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Original Article

Social Life Cycle Assessment of Rice Production: A Systematic Review and Implications for Sustainable Rural Development

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Abstract

Purpose- Rice production plays a fundamental role in ensuring food security and sustaining rural livelihoods worldwide. Despite its economic importance, rice production systems are often associated with social challenges such as inadequate working conditions, income inequality, and occupational health risks.

Design/methodology/approach- This study systematically reviews the application of Social Life Cycle Assessment (S-LCA) in rice production systems with a focus on its contribution to sustainable rural social development. A systematic review was conducted following the PRISMA protocol. Relevant studies were retrieved from international scientific databases, and after screening, the selected studies were analyzed based on stakeholder groups, social indicators, assessment approaches, and reported social impacts.

Finding- The resuls reveal that occupational health and safety, fair wages, labor rights, and the well-being of farmers are the most frequently assessed social issues. Organic and socially oriented production systems generally demonstrate better social performance than conventional systems. However, concerns such as child labor, labor exploitation, and unequal access to economic opportunities remain evident. Most existing studies focus primarily on workers and farmers, while broader dimensions of rural social development, including social resilience and community participation, receive considerably less attention. The limited number of available studies and methodological heterogeneity highlight the need for greater standardization in future S-LCA research.

Originality/value- The results emphasize the importance of incorporating social dimensions into agricultural policies and demonstrate the potential of S-LCA as a decision-support tool for promoting socially sustainable rice production systems. This study provides an integrated synthesis of S-LCA applications in rice production and explicitly links social life cycle assessment outcomes to sustainable rural social development.

Keywords- Rice production; Social life cycle assessment; Social sustainability; Sustainable rural development; Rural livelihoods; Sustainable agriculture.

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1. Introduction

Sustainable development has emerged as one of the most influential global paradigms for improving human well-being while safeguarding natural resources. Since its formal introduction in the Brundtland Report, the concept has emphasized balancing environmental, economic, and social dimensions to meet present needs without compromising the ability of future generations to meet their own needs (Akinsemolu & Onyeaka, 2025). Within this framework, the social dimension of sustainability encompasses issues such as social equity, public welfare, equitable access to resources, and food security, all of which play a fundamental role in achieving long-term sustainability (Eghbali et al., 2021).

Sustainable rural development comprises economic, environmental, and social dimensions. Among these, social sustainability represents a key pillar, emphasizing equitable resource distribution, community cohesion, livelihood security, and workers' well-being. Neglecting this dimension may result in increasing inequalities and the erosion of social capital within rural communities. Agriculture plays a critical role in this regard, not only as a source of food and employment but also as a driver of social stability, poverty reduction, and livelihood improvement in rural areas (Salahi Esfahani, 2018). Consequently, the sustainability of agricultural systems extends beyond productivity enhancement and requires simultaneous attention to social welfare, employment security, and the quality of life of rural populations.

Among agricultural commodities, rice (*Oryza sativa* L.) occupies a particularly important position. More than 3.5 billion people, nearly half of the world's population, rely on rice as a staple food source. Rice cultivation is practiced on over 160 million hectares worldwide and contributes substantially to food security and rural livelihoods, particularly in tropical and subtropical regions (FAO, 2024). In many rice-producing areas, rice serves as the backbone of rural employment, household income, and agricultural identity. Consequently, any changes occurring within rice production, processing, or distribution systems may directly affect the social well-being of rural communities. Evaluating such impacts within a social sustainability framework is therefore essential for achieving sustainable rural development.

Social Life Cycle Assessment (S-LCA) provides a suitable framework for addressing this challenge. By identifying and assessing social impacts across different stakeholder groups—including workers, farmers, and local communities—S-LCA enables the detection of social strengths and weaknesses throughout the rice production chain and supports evidence-based policymaking toward sustainable rural development (Benoît-Norris et al., 2011; Petti et al., 2018). In this context, S-LCA should not be viewed merely as a technical assessment tool; rather, it can serve as a decision-support approach for rural development planning and policy formulation. Through the systematic identification of vulnerable groups, social inequalities, and critical hotspots within production systems, S-LCA facilitates the design of more effective development interventions and social support policies (Benoît-Norris et al., 2011; Petti et al., 2018; Wei et al., 2022).

Despite the strategic importance of rice production for food security and rural livelihoods, previous research has predominantly focused on its environmental and economic dimensions, whereas social impacts have received comparatively limited attention (Nabavi-Pelesaraei et al., 2019). Issues such as wage inequality, poor working conditions, and health risks associated with pesticide exposure remain significant social concerns throughout rice production systems. The continued neglect of these issues may contribute to unsustainable policy decisions and exacerbate social disparities between rural producers and urban consumers (Kalvani et al., 2022). Furthermore, the fragmented and heterogeneous nature of existing studies has limited the ability of policymakers and rural development planners to identify and prioritize key social challenges within rice production systems effectively.

In response to these concerns, S-LCA has been developed as a component of Life Cycle Sustainability Assessment (LCSA) to evaluate the social and human impacts of products and services throughout their life cycles (Zarauz et al., 2025). Together with Environmental Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), S-LCA contributes to the comprehensive assessment of sustainability across environmental, economic, and social dimensions (Wei et al.,

2022). Existing guidelines emphasize stakeholder groups such as workers, farmers, local communities, consumers, and society at large, while addressing issues including working conditions, health and safety, welfare, food security, and social justice (Petti et al., 2018).

Nevertheless, the application of S-LCA within agriculture, particularly in rice production systems, remains comparatively limited and is still at an early stage of methodological development (Vinci et al., 2023). Many existing studies rely on generalized indicators and pay insufficient attention to the social and cultural complexities inherent in rice production systems (Jørgensen et al., 2008). Moreover, methodological challenges persist, including the lack of consensus regarding functional units, difficulties in defining system boundaries, the qualitative nature of many social indicators, and limited availability of reliable social data (Garfí et al., 2025). These challenges are especially important in agricultural systems, where social impacts are strongly shaped by local institutional, cultural, and socioeconomic conditions (Mancini et al., 2023).

Current research gaps can be classified into three major categories. First, methodological inconsistencies remain regarding functional units, system boundaries, and assessment approaches. Second, limitations associated with social data availability and the quantification of qualitative variables constrain the robustness of assessments. Third, conflicts of interest among different stakeholder groups within rice value chains create additional challenges for comprehensive social evaluation.

Given these limitations, systematic review studies can play an important role in synthesizing existing knowledge and identifying research trends, methodological challenges, and knowledge gaps regarding S-LCA applications in rice production. The diversity of social indicators, inconsistencies in methodological choices, and insufficient coverage of stakeholder groups have reduced the comparability and transferability of findings, thereby limiting their usefulness for policymaking. As a result, the absence of a comprehensive synthesis hinders efforts to improve farmers' welfare, reduce social vulnerability, and enhance social sustainability in rice-producing regions.

Therefore, this study aims to provide a systematic and comparative review of the application of S-LCA in rice production systems. Specifically, it seeks to identify commonly used social indicators, examine stakeholder representation, analyze methodological heterogeneity, and highlight key research gaps. Furthermore, the study aims to explore similarities and differences in functional units, system boundaries, and indicator quantification approaches to enhance conceptual consistency and improve the comparability of future studies. Ultimately, the research seeks to contribute to the practical use of S-LCA findings in rural development policymaking, the improvement of farmers' quality of life, and the strengthening of social sustainability within agricultural systems.

The specific objectives of this study are:

1. To identify and classify the most frequently used social indicators in S-LCA studies related to rice production, with particular emphasis on indicators affecting social sustainability and rural well-being;
2. To comparatively analyze stakeholder vulnerability patterns across different rice production systems;
3. To examine methodological heterogeneity in functional units, system boundaries, and indicator quantification approaches; and
4. To provide recommendations for improving conceptual consistency, enhancing study comparability, and adapting S-LCA frameworks to support sustainable rural development policies.

2. Research Theoretical Literature

2.1. Social Sustainability

Although sustainable development has become one of the most widely used concepts in development studies since the publication of the Brundtland Report, scholarly and policy attention has historically focused more on its economic and environmental dimensions, while the social dimension has received comparatively less consideration (WCED, 1987; Littig & Griessler, 2005). However, numerous scholars argue that neither economic nor environmental sustainability can be maintained in the absence of social sustainability, as it is ultimately human societies that are responsible for conserving resources, sustaining productive activities, and transferring development achievements to future generations (Sachs, 1999; Vallance et al., 2011).

Within the rural development literature, social sustainability extends beyond improvements in

welfare indicators or poverty reduction. It refers to the capacity of rural communities to maintain social cohesion, reproduce social capital, improve quality of life, ensure equitable access to opportunities, and facilitate meaningful participation in decision-making processes (Dempsey et al., 2011). From this perspective, sustainable rural development cannot be reduced to agricultural productivity growth or income expansion. Rather, it requires conditions under which different social groups can benefit equitably from development outcomes and maintain resilience in the face of economic, social, and environmental challenges (McKenzie, 2004).

Agriculture, as the dominant economic activity in many rural regions, plays a decisive role in shaping the various dimensions of social sustainability. Employment opportunities, livelihood security, occupational health, income distribution, food security, and the quality of social relationships within rural communities are often closely linked to the organization and functioning of agricultural systems. Consequently, assessing social sustainability in agriculture involves more than measuring isolated social outcomes; it seeks to understand how production systems influence human well-being, social justice, and the development capacity of local communities (Missimer et al., 2017). Evidence from other agricultural activities also confirms that rural sustainability depends on the simultaneous consideration of social, economic, and environmental dimensions, and that agricultural production can contribute differently to each of these dimensions across rural communities (Dehban Nejadian et al., 2023).

The social dimension of sustainability becomes particularly important in the production chains of strategic agricultural commodities such as rice. Beyond its role in ensuring food security, rice production supports the employment, income, and livelihoods of millions of rural households worldwide. Therefore, changes in the production, processing, and distribution of rice may generate substantial social consequences for local communities. Assessing working conditions, occupational health and safety, livelihood security, income distribution, and other social indicators throughout the rice value chain can thus be regarded as an integral component of sustainable rural development assessment.

