Revista Brasileira de Ciências Ambientais
Brazilian Journal of Environmental Sciences

Sustainability certifications in Brazilian coffee: a multidimensional comparative analysis

Certificações de sustentabilidade no café brasileiro: uma análise comparativa multidimensional

Gabriela Azevedo Rocha[1], *Marcelo Juliano Viviani*[1], *Milena Andrade Ferreira*[2], *Elise Soerger Zaro*[3], *Antonio Rodrigues da Cunha Neto*[1], *Rafael de Oliveira Tiezzi*[2]

ABSTRACT

The adoption of sustainability certifications in the coffee sector presents significant challenges for producers, who must balance the costs and requirements of these schemes with the expected economic and commercial benefits. This study addresses a gap in the literature by conducting an unprecedented multidimensional comparative analysis of major certifications applied to Brazilian coffee production (namely 4C, Fairtrade, Rainforest Alliance, and Certifica Minas Café) considering the sustainability pillars (social, environmental, agronomic, and management) and market dynamics, aiming at offering a systemic overview to support decision-making by farmers, researchers, and other coffee sector stakeholders. The methodology combines a comprehensive literature review, analysis of commercial data from a leading specialty coffee exporter, and the authors' practical expertise. The findings reveal varying degrees of complexity in sustainability requirements across certifications, as well as a disconnection between the sustainability efforts demanded of producers and the financial returns they receive, undermining the transformative potential of these systems. As a practical contribution, the study advocates for the integration of complementary valuation mechanisms (such as Payments for Socio-Environmental Services) into certification models to enhance their effectiveness. The proposed categorization also provides an innovative analytical tool to support producers, exporters, and policymakers in making strategic decisions regarding certification, fostering a fairer and more sustainable coffee value chain aligned with global market demands.

Keywords: sustainable coffee production in Brazil; Fairtrade; Rainforest Alliance; sustainability certifications, 4C certification; sustainable practices.

RESUMO

A adoção de certificações de sustentabilidade no setor cafeeiro impõe desafios significativos aos produtores, que precisam equilibrar os custos e exigências desses selos com os benefícios econômicos e comerciais esperados. Este estudo se propõe a preencher uma lacuna na literatura ao realizar uma análise comparativa multidimensional e inédita das principais certificações aplicadas à cafeicultura brasileira (4C, Fairtrade, Rainforest Alliance e Certifica Minas Café) considerando os pilares da sustentabilidade (social, ambiental, agronômico e gestão) e aspectos mercadológicos, com o objetivo de oferecer um panorama sistêmico que apoie tomadas de decisões por parte de agricultores, pesquisadores e demais atores da cafeicultura. A metodologia combina uma revisão bibliográfica abrangente, análise de dados comerciais de uma grande exportadora de cafés especiais e a experiência prática dos autores. Os resultados revelam diferentes graus de complexidade nas exigências de sustentabilidade entre os selos, além de uma desconexão entre os esforços exigidos dos produtores e os retornos financeiros obtidos, comprometendo o potencial transformador desses sistemas. Como contribuição prática, o estudo defende a integração de mecanismos complementares de valorização (como Pagamentos por Serviços Socioambientais) aos modelos de certificação para melhorar sua eficácia. A categorização proposta neste trabalho também oferece uma ferramenta analítica inovadora, útil para orientar cafeicultores, exportadores e formuladores de políticas públicas na escolha estratégica de certificações, promovendo uma cadeia de valor do café mais justa, sustentável e alinhada às exigências do mercado global.

Palavras-chave: cafeicultura sustentável no Brasil; Fairtrade; Rainforest Alliance; certificações de sustentabilidade; certificação 4C;práticas sustentáveis.

[1]Universidade Federal de Alfenas – Alfenas (MG), Brazil.

[2]Universidade Federal de São Carlos – São Carlos (SP), Brazil.

[3]Universidade Federal de Grande Dourados – Dourados (MS), Brazil.

Corresponding author: Gabriela Azevedo Rocha – Postgraduate Program in Environmental Science, Federal University of Alfenas – Rua Gabriel Monteiro da Silva, 700, Centro – CEP: 37130-000 – Alfenas (MG), Brazil. E-mail: gabiazevedoxd@gmail.com

Funding: The authors are grateful for the support of the Coordination for the Improvement of Higher Education Personnel (CAPES) and the Foundation for Research Support of Minas Gerais State (FAPEMIG).

Conflicts of interest: the authors declare no conflicts of interest.

Received on: 10/31/2024. Accepted on: 06/22/2025.

https://doi.org/10.5327/Z2176-94782338

Introduction

The impact of human activities on the planet has been widely discussed since the 1990s, and with the worsening of environmental crises, productive sectors such as agriculture have been under increasing pressure to adopt more sustainable practices, particularly in countries like Brazil, where coffee cultivation plays a crucial role in the global economy (Sachs et al., 2019; Rockström et al., 2020; IPCC, 2023; Panhuysen and Vries, 2023). As a mitigation measure, sectoral transformations are being discussed and implemented with great urgency, especially within the so-called FEW (Food, Energy, Water) nexus, to which the agricultural sector is highly interconnected. More specifically, this sector has been striving to find solutions to increase production by 70% by 2050 without further damaging ecosystems (Bahadur et al., 2018).

It is important to emphasize that as climate change, biodiversity loss, desertification, and water scarcity become increasingly evident, the concept of sustainability gains prominence. This stems from society's growing conviction that one of the few viable pathways to avoid irreversible transformations lies in economic development that integrates environmental and social balance (Sachs et al., 2019; Rockström et al., 2020; Moda et al., 2022). In this context, the global coffee sector stands out as a major consumer of natural resources and as a unique opportunity to implement sustainable transformations aligned with global demands and local specificities, given its high socioeconomic relevance and environmental impacts associated with its production chain.

Furthermore, according to a 2020 survey conducted by the IBM Institute for Business Value involving over 14,000 consumers across nine countries—including Brazil—66% of respondents expressed willingness to shift their purchasing behavior to help mitigate negative environmental impacts (IBM, 2021). This global trend is also reflected in the coffee market, where sustainability certifications have become an escalating demand among discerning consumers and markets. Consequently, this reality is driving behavioral shifts within the agricultural sector, which faces mounting pressure to demonstrate the sustainability of its processes to remain competitive in a globalized market.

Moving toward a more sustainable sector, laws, norms, and regulations governing agricultural practices have gained increasing relevance, particularly in light of intensifying climate change. In Brazil, while the 2012 Forest Code represents a milestone for sustainable land use and environmental protection, its implementation faces significant challenges, mostly regarding the Rural Environmental Registry (Cadastro Ambiental Rural). As noted by Milhorance et al. (2020), the lack of coordination between regulatory instruments and political limitations has hindered the integration of measures aimed at climate adaptation and sustainability. According to the authors, this issue is further exacerbated by the dismantling of environmental policies, which has weakened institutional mechanisms and reduced funding for crucial initiatives promoting sustainable agricultural practices.

In this scenario, voluntary sustainability standards emerge as a strategic alternative to address gaps left by public regulation. These standards not only demonstrate a more transparent commitment to responsible socio-environmental practices (Schaltz and Bork, 2019; Panhuysen and Vries, 2023) but can also help mitigate some of the negative socio-environmental impacts caused by agricultural practices—including deforestation, water scarcity, and violations of basic human rights—while simultaneously enabling productivity and profitability gains (Potts et al., 2014; Bermudez et al., 2022; Voora et al., 2022). As Brazil is the world's largest coffee producer and exporter, predominantly in the state of Minas Gerais, these challenges and opportunities are especially relevant to the Brazilian coffee sector, which contributes significantly to the global market (Conab, 2023; ICO, 2023).

Coffee cultivation has undoubtedly been one of the pioneering agricultural sectors in the pursuit of sustainability certifications, particularly since the 2000s (Potts et al., 2014; Barra and Ladeira, 2018; Scalco, 2019; Meier et al., 2020; Moda et al., 2022). According to Meier et al. (2020), the volume of coffee produced in compliance with the Voluntary Sustainability Standards increased from 13 to 19% between 2008 and 2019. Data from the Coffee Barometer report indicates that approximately 55% of global coffee production was certified during the 2020–2022 period (Panhuysen and Vries, 2023). Furthermore, as reported by Panhuysen and Vries (2023) and corroborated by data published by the Global Coffee Platform (GCP, 2023), the three most prominent third-party certifications in the coffee sector, ranked by their respective global production volumes in 2022, were: 4C (1,61 million tons), Rainforest Alliance/UTZ (1,08 million tons), and Fairtrade (0,82 million tons). This growth reflects simultaneously the increasing demands from international markets and the pressures faced by coffee growers to adapt to sustainability requirements and compete in more specialized market segments.

