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Integrating coordination mechanisms in the sustainability assessment of agri-food chains: From a structured literature review to a comprehensive framework

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ABSTRACT

The assessment of sustainability at the level of the agri-food supply chain is complex.Achieving sustainability in agri-food chains requires coordinated interaction between chain actors. The aspect of coordination is rarely included in the assessment of sustainability and current assessment methodologies do not allow conclusions about the linkage between coordination and sustainability. This paper analyzes the state of the art in the assessment of agri-food supply chain sustainability based on a structured literature review. Following the structured review that includes category analysis and content analysis, we develop a comprehensive sustainability assessment framework for agri-food chains across multiple stages. The novelty of the framework is to incorporate the dimension of coordination across chain stages as a critical sustainability dimension. The study contributes to research on the assessment of agrifood supply chain sustainability by incorporating the role of coordination across chain stages and its relationship with economic, environmental, and social performance. This essential relationship between coordination and sustainability offers several areas of interest for future research. The study also contributes to practice by providing scholars, chain actors, and policymakers with directions for improving sustainable strategies.

1. Introduction

The sustainability of agri-food supply chains is high on international and domestic policy agendas for corporations, governments, NGOs, academia, and societies. The issues commonly discussed are climate change (Godde et al., 2021), loss of biodiversity (Ivanov and Dolgui, 2020), and their linkages to agricultural production (Gouda and Saranga, 2018). Stakeholders have claimed that current actions are insufficient to achieve the sustainability of the supply chains (Kugelberg et al., 2021). The common issues are food waste (Vanlauwe et al., 2019), water contamination (Mihai and Ingrao, 2018), the inefficiency of energy use (Wang et al., 2020), and livelihoods deterioration (Huss et al., 2021). Concerns also exist over the increasingly imbalanced distribution of benefits across supply chain actors (Barbosa, 2021; Mani et al., 2020). These observations show that sustainability encompasses several dimensions (Kilelu et al., 2017; Um and Kim, 2019) and requires a transdisciplinary approach to tackle this priority (Green et al., 2020; Melkonyan et al., 2020).

Several authors assert sustainability in agri-food chains requires coordinated interaction between chain actors (Estevez et al., 2018; Kornher and Kalkuhl, 2019). Coordination between supply chain actors/ stages occurs through mechanisms such as direction (Bijman et al., 2006), planning methods (Macdonald, 2020), logistic arrangements (Paciarotti and Torregiani, 2021), incentives (Ward et al., 2016), mutual adjustment (Rydberg and Haden, 2006), and information transfer (Gerbens-Leenes et al., 2003), and it can involve formal or informal arrangements (Borgen and Hegrenes, 2005). Through such mechanisms, chain actors may achieve a better sustainability performance (Msaddak et al., 2017), for instance, by reducing food losses and contamination being more efficient and improving smallholders' position in the chain (Gimenez and Tachizawa, 2012; Zhong et al., 2018). The few existing studies that include coordination in the sustainability assessment focus primarily on cooperation for managing conflicts (Gonzalez-Perez and Gutierrez-Viana, 2012) and do not provide conclusions on the relationship between coordination and sustainability (Mausch et al., 2020). This is the knowledge gap that the current article seeks to address.

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Many reviews have provided guidelines and methods to estimate the sustainability performance of agri-food supply chains. These include Life-Cycle-Assessment (LCA), Balanced Score Cards (BSC), and Data Envelopment Analysis (DEA). Often these methods focus on only one chain stage or a dyad (Martins and Pato, 2019; Peterson, 2010; Fan et al., 2016) and do not simultaneously analyze all sustainability dimensions (Hoekstra et al., 2019; Kozlowski et al., 2015). Their limitations also are evidenced in their abstract approaches for measuring with incomplete interpretations (Charles et al., 2006) of the outcomes (Camargo et al., 2019; Shafiq et al., 2014), and the thoughtlessness of the potential of the coordination between stages to the sustainability of the supply chains (Beske and Seuring, 2014; Dania et al., 2018). More research on the sustainability assessment of agri-food chains is supported by Zhu et al. (2017) and Chen et al. (2017), while Ansari and Kant (2017) call for research on the integrated measurement of supply chain sustainability.

To shed light on the identified gaps, we will analyze the state of art in assessing agri-food supply chain sustainability based on a structured literature review. We consider the supply chain a suitable unit of analysis and include coordination between vertical linkages of chain stages as a crucial aspect of the assessment. Although we consider horizontal connections between actors at a specific chain stage, we do not consider the supply network as the unit of analysis because this would encompass clusters of chains and require more complex analysis that misled our goal, the supply chain level. Following the structured review, we develop a comprehensive sustainability assessment framework for agri-food chains across multiple stages. The novelty of the framework is to incorporate the dimension of coordination across chain stages as a critical sustainability dimension.

The following research questions will guide the structured literature review to determine a comprehensive framework for the assessment of agri-food chain sustainability:

a) What is the state of art in assessing agri-food chain sustainability, and which sustainability dimensions and assessment methods are reviewed in the existing literature?
b) Which chain-stages are included in the existing assessment approaches, and how is the connection across chain stages taken into account?
c) What are the key elements and indicators to be included in a comprehensive sustainability assessment for agri-food supply chains?

The research is based on a structured literature review and content analysis of 109 peer-reviewed articles published from 1997 to 2018 on agri-food supply chains. Criteria in the analysis include the agri-food industry, sustainability dimensions, chain levels, assessment methods, and theoretical perspectives.

To ensure relevance and feasibility, the study tested the assessment framework in Ecuador's fruit and vegetable chains since this country facilitated the logistics for the framework testing. To this end, we organized workshops with stakeholders from locations where there exists a prominent agro-alimentary sector. These locations allow easy access to a diversity of agri-food chain actors because their distribution centers are frequented by 25,000 (daily, as a minimum) local and foreign producers, intermediaries, wholesalers, transport companies, and consumers. Of interest to the study, these locations are ahead of other locations in adopting sustainability practices. Primary evidence of this is the launch of the agenda sustainable agriculture 2017 to reinforce the locations' sustainability.

The research makes several contributions to the literature on the sustainability assessment of agri-food supply chains. First, we provide a comprehensive overview of a vast number of studies on sustainability assessment approaches in agri-food supply chains. Second, we identify different types of coordination mechanisms in the evaluation of chain sustainability. Third, we discuss the limitations of existing sustainability assessments. Fourth, we present a novel conceptual framework for assessing agri-food supply chains' sustainability performance, and, fifth, we test the relevance and feasibility of this framework using a participatory approach.

The remainder of the article is structured as follows. Section 2 provides key concepts in the research. Section 3 presents the methodology for the structured literature review and the framework testing. Section 4 shows the content analysis findings and develops the foundations of the conceptual framework for assessing the sustainability performance of agri-food supply chains. Section 5 presents the outcomes of the framework testing. Section 6 discusses the relevance of the findings in the context of the literature on agri-food chain sustainability assessment, the implications for practice, and limitations of the research. Section 7 concludes the article.

2. Conceptual Background

2.1. Sustainability Performance

Sustainability performance relates to results and achievements in the domain of sustainability. Sustainability incorporates three core dimensions, namely, economic, environmental, and social. Considering the supply chain context, we define sustainability performance as the economic, social, and ecological potential to be met simultaneously for the supply chain to maintain supply operations over time. Environmental performance considers efficiency in resource utilization (Schanes et al., 2018), recycling (Boesen et al., 2019), and reduction of pollution (Rao and Holt, 2005). Social performance considers human rights and impact on local communities (Yawar and Seuring, 2017). Economic performance operationalizes profitability, and accounting-based metrics (Golicic and Smith, 2013).

2.2. Sustainability Assessment

Sustainability assessment involves an attempt to evaluate sustainability performance. Qualitative and quantitative tools and indicators are crucial elements of an assessment design (Von Wirén-Lehr, 2001). The vital aspects of its operationalization are stakeholder engagement and contextualization. The former involves key actors (Gregory et al., 2020; Moreno-Miranda et al., 2020), and the latter bridges the design with technical needs (Abildtrup et al., 2006). We define sustainability assessment in the supply chain context as the method to gather, analyze, and transfer economic, social, and ecological information and comprehend the supply chain context. Examples of assessment methods are hierarchy evaluation (Forman and Gass, 2001) and product lifecycle analysis (Baudino et al., 2017).