Moreover, the social sustainability of agricultural communities is influenced not only by production-related conditions but also by their wider spatial and socio-economic relationships. Evidence from a rice-producing rural area in Guilan, Iran, showed that rural–urban linkages significantly affected the social, economic, and cultural dimensions of rural households' lifestyles, including behavioral patterns, income-related activities, consumption patterns, and cultural change (Asheri-Gafsheh & Yasouri, 2024). These findings highlight the importance of considering the broader rural development context when interpreting the social consequences of agricultural production systems.

In recent years, increasing attention has been devoted to developing tools capable of systematically evaluating the social dimensions of production systems. Among these tools, Social Life Cycle Assessment (S-LCA) has emerged as one of the most prominent approaches for assessing the social impacts associated with products and services throughout their life cycles. Understanding the capabilities and limitations of this approach, however, requires a thorough examination of its conceptual and theoretical foundations, which are discussed in the following section.

2.2. Social Life Cycle Assessment

Social Life Cycle Assessment (S-LCA) emerged from the recognition that evaluating the sustainability of products and services solely through economic and environmental indicators provides an incomplete understanding of development outcomes. Although conventional Life Cycle Assessment (LCA) approaches have been successful in quantifying environmental impacts, many social consequences associated with the production, distribution, consumption, and disposal of products have remained beyond the scope of such assessments. Consequently, efforts to develop a systematic framework for assessing social impacts throughout product life cycles gained momentum in the late 1990s and were further strengthened through the publication of the UNEP/SETAC guidelines (UNEP/SETAC, 2009; UNEP, 2020).

The theoretical foundations of S-LCA can be traced to the intersection of three major intellectual traditions. First, the sustainable development paradigm emphasizes the simultaneous consideration of economic, environmental, and

social dimensions of development (WCED, 1987). Second, the human development approach views development as a process of expanding human capabilities, freedoms, and quality of life rather than merely increasing economic growth (Sen, 1999). Third, the literature on social justice and fundamental human rights highlights the importance of labor rights, equal opportunities, human dignity, and equitable access to resources (ILO, 2008; Benoît-Norris et al., 2011). In essence, S-LCA seeks to operationalize these principles within production and consumption systems.

Unlike Environmental Life Cycle Assessment, which primarily focuses on material and energy flows, S-LCA is concerned with people, social relationships, and institutional structures. Its central focus is therefore on stakeholders who are directly or indirectly affected by a product system. According to the UNEP guidelines, key stakeholder groups include workers, consumers, local communities, value chain actors, society, and children, each of whom is evaluated through a set of social impact subcategories and indicators (UNEP, 2020).

A distinctive characteristic of S-LCA is that it does not limit the assessment of social impacts to individual firms or production units. Rather, it seeks to evaluate social consequences throughout the entire life cycle of a product. From this perspective, an agricultural commodity is not merely the outcome of on-farm activities but the product of a complex network of economic, social, and institutional relationships extending from input supply to final consumption. Consequently, issues such as occupational health and safety, fair wages, employment security, discrimination, social participation, community well-being, and even intergenerational equity can be considered part of a product's social impacts (Petti et al., 2018).

The relevance of this approach is particularly evident in agriculture, where production systems are closely linked to the livelihoods, employment, and well-being of rural populations. Many social challenges in agricultural systems—including precarious employment, poor working conditions, income inequalities, limited access to support services, and the vulnerability of disadvantaged social groups—are often inadequately captured by conventional economic and environmental assessments. In this regard, S-LCA provides a valuable framework for revealing the social dimensions of agricultural development and their implications for rural communities (Jørgensen et al., 2008; Petti et al., 2018).

Despite its considerable potential, S-LCA remains less methodologically mature than Environmental Life Cycle Assessment. The complexity of social phenomena, the context-specific nature of social indicators, the difficulty of quantifying many social variables, and the diversity of conceptual frameworks have led researchers to adopt a wide range of assessment approaches (Dreyer et al., 2010; Mancini et al., 2023). Although this diversity complicates direct comparisons among studies, it also highlights the importance of understanding the theoretical foundations and methodological assumptions underlying different S-LCA applications.

One of the most significant methodological distinctions within the S-LCA literature concerns the contrast between performance-based and risk-based approaches. This distinction influences not only the methods used to collect and analyze data but also the interpretation of social impacts and the policy implications derived from assessment results. Therefore, understanding these two approaches is essential for analyzing and comparing S-LCA studies conducted within rice production systems.

2.3. Performance-Based and Risk-Based Approaches in S-LCA

One of the most important methodological and theoretical debates within the Social Life Cycle Assessment (S-LCA) literature concerns the measurement and interpretation of social impacts. Unlike many environmental indicators that can be directly quantified through physical measurements, social impacts are inherently complex, multidimensional, and highly dependent on local institutional and socio-cultural contexts. Consequently, different approaches have been developed to assess social impacts, among which performance-based and risk-based approaches are the most widely applied (Jørgensen et al., 2008; Benoît-Norris et al., 2011).

The performance-based approach focuses on the assessment of actual social conditions within a specific production system. Under this approach, researchers collect primary data through field surveys, interviews, questionnaires, audits, or

direct observations to evaluate the existing social performance of stakeholders. Indicators such as actual wages paid to workers, working hours, occupational accident rates, job satisfaction, access to social protection, and levels of social participation are commonly examined. Therefore, the results generated by performance-based assessments reflect the observed realities experienced by stakeholders within a particular context and provide a relatively direct representation of social conditions (Dreyer et al., 2010).

In contrast, the risk-based approach emphasizes the likelihood of adverse social impacts occurring within a product system. Rather than measuring actual performance, this approach relies on secondary databases, national statistics, international indicators, and contextual information to estimate the probability of social risks. For example, the likelihood of child labor, gender discrimination, labor rights violations, or unsafe working conditions may be assessed based on country-level or sector-level data. Consequently, the outputs of risk-based assessments primarily represent levels of social vulnerability and risk exposure rather than confirmed social outcomes within a specific production unit (UNEP, 2020; Benoît-Norris et al., 2011).

The distinction between these approaches extends beyond differences in data collection methods and reflects two fundamentally different levels of social analysis. Performance-based assessments concentrate on experienced social realities, whereas risk-based assessments seek to identify potential social hotspots and vulnerabilities. As a result, findings derived from the two approaches should not be regarded as interchangeable. Instead, each provides a distinct type of information that can support decision-making and policy formulation in different ways (Parent et al., 2010).

Performance-based approaches are particularly useful for evaluating the actual social conditions of workers, farmers, and local communities within a specific production system. However, they often require extensive fieldwork, significant financial resources, and access to reliable primary data. Risk-based approaches, on the other hand, facilitate broader geographical comparisons and enable the rapid identification of potential social concerns across regions and supply chains. Nevertheless, they may not fully capture the social realities experienced by stakeholders at the local level (Mancini et al., 2023).

From a rural development perspective, the distinction between performance-based and risk-based approaches is especially important. Policymakers seeking to design effective social interventions require a clear understanding of whether assessment results represent actual social conditions or merely indicate the probability of social problems occurring. Misinterpreting these two forms of evidence may lead to inappropriate policy responses and ineffective development strategies. Therefore, identifying the assessment approach adopted in a study is essential for interpreting findings, comparing research outcomes, and deriving meaningful policy implications.

In the context of rice production systems, both approaches can provide valuable insights into social sustainability. Performance-based studies may reveal the real conditions of farmers, agricultural workers, and local communities, whereas risk-based studies can identify structural vulnerabilities embedded within broader supply chains and institutional environments. Accordingly, a comprehensive understanding of social sustainability in rice production requires consideration of both approaches and recognition of their complementary roles in supporting sustainable rural development.

Table 1. Comparison of Performance-Based and Risk-Based Approaches

Comparison criterion	Performance-based approach	Risk-based approach
Assessment basis	Actual social conditions	Probability of social impacts
Data source	Primary and field data	Secondary databases and indicators
Unit of analysis	Production unit or specific value chain	Sector, region, or country
Nature of results	Observed performance	Potential risk level
Dependence on local data	High	Relatively low
Main application	Assessment of existing conditions	Identification of social hotspots
Suitable for	Evaluating stakeholder performance	Screening and prioritizing social risks

2.4. Analytical Framework of the Study

A systematic review of Social Life Cycle Assessment (S-LCA) studies requires an analytical framework that goes beyond the descriptive comparison of indicators and methodological choices. Accordingly, the present study developed a conceptual framework that explicitly links S-LCA assessment in rice production systems with stakeholder conditions, social hotspots, policy responses, social sustainability outcomes, and ultimately sustainable rural development.

As illustrated in Figure 1, the framework begins with the social assessment of the rice production chain through S-LCA. At this stage, two elements are considered simultaneously: stakeholder identification and the analytical orientation adopted by the assessment. The relevant stakeholder groups may include rice farmers, farm workers, rural households, local communities, intermediaries and traders, and consumers. The assessment itself may follow either a performance-based approach, which evaluates actual social conditions and performance gaps against reference standards, or a risk-based approach, which identifies potential social risks according to their likelihood, severity, and priority.