As Brazil is the world's largest coffee producer and exporter, with Minas Gerais being the leading production state (Conab, 2023; ICO, 2023), socio-environmental responsibility certifications have become deeply embedded in the reality of local producers. These producers seek to maintain their competitiveness in an increasingly demanding market and secure better prices in commercial negotiations, since sustainability-certified coffees are often classified as specialty coffees, commanding premium prices per sack (Melo et al., 2017). Of particular relevance in the state is the Certifica Minas Café (CMC) certification, a label developed by the Government of Minas Gerais in partnership with the State Technical Assistance and Rural Extension Company (Emater; Empresa de Assistência Técnica e Extensão Rural), the State Secretariat of Agriculture, Livestock, and Supply (Seapa; Secretaria de Estado de Agricultura, Pecuária e Abastecimento de Minas Gerais), and the Minas Gerais Agricultural Institute (IMA; Instituto Mineiro de Agropecuária), representing a genuinely Brazilian certification scheme (CMC, 2024). It is noteworthy that these four mentioned standards are specifically designed for the agricultural sector with tailored criteria, unlike broader certifications applicable to multiple sectors and organizations of varying sizes.

Despite the significance of certifications for coffee production in Southern Minas Gerais, Melo et al. (2017) identifies a substantial research gap regarding these certifications. Countries such as Nicaragua, Peru, and Mexico, despite their comparatively lower coffee export volumes, demonstrate a greater body of research on this topic (Barham and Weber, 2012; Mitiku et al., 2017). Furthermore, few studies have conducted comparative analyses between different certifications, and even those failed to adequately address the differences and similarities in socio-environmental criteria and their respective compositions. Examples include the works of Veiga et al. (2016) and Maguire-Rajpaul et al. (2020), which examined correlations between social and management aspects of certain certifications in the Brazilian coffee sector but neglected environmental and agronomic elements.

It is well-established that the pursuit of certifications in the coffee sector presents considerable complexity due to the extensive variety of available sustainability labels. This can create confusion among producers, who face challenges in understanding each standard's requirements and identifying certifications whose benefits justify the implementation and maintenance costs (Veiga et al., 2016). To address these challenges, it is imperative to develop comparative studies analyzing available certifications, with particular emphasis on their differences and similarities regarding socio-environmental responsibility. Furthermore, such research should examine the fundamental pillars of sustainability along with market-related aspects, providing practical guidance for the coffee industry and, most importantly, for coffee growers. This approach would enable certification selection to be better aligned with each producer's values, objectives, and specific conditions, thereby optimizing individual benefits while contributing to a more sustainable and ethical sector.

Given the scarcity of comparative studies on coffee certifications, particularly in Brazil, this study aimed to provide a systemic overview to support decision-making by farmers, researchers, and other coffee sector stakeholders. We conducted a novel multidimensional comparative analysis of the main certifications applied to Brazilian coffee production (4C, Fairtrade, Rainforest Alliance, and Certifica Minas Café), evaluating sustainability pillars—social, environmental, agronomic, and management (Mangabeira et al., 2021)—along with market-related aspects.

Key sustainability certifications in the coffee sector

The Rainforest Alliance 2020 certification (RA 2020), currently comprising 536 issued licenses in Brazil, represents a socio-environmental certification system designed to provide producers with an enhanced framework for improving livelihoods while protecting biodiversity and local ecosystems. This voluntary standard simultaneously promotes fair labor conditions through sustainable development plans, requiring certified producers to allocate investments toward achieving sustainability targets (Imaflora, 2024; Rainforest Alliance, 2024). Notably, in 2018, the UTZ program merged with Rainforest Alliance under the unified RA 2020 certification scheme, incorporating improved agricultural standards that combine the strengths of both organizations (Rainforest Alliance, 2024).

The Fairtrade certification system aims to ensure fair prices for agricultural products, including coffee, while promoting environmentally sustainable practices and improving social conditions. Specifically targeting smallholder farmers organized in associations or cooperatives, its framework emphasizes agricultural and commercial practices tailored to their needs. The certification's core objective is to establish requirements enabling small farmers' participation in the systems by guaranteeing: the Fairtrade Minimum Price for certified products and the Fairtrade Premium paid directly to certified organizations. These funds must be invested in community development through sustainable development plans (Fairtrade International, 2024).

The 4C certification (Common Code for the Coffee Community) currently has 30 issued licenses in Brazil, predominantly granted to cooperatives and associations. According to data published on the official certification website, this presently impacts about 65,500 Brazilian workers and covers a coffee production area of roughly 226,700 hectares. The 4C Code of Conduct focuses on sustainable coffee agricultural production and post-harvest activities, encompassing environmental, social, and economic dimensions. It establishes minimum sustainability standards while promoting gradual improvement of agricultural practices, delivering quality, independence, credibility, and innovation services to the coffee sector. The certification seeks to ensure good practices in product sourcing, production, and commercialization (4C Certification, 2024).

Within the Brazilian context, particularly in Minas Gerais, the state-level Certifica Minas Café certification stands out as a government-led program established to promote sustainable agricultural practices in coffee production. Implemented through State Law nº 22,926 of January 12, 2018, this initiative aims to enhance the visibility and competitiveness of Minas Gerais coffee in domestic and international markets. This certification seal serves as a reliable attestation that certified producers adhere to sound management practices while maintaining product quality standards (Assembleia Legislativa de Minas Gerais, 2018).

Each certification scheme presents distinct characteristics and benefits, requiring producers to carefully evaluate which system best aligns with their operational needs, values, and objectives (Rich et al., 2018; Castro et al., 2023). Key differentiating factors among certifications include: 1. Relative emphasis on environmental sustainability versus social responsibility; 2. Requirement of organic agricultural practices versus allowance of conventional methods; and 3. Specific management criteria encompassing production traceability and transparency requirements.

Nevertheless, the impacts on sustainability criteria—such as those concerning the economic and environmental aspects of certification—also reflect challenges and opportunities for producers. For example,

certifications like Rainforest Alliance and Fairtrade demonstrate potential in reducing deforestation and promoting environmental conservation. Takahashi and Todo (2013) found that shade-grown coffee certifications in Ethiopia significantly decreased deforestation, while Mitiku et al. (2017) identified that certification schemes improved income and reduced poverty. However, economic benefits are often mixed: studies such as those by Ibanez and Blackman (2015) highlight that while certifications encourage better environmental practices, they do not always lead to significant economic gains. This complexity underscores the need for an informed assessment of certifications, considering local contexts and market dynamics.

The multiplicity of certifications also poses significant challenges. Competition among labels can lead to "standards downgrade," that is, the relaxation of costs and a reduction in the rigor of requirements, which undermines the effectiveness of sustainable practices. This scenario underscores the importance of greater transparency in the information provided by certifiers to prevent ill-informed decisions that may harm producers. Understanding the nuances of different labels thus becomes essential for farmers to make more informed choices, avoid unnecessary expenses, and enhance their access to more demanding markets.

Therefore, to avoid losses and dissatisfaction, it is imperative to thoroughly understand the similarities and differences among sustainability certifications. An informed decision in selecting an ecolabel not only ensures compliance with high standards but also promotes practices that align with the specific values and objectives of each producer.

The influence of certifications on coffee pricing

Certifications can ensure better coffee pricing, as the market pays a premium for certified coffee (GCP, 2023; Panhuysen and Vries, 2023), a phenomenon observed in Minas Gerais. This additional value paid for certified coffee lots is commonly referred to as a "price premium." Major certification standards include commercial criteria that regulate the payment of this premium, which must be paid to producers as compensation for their efforts to improve the socio-environmental performance of their operations.

These socio-environmental certification standards incorporate criteria for continuous improvement initiatives, requiring certified farms to consistently enhance their processes through the PDCA (Plan-Do-Check-Act) cycle. The market compensates for this effort through specific mechanisms; in the case of Fairtrade certification, the Fairtrade Premium is paid to small producer organizations (associations/cooperatives), with its value determined by commercial criteria. Accordingly, these organizations must allocate the premium received from their members' coffee sales toward social development within their coffee-growing communities and organizational strengthening (Aguiar et al., 2022; Fairtrade International, 2024).

The Rainforest Alliance (RA 2020) certification requires payment of a "Sustainability Differential" to producers in addition to the coffee price. Furthermore, RA 2020 standards mandate that a "Sustainability Investment" amount must be negotiated between coffee producers and buyers, to be allocated for continuous farm improvement projects—a compensation mechanism framed as shared responsibility (Rainforest Alliance, 2024). In contrast, 4C certification stipulates payment of a premium to producers beyond the base coffee price but does not specify its amount (4C Certification, 2024). At present, the Certifica Minas Café certification does not employ such premium payment mechanisms.