2.3. Coordination and Coordination Mechanisms

The management of interdependencies (relationships) is done through coordination mechanisms (Koberg and Longoni, 2019; Tachizawa and Wong, 2014). Coordination is the creation, maintenance, and transformation of relationships between actors (Gimenez and Tachizawa, 2012; Malone and Crowston, 1994; Raynold, 2004). Coordination mechanisms are practices (Huang et al., 2016) and processes (Jiao et al., 2021) through which chain actors are governed (Carter and Easton, 2011). These mechanisms can be horizontal or vertical (Moreno-Miranda et al., 2019). Vertical mechanisms are practices to manage interdependencies across supply chain stages (Herzog et al., 2018; Peterson et al., 2001). Horizontal mechanisms indicate the relationship between peers positioned at the same chain level (Sting and Loch, 2016). Examples of these mechanisms include mutual adjustment (Douma and Schreuder, 2017), standards (Dasgupta, 1996), and direct supervision (Slange et al., 2008).

Coordination mechanisms play a crucial role in the sustainability performance of agri-food chains because they can reduce uncertainty and complexity of transactions. Unrelieved tensions may lead to significant transaction costs and affect sustainability (Gereffi et al., 2005; Vroegindewey et al., 2018). According to Formentini and Taticchi (2016), coordination mechanisms are elements adopted by actors to coordinate actions, optimize economic utility, promote social welfare and amplify ecological resilience.

3. Methodology

This paper will first perform a structured review of the literature to develop a comprehensive framework for assessing the sustainability of agri-food supply chains. Second, it will perform the framework testing to estimate the framework's relevance and feasibility.

3.1. Structured Literature Review

A structured literature review (SLR) allows for collecting and analyzing a large amount of evidence transparently and reliably (Sutton et al., 1999). The SLR brings the reader up-to-date with the current literature and sets future research directions (Cronin et al., 2008; Webster and Watson, 2002). We consult review examples performed by Farooque et al. (2019) and Gunawan et al. (2021); and we follow the methodology proposed by Seuring and Gold (2012) using a two-stage process: 1) material collection and 2) a structured review consisting of category identification and content analysis.

3.1.1. Material Collection

In the material collection stage, we define the scope of the material to be analyzed. To ensure that relevant studies are screened in the review, we limit the search based on the following considerations:

1. We account for the research domains of agricultural economics, food systems, supply chain research, agricultural sustainability, ecological economics, agricultural research, and development economics for proper interpretation and validity of the findings.
2. The analysis considers peer-reviewed articles and conference papers published in English since it is the language of choice for many international scholarly journals.
3. The search deploys a combination of key search terms to select relevant papers. For specifying the context, we use terms related to "agri-food" OR "agr*" OR "food*" OR "farm*" to cover agro-processing, agribusiness, food-processing, and farm-related settings. For specifying our interest in sustainability, we employ "sustain*" OR "environment*" OR "fair*" OR "feasib*" OR "life*" OR "renewab*" OR "social*" OR "coordinat*". For capturing the supply chain dimension, we use terms such as "network" OR "market chain" OR "supply chain" OR "value chain". For covering assessments in terms of performance, we use "perform*" OR "efficien*" OR "product*" OR "profit*" OR "manage*". We combine these key terms to generate a series of strings, e.g. ("agri-food" OR "food*" OR "farm*") AND ("sustain*" OR "environment*" OR "feasib*"OR "life*" OR "social*" OR "collaborat*") AND ("network"OR "supply chain"OR "value chain") AND ("perform*"OR "efficien*"OR "profit*").
4. We target documents written by experts in the field and published in the period ranging from 1997 to 2018. The search was performed in multiple databases, including CAB Abstract via Ovid (www.ovid.com), AgEcon search (ageconsearch.umn.edu), Web of Science (apps.webofknowledge.com), WUR library collection (www.wur.nl/Library.htm), and Scopus (www.scopus.com) since they provide powerful tools for optimizing results.
5. Criteria considered to exclude studies were the following:
   a. Publications aimed at chemistry, medicine, genetics, nanotechnology, computing, and physics because they differ from our socio-economic target.
   b. Publications focused on pure ecological issues, e.g., climate cycles and plant physiology. The interest in physical phenomena differs from our objective.
   c. Publications on product marketing and logistics because focus mainly on sales, and we exclude novel food chanis, e.g., insects, because of their emphasis on diets replacement.
   d. Publications related to supply chains outside of the agri-food sector such as chemicals, automotive, clothing, electronics, among others, because of the different nature of their exchanged goods.
6. After exclusion based on the criteria in step 5 and the exclusion of duplicates, 278 papers remain. We then proceed by screening abstracts to assess if they fit our research questions. We do not consider articles that emphasize personal opinions, legal conclusions, purely historical papers and lack meta-commentary to facilitate the abstracts screening. This results in 99 studies to be used for analysis.
7. Next, we also use references from these 99 studies to identify additional relevant papers. For example, from the article by (Pullman et al., 2010), which was retrieved from the search, we identify (Aramyan et al., 2006) as a relevant article not captured by our keyword search.
8. Finally, we account for 109 documents in the final sample. Fig. 1 presents the contribution of each database and steps in the material collection process.

Fig. 2 shows that most of the articles in our sample are published in the last seven years. This is in line with the growing interest of scholars in the sustainability evaluation of agri-food supply chains.

3.1.2. Structured Literature Review

The description of the structured review approach is shown in Fig. 3. The structured review follows two steps performed iteratively: 1) category analysis; 2) content analysis. Category analysis is based on inductive, deductive, or context review. The inductive review draws conclusions based on abstracts (Thomas, 2006). The deductive review outlines general principles (Manna and Waldinger, 1986). Further, context review incorporates insights from circumstances or events (Small, 1980).

We start the category review by reading each article's abstract in our sample to determine the agri-food supply chains and sustainability indicators (inductive phase). Next, we review the conceptual frameworks to elicit relevant theories and derive insights into the foundations of sustainability assessment (deductive review). For instance, Carter and Rogers (2008) use the resource dependence theory. Others have used systems theory (Holmberg, 2000), stakeholder theory (Mutebi Kalibwani et al., 2018; Neves, 2010), transaction cost theory (Gereffi, 1994), or the value-chain approach (Porter, 1985). We then complement the analysis by reviewing context features, such as transitions. Following the category analysis, we conduct a content analysis focused on chain configuration and coordination mechanisms. The aspect of chain configuration was present in the nested subsample of 27 documents, and 12 out of these 27 articles address coordination mechanisms. This analysis uses frequency, trend, and theme identification. The purpose of content analysis is to identify the chain-level and coordination elements to be part of the final framework.

3.2. Framework Testing

To test and operationalize the conceptual framework, a workshop was organized with actors and stakeholders involved in fruit and vegetable agri-food chains in Ecuador. The workshop was conducted in Spanish, the participants' native language. The event took place in December 2019 and was attended by 45 participants: representatives from the production (16), processing (8) and distribution (10) stages of the supply chains, from academia (6) and governmental institutions (5). The production-stage representatives included smallholders and leaders of farmers' associations. The heads of public distribution centers, intermediaries, and food processors represented downstream stages. The ministry of agriculture, the public water board, the agricultural

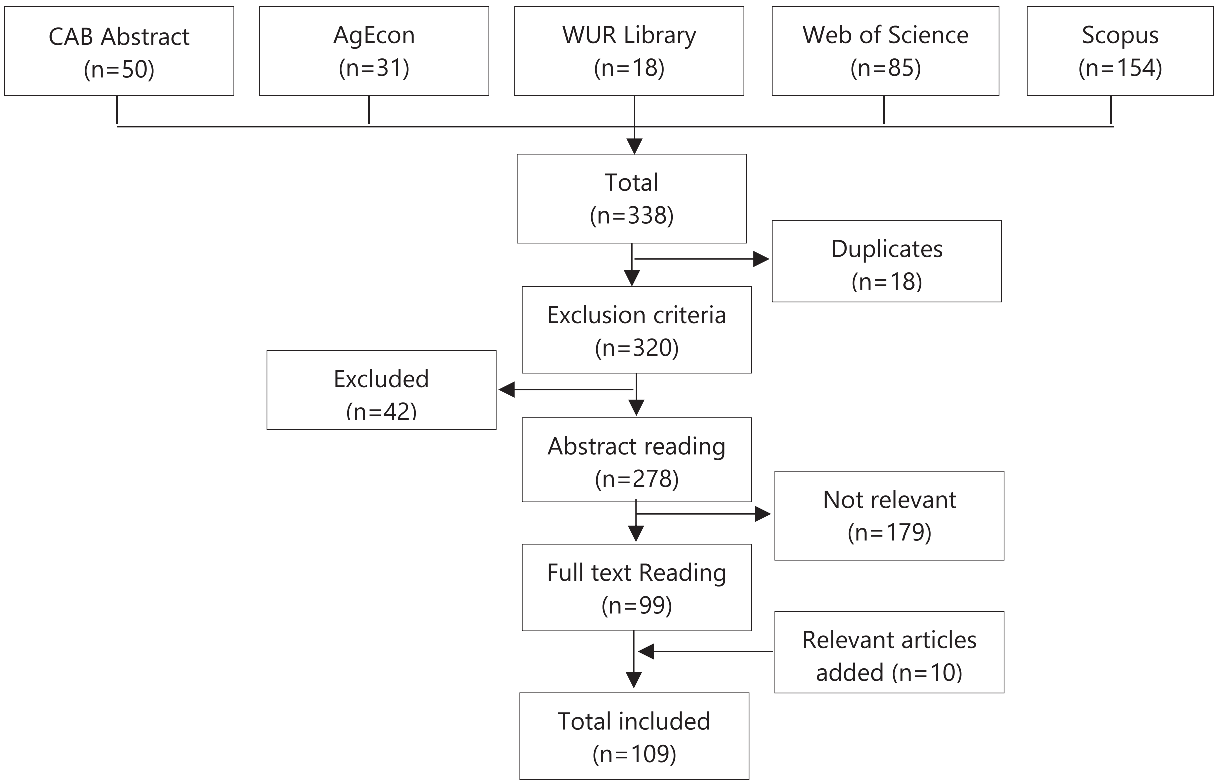

Fig. 1. Representation of the material collection process.
Source: Authors' own representation.