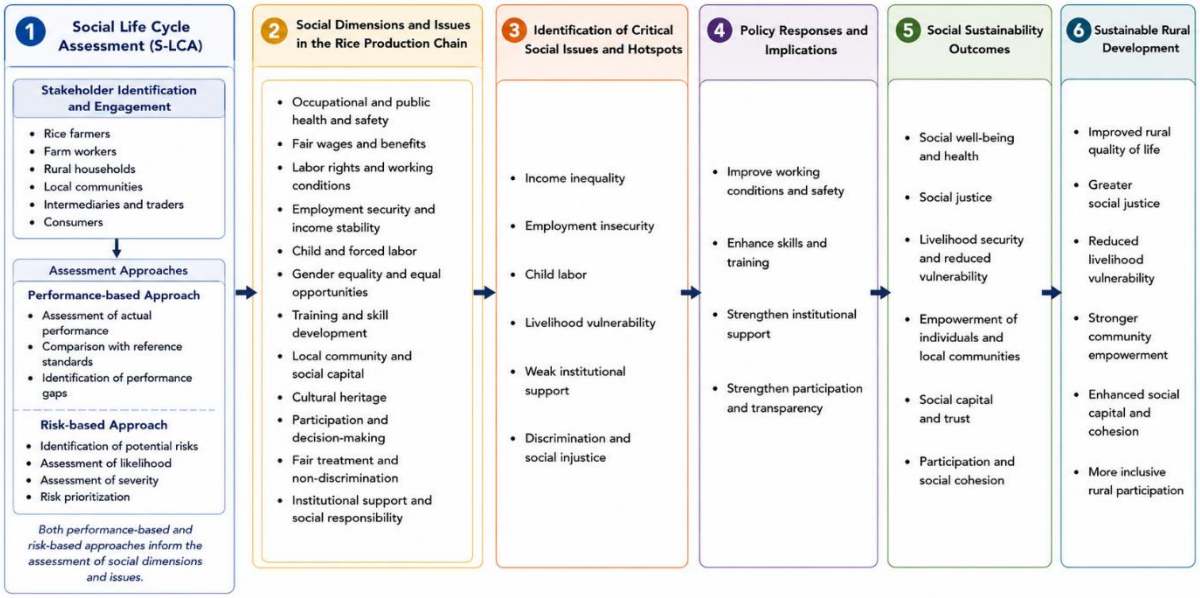

Figure 1. Conceptual framework linking S-LCA of rice production to social sustainability and sustainable rural development.

The outputs of these assessments are interpreted through a set of social dimensions relevant to rice production systems, including occupational and public health and safety, fair wages and benefits, labor rights and working conditions, employment security and income stability, child and forced labor, gender equality and equal opportunities, training and skill development, local-community relations and social capital, cultural heritage, participation in decision-making, non-discrimination, and institutional support and social responsibility. These dimensions provide the analytical basis for identifying critical social issues and hotspots within the rice production chain. The relevance of these dimensions is also supported by evidence from rural communities in Guilan. Previous research has identified social capital, educational and health conditions, financial constraints, cultural norms, and gender-related and institutional inequalities as important barriers to rural women's participation. These findings suggest that participation, gender equality, access to resources, social capital, and institutional support are closely linked in shaping the social sustainability and development capacity of rural communities (Asheri-Gafsheh et al., 2024).

The framework assumes that weaknesses detected within these dimensions may translate into broader social challenges such as income inequality, employment insecurity, child labor, livelihood vulnerability, inadequate institutional support, discrimination, and social injustice. Identification of these hotspots

therefore constitutes the link between S-LCA findings and policy-oriented interpretation. Rather than treating social indicators as isolated assessment outputs, the framework connects them to potential interventions, including improvements in occupational safety and working conditions, enhancement of training and skills, strengthening of institutional support, and greater participation and transparency within the rice value chain.

The proposed relationships further suggest that such interventions can contribute to broader social sustainability outcomes, including improved social welfare and health, greater social justice, enhanced livelihood security and reduced vulnerability, empowerment of individuals and local communities, strengthened social capital and trust, and increased participation and social cohesion. These outcomes, in turn, represent key components of sustainable rural development.

Thus, the framework establishes a sequential analytical pathway from S-LCA assessment → stakeholder and methodological characterization → identification of social dimensions and hotspots → policy implications → social sustainability outcomes → sustainable rural development. This pathway was used to guide the comparative interpretation of the selected studies and to evaluate not only which social indicators and stakeholder groups were addressed, but also how the reported S-LCA findings could contribute to broader rural development objectives.

3. Research Methodology

3.1. Systematic Review Strategy

The present study employed a systematic review approach to provide a structured analysis of the existing literature on the application of Social Life Cycle Assessment (S-LCA) in rice production systems. To enhance transparency, reproducibility, and methodological rigor while minimizing selection bias, the review process was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). The review focused on identifying eligible peer-reviewed studies addressing S-LCA applications in rice production systems, examining their methodological approaches, and synthesizing common patterns, methodological challenges, and research gaps within the field.

A systematic literature search was conducted in two major scientific databases, Scopus and Web of Science. These databases were selected because of their extensive coverage of peer-reviewed literature related to life cycle assessment, sustainability studies, and agricultural sciences. The search was performed within article titles, abstracts, and author keywords using combinations of relevant search terms connected by the Boolean operators AND and OR.

The same search terms and Boolean operators were applied in both Scopus and Web of Science. The exact search strings used in each database were as follows:

Scopus:

("rice*" OR "paddy*" OR "rice cultivation*" OR "paddy farming*" OR "rice production*" OR "paddy rice*") AND ("social life cycle assessment*" OR "S-LCA*" OR "social LCA*" OR "SLCA*")

Web of Science:

("rice*" OR "paddy*" OR "rice cultivation*" OR "paddy farming*" OR "rice production*" OR "paddy rice*") AND ("social life cycle assessment*" OR "S-LCA*" OR "social LCA*" OR "SLCA*")

The final database search was conducted on January 1, 2026, covering the ten-year period from January 1, 2016 to January 1, 2026. The search retrieved18 records from Scopus and 14 records from Web of Science, resulting in 32 records before duplicate removal. After the records retrieved from the two databases were combined, 14 duplicate records were identified and removed. Consequently, 18 unique records remained for title and abstract screening.

The titles and abstracts of these 18 unique records were then screened against the predefined eligibility criteria. At this stage, nine records were excluded because they did not directly address the systematic application of S-LCA to rice cultivation or rice production systems. The full texts of the remaining nine studies were subsequently assessed for eligibility. Following full-text assessment, two studies were excluded due to insufficient methodological information, leaving seven studies for inclusion in the final systematic review.

Inclusion Criteria- The following criteria were applied:

- Articles published in peer-reviewed scientific journals;

- Studies directly addressing the application of S-LCA in rice cultivation or rice production systems;
- Studies providing sufficient methodological information to evaluate the S-LCA framework, analytical scope or system boundary, social indicators, and assessment procedures; functional or reference units were extracted when explicitly reported;
- Publications written in English.

Exclusion Criteria- The following records were excluded:

- Conference papers, technical reports, theses, dissertations, book chapters, books, and other non-peer-reviewed publications;
- Studies referring to social issues without systematically applying an S-LCA framework;
- Publications written in languages other than English.

No supplementary backward or forward citation searching was conducted, and no review protocol was prospectively registered for this systematic review.

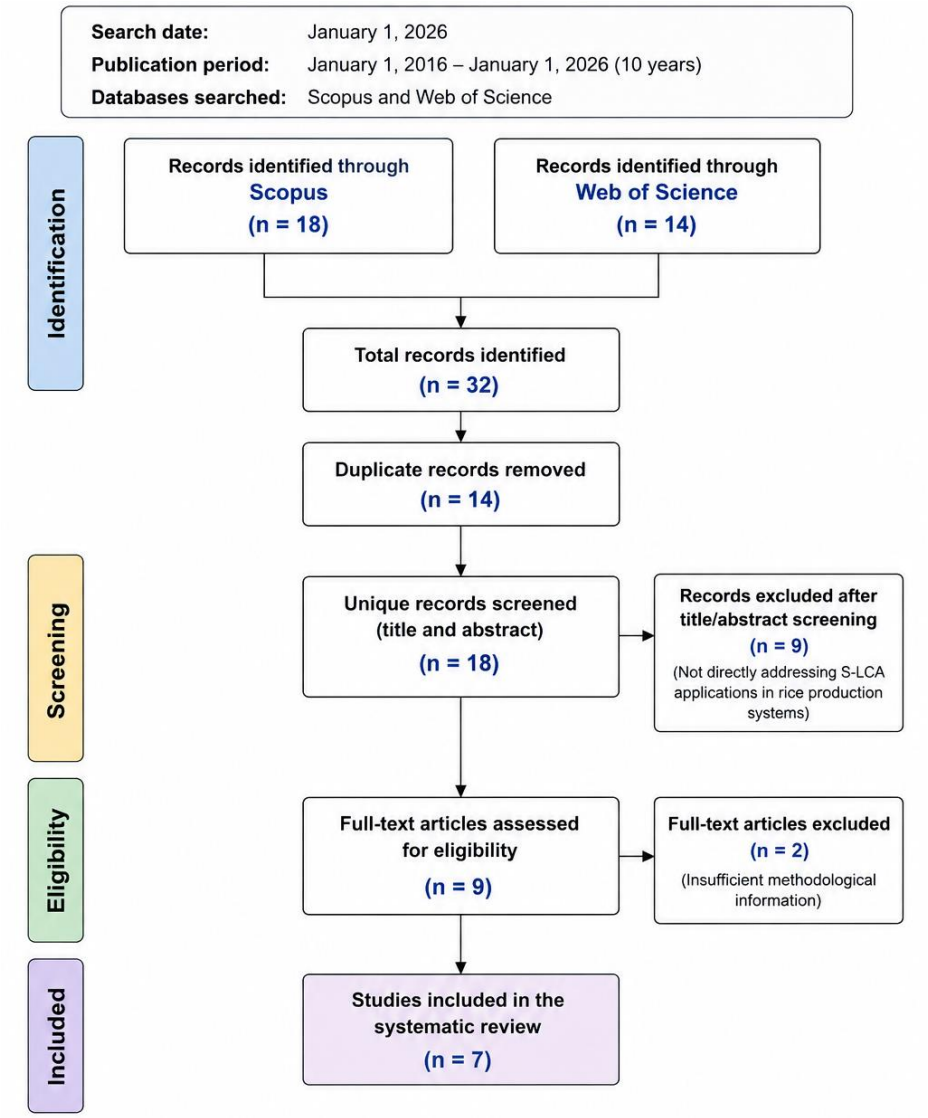

Figure 2. PRISMA flow diagram of study identification, screening, and selection.