These findings demonstrate that sustainability certifications provide value-adding mechanisms for coffee commercialization. However, the diversity in certification requirements and premium structures raises persistent questions regarding producer benefits from adopting specific standards. Key uncertainties include: 1. Actual financial returns from price premiums versus market recognition; 2. Mandatory cooperative membership requirements for certain certifications; and 3. Tangible sustainability gains achieved. This complexity underscores the need for empirical research to clarify these issues, enabling producers to make informed, strategic decisions aligned with their operational contexts.

Thus, by conducting a comparative analysis of the main sustainability certifications applied to coffee farming, this study aimed to provide practical and theoretical insights to assist producers, technicians, and policymakers in making more strategic, informed decisions aligned with the challenges and opportunities of the sector.

Materials and Methods

This is an exploratory descriptive study based on content analysis following Bardin's (2011) methodology, which divides the method into three stages: 1. Pre-analysis; 2. Material exploration, and 3. Results processing, interpretation, and inferences.

The first phase—pre-analysis—was grounded in the authors' practical experience and market knowledge, which highlighted the relevance of examining the four most prominent certifications in the coffee sector of Minas Gerais: 4C, Rainforest Alliance, and Certifica Minas Café. Additionally, this stage involved an extensive literature review on the impacts of certifications in the coffee sector, utilizing indexed databases such as Web of Science, SciELO, Google Scholar, and Scopus. Searches were conducted using key terms including the names of the analyzed certifications, "sustainability," "socio-environmental responsibility," "sustainability criteria," "impacts of certification in the coffee sector," and "comparative analysis of certifications," among others.

During this phase, a thorough review of all requirements established by the four certifications was also conducted, with the initial objective of identifying commonalities and differences between their standards. Although this preliminary analysis was less in-depth, it provided a broad yet essential overview to understand the specific demands of each certification, as well as their general objectives and historical data. This process thus consolidated a robust knowledge base

that guided subsequent stages, enabling a more structured and comprehensive approach to the comparative analysis.

In the second stage—material exploration—the requirements of the four standards were analyzed in detail and systematically, being categorized according to their sustainability dimensions: management, social, environmental, and agronomic. This categorization followed the framework proposed by Mangabeira et al. (2021), with necessary adaptations to the research context. Initially, each author independently conducted the reading and categorization of the requirements, totaling six independent reviews. Subsequently, a joint review was conducted, involving collaborative discussions to align interpretations and ensure consistency and reliability of the categorization. In total, the process involved seven reviews: six individual and one final consensus. The Microsoft Excel was used to organize data, enabling the grouping of each requirement into its respective sustainability dimension.

Following the completion of the categorization, a quantitative calculation (Equation 1) was applied to measure the composition of each certification. For instance, if a certification comprises 40 total requirements, with 10 related to social aspects, the equation indicates that 25% of that certification's requirements focus on the social dimension. This numerical breakdown enabled a straightforward understanding of the differences in focus among certifications. Consequently, the obtained results were crucial for elucidating the predominant sustainability focus of each standard, serving as the foundation for a more detailed comparative analysis explored in subsequent stages.

$$R = (Qtd\ RE/Qtd\ TR) * 100 \quad (1)$$

Where:
Qtd RE = quantity of specific requirements related to either social, environmental, management, or agronomic aspects; and
Qtd TR = total quantity of requirements per certification standard.

In the third stage—processing, interpretation, and inference—outcomes were processed by integrating information obtained in previous phases with the authors' expertise and existing literature. This procedure included an analysis of commercial data provided by a specialty coffee exporter located in Southern Minas Gerais. The data, processed using Excel software, comprised transaction records of certified coffee bags exported to various countries over the last ten years. The information was analyzed by filtering exports based on the certifications studied, enabling quantification of annual traded volumes per certification label. This analysis provided insights into market dynamics associated with international preferences for different certification types.

Additionally, broad market data were collected by examining global exports of certified coffee, aiming to map the main markets and companies purchasing coffee from Minas Gerais. Data collection was based on the review and interpretation of technical and annual reports from recognized coffee industry sources, including the Global Coffee Platform (GCP), International Coffee Organization (ICO), Global Market Report, and Coffee Barometer. The analyzed data were strictly limited to the certifications examined in this study, ensuring alignment between global indicators and the local context under evaluation.

The analysis of commercial transactions reveals how international markets engage with different certification labels, empirically demonstrating which sustainability dimensions are most valued in each region. Countries purchasing significant volumes of coffee certified under standards emphasizing social dimensions, for instance, show greater concern for issues such as labor rights, gender equality, and decent working conditions. This correlation between certification types and market sustainability priorities provides enhanced understanding of both global and regional demands, while simultaneously highlighting the challenges faced by Southern Minas Gerais producers in meeting these expectations.

Requirement categorization

Through qualitative analysis of requirements from each of the four certifications, these were systematically classified and categorized to enable quantitative comparison. This process employed the sustainability dimensions proposed by Mangabeira et al. (2021)—management, social, environmental, and agronomic—with context-specific adaptations for this study. The selection of these categories directly relates to the need for integrated assessment of sustainable practices, establishing a robust methodological foundation for subsequent economic valuation stages, following approaches implemented in the Chico Mendes Extractive Reserve in the Brazilian Amazon by Mangabeira et al. (2021) and Maciel et al. (2024). It should be emphasized that this work represents the initial phase of this process, focusing specifically on the comparative analysis of certifications and understanding of sustainability dimensions, while explicitly excluding direct economic valuation, which should be addressed in future research.

The requirements were organized into the following dimensions:

1. **Management:** Mangabeira et al. (2021) proposed governance and economic requirements, which in this study were grouped into the management category due to the diversity of certification demands. Management requirements encompass: (a) compliance with international, national, and local laws, and regulations; (b) traceability systems ensuring agricultural product monitoring throughout the supply chain; (c) record-keeping protocols, transparency mechanisms, and market/economic studies; and (d) certification-specific provisions including audit procedures and non-conformity management.
2. **Social:** These refer to the development of employees' skills and competencies; those related to the guarantee of human rights, such as the prohibition of child labor and slavery-like practices; requirements that ensure safe working conditions, such as sanitation, protective equipment, and adequate housing; provisions regarding

freedom of association, expression, and employee voice; guarantees of gender equality practices; and fair labor prerogatives, such as just wages, benefits, and reasonable working hours. Also included in this dimension are requirements linked to the entity's interaction with the community and cultural preservation.

3. **Environmental:** They focus on the conservation of natural ecosystems, protected areas, riparian zones, and forests; those requirements that ensure the protection of wildlife and biodiversity; those related to proper water, waste, and energy management; and those addressing climate adaptation and mitigation.
4. **Agronomic:** These requirements are more specifically directed toward proper soil and pest management; the correct use of pesticides; and the use of genetically modified organisms. They encompass appropriate cultivation, harvesting, and post-harvest practices; and procedures for compliance with the list of hazardous materials.

By categorizing requirements based on these dimensions, this study aimed to provide a detailed and comparative understanding of sustainability certifications applied to the coffee sector. Although this research does not intend to conduct an economic valuation of sustainable practices, it lays the necessary groundwork for future steps to explore the economic potential of these practices. Thus, the study seeks to contribute to the development of more informed public policies and market strategies, while also providing support for producers to make decisions better aligned with their socioeconomic and environmental realities.

Results

The comparative results presented in Table 1, compiled from information provided by the certifiers themselves (4C Certification, 2024; CMC, 2024; Fairtrade International, 2024; Rainforest Alliance, 2024) and various researchers (such as Mitiku et al., 2017; Melo et al., 2017; Piao et al., 2019; Cabrera and Caldarelli, 2021), demonstrate that these four certifications have important distinctions and similarities to consider when choosing an initial certification process. It is evident that Rainforest Alliance and Fairtrade certifications emerged from voluntary efforts at a time when environmental concerns were relatively new, gaining greater visibility through major and minor conferences held since 1972 (Squeff, 2020). In contrast, 4C and Certifica Minas were established decades later, originating from government initiatives.

Despite the similarity of inspection frequency between the four certifications, Certifica Minas stands out for being more inclusive of small-scale producers. It offers advantages to smallholders by exempting them from implementation and monitoring costs, provided they are registered with the National Family Farming Registry (CAF) (Law nº 11,326 – Family Farming Law, Brasil [2006]). On the other hand, the most significant distinction lies in the number of requirements to be followed, ranging from 47 in the case of 4C to 192 for Rainforest Alliance.