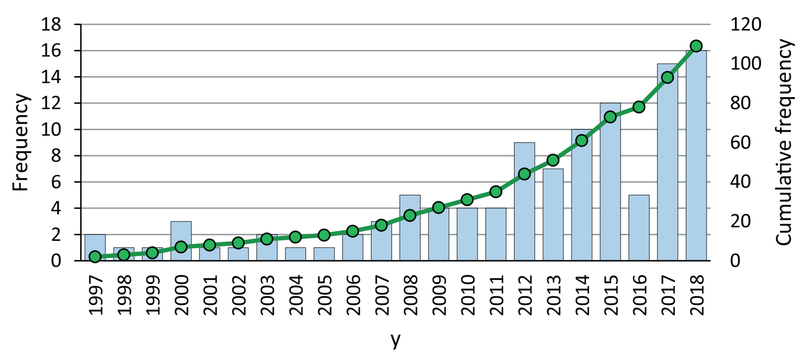

Fig. 2. Distribution of sample articles by year.
Source: Authors' own representation.

parliament, and universities represent governmental institutions and academia.

The workshop's primary purpose was to identify the conceptual framework's relevance and feasibility in a real-life context. The participants assessed both aspects to prevent the sustainability assessment becomes dominated by few stakeholders' views. The workshop started with a description of the framework's foundations and implications. The second phase of the workshop used a questionnaire based on the sustainability indicators derived from the structured literature review. Cronbach's alpha coefficient validated the questionnaire, and three experts checked the wording in the questionnaire. The survey was then pilot-tested[1] with five interviewees, who assisted further in eliminating ambiguous items. The final questionnaire includes 16 environmental, 11 social, 13 economic, and 18 coordination indicators.

[1] First, ten respondents validated each indicator in terms of consistency (understandability). The assigned scores followed a scale from 1 to 10. We estimate the Cronbach alpha coefficient by employing the formula CA = (K/K-1) x ((SUM variance of question i)/(variance of observed scores of individuals)), where K = number of questions. Cronbach alpha values range from 0 to 1.0 points. Scores between 0.60 and 0.70 mean acceptable reliability. We obtained coefficients of over 0.80.

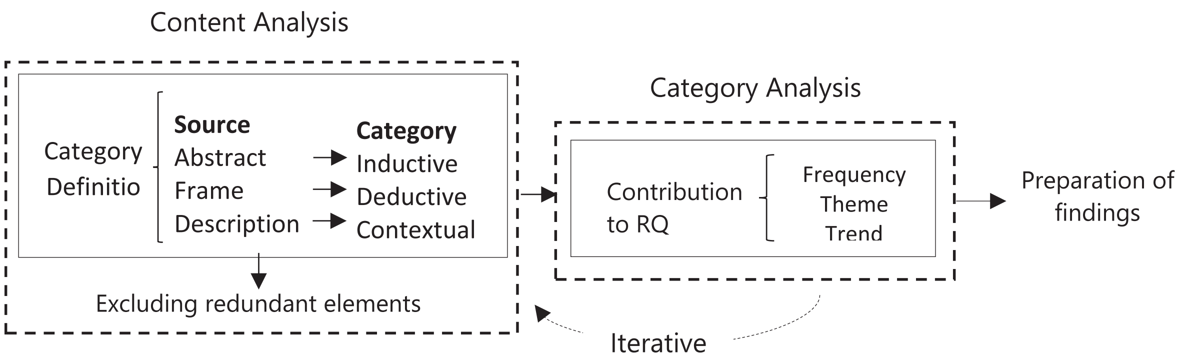

Fig. 3. Representation of the structured revision process.
Source: Authors' own representation.

During the workshop, participants assessed the relevance and feasibility of each indicator. Relevance refers to the degree of the practical usefulness in a real-life context. Feasibility refers to the ease of collecting the information. We estimate the relevance by using absolute frequencies of a 5-point Likert scale (1 extremely irrelevant, 2 irrelevant, 3 neutral, 4 relevant and 5 extremely relevant) per indicator and by using Eq. (1) as follows:

$$RR = \frac{(5^*n_5) + (4^*n_4) + (3^*n_3) + (2^*n_2) + (1^*n_1)}{A^*N} \quad (1)$$

Note: RR = relative relevance; n_5 = number of respondents indicating extremely relevant; n_4 = number of respondents indicating relevant; n_3 = number of respondents indicating neutral; n_2 = number of respondents indicating irrelevant; n_1 = number of respondents indicating extremely irrelevant; A = highest score (5); N = total number of respondents.

Outcomes of the relative relevance analysis are then used to create radar plots. Five experts from universities and public institutions and five stakeholder group representatives assessed the indicators' feasibility using a qualitative scale (low, medium, and high). The feasibility criteria that were used are applicability, execution, and data availability. Applicability refers to the appropriateness, execution refers to the measurement; and data availability involves access to primary data. Absolute frequencies of expert responses were used to generate bar charts.

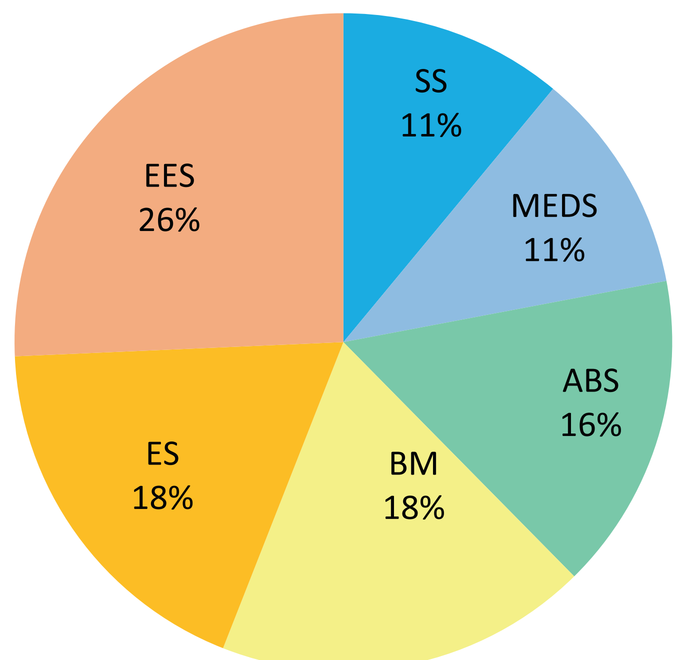

Fig. 4. Distribution of the articles by research subjects.
Source: Authors' own representation based on sample articles in Appendix A.
Note: SS social sciences; MEDS mathematics, economics, and decision sciences; ABS agriculture and biological sciences; BM management; ES environmental sciences; EES energy and engineering sciences.

4. Findings of the Content Analysis and Conceptual Framework

Fig. 4 shows that energy and engineering science contributes 26% (28 papers) of the total sample of 109 articles. This shows a clear interest in the linkage between energy efficiency and the performance of agri-food chains. Management and environmental science contribute 18% (20 articles) to the sample, and 11% (12 articles) come from the social sciences. In the following sections, we look more closely at the sustainability dimensions, the indicators and criteria, and the methodologies used in the sample articles (see Appendix A for the list of articles that provided guidelines to estimate sustainability). We then turn to the content analysis.

