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Inclusive by design? Rethinking sustainability standards and certification schemes for smallholders

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ABSTRACT

The transition to more sustainable models requires the active participation of all stakeholders in value chains. Although large producers tend to bear the majority of environmental, economic and social burdens, small producers also play a vital role in promoting sustainability and circularity. However, their ability to adapt and adopt technological innovations is often limited by narrower profit margins. Therefore, sustainability requirements must be applied flexibly and proportionately to small producers, without underestimating any criteria, while encouraging compliance wherever possible. Currently, most standards and certification schemes do not differentiate between actors in the value chain, focusing mainly on large producers. In this context, this manuscript aims to identify and propose a set of requirements tailored to small producers, using an integrated approach encompassing environmental, economic, social and circular sustainability. Various key certification schemes were used as the basis for defining evaluation indicators. The manuscript also introduces a scoring methodology that combines three complementary evaluation methods: (i) evaluation of the quality of certification schemes, (ii) evaluation of the minimum requirements applicable to small producers and (iii) evaluation of the suitability and practical applicability of the indicators. Thus, this manuscript aims to facilitate the meaningful integration of small producers into sustainable and circular development trajectories.

1. Introduction

In the pursuit of promoting and transitioning towards more sustainable and circular value chains, it is essential that all actors adopt appropriate production strategies [1]. Even though the largest producers are the ones exerting the greatest influence, both in terms of environmental loads, global economy and social welfare [2], smallholders (namely, small-scale producers), play a crucial role in the balanced performance of value chains. In fact, smallholders can have a significant impact and imply a critical contribution to food security, biodiversity conservation, and social communities [3,4,28].

Smallholders, commonly referred to as farmers who operate on a limited scale with restricted land and resources, constitute the backbone of agriculture and farming activities in many countries. However, their definition also includes small-scale pastoralists, fishers, and forest keepers [5]. Notably, a study published by the Food and Agriculture Organization (FAO) [32] in 2021 revealed that smallholder farmers account for approximately 35 % of the global food production. This represents five out of six farms globally that are less than 2 ha in size, accounting for around 12 % of all agricultural land. Furthermore, the influence of smallholder farmers can be even more pronounced in specific sectors, such as coffee and cocoa, which are responsible for 60 % and 80–95 % of the global production, respectively [6]. Given this substantial contribution, small-scale producers play a pivotal role in promoting sustainable resource management, global food security, and rural employment [7,8]. According to the World Census of Agriculture, as cited by Ricciardi et al. [9], farms under 2 ha make up 84 % of all farms across 167 countries.

Traditional practices applied by smallholders can contribute to the conservation of ecosystem services, highlighting their role as valuable stewards of natural resources [10,11]. However, their limited economic capacity—stemming from high costs and insufficient financial support—hinders their ability to adopt more advanced sustainable and circular practices [12]. Furthermore, the restricted access to training or

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Table 1
Summary of the state of research into the impact of certification systems on small-scale producers: methodological approaches, areas of analysis, and key findings.

	Focus/objective	Methodology	Main findings	Relevance to present study
Blackman y Rivera [19]	Assessment of the environmental, social and economic consequences of sustainability certification	A systematic literature review was conducted, focusing on the methodology followed by 46 empirical studies.	There is little evidence to suggest that certification has any benefits, and the research methods used are not consistent or reliable.	It justifies the need for adaptive, rigorous frameworks that are tailored to the capacities of smallholders.
Glasbergen [20]	From the perspective of small-scale coffee and palm oil producers in Indonesia, assessment whether certification can transform their livelihoods and bring real value.	A variety of research methods were used to gather data from RSPO[1]/ ISPO[2]/ISCoffee[3], including surveys, case studies, chain and profitability analyses, interviews and focus groups.	There are marginal and uneven economic benefits, uncertain premiums and high costs. There is also low understanding and weak organization, and the transformative capacity of certification alone is limited for smallholders.	A gradual framework that is adapted to smallholders' capacities is justified, with feasible indicators and complementary support beyond certification.
Schoneveld et al. [21]	Examine how the socio-economic heterogeneity of small palm oil producers in Indonesia influences their level of compliance with the ISPO standard and Good Agricultural Practices.	Survey of 947 producers in Kalimantan. Cluster analysis and regression models were used to identify typologies and the determinants of compliance.	There are six profiles of producers, which show varying levels of compliance. Most of them show poor results due to informality, weak organization, and a lack of technical support.	It emphasizes the importance of adapting certification frameworks to the varying capacities of smallholders and promotes progressive and inclusive approaches.
Meemken [17]	Economic impact of sustainability standards, such as Fairtrade, organic certification, Rainforest Alliance certification, UTZ[4] certification and GlobalGAP[5] certification, on small-scale producers in developing countries.	Systematic review and meta-analysis of 97 studies (1143 estimates), using standardized percentage differences, measures of central tendency, and meta-regressions.	Certified producers receive prices that are 20–30 % higher, resulting in higher incomes and profits (an increase of approximately 16 % in household income and 45 % in crop profits). However, the effects on yields are mixed, with particularly negative results in organic systems.	It provides a comprehensive quantitative synthesis showing high heterogeneity in the effects. This highlights the need for more rigorous research designs and policies adapted to institutional and productive contexts.

Note. [1] Roundtable on Sustainable Palm Oil; [2] Indonesian Sustainable Palm Oil; [3] Indonesian Sustainable Coffee Certification; [4] UTZ Certified Program for Sustainable Farming; [5] Global Good Agricultural Practices.

knowledge-sharing platforms reduces the smallholders' ability to adapt to novel production strategies in the agricultural, livestock, and forestry sectors (Murano et al., 2023; [13]). Furthermore, the lack of policy incentives also hinders their capacity to become agents in the transition to more sustainable and circular production models [14,29]. To address these gaps, it is imperative to enhance the development of inclusive policies, effective subsidies, and adapted training programs tailored for the smallholder level. This aligns closely with broader international efforts, such as the United Nations Sustainable Development Goals (SDGs), which include a dedicated target (SDG 2.3) to double the agricultural productivity and incomes of small-scale food producers by 2030, increasing their market and opportunities [15]. In contrast, numerous studies have underscored the obstacles that smallholders encounter in obtaining certification, as well as the potential benefits it can bring. Individual certification remains relatively uncommon among small-scale producers, mainly due to limited financial resources and the lack of technical capacity to the bureaucratic certification processes [16–18].