Table 1 – Comparison of general information and historical background of certifications.

	Rainforest Alliance	Fairtrade	4C	Certifica Minas Café
Year and Country	1986/USA	1988/Netherlands	2006/Germany	2018/Brazil
Initiative Promoter (Standard-setter)	Social movements/NGOs/researchers Sustainable Agriculture Network (SAN)	Social movements/NGOs Fairtrade International (FLO)	Business association of coffee roasters and Government Agency	Government of Minas Gerais/ State Department of Agriculture, Livestock and Supply (Seapa)
Certification Body in Brazil	Imaflora/Sustainable Agriculture Network (RAS), IBD Certifications, and Ecocert Brasil Certifier	FLOCERT	4C Services and local cooperating 4C bodies	Minas Gerais Agricultural Institute (IMA)
Costs	Producers: certification and monitoring costs	Producers: certification and monitoring costs. Certifier provides subsidies.	Producers: certification and monitoring costs.	Family farmers: free certification. Other producers: specific costs for each audit.
Audit Frequency	Monitoring: annual. Recertification: every three years.	Monitoring: annual. Recertification: every three years.	Documentation update: annual. Recertification: every three years.	Maintenance audits: annual.
Chapters*	6	4	3	7
General Criteria**	35	12	12	12
Requirements***	192	147	47	100

*Chapter refers to the main thematic area (broader category). Example: Certifica Minas – Environmental Responsibility; **General criteria represent broader subject categories within each chapter. Example: Certifica Minas C2 – Soil Conservation, C3 – Water Conservation. ***Requirements specify each individual mandatory provision in the certification standards. Example: Certifica Minas - C3.2 – The producer must implement spring protection practices.
NGOs: non-governmental organizations; FLOCERT: Fairtrade Labelling Organizations International Certification GmbH (company with limited liability);RAS: Rede de Agricultura Sustentável, in Portuguese); IMA: Instituto Mineiro de Agropecuária, in Portuguese); IBD: Biodynamic Institute of Certification (Instituto Biodinâmico de Certificação, in Portuguese).

Through the analysis of requirements across the four certification standards (Figure 1; Table 2), it becomes evident that all include criteria tied to environmental, social, agronomic, and management aspects; yet each adopts a distinct sustainability focus. Notably, for all four certifications, these criteria play a fundamental role in promoting sustainable practices, balancing productivity with socio-environmental responsibility, and ultimately securing the certification label (Potts et al., 2014; Panhuysen and Vries, 2023).

Management requirements are essential for legal and organizational compliance, encompassing traceability throughout the supply chain, audits, and transparency mechanisms that ensure certification credibility. As for social requirements, these focus on guaranteeing safe and dignified working conditions, emphasizing human rights, gender equality, fair wages, and engagement with local communities, thereby fostering social and cultural well-being in production regions. The environmental requirements ensure ecosystem conservation, water and energy management, biodiversity protection, and climate mitigation strategies. Finally, agronomic requirements target soil management, responsible farming practices, and reducing negative impacts from chemical inputs, among others.

Thus, the environmental and agronomic criteria directly reflect the demands of "safe and just limits" for Earth's systems, as discussed by Rockström et al. (2020), highlighting the importance of biodiversity preservation, sustainable water and energy use, and climate adaptation.

In this context, the criteria required by the analyzed certifications contribute to adapting local production chains to global demands, with distinct sustainability approaches aligned with specific objectives and target audiences. Thus, this diversity of approaches and perspectives may explain certain scenarios, such as each certification program's level of requirements, the difficulty in securing certification, coffee growers' preference for a particular seal, market access, and retailers' and roasters' preferences at the time of purchase.

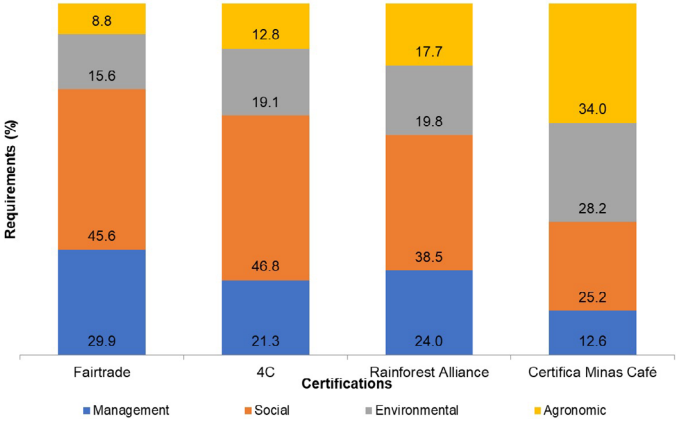

Figure 1 – Comparison of each certification's composition based on the number of requirements per category.
This distribution highlights the variable emphasis on specific criteria across different certifications.

The Fairtrade certification is a standard focused on strengthening small producer organizations by capitalizing them and improving their management. This makes it possible to ensure better living conditions in rural areas and stimulate interest among youth and women in family succession, as mentioned by Veiga et al. (2016), Mitiku et al. (2017), Maguire-Rajpaul et al. (2020), and Cabrera and Caldarelli (2021). It is a certification exclusively targeted at groups of small farmers with up to 30 hectares of cultivated area, organized into cooperatives or associations (Fairtrade International, 2024). Thus, the 75.5% share of management and social requirements demonstrates that its primary concern is ensuring that certified organizations are well-managed to maintain competitiveness and good social conditions for their members. From this perspective, if a group of small farmers has effective management focused on meeting social prerogatives, they are inherently better positioned to achieve Fairtrade International certification.

The 4C certification has a structure relatively similar to Fairtrade International regarding the percentage distribution of criteria. However, when analyzing the number of requirements, 4C presents a total of 47, making it the certification with the fewest requirements among those compared. It is noteworthy that this certification, while addressing all sustainability aspects, delves less deeply into the proposed criteria and demands less control, documentation, and evidence (Veiga et al., 2016). This simplified approach makes it more accessible to producers, consequently becoming the most widely adopted social-environmental certification in both the global and Brazilian coffee markets, following the Global Coffee Platform (2023).

Rainforest Alliance is a socio-environmental certification with a total of 192 requirements, many of which are highly specific. As evidenced by the data presented in Figure 1 and highlighted by other authors, farmers must dedicate considerable effort to obtain this certification, including greater investments and more rigorous record-keeping and evidence control (Hajjar et al., 2019; Maguire-Rajpaul et al., 2020). On the other hand, precisely because it has more stringent requirements, this standard tends to deliver better socio-environmental responsibility outcomes.

It is important to highlight that farmers must comply with a mandatory continuous improvement plan to ensure all non-conformities identified during external audits are resolved within two years or within an agreed timeframe with the certification team (Imaflora, 2024; Rainforest Alliance, 2024).

The categorization of the Certifica Minas Café standard, which comprises 103 total requirements, demonstrates a strong focus on environmental issues and good agricultural practices, totaling 64 requirements in these areas. These metrics clarify the primary concern of the Minas Gerais state government in creating this protocol: to ensure compliance with the Stockholm and Rotterdam Conventions, which established a list of prohibited chemical pesticides, and to safeguard grain quality (Assembleia Legislativa de Minas Gerais, 2018; CMC, 2024).

Table 2 – Descriptive data of sustainability certification requirements in the coffee sector.