4.1. Sustainability Dimensions and Indicators

Table 1 categorizes the sample's articles by sustainability dimension and agri-food chain. We identify articles with single and joint assessments of the three sustainability dimensions (e.g., Van Der Werf and Petit, 2002), namely economic, social, and environmental as single assessments and economic-environmental, socio-economic, socio-environmental, and triple-bottom-line (3BL) as joint assessments (e.g., Chaparro and Calle, 2017; Longo et al., 2017; Thomassen et al., 2009). The organizational dimension is identified in articles across the different categories. In the subgroup of single assessments, the environmental dimension is most frequent in scientific contributions (34%). The economic and the social perspective have received limited coverage (6% and 9% of all manuscripts, respectively). Joint assessments contribute between 11 and 15 articles to the sample. Only 11% (12 articles) tackle the organizational aspect of sustainability, of which 4 articles are single assessments, and 8 articles contribute to the socio-economic subgroup. The identified organizational aspects include supply chain contracts, interdependencies, vertical and horizontal collaboration, cooperation, and transaction costs.

More than 40% of the sample articles examine foodstuffs in general without product specification. Fruits and vegetables and cereals are the most common chains assessed. Dairy, meat, and coffee chains have also received attention in the relevant literature.

Table 1
Distribution of studies by agri-food chain and sustainability dimension (%).

		Sustainability dimension							
		Single			Joint				
		Economic	Social	Environmental	Economic-environmental	Socio-economic	Socio-environmental	3BL	Total %
Agri-food chain	Oil					2 (2)			2
	Cereals	1 (1)	1 (1)	6 (6)	4 (4)	2 (2)*	1 (1)	2 (2)	16
	Honey			1 (1)					1
	Coffee	1 (1)*			1 (1)		4 (4)		6
	Egg-hen		1 (1)	2 (2)					3
	Dairy		1 (1)	1 (1)	1 (1)	1 (1)*	1 (1)	2 (2)	6
	Sugar			1 (1)					1
	Meat products			2 (2)	1 (1)				3
	Fruit & Vegetables		1 (1)	15 (16)	1 (1)	4 (4)*		2 (2)	22
	Wine						1 (1)		1
	Foodstuff	5 (5)*	6 (6)*	7 (8)*	6 (7)	6 (6)*	6 (6)*	6 (6)	40
	Total %	6	9	34	14	14	12	11	100

Source: Authors' own representation based on sample articles in Appendix A.
Notes: * identifies categories that include one or more articles covering aspects of organizational sustainability; 3BL - triple-bottom-line is a framework with a focus on all three sustainability dimensions: economic, social and environmental; xx (xx) – percentage (absolute value) of articles per subgroup.

Next, we discuss the sustainability indicators used in the sample articles. We focus on the sustainability dimensions commonly used in the literature: economic, environmental, and social. The organizational dimension will be discussed in Section 4.3.2. Tables 2a to 2c provide an overview. The economic indicators refer to elements of productivity, profit, and prices. The environmental indicators are related to resource use and ecological consequences. Social indicators refer to the worker, the value chain actor, and the local community. We elicit 13, 16, and 11 indicators for economic, environmental, and social dimensions, respectively. Economic indicators measure the financial situation of value chains (Diener and Suh, 1997). Environmental indicators are metrics of ecological conditions (e.g., energy use, land conservation) (Niemeijer and de Groot, 2008; Schmidt et al., 2014; Tost et al., 2018) to assess environmental objectives, support stakeholders in their decision-making processes and detect trends. Social indicators describe features and operations of populations in an aggregate way (Panagiotakopoulos et al., 2016; Xie, 2016). They evaluate the degree of wellbeing goals achieving (e.g., health, education, and housing).

4.2. Sustainability Assessment Methods

Table 3 categorizes the sample articles based on the assessment method used. We identify twelve methods and group them into four categories. The integrated assessment (IA) method is the most common in articles (52%). This method stresses the appropriateness of indicators and uses qualitative and quantitative tools (Hasna, 2009; Moustier and Leplaideur, 1999; Wustenberghs et al., 2015). The integrated assessment method allows applying frameworks and tools (e.g., interviews, chain schemes) to cover sustainability dimensions jointly (see the red dashed box in Table 3). A drawback is that many articles that use IA remain conceptual and lack an application to real-life settings. The second most common category includes articles using life-cycle assessments (LCA) and variations (life-cycle costing, social life-cycle) (27%). This method has been mainly used to assess the environmental dimension (Engert and Baumgartner, 2016; Luo et al., 2009; Dreyer et al., 2006). Third, we identify the interdependency assessment category, which evaluates mutual relationships (e.g., economic and environmental). This includes mathematical optimization, input-output models, cross-case analysis, cluster analysis, cost-benefit analysis, and participatory design. These methods contribute 16% of articles in the sample, and almost half of them have examined economic-environmental sustainability. The fourth category includes articles using a multi-criteria approach, contains fuzzy logic, analytical hierarchy process, and data envelopment analysis (e.g., Cornelissen et al., 2001; Van Cauwenbergh et al., 2007) and contributes 5% of articles.

Fig. 5 presents the occurrence of assessment methods in articles in the period from 1997 to 2018. The integrated assessment approach have been published throughout this period. LCA approach emerged in 2008 but has taken off rapidly since 2012. Interdependency and the multi-criteria approaches have gained popularity in recent years.

So far, we have categorized the articles based on their coverage of the sustainability dimensions, the agri-food chains they focus on, and their assessment method. We have also provided an overview of the indicators. The next section will discuss the chain configurations and coordination mechanisms in supply chains sustainability.

4.3. Content Analysis

The content analysis will be based only on the articles covering the aspects of interest for developing a comprehensive conceptual framework in Section 5: i) joint sustainability dimensions and ii) the integrated assessment as the method for evaluation. The joint sustainability dimensions encompass economic, ecological, and social performance. The integrated assessment method is flexible in introducing variables, its extensive application in the literature, and its capacity to include multiple analysis tools. In total, 27 papers present these features.

4.3.1. Chain Configurations

The chain configurations, also called chain arrangements, are essential for determining supply chain sustainability. Chain configurations include features such as the actors, functions, and the existing linkages between stages. Fig. 6 shows seven chain configurations (and frequencies) derived from the 27 selected papers. We distinguish configurations of only one chain-stage (single, e.g., production) and multiple chain stages (multi-stage, e.g., production and distribution). The production is the most examined stage (58%). Articles focusing on the processing stage represent 3% of the sample, whereas the literature search identified no studies on the distribution stage. Articles covering multi-stage configurations (production-processing, production-distribution, and processing-distribution) represent 24% of all contributions. About 15% of the articles consider the whole chain (cases of multinationals) in their analysis. The next section will look at the interlinkages or coordination mechanisms of the chain stages.

4.3.2. Coordination Mechanisms

We identify 12 articles within the full sample of 109 documents that examine coordination mechanisms as one aspect of sustainability in agri-food supply chains. Table 4 presents the vertical and horizontal indicators. Vertical indicators tackle coordination between trading partners, and horizontal indicators address coordination between

Table 2a
Economic indicators retrieved from the structured literature review.

Economic													
Category	Productivity					Profit							Price
Indicator	Labour productivity	Capital productivity	Total factor productivity	Patent	R&D	Return on assets	Return on capital employed	Return on equity	Return on sales	Debt as financing	Own financing	Training	Price volatility
Measurement unit	Ratio	Ratio	Ratio	Level	Level	Ratio	Ratio	Ratio	Ratio	Level	Level	Level	Ratio

Source: Authors' own representation based on sample articles in Appendix A.

Table 2b
Environmental indicators retrieved from the structured literature review.

Environmental																
Category	Resource use												Ecological consequences			
Indicator	Water use	Irrigation water productivity	Water conservation	Organic matter use	Organic matter productivity	Agrochemical use	Fossil Fuel Use	Crop diversification	Crop rotation	Electricity use	Deforestation	Land conservation	CO2 emissions	Acidification potential	Food loses	Training
Measurement unit	ha/m^3	kg/m^3	Ratio	ha/kg	Ratio	kg/ha	%, J, cal, kWh	Ratio	Ratio	Watts/week	Ratio	Ratio	kg CO2 equivalent	g SOx equivalent	Ratio	Level

Source: Authors' own representation based on sample articles in Appendix A.

Table 2c
Social indicators retrieved from the structured literature review.

Social											
Category	Worker								Value chain actor		
Indicator	Ethnicity	Gender	Age	Education level	Child labour	Salary ranges	Working hours range	Migration	N-firm concentration	Activation of social insurance	Customer satisfaction
Measurement unit	Share	Share	Share	Share	Share	Range	Range	Rate	Market share	Level	Score

Source: Authors' own representation based on sample articles in Appendix A.

Table 3
Distribution of studies by assessment method and sustainability dimension (%).