Aiming at providing a general overview on the research reports available in the literature about sustainability requirements applicable to smallholders, Table 1 summarizes the key findings. It summarizes the most relevant objectives, methodologies and findings, enabling to identify common patterns and differences between the sectors, regions and standards analyzed. As it could be seen, there is a lack of analysis about requirements applicable for smallholders to pave the way for more sustainable and circular value chains. In light of this, this research takes things a step further by developing a structured framework that identifies and classifies the most relevant sustainability and circularity requirements for smallholders. The proposed approach fills an existing research gap and provides practical guidance to support the progressive integration of smallholders into certification systems and circular value chains. This ensures inclusiveness and feasibility across diverse production contexts.

In this context, the primary objective of this manuscript is not to measure the level of direct compliance of smallholders, but rather to develop and apply a methodological framework that identifies and proposes requirements specifically tailored to their needs. To this end, a systematic analysis of key certification schemes has been conducted in accordance with the methodology developed by Ares-Sainz et al. [22]. This approach analyses the specific requirements identified in certification schemes that could be potentially applicable for smallholders. For this analysis, a scoring system has been developed aiming at assessing the adequacy, applicability and relevance of the requirements for smallholders. The study aims to generate a set of adapted requirements that reflect the unique conditions and capacities of small-scale producers, thereby supporting their meaningful integration into sustainable and circular value chains.

Table 2
Identification of the certification schemes (CSLs) that have specific standard for smallholders.

CSLs	Does the CSL include smallholders' requirements?
RSB Global Advanced Products Certification	Yes
ISCC Plus	No
OK Biobased	No
Bio-Based Content	No
REDcert	No
Green Gold Label	No
Better Biomass	Yes
OK Compost	No
OK Biodegradable	No
Cradle to Cradle	No
Rainforest Alliance	Yes
Forest Stewarship Council (FSC)	No
Programme for the Endorsement of Forest Certification (PEFC)	No
ASC-MSC Seaweed Standard	No
GoodWeave	No
Green Button	No
COSMOS	No
Fair for Life	Yes
Fairtrade International	Yes

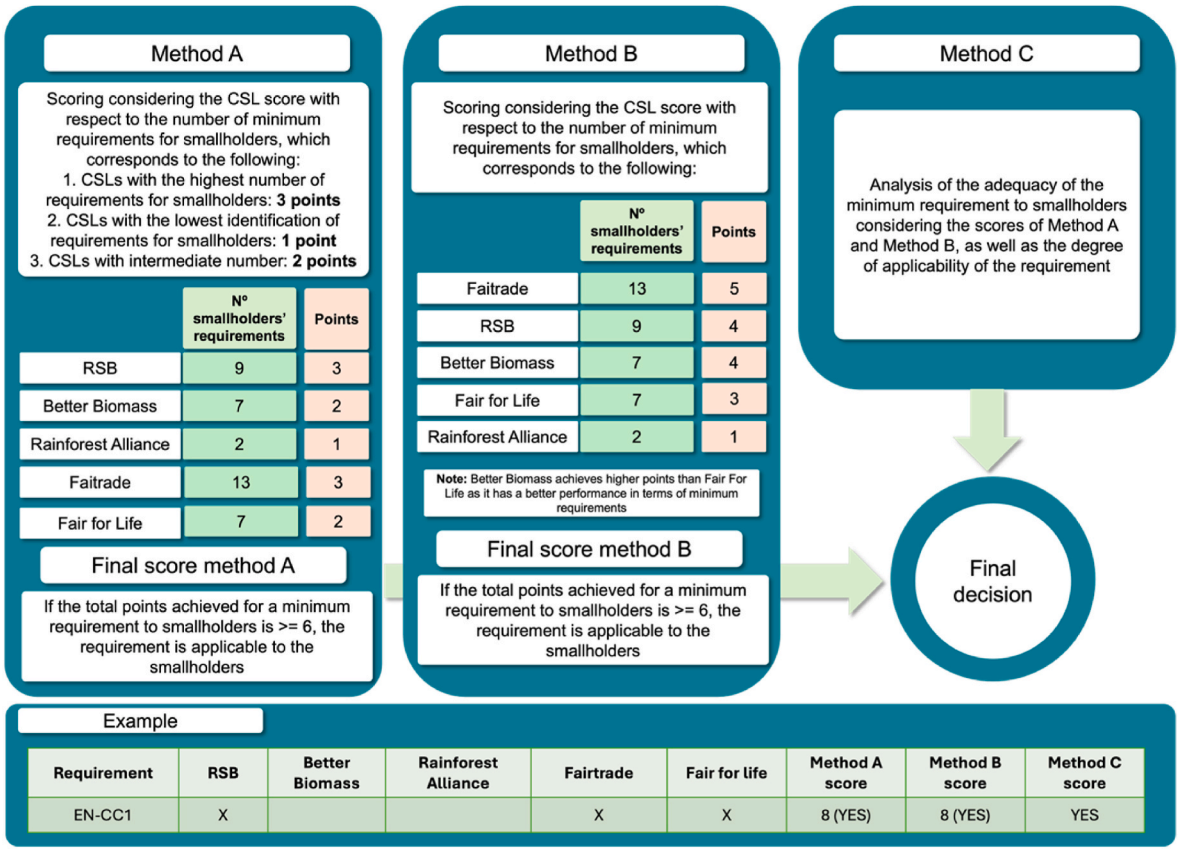


Fig. 1. Scoring system methodology proposed.