Requirements	General description of requirements	Requirement numbering			
		Rainforest Alliance	Fairtrade	4C	Certifica Minas Café
1. Management	1.1 Requirements related to compliance with international, national, and local laws and regulations; 1.2 Requirements aimed at traceability systems that ensure monitoring of agricultural products throughout the entire supply chain; 1.3 Requirements related to proper record management; 1.4 Mechanisms for transparency and economic and market studies; and 1.5 Requirements addressing matters related to the certification itself, such as audits and non-conformity treatments.	1.1.1, 1.1.2, 1.2.1,1.2.2,1.2.3, 1.2.4,1.2.8,1.2.9, 1.2.10, 1.2.11, 1.2.12, 1.2.13,1.2.14,1.2.15, 1.3.1, 1.3.2, 1.3.3, 1.3.4, 1.3.7,1.4.1,1.4.2, 1.4.3, 1.4.5,.4.6, 1.5.1, 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.1.6, 2.1.7, 2.1.8, 2.1.9, 2.1.10, 2.2, 2.3, 3.1.1, 3.2.6,3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.5, 3.3.6, 5.1.5	1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5, 1.1.6, 1.1.7, 1.1.8, 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.1.6, 2.1.7, 2.1.8, 2.2.1, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.4.1, 2.4.2, 3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.1.5, 3.1.6, 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.1.8, 4.1.9, 4.1.10, 4.1.11, 4.1.12, 4.1.13, 4.1.14, 4.1.15	1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5, 1.3.1, 1.3.2, 1.4.1, 1.4.2, 1.4.3	A.1, A.2, B.1, B.2, B.3, E.1, E.2, 2.1, 2.2, 2.3, 2.4, 2.5, 4.1
2. Social	2.1 Development of employees' skills and competencies; 2.2 Guarantees of human rights, such as the prohibition of child labor and slavery-like practices; 2.3 Requirements that ensure safe working conditions, including sanitation, protective equipment, and adequate housing; 2.4 Requirements related to freedom of association, expression, and ensuring employees' voice; 2.5 Guarantees of gender equality practices; 2.6 Decent labor prerogatives, such as fair wages, benefits, and adequate working hours; 2.7 Requirements related to the entity's interaction with the community; and 2.8 Cultural preservation.	1.2.7, 1.6.1, 1.6.2, 1.7.1, 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.2.5, 3.2.7, 4.5.4, 4.6.3, 5.1.1, 5.1.2, 5.1.3,5.1.4, 5.1.6 , 5.1.7, 5.1.8, 5.2.1, 5.2.2,5.2.3, 5.2.4, 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5, 5.3.6, 5.3.7, 5.3.8, 5.3.9, 5.3.10, 5.3.11, 5.3.12, 5.3.13 , 5.4.1, 5.4.3, 5.5.1, 5.5.2, 5.5.3, 5.5.4, 5.6.2, 5.6.4, 5.6.5, 5.6.6, 5.6.7, 5.6.8, 5.6.9, 5.6.10, 5.6.11, 5.6.12, 5.6.13, 5.6.14, 5.6.15, 5.6.16, 5.6.17, 5.6.18, 5.7.1, 5.7.2, 5.7.3, 5.7.4, 5.7.5, 5.7.6, 5.7.7, 5.8.1, 5.8.2, 5.8.3, 5.8.4	1.2.1, 1.2.2, 1.2.3, 1.2.4, 3.2.2, 3.2.4, 3.2.5, 3.2.6, 3.2.21, 3.2.22, 3.2.26, 3.2.29, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.5, 3.3.6, 3.3.7, 3.3.8, 3.3.9, 3.3.10, 3.3.11, 3.3.12, 3.3.13, 3.3.14, 3.3.15, 3.3.16, 3.3.17, 3.3.18, 3.3.19, 3.3.20, 3.3.21, 3.3.22, 3.3.23, 3.3.24, 3.3.25, 3.3.26, 3.3.27, 3.3.28, 3.3.29, 3.3.30, 3.3.31, 3.3.32, 3.3.33, 3.3.34, 3.3.35, 3.3.36, 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.2.5, 4.2.6, 4.2.7, 4.2.8, 4.2.9, 4.2.10, 4.2.11, 4.2.12, 4.2.13, 4.2.14, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5	1.2.1, 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.1.6, 2.1.7, 2.1.8, 2.1.9, 2.1.10, 2.1.11, 2.1.12, 2.1.13, 2.1.14, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 2.2.7	D.1, D.2, D.3, D.4, D.5, D.6, D.7, D.8, D.9, D.10, D.11, D.12, D.13, D.14, D.15, D.16, D.17, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9
3. Environmen-tal	3.1 Address the conservation of natural ecosystems, protected areas, riparian zones, and forests; 3.2 Requirements that ensure the protection of wildlife and biodiversity; 3.3 Related to proper water, waste, and energy management; 3.4 Address issues of climate adaptation and mitigation.	1.3.1, 1.3.5, 6.1.2, 6.1.3, 6.1.4, 6.2.1, 6.2.2 , 6.2.3, 6.2.4, 6.2.6, 6.3.1 , 6.3.2, 6.3.3, 6.4.3, 6.4.4, 6.4.5, 6.4.6, 6.4.7, 6.4.8, 6.4.9, 6.5.1, 6.5.2, 6.5.3, 6.5.4, 6.5.5, 6.5.6, 6.5.7, 6.6.1, 6.6.2, 6.6.3, 6.7.1, 6.7.2, 6.7.3, 6.8.1, 6.8.2, 6.8.3, 6.9.1	3.2.1, 3.2.12, 3.2.13, 3.2.14, 3.2.20, 3.2.24, 3.2.25, 3.2.27, 3.2.28, 3.2.30, 3.2.31, 3.2.32, 3.2.33, 3.2.34, 3.2.35, 3.2.36, 3.2.37, 3.2.38, 3.2.39, 3.2.40, 3.2.42, 3.2.43, 3.2.44	3.1.1, 3.1.2, 3.1.4, 3.4.1, 3.4.2, 3.4.3, 3.4.4, 3.5.1, 3.6.1	C.1.1, C.1.2, C.1.3, C.3.1, C.3.2, C.3.3, C.3.4, C.3.5, C.3.6, C.3.7, C.3.8, C.3.9, C.3.10, C.3.11, C.3.12, C.4.1, C.4.2, C.4.3, C.4.4, C.4.5, C.4.6, C.5.1, C.6.1, C.6.2, C.6.3, C.6.4, 1.3.9,1.3.10, 1.3.11
4. Agronomic	4.1 Requirements focused on proper soil and pest management; 4.2 Correct and conscious use of agrochemicals; 4.3 Use of genetically modified organisms; 4.4 Include appropriate cultivation, harvesting, and post-harvest practices; and 4.5 Procedures to comply with the list of hazardous materials.	4.1.1, 4.1.2, 4.1.3, 4.2.1, 4.2.2, 4.2.3, 4.3.1, 4.3.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.5.1, 4.5.2, 4.5.3, 4.5.5, 4.5.6, 4.5.7, 4.6.1, 4.6.2, 4.6.5, 4.6.6, 4.6.7, 4.6.8, 4.6.9, 4.6.10, 4.6.11, 4.6.12, 4.6.13, 4.6.14, 4.7.1, 4.7.2	3.2.3, 3.2.7, 3.2.8, 3.2.9, 3.2.10, 3.2.11, 3.2.15, 3.2.16, 3.2.17, 3.2.18, 3.2.19, 3.2.23, 3.2.41	3.1.3, 3.2.1, 3.2.2, 3.2.3, 3.3.1, 3.3.2	C.2.1, C.2.2, C.2.3, 1.1.1, 1.1.2, 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5, 1.2.6, 1.2.7, 1.2.8, 1.2.9, 1.2.10, 1.3.1, 1.3.2, 1.3.3, 1.3.4, 1.3.5, 1.3.6, 1.3.7, 1.3.8, 1.3.12, 1.3.13, 1.4.1, 1.4.2, 1.4.3, 1.4.4, 1.4.5, 1.4.6, 1.4.7, 1.4.8, 1.4.9, 1.4.10

The numbering presented in the table corresponds to the identification of requirements as stipulated by each certifier in their official documents. In the case of Certifica Minas Café, the letters (A, B, C, D, and E) indicate the general criteria of the standard, with A referring to property georeferencing, B to production traceability, C to environmental responsibility, D to social responsibility, and E to activity management. Items without letters refer to specific requirements related to coffee cultivation, harvesting, and post-harvesting.

The analysis of certification frameworks conducted in this research, from a sustainability perspective using the four classification categories (environmental, social, management, and agronomic) reveals results that stand out for their uniqueness compared to other sources. Relevant differences emerge when comparing these results with data presented by other authors such as Veiga et al. (2016), Maguire-Rajpaul et al. (2020), and Piao et al. (2019). It is important to underline that none of these studies conducted research with the same comparative focus, but rather presented such compositions in other contexts, mostly only as references or specific data points. The resulting compositions from this research also differ from those presented by StandardsMap.org, a database created by the International Trade Centre (ITC), a United Nations agency dedicated to providing information and comparisons on various voluntary sustainability standards (International Trade Centre, 2024).

This is explained by the novel categorization framework introduced in this study, which innovatively separates environmental from agronomic criteria, alongside a detailed analysis and review of social and management criteria from the authors' practical perspective. This approach enabled a more contextually appropriate categorization for coffee farm realities. The decoupling of agronomic requirements from environmental ones represents a significant contribution, diverging from conventional approaches. It reflects the understanding that soil management and agricultural demands—particularly in coffee cultivation—have distinct particularities compared to broader environmental concerns. Notably, this categorization model was informed by successful outcomes observed in the Chico Mendes Extractive Reserve (Amazon), where similar dimensional frameworks for rubber-tapping contributed to developing sustainability indices that ultimately enabled Payments for Socio-Environmental Services (Mangabeira et al., 2021; Maciel et al., 2024).