		Sustainability dimension							
		Economic	Social	Environmental	Economic-environmental	Socio-economic	Socio-environmental	3BL	Total
IA	Integrated assessment	2 (2)	6 (6)	8 (8)	9 (9)	10 (10)	9 (9)	8 (8)	52
LCA	Life-cycle-assessment (LCA)			23	2 (2)		1 (1)	2 (2)	27
Interdependency assessment	Mathematical optimization			1 (1)	1 (1)	1 (1)		1 (1)	4
	Input-output model IO				1 (1)	1 (1)			2
	Cross Case analysis	1 (1)	2 (2)	1(1)			1 (1)		5
	Cluster Analysis					1 (1)			2
	Cost-benefit-analysis	1 (1)							1
	Participatory design		1 (1)				1 (1)		2
Multi-criteria approach	Fuzzy Logic	1 (1)							1
	Analytical Hierarchy Process (AHP)	1 (1)		1 (1)					2
	Data Envelopment Analysis (DEA)				1 (1)				1
	Hybrid Fuzzy-AHP-DEA					1 (1)			1
	Total	6	9	34	14	14	12	11	100

Source: Authors' own representation based on sample articles in Appendix A.
Notes: xx (xx) – percentage (absolute value) of articles per subgroup.

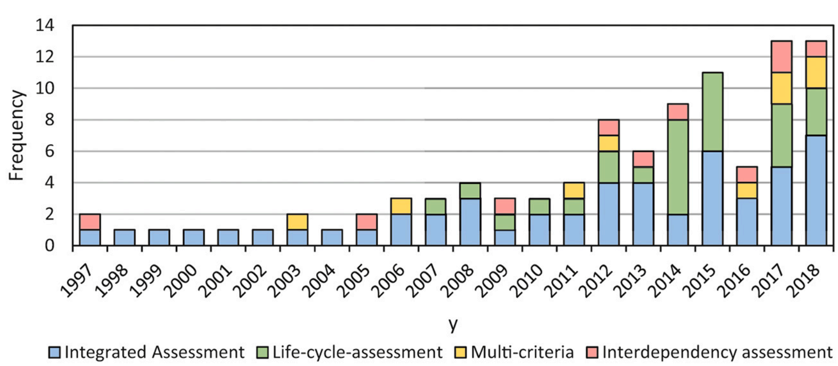

Fig. 5. Distribution of assessment methods by year.
Source: Authors' own representation based on sample articles in Appendix A.

organization members.

4.4. A Conceptual Framework for Assessing Sustainability in Agri-Food Supply Chains

Assessing the sustainability of agri-food chains as a whole requires a multi-stage analysis and identification of vertical and horizontal mechanisms. The comprehensive framework presented in Fig. 7 incorporates includes the three key aspects of joint sustainability dimensions, a multi-stage analysis, and vertical and horizontal relationships. These three core aspects are operationalized using an integrated sustainability performance assessment methodology, with suitable indicators and analytical tools based on the chain context. The novelty and comprehensiveness of the framework lie in integrating the core dimensions of sustainability with characteristics of the supply chain, namely individual chain stages and interconnections between these stages.

5. Results of the Framework Testing

Figs. 8, 9, 10, 11a, and 11b show the relevance perception of the framework's indicators. Radar plots present the perception of each stakeholder's group.

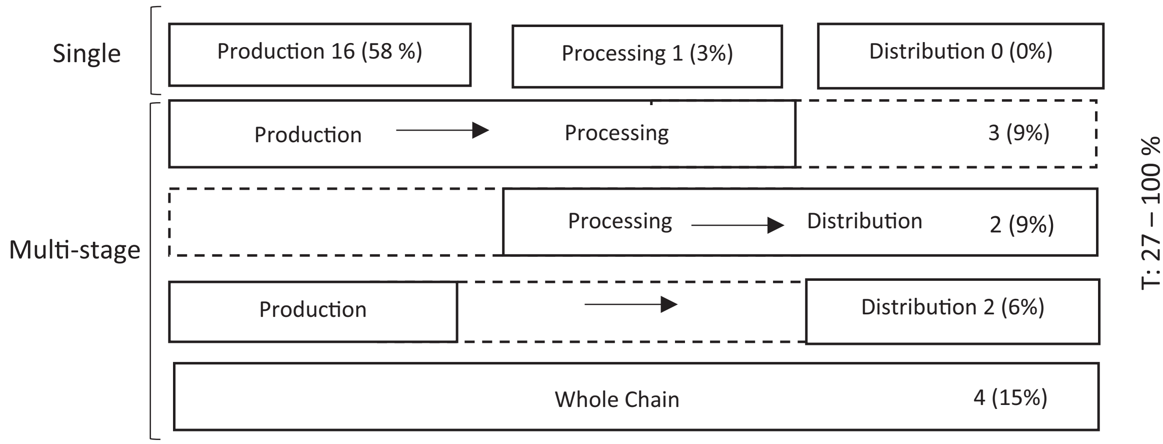

Fig. 6. Chain-stage modes retrieved through the content analysis.
Source: Authors' own representation based on sample articles.
Note: xx (xx%) number of articles (share in the 27 sample articles).

5.1. Economic Dimension

Fig. 8 shows the relative relevance of economic indicators according to the stakeholders. All stakeholder groups put forward *price volatility*, *return on sales*, and *training level* as highly relevant indicators. On average, *research and development (R&D) and return on equity* are regarded as the least pertinent. Indicators such as *capital productivity*, *total factor productivity*, show a discrepancy of relevance perception between groups.

5.2. Environmental Dimension

Three out of sixteen environmental indicators are scored extremely relevant by all the groups (Fig. 9). These indicators are *CO_2 emissions*, *food losses*, and *training levels*. *Water conservation* and *fossil fuel use* scored with high. O*rganic matter productivity* and *potential acidification* indicators have significant differences in relevance perception.

5.3. Social Dimension

Fig. 10 shows that *working hours range* and *salary range* indicators are deemed highly relevant across stakeholders. *Ethnicity and age distribution* are scored as less relevant by the stakeholders. Indicators such as *customer satisfaction,* and *migration rate,* show a discrepancy in the relevance perception of different stakeholder groups.

5.4. Coordination Dimension

Fig. 11a and Fig. 11b show the relative relevance allocated by stakeholder groups to each coordination indicator. Within the vertical indicators (coordination between trading partners), stakeholders find the *interaction frequency*, *informal transactions*, and *written contracts* the most relevant to agri-food sustainability. I*nformation sharing* is scored as less relevant by the stakeholders. The relevance of *trust* and *distribution of bargaining power* show significant discrepancies between stakeholders.

Regarding the horizontal indicators (coordination between organization members), the stakeholders consider *association and cooperative memberships* as extremely relevant indicators. Indicators such as *membership duration* and *interaction frequency within organizations* also score high relevance values across groups. *Trust level* and *informal/formal interaction frequency* have the lowest relevance.

5.5. Feasibility Analysis

Fig. 12 shows that *training, return on sales,* and *financing sources* – own and debt- are regarded as the most feasible economic indicators. P*rice volatility* is assessed as medium-feasible by experts due to limited information availability. *R&D* is considered the least feasible indicator for an assessment across all chain levels.

Experts and stakeholder representatives indicate the *training level* as the most feasible environmental indicator (Fig. 13). *CO2 emissions*, *food losses,* and *water use* are reasonably feasible with current technological tools. *Land conservation* and *acidification potential* are considered not feasible in a supply-chain context.

Fig. 14 shows that experts consider *salary* and *working hours range* very feasible to assess the social aspect. *Social insurance activation* and *migration rate* are deemed workable as long as secondary data support the assessment. *Customer satisfaction* is seen as the most impractical indicator by experts.

Fig. 15a and Fig. 15b show the feasibility of coordination indicators. Concerning the vertical indicators, experts see *interaction frequency*, *information sharing*, and *informal transaction frequency* as the most feasible indicators. Indicators such as the *written contract frequency*, *relationship duration,* and *trust level* have medium feasibility. B*argaining power distribution* is the least feasible because it demand too much effort.

Concerning the horizontal indicators, the experts consider *association / cooperative membership* as highly feasible indicators. Medium feasibility is assigned to the *organization frequency interaction* and *membership duration*. *Written contracts* and *informal interaction* have the lowest feasibility.

6. Discussion

This paper aimed to develop a comprehensive sustainability assessment framework for agri-food supply chains. Specific attention was paid to the assessment across chain stages. The coordination across chain stages and its connection with sustainability is integrated into the framework. This is the study's major contribution to the literature, which currently lacks the integration of the multi-stage element. The framework developed is tested in the context of fruit and vegetable chains. The following sections discuss the research about the existing literature, practical implications and its limitations.

6.1. Joint Sustainability Dimensions and the Integrated Assessment Method

The structured literature review shows that most of the existing research is focused on the environmental dimension of sustainability. This focus can be explained by the attention of agricultural stakeholders and the community for scarcity of resources (e.g., irrigation water) and

Table 4
Coordination indicators retrieved from the structured literature review.