The relatively small number of eligible studies should be interpreted in light of the deliberately narrow scope of the review. The search was restricted to studies that explicitly applied, or directly addressed, an S-LCA framework in relation to rice cultivation or rice production systems, rather than to the much broader literature on social sustainability, environmental LCA, or

general sustainability assessment in rice production. In addition, eligibility required publication in a peer-reviewed journal and sufficient methodological information to evaluate the assessment framework, analytical scope or system boundary, social indicators, and assessment procedures. Functional or reference units were recorded when explicitly reported by the original studies. Consequently, studies that discussed social issues in rice production without systematically applying an S-LCA framework were excluded. The final number of seven studies therefore reflects both the specificity of the research question and the still limited development of S-LCA applications in rice production, rather than an intentionally restricted sample size. The complete identification, screening, eligibility assessment, and selection process is presented in Figure 2 following the PRISMA framework.

3.2. Data Extraction and Analysis

To facilitate systematic comparison, key information from each selected study was extracted using a predefined data extraction form and subsequently organized into a structured database. Extracted variables included authorship, publication year, geographical scope, study type, stakeholder groups, social indicators, functional units, system boundaries, and methodological approaches.

The analysis was conducted using a comparative qualitative approach aimed at identifying common patterns, structural differences, and methodological gaps among the selected studies. In addition to descriptive synthesis, study quality was evaluated according to three main criteria:

1. Methodological consistency, particularly regarding the definition of functional units and system boundaries;
2. Quality and limitations of social data, including the approaches used to transform qualitative variables into measurable indicators;
3. Representation and balancing of stakeholder interests throughout the rice value chain.

These criteria were selected because they directly influence the robustness, comparability, and policy relevance of S-LCA studies and therefore provide an appropriate basis for evaluating the current state of the literature.

To operationalize the quality appraisal, each included study was assessed separately against the three predefined criteria using a three-level qualitative rating system: Strong, Moderate, and Limited. A rating of Strong indicated that the criterion was clearly and comprehensively addressed; Moderate indicated generally adequate reporting with identifiable methodological or data-related limitations; and Limited indicated substantial restrictions in coverage or reporting. The quality appraisal was used to support the interpretation and comparative synthesis of the evidence and was not applied as an additional exclusion criterion.

4. Research Findings

4.1. Overview of S-LCA Applications in Selected Studies

A systematic review of the selected studies revealed that although Social Life Cycle Assessment (S-LCA) was adopted as a common assessment framework across all investigations, substantial heterogeneity exists in its operationalization with respect to conceptual frameworks, functional unit definition, system boundary selection, stakeholder identification, and quantification approaches.

From a conceptual perspective, four studies explicitly referred to the UNEP/SETAC guidelines and structured their analyses according to the stakeholder categories and subcategories proposed by this framework (Kalvani et al., 2022; Wei et al., 2022; Sharaai et al., 2022; Prasara-A & Gheewala, 2025). In the study by Prasara-A and Gheewala (2025), the “Reference Scale Approach” was explicitly introduced and justified as a suitable method for evaluating the social performance of agricultural products. In contrast, Mancini et al. (2023) and Vinci et al. (2023) primarily relied on risk-based approaches and the PSILCA database, which adopts a large-scale, supply-chain-oriented perspective. Although Phantha et al. (2021) did not explicitly classify their assessment approach within the S-LCA literature, their framework was stakeholder-oriented and based on indicator scoring. These differences indicate that only one study explicitly identified its S-LCA approach, whereas in the remaining studies the approach could only be inferred from the assessment methodology employed.

Considerable heterogeneity was observed in the definition and reporting of functional or reference units across the reviewed studies. Phantha et al. (2021) explicitly defined the reference unit as one

hectare of paddy rice growing area, while Prasara-A and Gheewala (2025) similarly adopted one hectare of plantation as the reference unit. In contrast, Wei et al. (2022) employed a system-level functional unit, defining it as the complete life cycle of the rice industry, whereas Mancini et al. (2023) used an economic modeling basis of one euro of representative food product. Kalvani et al. (2022), Sharaai et al. (2022), and the S-LCA component of Vinci et al. (2023) did not explicitly report a standardized functional or reference unit for their social assessments. Thus, the reviewed literature ranges from land-based physical reference units to economic and system-level units, while several studies do not explicitly define such a unit. This heterogeneity in functional-unit definition and reporting limits direct comparison of social performance and risk results across studies.

Substantial variation was also found in the definition of system boundaries. Three studies focused primarily on the farm production stage (Phantha et al., 2021; Kalvani et al., 2022; Sharaai et al., 2022). One study expanded the system boundary to include cultivation, transportation, collection, and consumption stages (Prasara-A & Gheewala, 2025). Wei et al. (2022) defined the system boundary from cultivation to product recycling at the national scale, while Mancini et al. (2023) modeled upstream supply chains within the context of international trade. Similarly, Vinci et al. (2023) conducted their analysis at the global supply-chain level using PSILCA data. Consequently, three studies adopted farm-gate boundaries, two employed value-chain boundaries, and two considered full life-cycle or macro-scale system boundaries.

With regard to stakeholder selection, workers were considered a primary stakeholder group in all reviewed studies. Farmers or farm owners were treated as independent stakeholder categories in four studies, while local communities were explicitly included in five studies. Consumers received comparatively limited attention across the reviewed studies. They were explicitly represented in Wei et al. (2022), while Prasara-A and Gheewala (2025) incorporated consumer-related aspects through the local-community stakeholder group at the consumption stage. In contrast, Mancini et al. (2023) excluded the consumer stakeholder category because of data limitations. This pattern suggests that the current literature remains largely production-oriented, with relatively limited attention paid to downstream actors in the rice value chain.

From the perspective of data sources and quantification approaches, three studies relied primarily on field surveys and questionnaire-based data collection (Phantha et al., 2021; Kalvani et al., 2022; Sharaai et al., 2022), whereas two studies employed secondary databases and large-scale modeling approaches (Mancini et al., 2023; Vinci et al., 2023). Wei et al. (2022) combined quantitative indicators with weighting and regional aggregation techniques, while Prasara-A and Gheewala (2025) applied a reference-scale scoring method. Overall, four studies adopted semi-quantitative approaches, two employed risk-based social assessment methods, and one utilized a combined weighting and aggregation framework.

In summary, although all reviewed studies applied the concept of Social Life Cycle Assessment, methodological convergence remains limited. Differences in functional unit definition, system boundary selection, data sources, and quantification methods indicate that the current literature is still in a phase of conceptual consolidation and requires greater methodological harmonization to improve the comparability and transferability of findings. These inconsistencies can be observed across all methodological dimensions, from conceptual frameworks to quantification procedures, reflecting the diversity of approaches currently employed in S-LCA studies of rice production systems.

Table 2. Quality appraisal of the included studies based on the three predefined criteria

Study	Methodological consistency	Social data quality	Stakeholder representation
Phantha et al. (2021)	Moderate	Strong	Moderate
Kalvani et al. (2022)	Strong	Strong	Moderate
Sharaai et al. (2022)	Moderate	Strong	Moderate
Wei et al. (2022)	Strong	Moderate	Strong
Mancini et al. (2023)	Strong	Moderate	Moderate

Study	Methodological consistency	Social data quality	Stakeholder representation
Vinci et al. (2023)	Moderate	Moderate	Limited
Prasara-A & Gheewala (2025)	Strong	Strong	Strong

Quality Appraisal of the Included Studies- The criterion-specific quality appraisal of the seven included studies is presented in Table 2, highlighting differences in methodological consistency, social data quality, and stakeholder representation across the reviewed studies.

The quality appraisal revealed considerable variation across the included studies. Methodological consistency was generally strong in studies that explicitly defined the reference or functional unit, system boundary, and S-LCA framework, whereas some studies provided less standardized methodological reporting. Social data quality was strongest in field-based studies employing primary stakeholder data, questionnaire validation, and explicit characterization procedures, while studies relying mainly on secondary databases or proxy indicators were rated as moderate in this criterion. Stakeholder representation also varied substantially; most studies concentrated on workers, farmers, and local communities, whereas broader stakeholder coverage, particularly consumers and value-chain actors, was less consistently addressed. These differences were taken into account when interpreting and comparing the findings across studies.

4.2. Analysis of Selected Studies from the Perspective of Social Sustainability and Rural Development

The review of the selected studies indicates that although most investigations were originally designed to assess social impacts within the framework of Social Life Cycle Assessment (S-LCA), a considerable proportion of the indicators employed are directly associated with the broader concepts of social sustainability and sustainable rural development. This relationship is particularly evident in indicators such as income, job satisfaction, occupational health and safety, fair wages, food security, land-use rights, local employment, social participation, and access to technology.

In the study conducted by Phantha et al. (2021), three stakeholder groups, namely workers, local communities, and rice farmers, were assessed. For farmers, indicators such as food security, income satisfaction, land-use rights, and women's participation in farm decision-making were considered. For local communities, local employment opportunities, participation in cultural activities, and the absence of social conflicts associated with rice cultivation were evaluated. These indicators demonstrate that S-LCA in this study extended beyond the assessment of working conditions and incorporated several livelihood, participatory, and community-related dimensions of rural life.

Kalvani et al. (2022), through a comparative assessment of rice production systems in Iran and Malaysia, demonstrated that geographical, institutional, and production-related differences can substantially influence the social performance of stakeholders. The principal stakeholder groups included workers, local communities, and farmers. Indicators such as occupational health and safety, discrimination, wages, forced labor, labor relations, land rights, water rights, access to credit, technological support, living standards, income, and employment opportunities were evaluated. The results revealed that the social performance of both workers and farmers was generally higher in Malaysia than in Iran. This difference was primarily attributed to lower production costs and higher rice productivity in Malaysia. Furthermore, the weaker performance observed among Iranian farmers was associated with lower income satisfaction, lower productivity, and higher production costs.