2. Methodology

2.1. Identification of certification schemes that have a specific standard for smallholders

As a preliminary step, a systematic review was conducted of certification schemes applied to bio-based value chains. The review focused particularly on schemes that incorporate differentiated standards, customised guidelines, or adapted mechanisms for small producers. This review builds on the work of Ares-Sainz et al. [22], who identified a wide range of sustainability, circularity and governance indicators in certification systems. However, that study did not explicitly address the particular challenges that small producers face when implementing them.

Within the framework of this study, 19 certification schemes were identified (see Table 2), forming the initial set of documents reviewed. From this preliminary set of documents, to which two main inclusion criteria were applied in order to ensure the relevance and consistency of the selected certification schemes:

1. Relevance to bio-based value chains, excluding schemes not applicable to the agricultural, forestry, fisheries or related sectors.
2. The existence of specific provisions for small producers, such as group certification, simplified audits or scaled requirements.

The outcome of the selection process is summarized in Table 2, which lists the schemes that were included or excluded and the reasons for this decision.

It should be noted that some certification schemes and labels (CSLs) incorporate mechanisms such as group certification, simplified audits or scaled-down requirements, all of which facilitate access for small producers. These approaches provide valuable guidance on how to proportionally adapt sustainability requirements without compromising the core principles and pillars of sustainability and circularity.

Finally, given the growing adoption of Global GAP by small-scale producers worldwide, this review evaluated its relevance. However, it was not included in the final selection, as its scope focuses primarily on good agricultural practices and food safety without explicitly addressing the sustainability and circularity criteria of bio-based chains or making specific provisions for small producers within the framework of this study.

2.2. Identification of initiatives and policies for smallholders

As part of the methodology, a systematic analysis was conducted on the most relevant CSLs to identify those incorporating specific requirements or adaptations for smallholders. For this purpose, the review of regulatory documents, technical guidelines, audit criteria, and implementation frameworks for each scheme was conducted, with the goal of determining which minimum requirements outlined by Ares-Sainz et al. [22] can be applicable to lower production capacities. The primary focus during this phase was to detect the explicit inclusion of provisions, procedures, or tools designed to support the participation of small producers without compromising core sustainability principles. To achieve this, certification schemes encompassing the four pillars of sustainability and circularity—environmental, social, economic, and circular—were examined across various stages of the value chain. The review considered factors such as tailored adaptations for smallholders, group certification approaches, clarity and accessibility of technical language, simplified verification mechanisms, and the level of operational flexibility based on operator size.

The review applied three main criteria: (i) the explicit inclusion of standards, requirements, criteria or adaptations for smallholders; (ii) the technical and operational feasibility of each requirement for low-

capacity producers; (iii) consistency in terms of coverage of the four sustainability and circularity pillars across schemes.

Additionally, a review of relevant European strategic and regulatory frameworks was conducted to identify overarching guidelines that could inform the proportional application of sustainability and circularity criteria. While the previous study focused on aligning certification systems with overarching public policies, this part of the methodology examines more closely how specific European strategies and legislative instruments may shape the inclusion of small producers in certified value chains.

The analysis considered key documents such as the EU Bioeconomy Strategy, the European Green Deal and guidelines related to bioeconomy transition and social inclusion. Although these frameworks do not always include specific provisions for small-scale operators, they often acknowledge general principles such as proportionality, gradual implementation and the need for technical and financial support, particularly for small and medium enterprises or actors with limited operational capacity. These principles provide a useful conceptual basis for justifying the design of differentiated mechanisms in certification systems, particularly with regard to minimum requirements adapted to small producers.

2.3. Identification of minimum requirements applicable to smallholders

This section outlines a methodological adaptation designed specifically for small-scale producers. It is based on the idea that while the fundamental principles of sustainability must be met, the implementation mechanisms and requirements should be scaled down proportionally according to the producers' size, operational capacity and socioeconomic context.

To this end, the indicators and minimum requirements identified by Ares-Sainz et al. [22] were reviewed and reinterpreted based on the criterion of functional proportionality. These criteria enable the previously established indicators to be applied in environments with limited technical, labor or financial resources. For instance, rather than requiring the direct measurement of greenhouse gas emissions, the use of predefined emission factors or simplified models endorsed by the certification schemes themselves is recommended. In terms of governance, priority is given to basic participation and accountability mechanisms, even when these are not formally structured within complex institutional frameworks.

A scoring system was developed that integrates three complementary methods (A, B and C) to assess the applicability of minimum sustainability requirements to small producers. These methods combine objective criteria with practical considerations, enabling a final decision to be made on the applicability of each requirement.

Method A: assessment of differentiated requirements for small producers

This method involves counting and weighing up the number of provisions specifically aimed at small producers included in each certification scheme. A three-level scale (1–3) is used for this purpose:

- 1 point: The scheme has a small number of differentiated requirements.
- 2 points: the scheme incorporates a moderate number of adapted provisions.
- 3 points: the scheme presents a comprehensive and clearly defined set of specific requirements.

To harmonize the results with the scale used in Method A and ensure comparability of the final score, the values are converted into the following ranges: 2 = low, 7 = intermediate, and 9–13 = high (see Fig. 1). This classification was established based on the distribution of the results obtained in the set of schemes analyzed.

Using a different scale (1–5 versus 1–3 in Method A) reflects this criterion's more limited nature, as it focuses exclusively on the presence and number of differentiated provisions for small producers rather than assessing broader coverage.