Thus, the targeted approach to each criterion across the four certification standards analyzed in this research resulted in a categorization more closely aligned with sustainable agriculture principles by incorporating coffee-sector-specific variables and the authors' practical field experience. This distinct methodology reflects a nuanced understanding of the unique demands of coffee production, enabling a more precise and actionable analysis for coffee growers' realities. By acknowledging the differences from other approaches in the literature, it becomes evident that this study's innovative, context-sensitive categorization offers significant contributions to understanding sustainability in coffee cultivation. Moreover, it serves as a valuable reference tool, enabling Minas Gerais coffee producers to conduct more accurate preliminary diagnostics when entering certification processes.

From this perspective, it is important to highlight the differences in certification initiation processes, as each certifier has specific prerequisites that influence both the choice and maintenance of the certification. In the case of Fairtrade, small coffee farmers must belong to an organized group, association, or cooperative, since certification is granted to the organization rather than individual production units. Consequently, only a group has the authority to market certified coffee. To begin the 4C certification process, the producer—referred to in this context as a Farmer Partner—must belong to a 4C Unit, which is represented by one or more Business Partners (BPs). These BPs maintain the certification and assume commercial responsibility for the certified green coffee (Piao et al., 2019; 4C Certification, 2024). Unlike Fairtrade and 4C certifications, Rainforest Alliance and Certifica Minas Café do not require farmers to organize into larger groups. They allow autonomous and independent certification processes, enabling farmers to independently market their sustainably certified coffee. However, it should be noted that while not mandatory, Rainforest Alliance certification can also be pursued collectively (Maguire-Rajpaul et al., 2020).

The presented data further demonstrate that before choosing a certification, two fundamental aspects of current operations must be analyzed. First, it is essential to assess the farm's management capacity—specifically, the team's managerial aptitude, record-keeping standards, and compliance with applicable regulations. Second, one must evaluate market positioning: understanding both current standing and future goals is critical, as establishing reliable business partnerships and strengthening these relationships is imperative. Attention must be paid to the market demands articulated by these partners, since pursuing a certification not recognized by one's business partners yields no benefit (Panhuysen and Vries, 2023).

Note that Rainforest Alliance and Fairtrade certifications require great attention from all stakeholders (Melo et al., 2017), as they demand more detailed procedural assessments and adaptations. However, they also command a higher price premium per traded coffee bag, meaning these certifications are associated with higher-value-added products whose consumers prioritize social and environmental considerations. These buyers are also more attentive to product quality, willing to pay more for coffee that meets superior standards across all dimensions: intrinsic quality, packaging, communication (product information, origin, processing methods, etc.). Furthermore, these standards typically require certified social responsibility across the supply chain. Consequently, all involved parties must comply with high socio-environmental quality and traceability standards.

Conversely, the 4C certification requires less rigorous data and record-keeping, thereby placing fewer demands on farm internal teams (Piao et al., 2019). Naturally, its price premium is lower than certifications like Rainforest Alliance. However, it serves price-sensitive markets where competitive pricing—lower prices in this case—strongly influences purchasing decisions and enables higher trading volumes, as evidenced by the Global Coffee Platform (GCP, 2023) data.

It is important to consider that today's coffee market has diversified branches, reflecting distinct interests and demands. A significant segment has shifted away from the traditional focus on sensory quality—flavor, aroma, and other attributes valued in specialty coffees—to prioritize caffeine content as the primary element of interest. This caf-

feine is extensively used in manufacturing stimulant pills, pre-workout supplements, energy drinks for sports and social events, and other cognitive-enhancement products. This market segment is not inherently aligned with the socio-environmental attributes promoted by rigorous certifications or premium-quality coffees.

Moreover, in some cultures, coffee is widely consumed as a base for traditional beverages combined with spices and other ingredients that neutralize or mask the bean's original flavor. This approach also reflects a departure from traditional quality appeal, emphasizing coffee's role as a functional ingredient rather than a sensory-driven beverage. From this perspective, the 4C certification, with its broader market reach (GCP, 2023), appears well-suited to meet this diversified demand, particularly through its focus on minimum sustainability standards and gradual improvement, which align with volume-driven and functionality-focused markets like the caffeine industry.

It is also worth noting, in 4C certification, that one coffee quality parameter involves measuring the quantity of residues removed from samples, similar to standard product quality assessments. Here, impurity levels are quantified, and higher percentages in analyzed samples typically result in lower coffee valuation. This is because such coffee is considered low-grade when sent for roasting with high impurity content, inevitably yielding inferior quality. These high-impurity coffees generally originate from large-scale producers, incapable of proper bean sorting, which still obtain certifications as 4C and are traded as commodities.

The Certifica Minas Café certification, meanwhile, is a pioneering instrument with unique merit as the only sustainability recognition program created by a government entity—specifically, the state of Minas Gerais, the world's largest coffee producer (Conab, 2023; Embrapa, 2023). While this certification still requires broader recognition among international roasters and retailers, it is already highly regarded on Minas Gerais farms and in the Brazilian market for effectively streamlining documentation and implementing agricultural best practices. Amidst global market shifts, with higher inflation rates in key consuming countries, roasters are seeking cost reductions in green coffee purchases without compromising regenerative and responsible practices (Panhuysen and Vries, 2023). In this context, Certifica Minas Café may find new opportunities due to its lower price premium, offering a more affordable product while maintaining effective sustainable practices.

Global data published by the Global Coffee Platform on sustainable coffee trade in 2022 transparently disclosed metrics from eight major industry players (roasters and retailers), including coffee origin countries and sustainability certifications required by these buyers in commercial transactions (GCP, 2023). This data revealed Brazil as the world's largest supplier of sustainable green coffee, utilizing various certifications. Focusing on the four certifications analyzed in this study, the export volumes in descending order, examining both individual and correlated certification shares, were: 4C accounting for approximately 38% of total exports, Rainforest Alliance representing about 23%, Certifica Minas with 0.65% market share, and Fairtrade comprising 0.27% of Brazil's sustainable coffee exports (GCP, 2023).

It is important to emphasize that the data presented above is partial, covering only a fraction of Brazil's total sustainable coffee exports. This limitation stems from the fact that only a subset of roasters and retailers contributed information to the Global Coffee Platform. Additionally, it was not possible to obtain total certified coffee trade volumes—neither from major coffee sector databases nor from the certifiers' official platforms. Notably, this study made multiple attempts to contact certifiers through various channels; however, none succeeded in acquiring the data needed for a more precise market diagnosis of sustainable coffee or its most recurring non-conformities. This information gap underscores the need to improve communication channels and transparency within the sector to enable more comprehensive and detailed assessments of the certified coffee landscape. The lack of transparency and inadequate data disclosure in the coffee industry was also highlighted by Panhuysen and Vries (2023) in the Coffee Barometer report.

From this perspective, to conduct a more accurate analysis of the sustainable and certified coffee market, this research obtained data from one of Brazil's and the world's largest specialty coffee exporters, located in Southern Minas Gerais. The study collected information on the company's commercial transactions over the last ten years, revealing an average annual trade volume of 124,000 coffee bags—a significant figure, given these are classified as high-quality specialty coffees. This direct focus on a key sector player helps build a more reliable and comprehensive analysis of the sustainable coffee landscape, providing valuable insights into this specific segment's trends and dynamics.

As a specialty coffee exporter, the company's coffee quality is tied not only to essential beverage attributes but also to compliance with humane and environmentally sound production standards. Thus, obtaining certifications adopted by the end of the supply chain becomes a strategic imperative for the producing farm. To better understand these market demands, only data related to the certifications in this study were tabulated.

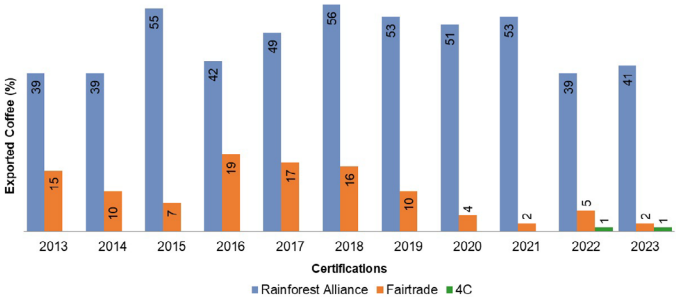

Figure 2 – Comparison of exports by the Minas Gerais exporter across Rainforest Alliance, Fairtrade, and 4C certifications.
This arrangement demonstrates the significance of sustainability-certified coffees for this exporter's operations.