Similarly, Sharaai et al. (2022), in their assessment of rice production systems in Selangor, Malaysia, focused on three stakeholder groups: rice mill workers, farmers, and local communities. Their findings indicated that farmers exhibited the lowest social performance among the stakeholder groups considered. Key challenges included income generation, occupational health and safety, access to agricultural technologies, and living standards. Only 36% of farmers reported satisfaction with their income, while merely 38% indicated that they had not experienced health and safety concerns. These findings suggest that farmers' income and occupational well-being remain among the most critical social vulnerability points within rice production systems from a rural development perspective.

Among the reviewed studies, Wei et al. (2022) established the strongest linkage between S-LCA and rural development. Their framework incorporated stakeholders such as farmers, agricultural value-chain actors, consumers, rural areas, and society as a whole. The assessment included indicators related to fair wages, health and safety, social security, access to material and non-material resources, safe and healthy living conditions, social participation, local employment, technological development, and the contribution of agriculture to regional economic development. Notably, this study explicitly linked social assessment outcomes to China's Rural Revitalization Strategy and organized its impact assessment around three key dimensions: high-quality agricultural development, desirable rural living conditions, and rural well-being. This approach represents one of the clearest examples of integrating S-LCA into a broader rural development framework.

At the macro level, Mancini et al. (2023) identified rice as one of the food products associated with considerable social risks within European consumption systems. The study reported significant risks related to fair wages, forced labor, social benefits, illiteracy, and community health and safety. These findings suggest that the assessment of social sustainability in rice production should not be confined to production sites alone, as international supply chains and trade relationships may also transmit substantial social risks.

Although not exclusively focused on rice, the study by Prasara-A and Gheewala (2025) evaluated rice alongside sugarcane, cassava, and maize within an S-LCA framework. Six stakeholder groups were considered, including farm owners, workers, machinery contractors, suppliers, collectors/processors, and local communities. For rice production, indicators such as land rights, water rights, net profit, governmental financial support, knowledge transfer, marketing support, occupational health and safety, women's empowerment, labor availability, access to machinery, job satisfaction, social participation, and food security were assessed. The breadth of stakeholder representation in this study highlights that social assessments become more closely aligned with rural development objectives when they extend beyond farm-level actors and incorporate the wider network of local stakeholders.

Finally, the review conducted by Vinci et al. (2023) demonstrated that the application of S-LCA within rice production systems remains considerably less developed than environmental life cycle assessment. The authors highlighted child labor, forced labor, fair wages, working hours, labor rights, discrimination, health and safety, access to material resources, and migration as some of the most important social issues requiring further investigation. This observation is consistent with the limited number of eligible studies identified in the present review and supports the interpretation that S-LCA applications in rice production remain an emerging and comparatively underdeveloped field of research. Overall, the reviewed studies differ substantially in the extent to which they engage with rural development concerns. Studies such as Phantha et al. (2021), Kalvani et al. (2022), and Sharaai et al. (2022) primarily focused on field-based assessments of production-oriented stakeholders. In contrast, Wei et al. (2022) and Prasara-A and Gheewala (2025) expanded the scope of analysis to encompass broader dimensions of agricultural development, rural well-being, and local stakeholder networks. Meanwhile, Mancini et al. (2023) and Vinci et al. (2023) emphasized social risks at broader supply-chain and international levels. Therefore, while the existing literature demonstrates considerable potential for linking S-LCA with social sustainability and rural development, it still lacks an integrated analytical framework capable of directly connecting technical S-LCA indicators with core rural development objectives, including livelihood security, social welfare, social justice, empowerment, and community participation.

4.3. Geographical Differences and Production Systems

The reviewed studies indicate that the social performance of rice production systems is strongly influenced by geographical conditions, institutional structures, and production system characteristics. Although all studies adopted the S-LCA framework to assess social impacts, differences in economic, social, and policy contexts resulted in substantial variation in outcomes across regions. The selected studies were conducted at different geographical scales, including cross-country,

regional, and production-system comparisons, each highlighting distinct aspects of social performance.

At the international level, Kalvani et al. (2022) demonstrated that differences in labor market structures, levels of mechanization, governmental support mechanisms, and access to social services between Iran and Malaysia resulted in variations in indicators related to working conditions, employment security, and stakeholder well-being. These findings suggest that social performance is not solely determined by technical production characteristics but is also strongly shaped by institutional quality, support policies, and the broader level of social development within a country. Consequently, direct comparisons of S-LCA results across countries without considering institutional and social differences may lead to misleading conclusions.

At the regional scale, Wei et al. (2022) reported that provinces with stronger economic and social infrastructures achieved higher social performance scores within rice production systems across 31 provinces of China. This finding highlights that even within a single governance system, regional development levels, access to public services, employment opportunities, and infrastructure quality can significantly influence social assessment outcomes. Therefore, regional disparities constitute an important explanatory factor for variations in the social performance of rice production systems.

In addition to geographical differences, production systems also influenced several social indicators. Phantha et al. (2021) found that the main difference between conventional and organic rice farming occurred among rice farmers. The social performance score for rice farmers was higher under organic farming (0.93) than under conventional farming (0.65), primarily because of better performance in food security and income satisfaction. In contrast, workers achieved the same social performance score in both systems (0.96), while local communities also showed identical performance (1.00). These findings indicate that the transition from conventional to organic production did not uniformly improve all social dimensions, but mainly affected farmer-related livelihood indicators.

Overall, the reviewed studies indicate that while production systems can affect specific social dimensions, geographical and institutional factors play a more fundamental role in shaping S-LCA outcomes. Economic development levels, governance quality, access to social services, and labor market conditions represent key determinants of social performance within rice production systems. Therefore, the interpretation and comparison of S-LCA results should always take into account the geographical and institutional contexts in which assessments are conducted.

In large-scale studies such as Mancini et al. (2023) and Vinci et al. (2023), dependence on global supply chains linked to countries with elevated social risks contributed to higher aggregated risk levels for several social indicators. These studies demonstrate that even when production takes place in developed countries, sourcing inputs from high-risk regions may substantially affect overall social performance. The structural characteristics of these geographical and system-related differences are summarized in Table 3.

Table 3. Comparison of Selected S-LCA Studies According to Geographical Context, Production System, and Analytical Scale

No.	Study	Country / Region	Analytical Scale	Production System	Type of Comparison	Main Finding Related to Geographical or System Differences
1	Phantha et al. (2021)	Thailand	Farm level	Conventional vs. Organic	System comparison	Rice farmers showed higher social performance under organic farming (0.93) than conventional farming (0.65), mainly due to food security and income satisfaction; worker (0.96) and local-community (1.00) scores were identical across both systems.

No.	Study	Country / Region	Analytical Scale	Production System	Type of Comparison	Main Finding Related to Geographical or System Differences
2	Kalvani et al. (2022)	Iran – Malaysia	Farm level	Conventional	Cross-country comparison	Differences in institutional structures and working conditions resulted in variations in social performance scores.
3	Sharaai et al. (2022)	Selangor, Malaysia	Farm level	Conventional	Single-country assessment	Social performance was influenced by production-cycle characteristics and regional conditions.
4	Wei et al. (2022)	China (31 provinces)	Regional level	Conventional	Inter-provincial comparison	More developed provinces exhibited higher levels of social performance.
5	Mancini et al. (2023)	European Union (global supply chains)	Global level	Supply chain	Dependency analysis	Dependence on high-risk countries increased aggregated social risks.
6	Vinci et al. (2023)	Multiple countries	Global level	Supply chain	Cross-country comparison	Considerable structural differences in social risk levels were observed among countries.
7	Prasara-A & Gheewala (2025)	Thailand	Value-chain level	Conventional	Stage comparison	No social hotspot was identified for rice at either the actual or adjusted performance level, although several social indicators showed moderate performance.

In summary, the reviewed literature indicates that geographical context, economic development level, institutional structure, and production system characteristics are among the most influential determinants of S-LCA outcomes in rice production. No uniform pattern of social performance was observed across countries and regions, emphasizing the importance of contextualized interpretation when assessing social sustainability in agricultural systems.

4.4. Overall Patterns of Social Performance and Risk Levels

A comparative analysis of the reviewed studies indicates that the selected literature can be broadly classified into two main categories according to the nature of their outputs:

Performance-based assessments and risk-based assessments- In performance-based studies, which were predominantly conducted at the farm level, results were reported as social performance scores or aggregated social indicators. These studies primarily focused on the direct comparison of social performance among production systems, countries, or stages of the value chain. Their central objective was to determine whether one production system exhibited better social performance than another. Within this framework, indicators such as farmers' income, occupational health and safety, working conditions, and livelihood security contributed most significantly to overall social performance scores (Phantha et al., 2021; Sharaai et al., 2022; Kalvani et al., 2022).

In contrast, risk-based studies, which mainly relied on secondary databases and large-scale modeling approaches such as PSILCA and Multi-Regional Input–Output (MRIO) models (Mancini et al., 2023; Vinci et al., 2023), reported their findings in terms of social risk levels or indicators of structural vulnerability. Rather than comparing the relative performance of production systems, these studies focused on identifying social hotspots and high-risk segments within supply chains. Indicators such as child labor, forced labor, fair wages, and occupational safety frequently exhibited the highest levels of social risk in specific countries or economic sectors.

Wei et al. (2022) adopted an intermediate approach by combining quantitative indicators with weighting procedures to construct a regional social performance index. In this framework, differences among provinces reflected inequalities in social development at the national level. Similarly, Prasara-A and Gheewala (2025) employed a

reference-scale approach to compare the social performance of four major economic crops across cultivation, transportation, collection, and consumption stages. For rice, no social hotspot was identified at either the actual or adjusted social performance level, although several indicators showed moderate performance and required continued monitoring. This finding is largely consistent with the results reported in farm-level performance-based studies.