Method B: assessment of the quality of certification schemes. This method focuses on three key dimensions:

1. Sectoral coverage of the bioeconomy: a scheme covering a larger number of sectors is considered to offer greater flexibility and relevance to small producers with diversified activities. Previous studies suggest that greater sectoral breadth facilitates the integration of producers into multiple value chains [23]. While the 'ideal' number is not defined in absolute terms, it is clear that schemes with greater cross-sectoral coverage receive higher scores.
2. Stages of the value chain: Certification schemes that cover multiple stages of the value chain, such as primary production, processing, distribution and consumption, are considered more comprehensive. This is because their broader scope improves overall traceability and ensures consistent sustainable performance throughout the entire chain.
3. General applicability: this refers to the extent to which the requirements of a scheme can be implemented in various production contexts, especially in the case of small producers. To this end, aspects such as the presence of flexibility clauses, simplification mechanisms or provisions specifically designed to facilitate compliance are taken into account.

The score (1–5) is derived from combining these three dimensions: the greater the sectoral and stage coverage, and the greater the general applicability, the higher the score. Fig. 1 illustrates the allocation logic, demonstrating that the score is derived from the accumulation of these three dimensions rather than an arbitrary ranking.

Decision threshold: it was determined that a requirement must receive a score of at least 6 points to be considered applicable to small producers. This value was defined as the point at which an appropriate level of rigor is ensured while maintaining the feasibility of implementation in contexts with limited resources.

Method C: Qualitative assessment of suitability and applicability

This method uses qualitative analysis to evaluate the relevance of requirements within the operational context of small-scale producers. The following factors are considered:

1 Implementation cost
2 Availability of technical and human resources
3 Compatibility with traditional practices.

The results of the three methods are integrated as follows:

If all three methods yield positive results (A $\geq$6, B $\geq$ 2 and C applicable), the requirement is considered fully applicable. If two methods are positive and one is negative, each case is reviewed by an expert to decide whether the requirement remains or is adapted. If only one method is positive, the requirement is discarded or reformulated. This ensures that the final decision avoids ambiguities and that the requirements applied to small producers are justified from technical and practical standpoints. Fig. 1 presents the complete logic of the system together with an illustrative example.

3. Results and discussions

3.1. Analysis of the requirements applicable to smallholders

The analysis of the applicability of minimum sustainability requirements to small producers was based on certification schemes that set out specific standards for this group. Of the 19 schemes evaluated, only five — the Roundtable on Sustainable Biomaterials (RSB), Better Biomass, Rainforest Alliance, Fair for Life and Fairtrade International — make explicit reference to small producers or include differentiated standards. The complete list of evaluated certification and labelling

Table 3
Overview of the five certification schemes that include specific provisions for smallholders. *Note*: The numbers indicate the value chain stages covered (1 = production, 2 = manufacturing, 3 = distribution, 4 = consumption), while the colour of each cell reflects applicability: green for applicable and orange for not applicable. The last column includes the performance score based on sectoral and value chain coverage.

CSLs	Bioeconomy sectors included	Value chain stages				Main description	Order and score	
		1	2	3	4			
RSB Global Advanced Products Certification	Agriculture, silviculture, energy, forestry /chemical / textile / paper industries, liquid biofuels					Comprehensive and complete approach to sustainability, covering social and environmental aspects in depth. It has a very wide geographical coverage, and it considers and is applicable to all sectors of the bioeconomy.	1st	5
Better Biomass	Agriculture, silviculture, forestry /chemical / textile industries					Robust certification like RSB, but applicable to less bioeconomy sectors in comparison.	2nd	4
Rainforest Alliance	Forestry / chemical / textile industries					It is robust in terms of environmental and social criteria, but its applicability is limited as it covers a smaller number of bioeconomy sectors.	3rd	3
Fair for Life	Agriculture, paper industries					The standard mainly focuses on biodiversity and conservation issues, and it has limited applicability to small producers.	4th	2
Fairtrade International	Agriculture, silviculture, energy, liquid biofuels					It provides limited information on environmental and social aspects, and its geographical coverage is limited to Europe.	5th	1

schemes is presented in Table 2. Twenty-one minimum requirements from the environmental pillar, seven from the social pillar, two from the economic pillar, and thirteen from the circularity pillar were analyzed. The technical and operational feasibility of each requirement for small producers was assessed using the cross-scoring methodology, which considers sectoral coverage, level of differentiation and practical feasibility (methods A, B and C), as defined in the previous section.

The five certification schemes that include provisions for small-scale producers span key sectors of the bioeconomy and vary in their focus on sustainability. The RSB scheme is applicable to a wide range of sectors, including agriculture, forestry, bioenergy and the chemical industry. It is distinguished by its holistic approach and specific standards for small producers. Better Biomass mainly focuses on bio-based materials in the agricultural and forestry sectors, although it pays less explicit attention to small-scale producers. Rainforest Alliance operates in the agricultural and forestry product sectors, incorporating robust social and environmental criteria, as well as mechanisms such as group certification. Fair for Life focuses on agricultural and paper products, promoting fair trade and biodiversity, and includes provisions for small-scale organizations. Fairtrade International specialises in agriculture and has a strong focus on small producers, with customised requirements that aim to improve their socio-economic and environmental conditions. Although Fairtrade International appears in Table 3 with a lower score in terms of sector coverage and value chain stages, its differentiated focus on small producers makes it a highly relevant scheme for this study.

Analysis of these five CSLs reveals initiatives within their regulatory structures that facilitate compliance with adapted minimum requirements. These initiatives act as internal mechanisms that adjust the

Table 4
Description of the 14 minimum sustainability requirements applicable to smallholders, organized by pillar.