The findings, presented in Figure 2, reveal that the company trades significant volumes of certified coffee by Rainforest Alliance averaging 58,397 bags/year, followed by Fairtrade (11,594 bags/year). More modest volumes were identified for 4C with 2,000 bags/year since 2022, while no certified coffee by Certifica Minas Café has been traded to date.

Additional data provided by the exporter warrants emphasis in this analysis. For instance, the top three purchasers of Rainforest Alliance-certified green coffee were Switzerland, the United States, and Sweden, respectively, while Fairtrade-certified green coffee was primarily bought by the United States, Switzerland, and the United Kingdom in that order. These findings align with International Coffee Organization (ICO, 2023) data, which recently revealed that over half of global coffee consumption, exceeding 168,5 million bags in 2021–2022, occurred in established markets like Europe, Japan, and North America. This coherence extends to the dynamics of the global coffee value chain (GVC), where these countries host the largest roasters, positioning them as top exporters of roasted coffee worldwide. Essentially, they import premium certified green beans for roasting and commercialization (Barbosa et al., 2021).

Interestingly, when contrasting these findings with the GCP (2023) report data, which indicated higher export volumes for 4C-certified sustainable coffees in 2022, it becomes evident that even as a sustainability certification, 4C lacks the same prominence in the specialty coffee segment compared to Rainforest Alliance and Fairtrade. Thus, the export data from this Southern Minas Gerais exporter corroborates this study's analysis: Rainforest Alliance and Fairtrade certifications, with their more stringent socio-environmental requirements, are more sought-after in specialty coffee markets. This preference translates into higher added value for the beans, as consumers in this market segment are willing to pay premium prices for products meeting stricter sustainability and socio-environmental responsibility standards. These insights underscore the need to understand coffee market dynamics, consumer preferences, and the economic-social implications of different sustainability certifications.

Finally, it is important to emphasize that while this study provides a comprehensive and detailed analysis of the key sustainability certifications applied to the Brazilian coffee sector, certain limitations affecting the scope and interpretation of the results must be acknowledged. First, the research focuses on four specific certifications selected for their sectoral relevance and representativeness, which do not encompass all available standards. Furthermore, the lack of transparency in certifiers' data, including audit reports, certification numbers, and certified farms, hinders deeper analysis of these standards' reach and effectiveness. While strategically chosen, the geographical focus on Southern Minas Gerais also limits the applicability of the findings to other regions with distinct socioeconomic and environmental contexts. We recommend that future studies expand the analysis to include other certifications and producing regions, incorporating quantitative data for a more holistic understanding of certification impacts across the coffee sector.

Conclusion

This study conducted a critical analysis of four certifications operating in the Brazilian coffee sector, highlighting their requirements across sustainability pillars. While differing in focus, all certifications were found to promote more sustainable practices through social, environmental, and agronomic criteria aligned with global agricultural challenges, as noted by Rockström et al. (2020). However, certifiers' lack of transparency, identified by Panhuysen and Vries (2023), remains a significant barrier for producers, particularly in assessing concrete benefits.

The key contribution consisted of proposing a multidimensional certification categorization framework encompassing social, environmental, agronomic, and management aspects. This approach revealed that 4C, Fairtrade, Rainforest Alliance, and Certifica Minas Café serve distinct producer profiles and market segments, offering solutions tailored to different production and commercial realities.

Economically, the study highlighted the challenge of translating sustainability efforts into proportional financial returns, suggesting complementary mechanisms such as Payments for Socio-Environmental Services, as reported in the literature and discussed in the results.

Methodologically, this work advanced the field by providing an analytical tool transferable to other agricultural contexts, supporting future research and sustainability policy decisions.

In conclusion, beyond systematizing certification approaches, this study established a robust theoretical foundation and practical recommendations for producers, technicians, and policymakers in selecting and valuing sustainability certifications. To amplify their positive impacts, we emphasize the need for public policies improving certification accessibility—especially for smallholders—to strengthen sustainability and socio-environmental justice in Brazilian coffee production.

Authors' Contributions

Rocha, G.A.: conceptualization; data curation; formal analysis; investigation; methodology; funding acquisition; writing – original draft; writing – review & editing. **Viviani**, M.: formal analysis; investigation; methodology; funding acquisition; writing – original draft; writing – review & editing. **Ferreira**, M.A.: formal analysis; investigation; writing – original draft; writing – review & editing. **Zaro**, E.S.: writing – review & editing. **Cunha Neto**, A.R. da: data curation; writing – review & editing. **Tiezzi**, R.O.: conceptualization; supervision; funding acquisition; writing – original draft; writing – review & editing.

References

4C Certification, 2024. 4C Certification (Accessed November 7, 2023) at:. https://www.4c-services.org/process/.

Aguiar, B.H.; Romaniello, M.M.; Pelegrini, D.F., 2022. A influência do Fairtrade no desenvolvimento do capital social : o caso dos cafeicultores da Cooperativa "Dos Costas". Revista de Economia e Sociologia Rural, v. 60 (2), 1-21. https://doi.org/10.1590/1806-9479.2021.224545.

Assembleia Legislativa de Minas Gerais, 2018. Lei no 22.926 - Certifica Minas (Accessed January 14, 2024) at:. https://www.almg.gov.br/legislacao-mineira/LEI/22926/2018/.

Bahadur KC, K.B.; Dias, G.M.; Veeramani, A.; Swanton, C.J.; Fraser, D.; Steinke, D.; Lee, E.; Wittman, H.; Farber, J.M.; Dunfield, K.; McCann, K.; Anand, M.; Campbell, M.; Rooney, N.; Raine, N.E.; Van Acker, R.; Hanner, R.; Pascoal, S.; Sharif, S.; Benton, T.G.; Fraser, E.D.G., 2018. When too much isn't enough: Does current food production meet global nutritional needs? PLoS ONE, v. 13 (10), 1-16. https://doi.org/10.1371/journal.pone.0205683.

Barbosa, L.O.S.; Aguilar, C.; Maciel, L., 2021. A participação de Minas Gerais e do Brasil na cadeia produtiva global do café. Economia and Região, v. 9 (1), 147-166. https://doi.org/10.5433/2317-627x.2021v9n1p147.

Bardin, L., 2011. Análise de conteúdo. Edições 70, São Paulo.

Barham, B.L.; Weber, J.G., 2012. The Economic sustainability of certified coffee: recent evidence from Mexico and Peru. World Development, v. 40 (6), 1269-1279. https://doi.org/10.1016/j.worlddev.2011.11.005.

Barra, G.M.J.; Ladeira, M.B., 2018. Certified processes in agro-industrial systems: A study on the sustainable production of certified coffee. Revista em Agronegócio e Meio Ambiente, v. 11 (4), 1171-1194. https://doi.org/10.17765/2176-9168.2018v11n4p1171-1194.

Bermudez, S.; Voora, V.; Larrea, C., 2022. Coffee prices and sustainability. International Institute for Sustainable Development (Accessed January 8, 2024) at:. https://www.iisd.org/system/files/2022-09/2022-global-market-report-coffee.pdf.

Brasil, 2006. Lei nº 11.326 de 24 de julho de 2006. Estabelece as diretrizes para a formulação da Política Nacional da Agricultura Familiar e Empreendimentos Familiares Rurais. Diário Oficial da União, Brasília.

Cabrera, L.C.; Caldarelli, C.E., 2021. Viabilidade econômica de certificações de café para produtores brasileiros. Revista de Política Agrícola, v. 30 (4) (Accessed January 20, 2024) at:. https://seer.sede.embrapa.br/index.php/RPA/article/view/1651

Castro, C.V.; Lira, J.M.S.; Salgado, E.G.; Beijo, L.A., 2023. Socio-Environmental Impacts of Certifica Minas Café Program on Coffee Plantations in Southern Minas Gerais. Journal of Sustainable Development, v. 16 (5), 76. https://doi.org/10.5539/jsd.v16n5p76.

Certifica Minas Café (CMC), 2024. Certifica Minas Café (Accessed 19, 2023) at:. http://www.agricultura.mg.gov.br/certificaminas/website/index.php/programa-cert/sobre-o-certifica-minas.

Companhia Nacional de Abastecimento (CONAB), 2023. Acompanhamento da Safra Brasileira. Boletim da Safra 2023, v. 10 (2), 45 (Accessed April 14, 2024) at:. https://www.conab.gov.br/info-agro/safras/

Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), 2023. Produção dos Cafés do Brasil ocupa 1,9 milhão de hectares em 2023. Ministério da Agricultura, Pecuária e Abastecimento (Accessed January 15, 2024) at:. www.embrapa.br/busca-de-noticias/-/noticia/81515963/producao-dos-cafes-do-brasil-ocupa-19-milhao-de-hectares-em-2023.