Category	Vertical						Horizontal											
	Price, quality, quantity						Cooperation					Collaboration					Empowerment	
Indicator	Contract Formality	Price Setter	Contract Duration	Contract Compliance	Transaction Simplicity	Device Type	Duration	Material Resources Affordability	Human Capital Availability	Task Efficiency	Communication Level	Duration	Adaptation Level	Task Compliance	Tolerance Level	Communication level	Social Integration Activities	Proactiveness Level
Measurement unit	Relative share	Lead firm	d	Ratio	Perception	Written, verbal agreement	d	Ratio	Ratio	Ratio	Score	d	Score	Ratio	Score	Score	Relative share	Score

Source: Authors' own representation based on sample articles.

the restoration of critical impacts (Lejars et al., 2012). Govindan (2018) suggests that improving agri-food sustainability requires that stakeholders' goals cover a broad spectrum of purposes and users.

Sustainability research in recent years increasingly covers the multiple dimensions of sustainability jointly. Public and private actors increasingly call for integrated approaches to replace one-dimensional assessments. This is supported by Grimm et al. (2016), who find that firms are increasingly writing reports on economic, environmental, and social outcomes. Joint sustainability dimensions boost the integrated assessment by allowing stakeholders to critically analyze their impacts (Lee et al., 2021; Lie et al., 2012). A comprehensive framework, therefore, covers all three sustainability dimensions.

Assessment methods are diverse and include integrated assessments, life cycle assessments, interdependency assessments, and multi-criteria approaches. The main reason for this diversity is the multitude of sustainability dimensions ranging from environmental standards to corporate social responsibility. The diversity in methods brings challenges in terms of the interpretation and communication of outcomes. This claim is supported by De Olde et al. (2016), who find that producers hesitate to apply assessment tools because of the low degree of user-friendliness. Manfredi et al. (2018) support the demand for flexible methods to operationalize the assessment of agri-food sustainability. The comprehensive assessment framework developed in our research is based on an integrated approach, and it is tested for relevance and feasibility to facilitate the interpretation of outcomes.

6.2. Multi-Stage Analysis and Vertical and Horizontal Mechanisms

The literature on agri-food chain sustainability assessment mostly analyzes single-chain stages. The most evaluated is the production stage. The dominance of single-stage analyses can be explained by the complexity of assessing across different chain stages. For Biénabe et al. (2017) this complexity is due to geographical and sector-specific conditions. El Bilali (2019) also finds that legislation, policies, and standards at each supply chain stage complicate across-stage comparisons. Hassini et al. (2012) also claim that small and medium-sized enterprises are of limited concern to evaluators, which leads to key chain stages being ignored in assessment frameworks. Our comprehensive sustainability assessment framework covers multiple chain stages (from input supply to distribution and retail) and builds on a participatory approach. Future research could further explore the implications of integrating the consumption stage.

Including multiple supply chain stages in the analysis begs how these stages are interrelated and what this means for sustainability. Arshinder and Deshmukh (2008) argue that there is a lack of attention for the coordination dimension when assessing supply chain performance. Our structured literature review shows that the existing literature is still immature in defining the relationship between supply chain coordination and sustainability. Craven et al. (2016) find few connections between farmers' horizontal relations and economic performance and suggest more investigation on the relationship between farmers' ecological commitment and fair price mechanisms. We find agreement in the literature regarding the inclusion of coordination mechanisms being important in the multi-stage. The comprehensive sustainability assessment framework, therefore, includes both vertical and horizontal coordination indicators. These indicators support smallholders and small- and medium-sized enterprises in adopting sustainability practices.

Some studies within the sustainability assessment literature of agri-food chains seek to comprehend the connection between sustainability and chain coordination. Topics of these studies include the link between interdependencies and cooperation to reduce negative socio-economic or environmental impacts (Severo et al., 2018). Stakeholders committed to sustainable development could lean on the sustainability-oriented coordination where responsibilities are clearly stated. Future research can further explore sustainability-oriented coordination to

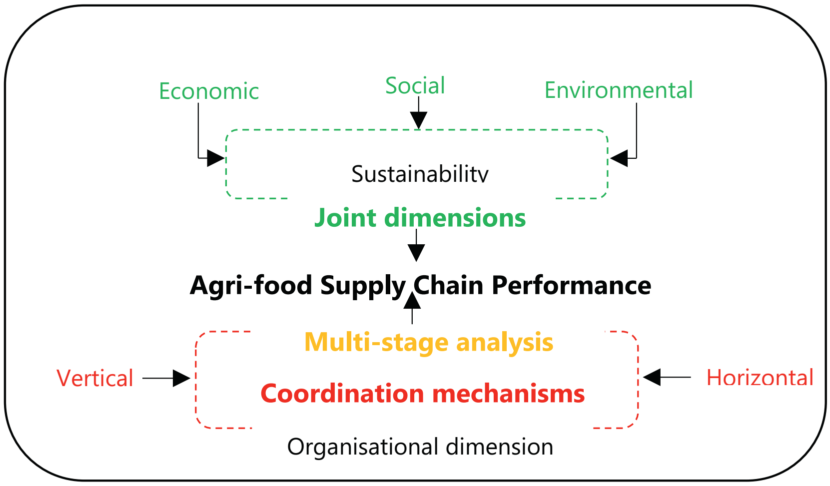

Fig. 7. A conceptual framework for assessing sanustainability performance.
Source: Authors' own representation

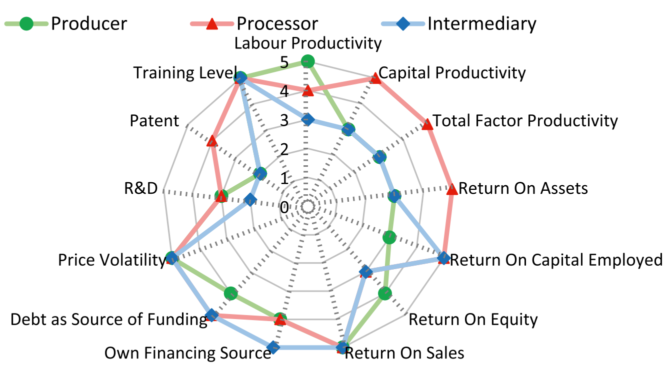

Fig. 8. Relevance of economic sustainability indicators.
Source: Authors' own representation.

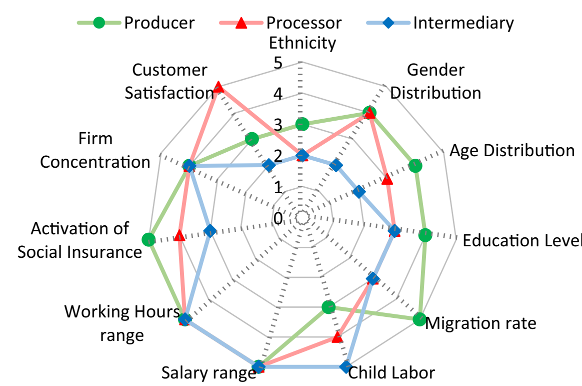

Fig. 10. Relevance of social sustainability indicators.
Source: Authors' own representation.

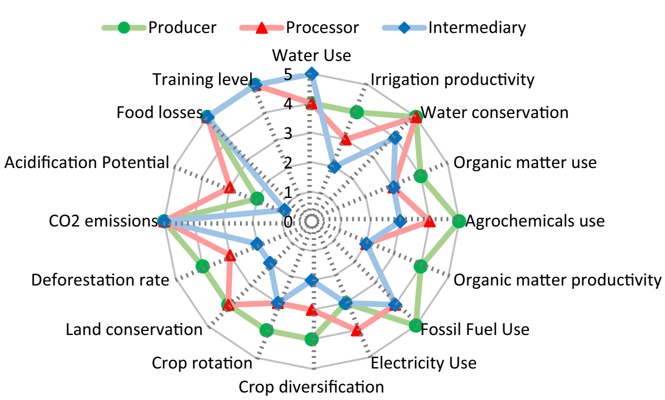

Fig. 9. Relevance of environmental sustainability indicators.
Source: Authors' own representation.

derive the best practices. This may involve the inclusion of non-traditional actors, such as financial organizations or policymakers.

6.3. *Architecture of the Comprehensive Framework*

A broad range of appraisal methods responds to concerns recognised by the scientific community, chain actors, and policymakers. Concerns include the comprehensiveness of the framework and its robustness. Malak-Rawlikowska et al. (2019) and Roy and Chan (2012) strongly suggest that frameworks should move from a partial perspective towards an integrated and transdisciplinary approach (van der Ven, 2015; Sala et al. (2015). In this context, our assessment framework aims not to define an optimal framework but to define essential foundations. These specifications are joint sustainability dimensions, multi-stage chain analysis, vertical and horizontal mechanisms, and operationalization by applying an integrated assessment approach. The agri-food sustainability assessment literature suggests considering trade-offs between theory-based and empirical-based designs. This may also map out the steps forward to fulfill contextual perceptions that are vital in scientific research.