Minimum Requirements	
Environmental pillar	
EN-CC-1	Does the standard require a plan/policy on GHG emissions, mitigation strategies and adaptation measures to climate change?
EN-W-1	Does the standard require the prevention of contamination of surface water and ground water?
EN-W-8	Does the scheme require water use reduction practices?
EN-S-1	Does the standard require soil conservation and enhancement practices?
EN-B-3	Does the standard include criteria on the use of alien invasive species?
EN-B-7	Does the standard require strategies and actions on ecosystem protection through spatial management (conservation areas, 'set aside' or buffer zones)?
EN-B-8	Does the standard require the restoration or rehabilitation of natural habitats and/or ecosystems?
Social pillar	
WO-1	The certification scheme shall require compliance with the minimum age for work as defined by applicable national legal requirements or the age of completion of compulsory education, or the prohibition of child labour.
WO-4	The certification scheme shall include criteria on equal opportunities or discrimination
WO-6	The certification scheme shall require operators to implement measures to safeguard rights relating to forced labour, considering both physical or psychological violence against workers.
WO-9	The certification scheme shall require the presence of adequate protection measures are in place to ensure that the workers safety is guaranteed.
WO-11	The certification scheme shall have requirements related to: working hours and rest periods, worker representation and communication, training, overtime compensation, flexible working conditions, grievance mechanisms.
Economic pillar	
ER-1	The certification scheme shall require operators to document and quantify all the economic related items to evaluate the long-term economic viability of the process.
Circularity pillar	
EOLS-9	The certification scheme shall require measures to reduce waste production.
	The certification scheme shall calculate the waste-factor of production phase.

Table 5
Environmental pillar – analysis and final decision for minimum requirements applicable to smallholders. Acronyms: MR (minimum requirement), SHs (smallholders).

MR	Scoring according to Table 3	MR for SHs?	Scoring according to level of compliance	MR for SHs?	Adequate MR for SHs?	Final decision – MR applicable to SHs?
EN-CC-1	8	**YES**	8	**YES**	Yes, feasible to be applicable for SHs	**YES**
EN-CC-2	9	**NO**	9	**YES**	**No:** Quantifying lifecycle GHG emissions with a specific methodology is challenging without training for smallholders	**NO**
EN-CC-3	2	**NO**	2	**NO**	Not applicable according to CSLs	**NO**
EN-W-1	12	**YES**	12	**YES**	Yes, feasible to be applicable for SHs	**YES**
EN-W-2	0	**NO**	0	**NO**	Not applicable according to CSLs	**NO**
EN-W-4	4	**NO**	4	**NO**	Not applicable according to CSLs	**NO**
EN-W-8	12	**YES**	12	**YES**	Yes, feasible to be applicable for SHs	**YES**
EN-S-1	12	**YES**	12	**YES**	Yes, feasible to be applicable for SHs	**YES**
EN-B-3	7	**YES**	7	**YES**	Yes, feasible to be applicable for SHs	**YES**
EN-B-5	8	**YES**	8	**YES**	**No:** Creating a biodiversity plan involves technical expertise, regular monitoring, and often external assistance, making it difficult for smallholders to implement.	**NO**
EN-B-6	0	**NO**	0	**NO**	Not applicable according to CSLs	**NO**
EN-B-7	7	**YES**	7	**YES**	Yes, feasible to be applicable for SHs	**YES**
EN-B-8	11	**YES**	11	**YES**	**No:** Restoration practices are resource-intensive and challenging for smallholders without significant external support.	**NO**
EN-B-9	2	**NO**	2	**NO**	Not applicable according to CSLs	**NO**
EN-NR-1	0	**NO**	0	**NO**	Not applicable according to CSLs	**NO**
EN-NR-4	0	**NO**	0	**NO**	Not applicable according to CSLs	**NO**
EN-NR-7	0	**NO**	0	**NO**	Not applicable according to CSLs	**NO**
EN-HS-1	0	**NO**	0	**NO**	Not applicable according to CSLs	**NO**
EN-HS-3	7	**YES**	7	**YES**	Yes, feasible to be applicable for SHs	**YES**
EN-HS-6	2	**NO**	2	**NO**	Not applicable according to CSLs	**NO**
EN-G-1	2	**NO**	2	**NO**	Not applicable according to CSLs	**NO**

level of technical and administrative requirements according to the size and operational capacity of producers. These CSLs are therefore crucial in determining the actual feasibility of the evaluated requirements.

The results show that schemes such as the Roundtable on Sustainable Biomaterials (RSB) and Fairtrade International stand out: The RSB is notable for its broad coverage and comprehensive approach, while Fairtrade International is recognised for its strong focus on small producers. This is evident through the incorporation of tools such as group certification, simplified audits, the use of default factors for environmental estimates, and access to technical support programmes. Fair for Life and Rainforest Alliance also include adaptive guidelines and proportionality principles, albeit less systematically. Better Biomass takes a more limited approach, with no clearly differentiated mechanisms for small producers.

The minimum requirements were selected based on a predefined criterion, with a focus on those that are universally relevant and technically feasible for smallholders. Following the selection process, a final set of 14 requirements were identified for smallholders. These requirements span the four pillars of sustainability and are summarized in Table 4, adopting a similar structure to the one proposed by Ares-Sainz et al. [22]. This selection aims to ensure consistency with the fundamental principles of sustainability and facilitate the progressive implementation of good practices while taking into account the technical and financial constraints of small producers. The detailed justification for the inclusion or exclusion of each requirement can be found in Tables 5–8, which correspond to the environmental, social, economic and circularity pillars, respectively.

In the case of the environmental pillar, the analysis shows that 7 requirements could be applicable to smallholders. These requirements are related to general good practices, such as water management (EN-W-1), indirect carbon emissions measurement (EN-CC-1) and environmental safety (EN-S-1), among others (Table 5). Conversely, 14 requirements were deemed impracticable, particularly those involving advanced monitoring (e.g. EN-W-2, EN-B-6 and EN-NR-7), the use of specific technologies, and formal restoration and biodiversity plans (EN-CC-2, EN-B-5, EN-B-8). The main obstacle identified was the lack of technical training, infrastructure, and investment capacity among smallholders.

In the case of the social pillar, 5 of the 7 requirements were selected as applicable for smallholders (Table 6). These include basic labor conditions and protection against forced labor (WO-6), as well as respect for rights such as gender equality and a minimum working age. Two requirements were discarded: LC-5, which is linked to the promotion of local employment, and SO-3, which is related to ensuring food security. It has been argued that, while these aspects are relevant, they require an operational and reporting structure that exceeds the capabilities of most small producers. Therefore, the protection of fundamental rights was prioritized over structural objectives that are difficult to achieve in practice.

