposed by (Saaty, 1980).

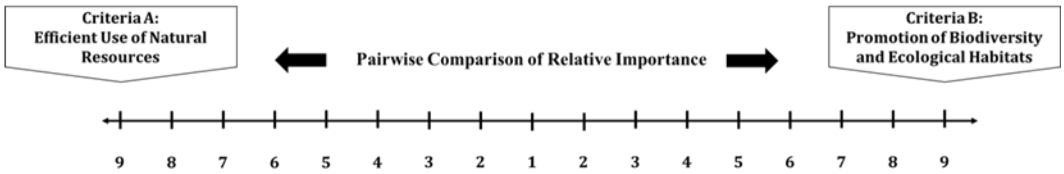

Figure 3: Sample pairwise comparison survey using a nine-point Likert scale

The above figure shows the pairwise comparison scale applied in the course of expert interviews to compare the relative importance of two sustainability criteria namely Efficient Use of Natural Resources (Criteria A) and Promotion of Biodiversity and Ecological Habitats (Criteria B). The number of importance "1" means that the two criteria are equally significant. The values lower than one (between 2 and 9) indicate a preference of Efficient Use of Natural Resources where the higher the value, the greater the preference. On the right, on the other hand, values (also between 2 and 9) register a preference to Promotion of Biodiversity and Ecological Habitats, which again increases in intensity.

To illustrate, when an expert puts 7 on the right hand side, then that person regards Promotion of Biodiversity and Ecological Habitats to have a lot more significance than Efficient Use of Natural Resources. When they choose to mark 4 on the left hand side, it would mean that their preference is moderate to Efficient Use of Natural Resources in favor of; Promotion of Biodiversity and Ecological Habitats. Structured, fine-grained comparisons can be made in this way that captures the expert judgment and can be analyzed to a Fuzzy AHP analysis.

Step 3: Fuzzification of Responses

The rating numbers given by the experts are then converted into triangular fuzzy numbers which are more appropriate to depict the imprecision and subjectivity of human judgement.

Table 3: Fuzzy scale and interpretation of linguistic values

Rating	Fuzzy number	Reciprocal Fuzzy number	Definition
1	(1,1,1)	(1,1,1)	Equally important
2	(1,2,3)	(1/3,1/2,1)	Judgment values between equally and moderately
3	(2,3,4)	(1/4,1/3,1/2)	Moderately more important
4	(3,4,5)	(1/5,1/4,1/3)	Judgment values between moderately and strongly
5	(4,5,6)	(1/6,1/5,1/4)	Strongly more important
6	(5,6,7)	(1/7,1/6,1/5)	Judgment values between strongly and very strongly
7	(6,7,8)	(1/8,1/7,1/6)	Very strongly more important
8	(7,8,9)	(1/9,1/8,1/7)	Judgment values between very strongly and extremely
9	(9,9,9)	(1/9,1/9,1/9)	Extremely more important

Step 4: Building the Fuzzy Pairwise Comparison Matrix

The fuzzy values are used to construct a pairwise comparison matrix. Each element c_{ij} in the matrix represents the fuzzy preference of criterion C_i over C_j, incorporating all expert evaluations.

$$C = \begin{bmatrix} 1 & c_{12} & c_{13} & & c_{1n} \\ \frac{1}{c_{12}} & 1 & c_{23} & \cdots & c_{2n} \\ \frac{1}{c_{13}} & \frac{1}{c_{23}} & 1 & & c_{3n} \\ & \vdots & & \ddots & \vdots \\ \frac{1}{c_{1n}} & \frac{1}{c_{2n}} & \frac{1}{c_{3n}} & \cdots & 1 \end{bmatrix} \quad \text{Equation (1)}$$

Step 5: Calculating Fuzzy Weights

To derive the priority weights for each criterion, the average of the normalized values in each row of the fuzzy matrix is computed. This gives the fuzzy weight vector:

$$\omega_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \quad \text{Equation (2)}$$

Step 6: Consistency Check

A consistency analysis ensures the logical soundness of the comparisons. The Consistency Index (CI) is calculated as:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad \text{Equation (3)}$$

Here, λ_{max} is the maximum eigenvalue of the matrix, and n is the number of criteria. The Consistency Ratio (CR) is then found by dividing the CI by the Random Index (RI):

$$CR = \frac{CI}{CR} \quad \text{Equation (4)}$$

A CR value less than or equal to 0.1 indicates that the judgments are sufficiently consistent (Saaty, 1980).

4 . Results and Discussion

The sustainability impact assessment criteria analysis of the organic food supply chain of Sri Lanka based on the Fuzzy Analytic Hierarchy Process (FAHP) showed some interesting priorities under the three central dimensions of sustainability, namely, economical, environmental, and social.