A structured summary of the principal indicators, analytical approaches, and key quantitative findings reported in each selected study is presented in Table 4. Overall, the results indicate that the assessment approach adopted—performance-based versus risk-based—directly influences the interpretation of social sustainability outcomes. Farm-level studies tend to emphasize relative social improvement, whereas large-scale assessments primarily focus on structural social vulnerabilities and risk exposure within supply chains.

Table 4. Classification of Quantitative and Qualitative Findings of the Selected Studies According to Social Indicators and Analytical Approaches

No.	Study	Analytical Approach	Key Social Indicators	Main Quantitative Evidence	Dominant Result Pattern
1	Phantha et al. (2021)	Performance-based (Conventional vs. Organic)	Farmers, workers, local communities; food security, income satisfaction, health and safety, local employment	Rice farmers' social performance: Organic = 0.93, Conventional = 0.65; Workers = 0.96 in both systems; Local communities = 1.00 in both systems.	(i) Higher social performance of rice farmers under organic farming, mainly due to food security and income satisfaction; (ii) No difference between the two systems for workers and local communities.
2	Kalvani et al. (2022)	Performance-based (Comparative farm-level assessment)	Workers, local communities, farmers; health and safety, discrimination, wages, employment, land and water rights, technology access, income satisfaction	Weighted social scores (Iran vs. Malaysia): Workers = 29.64 vs. 62.00; Local communities = 68.50 vs. 64.00; Farmers = 15.60 vs. 66.00	(i) Significant differences in social performance between countries; (ii) Strong sensitivity to institutional support systems and mechanization levels
3	Sharaai et al. (2022)	Performance-based (Production-processing chain)	Mill workers, farmers, local communities; income, health and safety, technology access, living standards	Overall social performance scores (%): Local communities = 62; Workers = 59; Farmers = 53	(i) Lower social performance among farmers compared with other stakeholder groups; (ii) Income and health and safety identified as major concerns
4	Wei et al. (2022)	Hybrid (Regional index and weighting approach)	Farmers, consumers, society, rural areas; composite social index (SI)	Highest reported indicator weight = 0.122 (consumer health and safety); strong regional disparities across provinces	Social performance strongly associated with regional development levels and social infrastructure
5	Mancini et al. (2023)	Risk-based (Macro-scale assessment)	Child labor, forced labor, fair wages, workers' rights, corruption, literacy, health and safety	Selected risk scores for rice: Fair wages = 8.6; Responsible business conduct = 5.26; Workers' rights = 5.25; Child labor = 5.8	(i) Structural vulnerability transmitted through global supply chains; (ii) High social risks related to labor rights and fair wages
6	Vinci et al. (2023)	Risk-based (Cross-country comparison)	Child labor, forced labor, fair wages, working hours, workers' rights,	Child labor ranged from 0.4% (Sri Lanka) to 21% (Senegal); Iran = 3%;	(i) Social risks strongly dependent on national contexts; (ii) Child labor,

No.	Study	Analytical Approach	Key Social Indicators	Main Quantitative Evidence	Dominant Result Pattern
			discrimination, migration	Forced labor in Iran = 16.2 cases per 1,000 people	forced labor, and working hours emerged as key risk factors
7	Prasara-A & Gheewala (2025)	Performance-based (Reference-scale/value-chain assessment)	Land and water rights, economic performance, health and safety, labor and machinery access, fair competition, women's empowerment, career satisfaction, and food security	No rice-related social hotspot was identified at either the actual level (PSact = 1) or the adjusted level (PSadj = 0).	(i) No rice-specific social hotspots were identified; (ii) several indicators nevertheless showed moderate or attention-requiring performance, highlighting the need for continued monitoring.

4.5. Stakeholder-Based Analysis of Social Life Cycle Assessment Results

A review of the selected studies from a stakeholder perspective indicates that workers were consistently identified as the most sensitive social group across all studies. In farm-level assessments, indicators such as working conditions, working hours, occupational health and safety, and fair wages contributed most substantially to variations in overall social performance scores. In particular, the comparative study conducted in Iran and Malaysia demonstrated that differences in several labor-related sub-indicators significantly influenced overall social performance outcomes (Kalvani et al., 2022). Similarly, Phantha et al. (2021) found no difference between conventional and organic rice farming in the overall social performance of workers (0.96 in both systems) or local communities (1.00 in both systems). The principal difference was observed among rice farmers, whose social performance was higher under organic farming (0.93) than under conventional farming (0.65), primarily because of better food security and income satisfaction.

In studies relying on secondary databases and large-scale modeling approaches, such as Mancini et al. (2023) and Vinci et al. (2023), indicators including child labor, forced labor, and fair wages exhibited elevated social risk levels in several countries. These studies emphasize that even when social performance appears satisfactory at the farm level, structural vulnerabilities embedded within supply chains may still adversely affect workers' social conditions. The strong emphasis placed on workers throughout the reviewed literature highlights that a substantial component of social sustainability in rice production systems depends on the quality of rural employment. Indicators such as occupational health and safety, fair wages, and employment security represent not only social assessment variables but also fundamental dimensions of social welfare and social justice within rural communities. Consequently, poor performance in these indicators may undermine livelihood sustainability and the overall quality of life of the agricultural workforce.

Farmers, as owners or operators of agricultural production systems, also played a central role in farm-based studies. Comparative investigations such as those conducted by Phantha et al. (2021) and Kalvani et al. (2022) demonstrated that income, economic security, and livelihood stability were among the most influential factors distinguishing production systems and countries. Likewise, Wei et al. (2022) reported that regional variations in social indicators were strongly associated with differences in economic development and farmers' income levels. The prominence of indicators such as income, economic security, and livelihood stability suggests that S-LCA in rice production is directly linked to one of the core objectives of rural development, namely livelihood sustainability. Overall, the reviewed studies indicate that improvements in the social performance of rice value chains are closely tied to the ability of production systems to ensure economic security and maintain the continuity of rural household livelihoods.

Local communities received greater attention in value-chain and regional-scale studies. In the work of Prasara-A and Gheewala (2025), the social performance of different stages of the value chain was assessed with particular emphasis on employment generation and regional development.

Similarly, Wei et al. (2022) examined indicators related to social development and regional infrastructure at the provincial level. In global-scale studies such as Mancini et al. (2023), local communities were considered through broader indicators of social development and social risk in input-supplying countries. In contrast, consumers were either excluded from the assessment or only marginally addressed in most studies. This limited representation suggests that the current S-LCA literature on rice production remains largely focused on production-oriented stakeholders, while downstream actors in the value chain receive considerably less attention. Although local communities have generally received less attention than workers and farmers, indicators related to local employment, regional development, social infrastructure, and social participation demonstrate that the social impacts of rice production extend beyond the farm level and may influence broader patterns of rural development. This relationship is particularly evident in regional and value-chain studies that explicitly attempt to connect agricultural activities with social development processes in rural areas.

A stakeholder-based summary of the main findings reported in the reviewed studies is presented in Table 5. As shown in the table, the scope and intensity of reported social impacts were generally greater and more explicitly documented for workers and farmers than for other stakeholder groups, whereas local communities and especially consumers received comparatively limited attention.

Overall, the stakeholder-based analysis reveals that workers and farmers constitute the primary focus of existing S-LCA studies in rice production systems, while local communities and consumers remain underrepresented. This imbalance may reduce the comprehensiveness of social life cycle assessments and contribute to the neglect of important dimensions of social sustainability in rural areas. Consequently, it represents one of the major gaps in the current literature. More broadly, the reviewed studies indicate that S-LCA applications in rice production have primarily focused on three fundamental dimensions of social sustainability: employment quality, livelihood security, and community well-being. Workers are represented through indicators such as occupational health and safety, fair wages, and labor rights; farmers through income, economic security, and livelihood sustainability; and local communities through employment opportunities, social participation, and regional development. Therefore, S-LCA should be viewed not merely as a tool for measuring the social performance of production systems, but also as a framework capable of identifying strengths and weaknesses in rural social development. Nevertheless, the limited attention paid to local communities and consumers indicates that the existing literature has not yet achieved a comprehensive assessment of the multiple dimensions of social sustainability and sustainable rural development.

Table 5. Stakeholder-Oriented Summary of the Main Findings Reported in the Selected S-LCA Studies

No.	Study	Workers	Farmers	Local Communities	Consumers
1	Phantha et al. (2021)	Workers showed identical overall social performance in conventional and organic rice farming (0.96 in both systems), with no differences in minimum wage, equal opportunity, health and safety, freedom of collective bargaining, or forced labor.	Rice farmers showed higher social performance under organic farming (0.93) than under conventional farming (0.65), primarily due to better food security and income satisfaction.	Local communities showed identical social performance in both conventional and organic systems (1.00), with no differences in community strength, community engagement, or local employment.	Not assessed.
2	Kalvani et al. (2022)	Workers in Malaysia exhibited better performance than those in Iran regarding	Income levels and livelihood stability differed significantly between the two countries and played a major role in	Social performance was indirectly influenced by national levels of social	Not assessed.