Concerning the economic pillar, requirement ER-1 was deemed applicable because it is crucial for maintaining stability in the value chain and is linked to the long-term economic sustainability of production activities (Table 7). However, the LTI-4 requirement, which calls for investments in innovation or sustainability, was considered impracticable given the limited financial resources of smaller operators. If imposed as mandatory, this could jeopardize their competitiveness.

Finally, in the circularity pillar — the least developed area in current schemes — only 1 of the 13 requirements was considered applicable: EOLS-9, which is linked to waste reduction in the production phase (Table 8). The rest of the requirements, which include product design strategies, the measurement of circular inputs and the implementation of industrial symbiosis models, were discarded as they require technologies, specific training and management frameworks that are not suited to small-scale production.

3.2. Proposal of a sustainability roadmap for smallholders

The analysis carried out enabled the creation of a sustainability roadmap tailored to the specific circumstances of small-scale producers. This proposal recognizes that, while minimum sustainability requirements are essential for promoting responsible practices within the value chain, applying them uniformly may exclude those with lower technical, economic, and organizational capacities. For this reason, a progressive, tiered approach has been suggested, which enables small producers to gradually work towards fully complying with the principles of sustainability and circularity. It should be mentioned that the

Table 6
Social pillar – analysis and final decision for minimum requirements applicable to smallholders. Acronyms: MR (minimum requirement), SHs (smallholders).

MR	Adequate MR for SHs?	Final decision – MR applicable to SHs?
LC-5	**No:** measurement and accounting for the promotion of local employment could be challenging to smallholders, as those don't have the resource capacity to largely promote local employment and are more subject to market pressures	**NO**
SO-3	**No:** analyzing and measuring local food security and carrying out impact assessments to identify potential risks could not be asked for smallholders, as those are not having the sufficient financial support and training.	**NO**
WO-1	Yes, feasible to be applicable for SHs	**YES**
WO-4	Yes, feasible to be applicable for SHs	**YES**
WO-6	Yes, feasible to be applicable for SHs	**YES**
WO-9	Yes, feasible to be applicable for SHs	**YES**
WO-11	Yes, feasible to be applicable for SHs	**YES**

Table 7
Economic pillar – analysis and final decision for minimum requirements applicable to smallholders. Acronyms: MR (minimum requirement), SHs (smallholders).

MR	Adequate MR for SHs?	Final decision – MR applicable to SHs?
ER-1	Yes, feasible to be applicable for SHs	**YES**
LTI-4	**No:** The lack of financial support for smallholders makes it challenging to allocate a percentage of the available budget for sustainable and innovative activities and strategies	**NO**

classification of the minimum requirements developed in this section is based on the approach explained on *Section 2.2*.

As previously mentioned, of the 43 minimum requirements assessed, only 14 were considered applicable to small producers: 7 from the environmental pillar, 5 from the social pillar, 1 from the economic pillar and 1 from the circularity pillar. This selection responds to criteria of operational feasibility, availability of support mechanisms and compatibility with existing standards. Although this number may seem low, it is important to note that most of the remaining requirements involve complex tasks such as monitoring, calculating indicators, or creating detailed action plans, which usually require technology, training, and funding that small producers often lack.

Based on this selection, a roadmap was proposed to guide smallholders in implementing sustainability requirements. These requirements were organized into three implementation levels (basic, intermediate and advanced) through a comparative assessment based on three objective dimensions: (i) technical complexity, (ii) resource intensity, and (iii) organizational dependence. This classification aims to provide smallholders with a coherent, transparent and scalable adaptation in line with their capacities and resources.

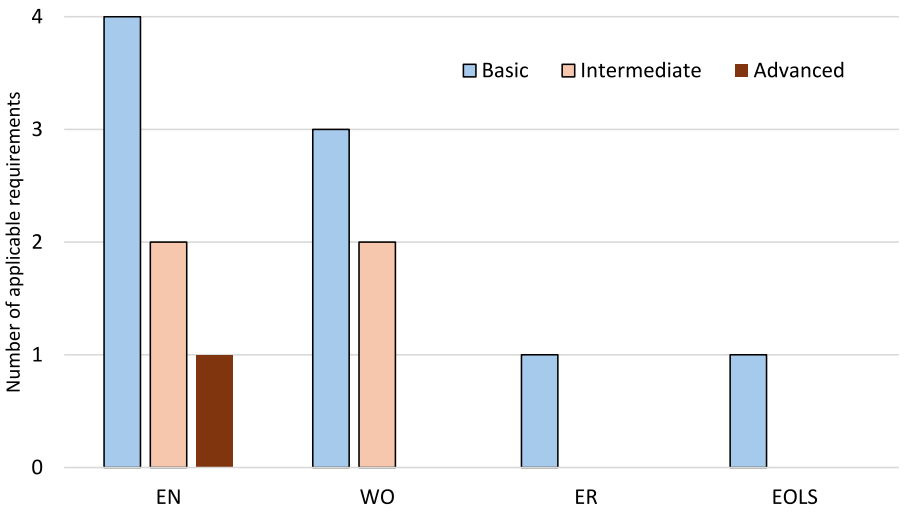
- Level 1 (Basic): requirements that are easy to implement, technically accessible, low-cost, and feasible with minimal infrastructure. There requirements are considered as essential for smallholders to move forward to sustainable and circular practices.
- Level 2 (Intermediate): requirements that demand some degree of organization, technical knowledge, or external support (e.g., through cooperatives, external services, or simplified certification mechanisms). Some costs could be associated with this level of requirements, as well as certain infrastructural changes to accomplish them.

Table 8
Circularity pillar – analysis and final decision for minimum requirements applicable to smallholders. Acronyms: MR (minimum requirement), SHs (smallholders).