Fairtrade International, 2024. Fairtrade International (Accessed November 27, 2023) at:. https://www.fairtrade.net/

Global Coffee Platform (GCP), 2023. Global Coffee Plataform: Sustainable Coffee Purchases Snapshot 2022 (Accessed January 13, 2024) at: https://www.globalcoffeeplatform.org/latest/2023/gcp-snapshot-report-2022/.

Hajjar, R.; Newton, P.; Adshead, D.; Bogaerts, M.; Maguire-Rajpaul, V.A.; Pinto, L.F.G.; McDermott, C.L.; Milder, J.C.; Wollenberg, E.; Agrawal, A., 2019. Scaling up sustainability in commodity agriculture: Transferability of governance mechanisms across the coffee and cattle sectors in Brazil. Journal of Cleaner Production, v. 206, 124-132. https://doi.org/10.1016/j.jclepro.2018.09.102.

Ibanez, M.; Blackman, A., 2015. Environmental and Economic Impacts of Growing Certified Organic Coffee in Colombia. Resources for the Future Discussion Paper No. 15-03. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2561375.

IBM, 2021. Estudo da IBM: COVID-19 impactou 9 em 10 pontos de vista dos consumidores sobre sustentabilidade. IBM Institute for Business Value (Accessed March 8, 2024) at:. https://www.ibm.com/blogs/ibm-comunica/estudo-sustentabilidade-pandemia/.

Imaflora, 2024. Rainforest Alliance. Instituto de Manejo e Certificação Florestal e Agrícola (Imaflora) (Accessed March 17, 2024) at:. https://www.imaflora.org/projetos//rainforest-alliance

Intergovernmental Panel on Climate Change (IPCC), 2023. IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001.

International Coffe Organization (ICO), 2023. Coffe Report and Outlook. International Coffe Organization (Accessed February 5, 2024) at:. https://icocoffee.org/documents/cy2023-24/Coffee_Report_and_Outlook_December_2023_ICO.pdf.

International Trade Centre, 2024. Standards Map (Accessed March 1, 2024) at:. https://standardsmap.org/en/home

Maciel, R.C.G.; Mangabeira, J.A.C.; Lima, L.F.; Romeiro, A.R., 2024. A valoração e o pagamento por serviços socioambientais na Reserva Extrativista Chico. Texto Para Discussão, (464). ISSN 0103-9466.

Maguire-Rajpaul, V.A.; Rajpaul, V.M.; McDermott, C.L.; Guedes Pinto, L.F., 2020. Coffee certification in Brazil: compliance with social standards and its implications for social equity. Environment, Development and Sustainability, v. 22 (3), 2015-2044. https://doi.org/10.1007/s10668-018-0275-z.

Mangabeira, J. A. de C., Pinto, D. M., and Scarazatti, B. (2021). Guia Metodológico: geração de indicadores de desempenho e índice multicritério de sustentabilidade para agricultura familiar no bioma Amazônia. In: Embrapa Territorial (Ed.), Embrapa Territorial. v. 1 (138) (Accessed April 22, 2024) at:. https://www.embrapa.br/en/busca-de-publicacoes/-/publicacao/1133822/guia-metodologico-geracao-de-indicadores-de-desempenho-e-indice-multicriterio-de-sustentabilidade-para-agricultura-familiar-no-bioma-amazonia

Meier, C.; Sampson, G.; Larrea, C.; Schlatter, B.; Voora, V.; Dang, D.; Bermudez, S.; Wozniak, J.; Willer, H., 2020. The State of Sustainable Markets 2020: Statistics and Emerging Trends. ITC, Geneva.

Melo, M.F.S.; Souza, R.C.; Campos-Silva, W.L.; Neto, J.A., 2017. Certificação Sustentável para café: Revisão sistemática da literatura e lacunas de pesquisa. Espacios, v. 38 (17). ISSN: 0798 1015.

Milhorance, C.; Sabourin, E.; Le Coq, J.-F.; Mendes, P., 2020. Unpacking the policy mix of adaptation to climate change in Brazil's semiarid region: enabling instruments and coordination mechanisms. Climate Policy, v. 20 (5), 593-608. https://doi.org/10.1080/14693062.2020.1753640.

Mitiku, F.; de Mey, Y.; Nyssen, J.; Maertens, M., 2017. Do private sustainability standards contribute to income growth and poverty alleviation? A comparison of different coffee certification schemes in Ethiopia. Sustainability (Switzerland), v. 9 (2), 246. https://doi.org/10.3390/su9020246.

Moda, L.R.; Spers, E.E.; Almeida, L.F. de; Schiavi, S.M. de A., 2022. Brazilian coffee sustainability, production, and certification. Sustainable Agricultural Value Chain. IntechOpen, Rijeka. https://doi.org/10.5772/intechopen.105135.

Panhuysen, S.; de Vries, F., 2023. Coffee Barometer 2023 (Accessed January 28, 2024) at:. https://coffeebarometer.org/.

Piao, R.S.; Fonseca, L.; de Januário, E.C.; Saes, M.S.M.; de Almeida, L.F., 2019. The adoption of Voluntary Sustainability Standards (VSS) and value chain upgrading in the Brazilian coffee production context. Journal of Rural Studies, v. 71, 13-22. https://doi.org/10.1016/j.jrurstud.2019.09.007.

Potts, J.; Lynch, M.; Wilkings, A.; Huppe, G.; Cunningham, M.; Voora, V., 2014. The State of Sustainability Initiatives Review 2014, Standards and the Green Economy. International Institute for Sustainable Development (IISD) and the International Institute for Environment and Development (IIED), January, 332 (Accessed April 24, 2024) at:. https://www.iisd.org/system/files/pdf/2014/ssi_2014.pdf.

Rainforest Alliance, 2024. Rainforest Alliance. Rainforest Alliance (Accessed February 9, 2024) at:. https://www.rainforest-alliance.org/.

Rich, K. M.; Chengappa, P. G.; Muniyappa, A.; Yadava, C. G.; Manjyapura, G. S.; Pradeepa Babu, B. N.; Shubha, Y. C.; Rich, M., 2018. Coffee certification in India: Awareness, practices, and sustainability perception of growers. Agroecology and Sustainable Food Systems, v. 42 (4), 448-474. https://doi.org/10.1080/21683565.2017.1361497.

Rockström, J.; Beringer, A.; Crona, B.; Gaffney, O.; Klingenfeld, D., 2020. Planetary boundaries: A compass for investing for the common good. In: Bril, H.; Kell, G.; Rasche, A. Sustainable Investing Sustainable Investing A Path to a New Horizon, Routledge, London, pp. 109-128.

Sachs, J.D.; Schmidt-Traub, G.; Mazzucato, M.; Messner, D.; Nakicenovic, N.; Rockström, J., 2019. Six Transformations to achieve the Sustainable Development Goals. Nature Sustainability, v. 2 (9), 805-814. https://doi.org/10.1038/s41893-019-0352-9.

Scalco, A.R., 2019. Certificações socioambientais em sistemas agroalimentares: convergências e divergências de atributos. Sistemas and Gestão, v. 14 (2), 177-187. https://doi.org/10.20985/1980-5160.2019.v14n2.1523.

Schaltz, T.S.; Bork, F.K., 2019. Informal economy in coffee country: farmers' use of Western certification schemes. Diálogos Latinoamericanos, v. 20 (28), 104-117. https://doi.org/10.7146/dl.v20i28.117215.

Squeff, T.A.F.R.C., 2020. O papel da certificação ambiental na consecução do desenvolvimento e consumo sustentável. Revista da Faculdade de Direito da UFG, v. 43. https://doi.org/10.5216/rfd.v43.57757.

Takahashi, R.; Todo, Y., 2013. The impact of a shade coffee certification program on forest conservation: A case study from a wild coffee forest in Ethiopia. Journal of Environmental Management, v. 130, 48-54. https://doi.org/10.1016/j.jenvman.2013.08.025

Veiga, J.P.C.; Barbosa, A.F.; Saes, M.S.M., 2016. A Cadeia Produtiva do Café no Brasil: Impactos Sociais e Trabalhistas da Certificação. Technical Report (Accessed January 14, 2024) at:. https://www.researchgate.net/publication/304013749.

Voora, V.; Larrea, C.; Huppé, G.; Nugnes, F., 2022. IISD's State of Sustainability Initiatives review: Standards and investments in sustainable agriculture. International Institute for Sustainable Development. April (Accessed July 11, 2024) at:. https://www.iisd.org/system/files/2022-04/ssi-initiatives-review-standards-investments-agriculture.pdf.