No.	Study	Workers	Farmers	Local Communities	Consumers
		employment security and wage-related indicators, highlighting the influence of institutional factors.	determining overall social performance.	development and institutional quality.	
3	Sharaai et al. (2022)	Social performance differences were limited and highly dependent on the indicator considered; some indicators improved while others showed little variation.	Moderate and inconclusive socio-economic changes were reported.	The role of local communities was not strongly emphasized.	Not assessed.
4	Wei et al. (2022)	Social inequalities among provinces were evident, with more developed provinces achieving higher social performance scores.	Income and regional economic development were positively associated with improved social indicators.	Social infrastructure and regional development were identified as key drivers of social performance improvement.	Not assessed directly, although consumer-related indicators were incorporated within the composite assessment framework.
5	Mancini et al. (2023)	High levels of child labor and forced labor risks were reported in some supplier countries, generating structural risks throughout global supply chains.	Farmers in high-risk countries were exposed to institutional and governance-related vulnerabilities.	Social risks were higher in countries characterized by weaker governance structures.	Not assessed.
6	Vinci et al. (2023)	Structural risks associated with child labor, forced labor, and fair wages were highlighted, with trade dependencies playing a decisive role.	Indirectly affected through global trade and supply-chain structures.	Elevated social risks were reported in several input-supplying countries.	Not assessed.
7	Prasara-A & Gheewala (2025)	Workers were assessed across agriculture and transportation stages using indicators related to wages, working hours, working conditions, equality, occupational health and safety, and career satisfaction.	Farm owners were assessed in terms of land and water rights, economic development, governmental support, knowledge transfer, health and safety, women's empowerment, fair competition, and access to labor and machinery. For rice, several indicators were moderate, including net profit and access to machinery, but no social hotspot was identified.	Local communities were included across several life-cycle stages, particularly in relation to health and safety and the social effects of agricultural production, transportation, and collection.	Assessed through the local-community stakeholder group at the consumption stage, including food-security indicators related to access to locally available agricultural products at fair prices and acceptable quality.

Table 5 demonstrates that workers and farmers received the greatest attention across the reviewed studies, whereas local communities and particularly consumers were considerably underrepresented. This imbalance suggests that current S-LCA applications in rice production systems remain primarily focused on production-oriented stakeholders, highlighting an important gap in the literature regarding the broader dimensions of social sustainability and sustainable rural development.

4.6. Comparative Discussion of Findings

The findings of this systematic review indicate that the S-LCA literature on rice production, despite its recent expansion, still faces a significant conceptual and methodological duality. This

duality directly affects both the interpretation of results and their applicability to policy-making. On the one hand, performance-based studies, predominantly conducted at the farm or value-chain stage level, seek to evaluate the social performance of production systems through scoring methods or aggregated indicators and essentially address the question: *Which system performs better socially?* On the other hand, risk-based studies, relying on databases and large-scale modeling approaches, represent structural vulnerabilities through social risk indicators and primarily address the question: *Where are the major social risks located and why do they occur?*

Although these two approaches are often regarded as complementary, they may generate apparently contradictory interpretations if presented without adequate conceptual framing. This is particularly relevant for readers who expect S-LCA studies to provide a single, directly comparable assessment of social sustainability.

The reviewed studies demonstrate that differences among countries and production systems do not merely alter indicator values; they also influence the interpretation of social performance outcomes. For example, the comparative assessment of rice production systems in Iran and Malaysia revealed that institutional structures, labor arrangements, mechanization levels, and social support mechanisms substantially affected the relative importance of indicators such as employment security and working conditions, ultimately influencing overall social performance scores. These findings suggest that improvements in social sustainability cannot be achieved solely through technical interventions aimed at increasing productivity or reducing input use. Rather, they also depend on institutional reforms, including social insurance schemes, occupational safety standards, labor regulations, and support mechanisms for producers.

From this perspective, institutions may be viewed as an integral component of agricultural production systems. Just as inputs such as fertilizers, water, and machinery influence production outcomes, governance structures, labor regulations, and social welfare systems shape social sustainability outcomes.

The reviewed literature further suggests that policymakers should not assume that a particular production label, such as "organic" or "conventional," automatically guarantees improvements across all dimensions of social sustainability. Several indicators appear to be more strongly influenced by market conditions, access to services, and institutional support systems than by production methods themselves. Consequently, social improvement strategies should be designed around specific social indicators rather than being solely production-system oriented.

Regional-level assessments also indicate that social performance is strongly associated with levels of economic development and social infrastructure. This finding highlights the importance of intra-country heterogeneity. Even within a common national governance framework, regional disparities may significantly influence S-LCA outcomes. Therefore, uniform policy interventions may be insufficient, and region-specific strategies may be required to address social sustainability challenges effectively.

One of the most important interpretative challenges identified in the literature is the apparent discrepancy between performance-based and risk-based findings. Farm-level assessments may report acceptable social performance, whereas risk-based analyses may simultaneously identify substantial social risks within the same commodity supply chain. Rather than representing a contradiction, this reflects differences in analytical scale and assessment objectives. Performance-based approaches evaluate actual conditions within specific production systems, while risk-based approaches identify structural vulnerabilities embedded within broader supply chains and institutional contexts.

Accordingly, high social risk scores should not be interpreted as evidence that negative social outcomes are necessarily occurring in a particular production system. Instead, they indicate increased vulnerability and the potential occurrence of undesirable social impacts. Indicators such as child labor, forced labor, and excessive working hours therefore function primarily as warning signals that guide decision-makers toward critical intervention points within supply chains.

These findings suggest that future research and policy development would benefit from a more integrated framework that combines the strengths of both approaches. Performance-based studies are particularly useful for identifying local interventions, such as improvements in

occupational safety, worker training, and labor standards, whereas risk-based studies are more suitable for designing supply-chain policies related to responsible sourcing, traceability systems, and supplier evaluation. Consequently, the two approaches should be regarded as complementary rather than competing perspectives.

Another important finding is that workers emerged as the most sensitive stakeholder group across all reviewed studies. This predominance can be explained by two factors. First, many of the standard S-LCA indicators are inherently worker-oriented, including working conditions, occupational health and safety, wages, and working hours. Second, labor-intensive stages of rice production often constitute the primary sources of social vulnerability within the value chain.

While this focus facilitates the design of practical interventions, it may also lead to an overly narrow interpretation of social sustainability in which broader dimensions of rural social development remain insufficiently addressed. Similar concerns apply to farmers, whose social performance is frequently assessed through indicators such as income, economic security, and livelihood stability. Although these indicators are highly relevant, they often occupy the boundary between social and economic sustainability. Therefore, future S-LCA studies should expand beyond income-related measures and incorporate indicators such as access to healthcare, social insurance coverage, agricultural extension services, bargaining power, employment security, and equitable access to productive resources.

The review further reveals that local communities receive greater attention in regional and value-chain studies than in farm-level assessments. This suggests that community-level impacts are often more visible at broader analytical scales. Consequently, the effective assessment of local communities requires context-specific indicators addressing social participation, migration, social conflicts, cultural change, and community resilience, dimensions that remain underrepresented in the current rice S-LCA literature.

In contrast, consumers have been largely excluded from existing assessments. Given the strategic role of rice in food systems, this omission represents a significant limitation. Issues such as food accessibility, affordability, food security, traceability, and consumer trust remain insufficiently explored. As a result, current S-LCA applications in rice production remain predominantly production-oriented.

A further methodological challenge concerns the lack of consistency in functional units and system boundaries. Variations in the definition and reporting of functional units—including land-based reference units, economic units, and system-level units—as well as the absence of an explicitly defined unit in some studies, directly affect the interpretation and comparability of social indicators. Greater transparency and standardization in reporting functional units and system boundaries would therefore improve comparability across studies.

Overall, the reviewed literature demonstrates that S-LCA possesses considerable potential for identifying and explaining social impacts within rice production systems. However, while existing studies have been largely successful in diagnosing social issues, they have been less effective in translating their findings into operational frameworks capable of supporting sustainable rural development policies. Consequently, bridging the gap between social assessment and development-oriented policy-making remains one of the most important challenges for future research.

5. Discussion and Conclusion

This systematic review demonstrated that although Social Life Cycle Assessment (S-LCA) research in rice production has expanded considerably in recent years, important challenges remain regarding the comprehensive representation of social sustainability dimensions, particularly social justice, social welfare, livelihood security, social participation, and balanced stakeholder coverage. The comparative analysis revealed that geographical context, economic development level, institutional structures, and production system characteristics play decisive roles in shaping and interpreting S-LCA outcomes. Furthermore, the two dominant assessment approaches—performance-based and risk-based—although apparently generating different results, operate at different analytical levels and should therefore be regarded as complementary rather than contradictory perspectives.

The findings clearly indicate that addressing the social dimensions of rice production is not merely an optional addition to sustainability assessment

but a fundamental requirement for achieving sustainable rural development. Performance-oriented indicators such as farmers' income, occupational health and safety, and livelihood stability are directly associated with improvements in rural quality of life. At the same time, the reviewed studies suggest that social sustainability challenges may extend beyond farm boundaries and emerge through broader institutional and supply-chain structures. Therefore, achieving socially sustainable rice production requires simultaneous attention to local production conditions and wider socio-economic contexts affecting rural livelihoods.

Consequently, rural development policies in rice-producing regions should simultaneously address both farm-level and supply-chain dimensions. Farm-level interventions may include occupational safety standards, fair labor contracts, worker training programs, and social insurance schemes, whereas supply-chain interventions should focus on traceability systems, responsible sourcing practices, supplier evaluation, and the mitigation of structural social risks. Only through such an integrated approach can S-LCA evolve from a diagnostic assessment tool into a practical roadmap for promoting social justice, social cohesion, and resilience within rural communities.

The stakeholder analysis further revealed that workers and farmers have received the greatest attention in the existing literature, whereas local communities and consumers remain substantially underrepresented. This imbalance may reduce the comprehensiveness of social assessments and highlights the need for broader stakeholder coverage in future research. In addition, methodological heterogeneity regarding functional units, system boundaries, and indicator quantification continues to limit the comparability of findings across studies.

Another important conclusion emerging from this review is that many existing S-LCA studies, despite their emphasis on social indicators, have not established a sufficiently explicit connection between assessment outcomes and the broader objectives of social sustainability and rural development. Indicators such as income, occupational health and safety, employment, food security, and social participation frequently appear in the literature; however, they are often analyzed individually rather than being interpreted within broader frameworks of social justice, livelihood security, social welfare, and community empowerment. Strengthening the contribution of S-LCA to policy-making therefore requires a more explicit integration of assessment outcomes with the objectives of sustainable rural development.

Based on the findings of this review, several directions for future research and methodological advancement can be proposed. First, S-LCA frameworks should move beyond methodological standardization alone and facilitate the systematic assessment of key dimensions of social sustainability, including social justice, livelihood security, social welfare, and community participation. Such integration would enhance the applicability of S-LCA within rural development planning and policy-making processes.