Requirement	Adequate MR for SHs?	Final decision – MR applicable to SHs?
EOLS-3	**No:** Separation and recycling strategies imply the availability of advanced technologies, financial support and training.	**NO**
EOLS-6	**No:** To include criteria and requirements for process circularity, specific training is required	**NO**
EOLS-9	Yes, feasible to be applicable for SHs	**YES**
PP-1	**No:** Measuring and implementing recycling and renewable materials could be challenging for smallholders	**NO**
PP-3	**No:** Monitoring and quantifying the use of fossil resources in the activities require advanced technologies and training	**NO**
PP-5	**No:** Monitoring and quantifying the use of renewable energies in the activities require advanced technologies and training	**NO**
PP-8	**No:** Monitoring and quantifying the use of secondary raw materials in the activities required advanced technologies and training	**NO**
PP-12	**No:** Improving energy efficiency in the process and savings targets should not be directly applicable to smallholders, and they should focus on increasing production rather than efficiency	**NO**
G-1	**No:** The lack of training on circularity implies that developing a strategic plan for circularity is challenging	**NO**
PMD-1	**No:** Implementing strategies for extending the life of products and materials used in the production processes could be challenging for smallholders due to the lack of financial support, advanced technologies and training.	**NO**
PMD-4	**No:** Using biodegradable products and materials in the production processes could be challenging for smallholders as it could affect production capacity and product quality	**NO**
PMD-7	**No:** Implementing circularity strategies in product design for smallholders could be challenging due to the lack of training and financial support.	**NO**
CBM-1	**No:** The promotion of industrial symbiosis should not be applicable to smallholders as the amount of waste produced is expected to not be high enough to be used by other companies as input	**NO**

- Level 3 (Advanced): requirements that involve detailed monitoring, quantitative assessments (such as GHG calculations), or strategic planning for long-term sustainability. These are intended for producers who have already consolidated basic and intermediate practices and can access higher levels of technical or financial support.

This framework enables a gradual adoption process tailored to the operational capabilities of producers. Fig. 2 illustrates the distribution of applicable requirements by level and sustainability pillar, showing the proposed implementation sequence. The figure also highlights the need to support this roadmap with tools like group certification, technical help, financial incentives, and easier verification. These tools help smallholders move toward sustainability in a practical way.



	EN	WO	ER	EOLS
Basic	CC-1, W-1, W-8, S-1	WO-1, WO-4, WO-6	ER-1	EOLS-9
Intermediate	B-3, B-7	WO-9, WO-11		
Advanced	B-8			

Fig. 2. Distribution of minimum requirements applicable to small producers, categorised by sustainability pillar and level of implementation (basic, intermediate, or advanced). Acronyms: EN = Environmental, WO = Workers (social pillar), ER = Economic Risk, EOLS = End-of-Life Stage (circularity pillar). The description of the acronyms of the minimum requirements is included in Table 4.

4. Discussions

4.1. Main challenges

The capacity of smallholders to adopt and advance sustainability and circularity practices encounters substantial challenges, including the absence of financial incentives, restricted training opportunities, technological limitations, and market-related constraints [24]. Consequently, it is imperative to address these challenges in a manner distinct from that adopted by large corporations, which can allocate a portion of their economic gains towards developing sustainable and circular strategies, investing in technological advancements, and providing worker training [25]. Recognizing these disparities is pivotal for designing processes and products that promote more sustainable and circular practices, as smallholders frequently have limited access to these resources.

An analysis of the certification schemes, policies, and regulatory frameworks indicates that they primarily focus on large companies, neglecting the specific needs of smallholders. Not all certification schemes offer certification applicable to a smallholder setting [20]. Particularly in sectors with a significant proportion of small-scale producers, certification schemes should consider developing standards that support incremental improvement or continuous compliance models, which can be applied to a group of actors rather than individual producers [21]. Additionally, certification schemes should introduce market incentives such as price premiums to reward the efforts of small-scale producers in improving or reaching the desired level of performance [19]. It is likely that support mechanisms, including capacity building, information services, decision-making tools, access to inputs and technology, and financial support and services [26], may be necessary.

In this regard, the objective of this article was to assess whether the minimum requirements of CSLs that are applicable to larger production facilities could also be relevant to smallholders. Generally, the primary obstacle for smallholders is their limited access to financial resources, which is essential for implementing sustainability and circularity in areas such as infrastructure development, equipment design, process optimization, and end-of-life strategies.

Analyzing the minimum requirements reveals that most focus on monitoring input and output flows, especially in environmental and circular areas, along with the assessment of factors to ensure long-term viability (economic) and actions to ensure stakeholder benefits (social).

The multidimensional nature of sustainability and circularity requires integrating suitable mechanisms to make these requirements feasible for smallholders. For example, insufficient training and knowledge transfer often lead smallholders to rely on conventional, less sustainable production methods, resulting in inefficient resource use and environmental degradation.

The economic aspect is also critical. Smallholders usually operate with tight financial margins, limiting their ability to invest in advanced technologies, monitoring tools, or sustainable practices that lack immediate returns, which threaten their economic viability. Socially, smallholders frequently face barriers to accessing value chain networks, cooperatives, and certification programs, restricting their opportunities to improve market access and promote fair, equitable working conditions.

In addressing circularity, most strategies necessitate a profound understanding of advanced and emerging technologies. This encompasses assessing circular actions such as recovery strategies, product repurposing, recycling flows, and waste reduction. Furthermore, the application of sophisticated tools like life cycle assessments, material flow analysis, or digitalized monitoring systems is indispensable. These methods are intricate and require expert integration, which, without financial backing, is beyond the reach of smallholders. Consequently, smallholders often face challenges in implementing circular strategies within their production systems.