Table 4: Criteria ranking and weights

Main criteria	Main criteria weights	Ranking	Sub criteria	Sub criteria weights	Ranking
Economic	70.7% (ω_1)	1	Reduction of Food Waste	33.6% (ω_{11})	1
			Livelihood Development	19.5% (ω_{12})	2
			Market Accessibility for Organic Produce	15.9% (ω_{13})	3
			Diversification in Organic Farming	15.54% (ω_{14})	4
			Financial Viability and Profitability	15.53% (ω_{15})	5
Environmental	20.6% (ω_2)	2	Reduced Impact from Transportation & Emissions	26.3% (ω_{21})	1
			Sustainable Packaging and Recycling	25.4% (ω_{22})	2
			Efficient Use of Natural Resources	19.0% (ω_{23})	3
			Promotion of Biodiversity and Ecological Habitats	13.6% (ω_{24})	4
			Climate Resilience in Organic Agriculture	7.9% (ω_{25})	5
			Natural / Organic Pest and Weed Control	7.8% (ω_{26})	6
Social	8.7% (ω_3)	3	Transparency and Traceability	29.3% (ω_{31})	1
			Food Safety and Quality	27.6% (ω_{32})	2
			Food Security	22.2% (ω_{33})	3
			Access to Agricultural Knowledge and Support	20.9% (ω_{34})	4

The findings indicate economic sustainability came to be the most imperative dimension with a prevailing 70.7 weight and then environmental sustainability (20.6) and social sustainability (8.7).

This priority highlights the fact that, in the case of the stakeholders in the Sri Lankan organic food industry, the issue of financial viability and financial strength must be considered as the ultimate priority. This refers to the present structural issues that the industry is grappling with such as lack of access to good markets, high production prices, and livelihoods of smallholder farmers that is stable. Environmental and social factors are still relevant, but the fact that their weights are much less indicates that until economic feasibility is guaranteed, the development of organic food supply chains in a sustainable manner may not be as practical as it could be theoretically.

Reduction of Food Waste was the most important of the economic sub criteria to respond to (33.6%), which shows that the inefficiencies and losses of the existing systems of distributing and handling organic food are well understood. This is particularly applicable in Sri Lanka where the problem of post-harvest losses has been well documented (Rajapaksha et al., 2021).

The second most important economic need was Livelihood Development (19.5%). This is the impact of organic farming on the rural development and creation of jobs. Labor-intensive nature of organic farming provides more job opportunities, hence it leads to increase in living standards.

Next came Market Accessibility (15.9%) and Diversification in Organic Farming (15.54), as the key factors to create a stable market connection and diversified sources of income to make farmers less susceptible to climatic and market crises. Interestingly, Financial Viability and Profitability were the lowest sub criteria in the economic (15.53%), and it is slightly below diversification. This minor difference indicates that the profitability is seen as a basic expectation by stakeholders and other criteria are seen as possibilities of making a greater difference.

The highest ranking took place in the environmental domain where Reduced Impact from Transportation and Emissions was identified as the top (26.3%), indicating that the stakeholders know that there is a large environmental footprint in relation to food logistics. This applies especially in the case of Sri Lanka where fuel dependency and emissions are the pressing issues. In the close vicinity, there was the Sustainable Packaging and Recycling (25.4%) that puts a strong emphasis on the increasing worries about packaging waste and the need to establish distribution systems that are friendly to the environment. Nevertheless, this can be a practical issue to implement since Sri Lanka has a weak recycling system. Use of Natural Resources (19.0) was also rated highly and there is the need to maximize the inputs, water, soil and nutrients.

The comparatively low scores of Promotion of Biodiversity (13.6%), Climate Resilience (7.9%), and Natural Pest and Weed Control (7.8%) serve as an indicator that these factors are not perceived as urgent, although they are important, at least in comparison with logistical and packaging issues. Such a prioritization can be seen as implying that more visible, practical problems such as emissions and packaging are being prioritized over the long term benefits of the ecosystem, which may potentially require more awareness creation and capacity building.

The least weighted, however, social sustainability did show a few concerned areas. The most important sub criterion was Transparency and Traceability (29.3%), indicating the growing demand of the consumer to have trustful and traceable food systems. Given that food safety scandals and pesticides misuse are not the rare occurrences, it is crucial to inspire consumer confidence to increase the market.

The second priority was identified as Food Safety and Quality (27.6) and supports the fact that organic practices and their impact on the population health are linked to each other. The fact that these two sub criteria were ranked high in the list is an indicator that the credibility and safety of organic products is of the concern to both consumers and stakeholders. Other important ones, albeit to a lesser degree, were Food Security (22.2) and Access to Agricultural Knowledge and Support (20.9). These findings indicate that the research requires institutions to support these efforts and provide education to the smallholder farmers and equitable access to food.

The prevalent focus on economic standards displays an expedient, means of living mentality on the side of the stakeholders. In the Sri Lankan organic industry, sustainability should be initially, financially viable. Environmental issues are distinctly identified, yet more practical and infrastructure based sub criteria (e.g., emissions and packaging) prevail over the systemic ecological perks, such as biodiversity maintenance. Although social sustainability is the least weighted, it raises concerns related to transparency, food safety, and knowledge transfer that is essential in long term trust and engagement.