Second, the development and localization of social indicators should account for the cultural, institutional, and livelihood characteristics of rice-producing regions. Indicators such as livelihood security, access to resources, community participation, and rural resilience could complement conventional S-LCA indicators and provide a more realistic representation of social development conditions in rural areas.

Third, greater integration between performance-based and risk-based approaches is recommended. Such integration would enable simultaneous assessment of current social conditions and future vulnerabilities, thereby providing policymakers with a more comprehensive understanding of both existing challenges and emerging threats to long-term social sustainability.

Fourth, future studies should move beyond the exclusive use of aggregated social scores and incorporate measurable indicators directly linked to rural quality of life, employment security, social insurance coverage, access to social services, and local participation. This shift would significantly enhance the practical relevance of S-LCA findings for rural development planning and policy formulation.

In conclusion, the future development of S-LCA in rice production depends not only on methodological refinement but also on its capacity to function as a tool for monitoring and guiding social sustainability in rural areas. The success of future studies should therefore be evaluated not solely on methodological rigor, but also on their ability to contribute meaningfully to social justice,

livelihood security, social welfare, and the empowerment of rural communities.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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Original Article

مرور نظام‌مند ارزیابی چرخه حیات اجتماعی تولید برنج و پیامدهای آن برای توسعه پایدار روستایی

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چکیده

مبسوط

۱. مقدمه

توسعه پایدار به عنوان پارادایمی تأثیرگذار برای بهبود رفاه انسانی و حفاظت از منابع طبیعی، بر تعادل ابعاد اقتصادی، زیست‌محیطی و اجتماعی تأکید دارد. توسعه پایدار روستایی با تکیه بر پایداری اجتماعی، به دنبال توزیع عادلانه منابع، انسجام اجتماعی، امنیت معیشت و رفاه کارگران است. تولید برنج با تأمین غذای بیش از ۳/۵ میلیارد نفر، نقشی اساسی در امنیت غذایی و معیشت روستایی دارد. با وجود این اهمیت، پژوهش‌های پیشین عمدتاً بر ابعاد زیست‌محیطی و اقتصادی متمرکز بوده و ابعاد اجتماعی مانند نابرابری دستمزد، شرایط کاری نامناسب و مخاطرات سلامت شغلی کمتر توجه شده‌اند. ارزیابی چرخه حیات اجتماعی (S-LCA) چارچوبی مناسب برای شناسایی و ارزیابی پیامدهای اجتماعی در گروه‌های مختلف ذی‌نفعان فراهم می‌کند و از سیاست‌گذاری مبتنی بر شواهد به سوی توسعه پایدار روستایی حمایت می‌نماید. هدف این مطالعه، مرور نظام‌مند کاربرد S-LCA در تولید برنج، شناسایی شاخص‌های اجتماعی، بررسی نمایندگی ذی‌نفعان، تحلیل ناهمگونی روش‌شناختی و برجسته‌سازی شکاف‌های پژوهشی است.

۲. مبانی نظری تحقیق

پایداری اجتماعی در توسعه روستایی به ظرفیت جوامع برای حفظ انسجام اجتماعی، بهبود کیفیت زندگی، دسترسی عادلانه به فرصت‌ها و مشارکت در تصمیم‌گیری اشاره دارد. ارزیابی چرخه حیات اجتماعی از تلفیق سه سنت فکری نشأت گرفته است: پارادایم توسعه پایدار، رویکرد توسعه انسانی و ادبیات عدالت اجتماعی. برخلاف ارزیابی زیست‌محیطی، S-LCA به مردم، روابط اجتماعی و ساختارهای نهادی می‌پردازد. گروه‌های کلیدی ذی‌نفع شامل کارگران، مصرف‌کنندگان، جوامع محلی و کنشگران زنجیره ارزش هستند. دو رویکرد اصلی در S-LCA وجود دارد: رویکرد مبتنی بر عملکرد که شرایط واقعی اجتماعی را با داده‌های میدانی ارزیابی می‌کند و رویکرد مبتنی بر ریسک که احتمال وقوع پیامدهای نامطلوب را با استفاده از داده‌های ثانویه برآورد می‌نماید. چارچوب تحلیلی این مطالعه، مسیری ترتیبی از ارزیابی S-LCA، شناسایی ذی‌نفعان و رویکرد روش‌شناختی، شناسایی ابعاد اجتماعی و نقاط بحرانی، پیامدهای سیاستی، پیامدهای پایداری اجتماعی و توسعه پایدار روستایی را ترسیم می‌کند.

۳. روش تحقیق

این مطالعه با رویکرد مرور نظام‌مند و بر اساس رهنمودهای PRISMA انجام شد. جستجو در پایگاه‌های Scopus و Web of Science با عبارات مرتبط با تولید برنج و ارزیابی چرخه حیات اجتماعی برای دوره ده‌ساله (۲۰۱۶-۲۰۲۶) صورت گرفت. معیارهای ورود شامل مقالات مجلات معتبر، مطالعات مستقیم در ارتباط با کاربرد S-LCA در تولید برنج، ارائه اطلاعات روش‌شناختی کافی و نگارش به زبان انگلیسی بود. پس از غربالگری عنوان، چکیده و متن کامل، هفت مطالعه برای مرور نهایی انتخاب شدند. استخراج داده‌ها شامل متغیرهای نویسندگان، سال انتشار، محدوده جغرافیایی، گروه‌های ذی‌نفع، شاخص‌های اجتماعی، واحد کارکردی، مرز سیستم و رویکردهای روش‌شناختی بود. کیفیت مطالعات بر اساس سه معیار سازگاری روش‌شناختی، کیفیت داده‌های اجتماعی و نمایندگی ذی‌نفعان ارزیابی شد.

۴. یافته‌های تحقیق

مرور مطالعات نشان داد که علی‌رغم کاربرد چارچوب S-LCA در همه پژوهش‌ها، ناهمگونی قابل‌توجهی در عملیاتی‌سازی آن وجود دارد. از نظر رویکرد ارزیابی، چهار مطالعه به رهنمودهای

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UNEP/SETAC اشاره داشتند و دو مطالعه عمدتاً از رویکرد مبتنی بر ریسک استفاده کردند. تنوع در تعریف واحد کارکردی (از هکتار تا واحد اقتصادی و سطح سیستم) و مرز سیستم (سه مطالعه در مرحله مزرعه، دو مطالعه در زنجیره ارزش و دو مطالعه در چرخه حیات کامل) مشاهده شد. کارگران حساسترین گروه ذی‌نفع بودند و شاخص‌های سلامت و ایمنی شغلی، دستمزد منصفانه و حقوق کار بیشترین فراوانی را داشتند. جوامع محلی در پنج مطالعه و مصرف‌کنندگان کمترین توجه را دریافت کردند.

سیستم‌های تولید ارگانیک عملکرد اجتماعی بهتری نسبت به سیستم‌های متداول نشان دادند، اما نگرانی‌هایی مانند کار کودکان و استثمار نیروی کار همچنان وجود داشت. تفاوت‌های جغرافیایی و نهادی نقش تعیین‌کننده‌ای در عملکرد اجتماعی ایفا کردند؛ مطالعه تطبیقی ایران و مالزی نشان داد که تفاوت در ساختارهای نهادی و سطوح مکانیزاسیون، امتیازات عملکرد اجتماعی را به طور قابل‌توجهی تحت تأثیر قرار می‌دهد. ارزیابی کیفیت نشان داد که از نظر سازگاری روش‌شناختی، مطالعات دارای تعریف صریح واحد مرجع و مرز سیستم قوی‌تر بودند و کیفیت داده‌های اجتماعی در مطالعات مبتنی بر داده‌های میدانی بالاترین بود.

۵. بحث و نتیجه‌گیری

مرور نظام‌مند نشان داد که پژوهش‌های S-LCA در تولید برنج با چالش‌هایی در نمایش جامع پایداری اجتماعی، به ویژه عدالت اجتماعی، رفاه، امنیت معیشت و مشارکت اجتماعی، و همچنین پوشش متوازن ذی‌نفعان مواجه هستند. دو رویکرد مبتنی بر عملکرد و مبتنی بر ریسک اگرچه نتایج متفاوتی تولید می‌کنند، در سطوح تحلیلی متفاوتی عمل کرده و مکمل یکدیگرند. پرداختن به ابعاد اجتماعی تولید برنج نه یک افزودن اختیاری، بلکه شرط اساسی تحقق توسعه پایدار روستایی است. شاخص‌هایی مانند درآمد کشاورزان، سلامت و ایمنی شغلی و ثبات معیشت با کیفیت زندگی روستایی مرتبط هستند و چالش‌های پایداری اجتماعی ممکن است فراتر از مزرعه و در ساختارهای زنجیره تأمین ظهور کنند.

بر اساس یافته‌ها، چارچوب‌های S-LCA باید فراتر از استانداردسازی روش‌شناختی حرکت کرده و ارزیابی نظام‌مند ابعاد کلیدی پایداری اجتماعی را تسهیل کنند. توسعه و بومی‌سازی شاخص‌ها باید با در نظر گرفتن ویژگی‌های فرهنگی و نهادی مناطق تولیدکننده برنج انجام شود. ادغام رویکردهای مبتنی بر عملکرد و ریسک و استفاده از شاخص‌های قابل اندازه‌گیری مستقیم مرتبط با کیفیت زندگی روستایی توصیه می‌شود. در مجموع، توسعه آینده S-LCA در تولید برنج نه تنها به اصلاحات روش‌شناختی، بلکه به ظرفیت آن به عنوان ابزاری برای پایش و هدایت پایداری اجتماعی در مناطق روستایی وابسته است.

کلیدواژه‌ها: تولید برنج؛ ارزیابی چرخه حیات اجتماعی؛ پایداری اجتماعی؛ توسعه پایدار روستایی؛ معیشت روستایی؛ کشاورزی پایدار.

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