In this context, CSLs are encouraged to provide training on relevant circular strategies, including waste management and the measurement of input and outflow of materials, as part of their sustainability performance assessment. This may entail designing simplified and cost-effective monitoring tools to collect the required data. It is crucial to acknowledge that the ability of small-scale producers to adopt sustainable practices and secure fair and resilient livelihoods is influenced by the broader context in which they operate. CSLs should not be solely responsible for effecting change.

Without appropriate support from policies, government agencies, stakeholders, or larger corporations, the transition of smallholders to a

Table 9
Possible solutions for the challenges on sustainability and circularity certification found for smallholders.

Item	Solution	Mechanisms	Who should provide the solution?
Training and Knowledge Transfer on Sustainability and Circularity	Simpler assessment tools	Provide simplified assessment tools that directly incorporate input and output flow values. Adapt these tools to small-scale operations to provide an overview of the environmental, economic, social, and circular performance of production processes	Public authorities, government agencies, research institutes, NGOs or development organizations
	Access to training programs	Offer free access to training programs, including practical seminars or workshops on sustainable and circular strategies. Prioritize training focused on waste reduction and management strategies, as these can be more relevant to smallholders than quantifying GHG emissions, which may be more challenging.	
Financial incentives for having access to advanced technologies and infrastructures	Provide access to low-cost circular techniques or technologies	Provide access to low-cost circular techniques or technologies that can be easily applied and implemented by smallholders. For instance, provide data monitoring tools to collect the necessary data to track input and output flows throughout the process, enabling the commencement of monitoring activities.	Government bodies, public institutions, development agencies, as the World Bank for example or private cooperatives
	Introduce the option of subsidies or microfinancing	Such as grants or tax reductions, to help smallholders invest in advanced technologies, circular strategies, or sustainable practices	
Policy support	Consideration of Smallholding Capabilities	Ensure that policymakers take the capabilities of smallholdings into account when developing action plans. These plans must establish clear short-term and long-term objectives that are tailored to the production, economic, and logistical capabilities of smallholdings	National governments, local governments, municipal authorities, legislative bodies, and policymakers
	Flexible and Progressive Approach	Policies should also consider that the advancement of smallholders in sustainability and circular aspects should be flexible and progressive, thus within a long-term perspective.	
Strengthen collaboration between smallholders and enhance market access		Create partnerships with larger companies of the value chain	Provision of technical support and resources, facilitating a quicker market access
Simplify the certification and ecolabelling processes and requirements	Sectorial cooperatives, local authorities, development agencies and research institutes	Enable the accessibility of certification and ecolabelling processes.	

circular economy remains severely constrained. Without targeted interventions, such as access to affordable technologies, training programs, and the establishment of local collaborative networks, smallholders are likely to persist in relying on linear production models. This reliance leads to inefficiencies, resource scarcity, environmental degradation, and a loss of economic advantages.

4.2. Potential solutions identified

Once the actual challenges for smallholders seeking to adopt more sustainable and circular production strategies have been identified, this section proposes potential solutions that could be applied to address these challenges. These solutions should be provided by a range of stakeholders, including governments, research institutions, and civil society administrations. Some of them are included on Table 9.

The framework developed in this research demonstrates strong potential for applicability beyond the specific context of the smallholders analyzed, as it can be adapted to various value chains and sectors, thereby serving as a valuable tool for both policy formulation and practical implementation. In operational terms, the classification system, structured into basic, intermediate, and advanced levels, facilitates the progressive adoption of sustainability and circularity practices according to each smallholder's capacities and available resources. This structure also allows for the integration of context-specific constraints associated with different value chains or sectors, ensuring the framework relevance across diverse socio-economic and agroecological environments. Furthermore, the proposed approach can function as a decision-support and monitoring tool for certification bodies, cooperatives, and government agencies. Overall, the framework contributes both as a theoretical model and as a practical mechanism that can be adapted and scaled across contexts, driving broader transitions towards sustainable and circular agri-food systems.

Although the proposed methodological framework aims to provide a

tool that can be applied more widely to guide the inclusion of smallholders in certification systems, it is important to recognize that national and regional contexts can differ significantly. The capacity of smallholders to adopt sustainable and circular practices is conditioned by multiple interrelated factors, including institutional capacity, economic resources, technological development, market maturity, availability of productive infrastructure, and the level of policy and governmental support [27].

The classification system could be adapted to reflect both regional and sector-specific particularities, thereby enhancing its applicability to diverse production contexts. This could be achieved by incorporating contextual indicators such as the specific technological needs of each sector, the demand for products and services, and the level of access to resources and supporting infrastructures. Governments and institutions should then promote differentiated policies, such as technical training, specific certification, economic incentives and institutional support, to facilitate the adoption of sustainable practices for smallholders. Hence, the proposed framework would function both as a tool and a strategic roadmap for formulating policies that enhance the sustainability and competitiveness of smallholders within the bioeconomy.

5. Conclusions

Adapting sustainability and circularity requirements for smallholders is a key step toward promoting inclusivity and fair access to certification schemes and ecolabels. As discussed in this article, smallholders often face difficulties in adopting these practices due to limited technological and financial resources compared to larger producers. This research proposes a strategic approach to help smallholders meet evolving markets and sustainability demands. It identifies which requirements are directly applicable to them and introduces a classification system that organizes these into basic, intermediate, and advanced levels. This structure enables smallholders to progressively meet certification criteria according to their individual capacities, while encouraging ongoing improvement in sustainability and circularity practices.

The framework not only fills existing knowledge gaps but also recognizes the unique limitations and potential contributions of smallholders within value chains. In addition, the article offers practical guidance on addressing key barriers, such as the lack of financial incentives, limited training opportunities, and weak policy support, that hinder smallholders' participation in sustainable certification systems.

CRediT authorship contribution statement

Aroa Carballido: Writing – original draft, Methodology, Data curation. **Ana Arias:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Jose Luis Ares-Sainz:** Writing – review & editing. **Gumersindo Feijoo:** Writing – review & editing, Supervision. **Maria Teresa Moreira:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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