The ranking gives strategic roadmap of sustainability interventions in the organic food supply chain of Sri Lanka. It is therefore important to reduce the area of greatest concern and this can be achieved by increasing efficiency through investing in infrastructure and training farmers to minimize post-harvest losses, and reducing economic and environmental wastage. The stabilized incomes and the financial vulnerabilities of organic farmers can be decreased by improving market access cooperative models and the public-private partnership. In addition, there is the need to encourage the use of ecofriendly logistics, and packaging via special incentives and legal framework to reduce environmental effects. Enhancement of certification and traceability systems will increase consumer confidence in organic products and knowledge transfer and increased institutional support will enable farmers to adopt and maintain effective organic practices. Finally, this FAHP-oriented framework can present a model that can be used to make focused policy and investment decisions and can be used as a benchmarking instrument to determine whether the sustainability objectives are being met.

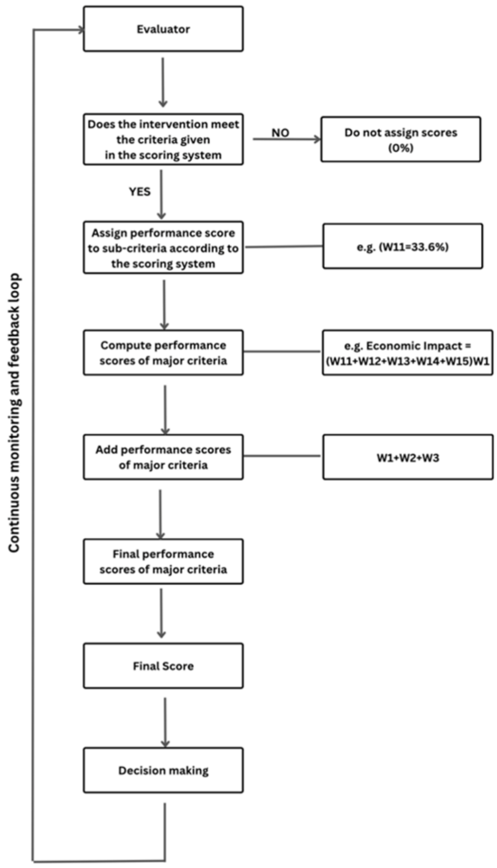

Figure 4: Framework for implementing the scoring system.

Figure 4 demonstrates the gradual process followed in an effort to implement the sustainability scoring system that is generated in this research. It starts with the evaluator, who decides whether a certain intervention (e.g., an organic farming practice, policy initiative or supply chain strategy) meets the corresponding sub criteria contained within the scoring framework. In case the intervention fails to comply with the criteria provided, the intervention will be rated 0 percent and the assessment will not be carried out.

In case the intervention satisfies the criteria, the evaluator will fill in performance score to the relevant sub criteria according to the scoring matrix (e.g., $\omega_{11} = 33.6\%$). These sub scores are then added to calculate the performance score of the major criteria (e.g., Economic Impact = $(\omega_{11} + \omega_{12} + \omega_{13} + \omega_{14} + \omega_{15}).\omega_1$) where the weights are the relativity of each sub-criterion.

Subsequently, the weighted scores for all major criteria, Economic (ω_1), Environmental (ω_2), and Social (ω_3) dimensions are aggregated (i.e., $\omega_1 + \omega_2 + \omega_3$) to generate the final performance score of the intervention. This composite score indicates the overall sustainability performance of the intervention and supports evidence-based decision making.

Importantly, the model is embedded within a continuous monitoring and feedback loop, ensuring that the scoring system remains responsive to contextual changes, policy updates, and emerging sustainability indicators. This dynamic mechanism enhances the adaptability and long-term relevance of the assessment framework.

5. Conclusion

The aim of the proposed study was to recognize and rank the criteria of sustainability impact assessment of organic food supply chains in Sri Lanka through a Fuzzy Analytic Hierarchy Process (FAHP) model. The structured decision-making model was created through a thorough literature review and consultation of the expert. It included environmental, economic and social aspects and each of them was further broken down into context differences sub criteria.

The results clearly indicate that the economic sustainability is the major concern by the stakeholders as per the realities on the ground, which are the volatile market, infrastructural shortcomings, and lack of livelihood security in the agricultural sector. The priority that is given to food waste reduction, livelihood development, and accessibility of markets is quite high, which means that strategic investments are needed to increase the efficiency of operations and provide organic farmers with a stable source of income.

Although with less weight, environmental criteria indicate the growing recognition of more realistic sustainability issues like emissions reduction and packaging waste. The least aggregate weight was given to social sustainability though the sub criteria such as transparency and food safety are an indication that consumer confidence and institutional goodwill will continue to be important to long term success.

The FAHP system was useful in the management of subjective expert information and the transformation of qualitative information into a quantitative ranking model. This prioritization is organized in a way that it not only justifies current areas of concern but also gives some basis to the policy direction, investment planning, and performance monitoring. This framework provides a realistic and context sensitive pathway to holistic sustainability because it unveils what is most important to practitioners and stakeholders in the organic industry of Sri Lanka.

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