6.4. *Practical Implications*

The architecture of the framework enables us to advance towards transdisciplinarity. Fig. 6 represents the three foundations of the sustainability assessment framework. The first foundation, joint sustainability dimensions – economic, social, and environmental, is shown in green to indicate that this aspect is more frequently investigated. The second foundation is the multi-stage approach colored in yellow because it is less regularly incorporated. The third foundation is the coordination dimension composed of vertical and horizontal mechanisms and shown in red because it is an element of novelty in the sustainability assessment in agri-food chains.

The joint assessment of the sustainability indicators allows chain actors to evaluate trade-offs in performance on economic, environmental, and social dimensions. The weighting of the dimensions would

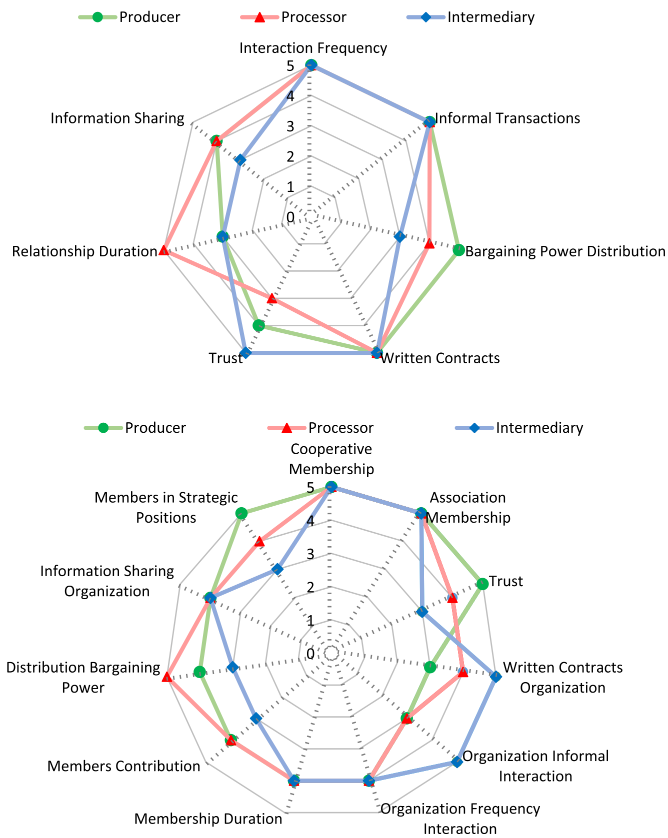

Fig. 11. a. Relevance of vertical coordination framework indicators. b. Relevance of horizontal coordination framework indicators.
Source: Authors' own representation.

reflect context-specific needs and priorities. Trade-offs may exist across sustainability dimensions and should be incorporated in a comprehensive sustainability assessment.

The foundation of the multi-stage approach identifies the supply chain as the unit of analysis. It aims at incorporating information by actor, chain stage, linkage, or function. Scholars could apply this foundation to expand knowledge and distribute research benefits among chain actors. It also allows the framework to be used as a support tool. For instance, evidence of differences in sustainability performance between supply chains could be brought back to individual chain stages and may guide policymakers in supporting the development of specific chain stages or supply chains as a whole. The versatility of this foundation allows investigating single or multiple stages of supply chains. This may also aid supply chain actors and policymakers in indentifying the chain's priorities, regulative developments, and sustainable progress.

The foundation of coordination allows researchers and other stakeholders to explore the sustainability-coordination nexus further. Coordination indicators have the potential to cause a positive impact on the economic, environmental, and social performance at each chain stage and linkage. Chain actors can use information collected through this foundation to design strategies to foster competitiveness. For scholars and policymakers, it is essential to construct a solid contextualization of the chain before implementing the core foundations of the assessment framework. This contextualization should tackle political, ecological, social, technological, and legal aspects.

The results of the testing of the framework also lead to some practical implications. Relative relevance perceptions and feasibility assessment provide insights for practitioners about the most promising indicators to include in an assessment. The relevance allows connecting relevant indicators on the one hand with specific chain stages on the other hand. Feasibility results provide researchers and practitioners with guidance to quickly identify the most feasible indicators in fieldwork and evaluation. The study also provides the user with insights into assessment implementation. The review suggests to scholars and policymakers the aggregation of temporal scales by applying an ex-ante and ex-post evaluation and the cross-comparison of outcomes across supply chain stages.

Our research also has some limitations that scholars, policymakers, and chain actors should be aware of. First, the authors only considered peer-reviewed journals in their review. Significant knowledge may be found in other sources such as books, Ph.D. theses, and business papers. Second, even though the authors tried to employ appropriate search terms, some relevant terms may have been excluded (e.g., bioeconomy or circular economy). Third, representatives of environmental public institutions did not attend the participatory workshop; thus, the ecological view may have been underrepresented. Fourth, responses from fruits and vegetable stakeholders could portray only a part of the

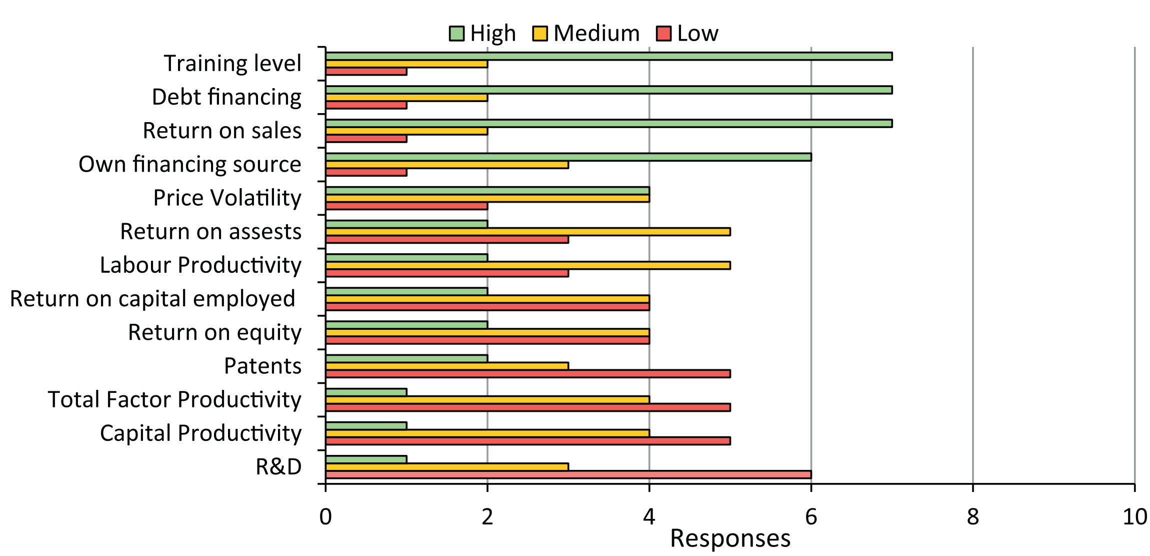

Fig. 12. Feasibility of economic framework indicators.
Source: Authors' own representation.

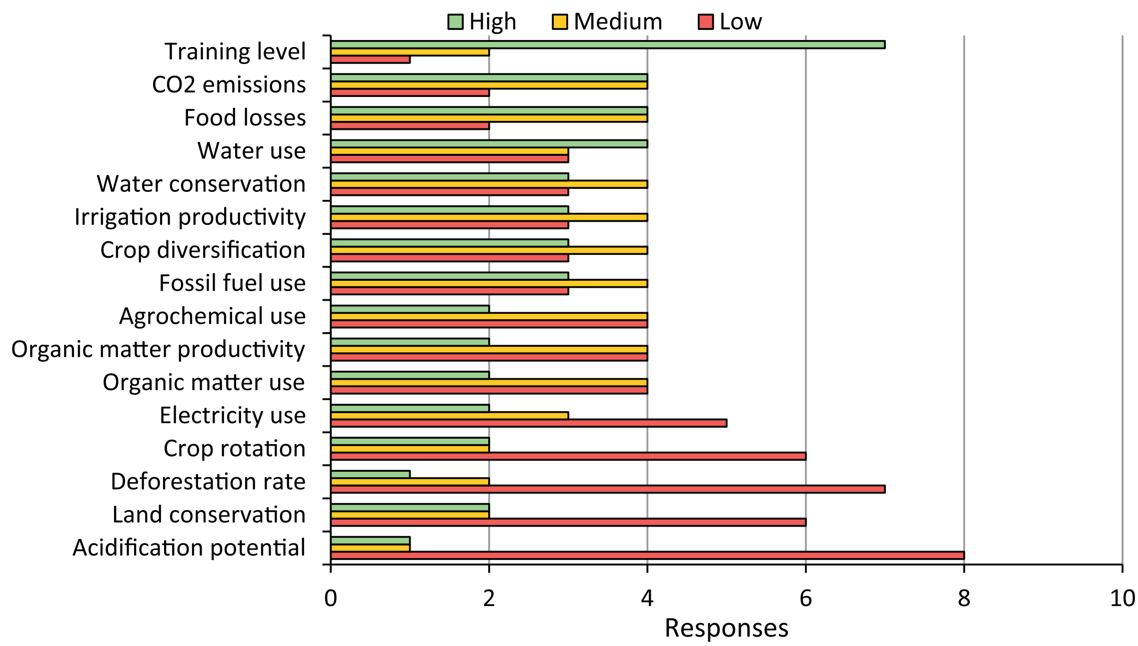

Fig. 13. Feasibility of environmental framework indicators.
Source: Authors' own representation.

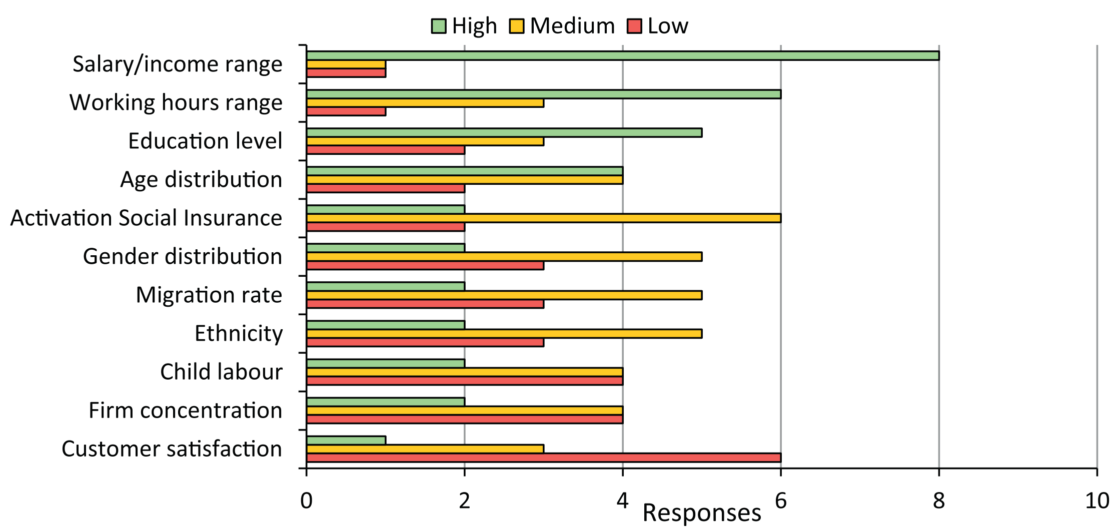

Fig. 14. Feasibility of social framework indicators.
Source: Authors' own representation.

sustainability challenges of the whole agri-food system since, for instance integrated supply chain would probably include more coordination and sustainable criteria.

7. Conclusions

This study performed a structured literature review of sustainability assessment frameworks in agri-food supply chains. Based on the structured literature review, we developed a comprehensive framework for measuring sustainability performance and tested this for relevance and feasibility. Four key findings follow from the study. First, the sustainability assessment framework developed in this article adds a relevant contribution to the existing literature on sustainability assessments. The proposed foundations of the framework operate as guidelines to generate insights into sustainability assessment implementation. Second, comprehensiveness, user-friendliness, transdisciplinarity, and robustness are imperative aspects of framework development. Methods need testing and validation to boost the interpretation and communication of outcomes, as was done in the participatory workshop in this research. Third, when the studied context is the agri-food sector, the joint dimensions approach and the supply chain as a unit of analysis are the most suitable foundations. The joint dimensions approach allows for understanding the relationships between economic, environmental, and social sustainability aspects. As a unit of analysis, the supply chain allows comprehending how stages are interrelated and what this means for sustainability performance. Fourth, due to the nature of chain-stage connections, coordination mechanisms are key to developing organizational models to optimize economic utility, social welfare, and

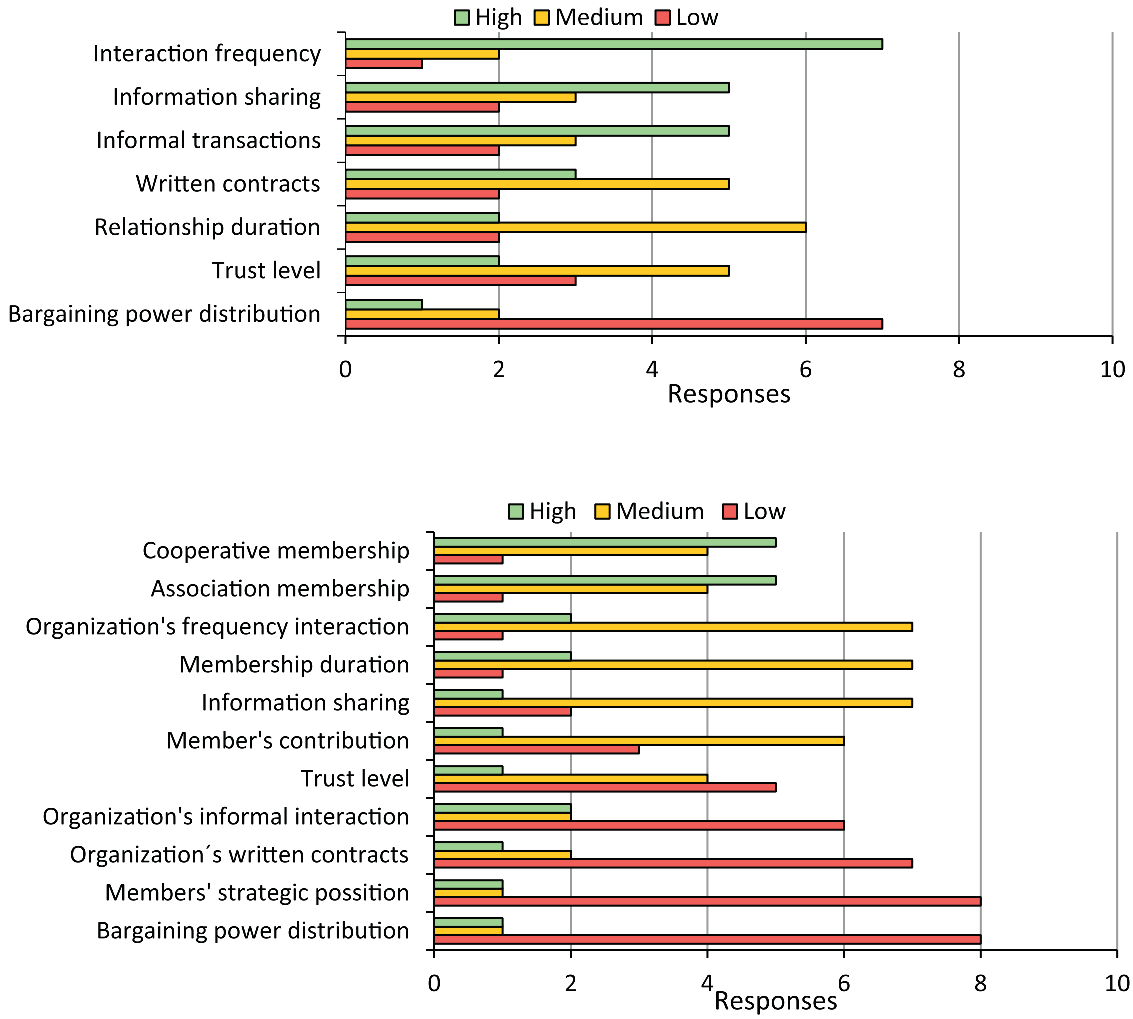

Fig. 15. a. Feasibility of vertical coordination framework indicators. b. Feasibility of horizontal coordination framework indicators.
Source: Authors' own representation.

ecological resilience.

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Declaration of Competing Interest

This manuscript has not been published and is not under consideration for publication elsewhere. **We have no conflicts of interest to disclose.** The Technical University of Ambato provided the funding of the resources used to carry out the research. The funds used for in situ visits, information gathering, data collection, and interpretation of results. Finally, I would like to extend an **acknowledgment** to the Faculty of Food Science and Engineering of the Technical University of Ambato to support the development of this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2021.107265.

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