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# Mapping the Value Chain of a Coffee Farm in the Interior of São Paulo: A Case Study Exploring Blockchain for Process Enhancement

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# MAPPING THE VALUE CHAIN OF A COFFEE FARM IN THE INTERIOR OF SÃO PAULO: A CASE STUDY EXPLORING BLOCKCHAIN FOR PROCESS ENHANCEMENT

## 1 INTRODUCTION

Coffee, derived from the beans of the *Coffea* plant, stands as one of the world's most widely consumed beverages. Its immense global popularity has spurred extensive research into its cultivation, processing, economic impact, and cultural significance, conducted from diverse perspectives and across multiple levels (Murthy and Naidu, 2012), reflecting the inherent complexity of its value chain. This comprehensive chain begins with foundational agricultural practices like soil preparation and planting, progresses through harvesting and intricate processing methods, and extends to international distribution, marketing strategies, and final retail sales.

This market has a direct effect on the economy of the environment, from political aspects to family farmers (Jha *et al.*, 2011). Coffee is worth billions a year and is also present in the premium market, making space for innovation and continuous development (Ponte, 2002). According to reports from Statista Market Insights (Statista, 2024), the coffee market is expected to reach a revenue of $93.46 billion, representing an increase of approximately 24.85% since 2018. The figure 1 shows the evolution of revenue since 2018 with growth projections until 2029, where it can reach $108.4 billion.

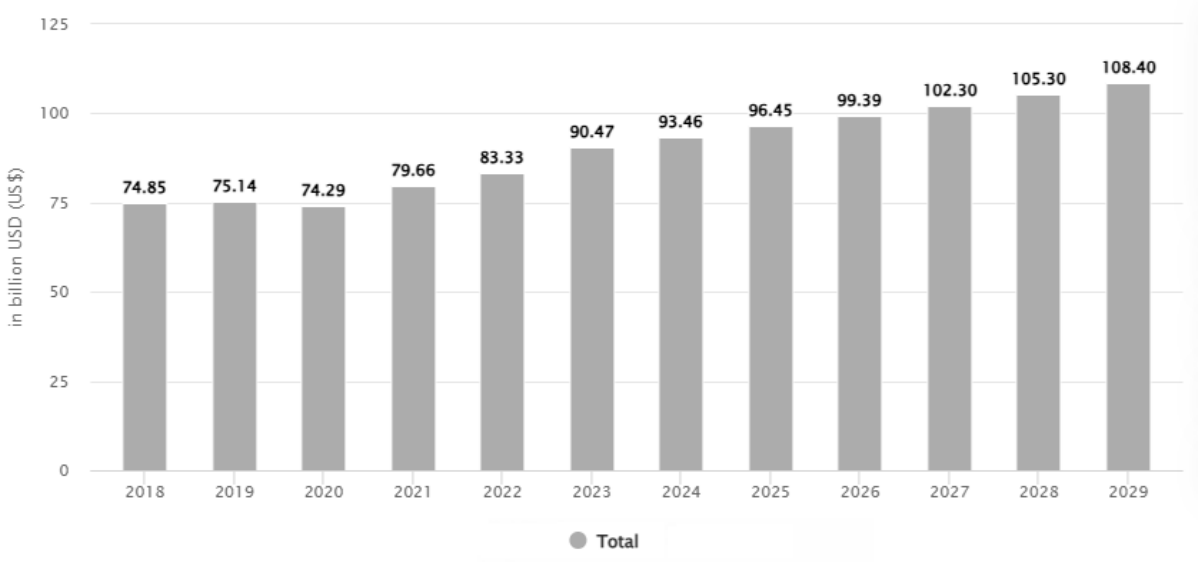


Figure 1: Revenue number of coffee market. Source: Statista Market Insights (Statista, 2024)

As an agricultural activity, coffee production is directly linked to environmental aspects, such as the preservation of natural habitats and concerns over the use of pesticides and fertilizers (Hidalgo *et al.*, 2023). It also serves as a vital source of income for thousands of families, generating significant social impact (Vicol *et al.*, 2018). Thus, we can affirm that coffee and its entire ecosystem are strongly connected to Environmental, Social, and Governance (ESG) practices.

The coffee value chain includes different actors in different sectors and is therefore considered a complex ecosystem that requires data capture and processing to enable automated and non-automated analyses that assist in strategic planning and decision-making. In addition, it also requires aspects such as monitoring, pricing, good governance practices, development of public policies, marketing, events, among others. These factors must be developed and improved to add even more value to the final product and also to improve integration among the agents (Utrilla-Catalan *et al.*, 2022).

It can be divided into four different parts, which include the stages of coffee cultivation, such as: (1) preparation: where the soil is prepared, studies are carried out and applied to choose the best place, period, and products to use, purchase of inputs and planning are carried out; (2) production: where machinery and specialized labor are used to carry out the necessary care to achieve good results; (3) harvesting and primary processing: where the coffee fruit is extracted also using specialized machinery and labor and separated for different purposes, which triggers the last stage; (4) market: which covers everything from the specific processing and distribution of the product to the final product in customers' houses, with the participation of retailers, local traders, and indirect

sales. Different actors can be found in each stage, and some of them are repeated in all of them (Beshah *et al.*, 2013).

The chain becomes even more complex when we talk about different types of beans and the final coffee product. Depending on the geographic and climatic conditions, as well as investments in studies and applications, the producer can obtain a product with specific characteristics, which can be focused on a higher segment, or, on the other hand, some practices can be adopted to offer a cheaper product, giving up high quality.

There are currently more than 124 species of coffee, although only 2 are commercialized and exploited globally (Gilbert, 2008). From these specific varieties, countless variations can emerge, bringing specific characteristics of flavor, tone, and texture to the product. According to the quality of the coffee beans and its characteristics, it can be classified as Extraordinary, Special, Gourmet, Superior, Traditional and Extra Strong. These classifications are awarded by regulatory, intermediary and quality certification bodies, such as the Specialty Coffee Association (SCA), the largest global coffee trade association. The classification, as well as the sensory characteristics of the coffees, are important value-adders and a quality differential, which influence price issues and the customer's decision when buying (Fitter and Kaplinksy*, 2001; Fromm and Dubon, 2006; Kiemen and Beuchelt, 2010).

In Brazil, coffee has a historic tradition and is an important product for the national economy, with a significant share of exports, especially specialty coffees. As shown in Table I, Brazil is number 1 in production, even though it has not grown constantly, in the last 3 years it has shown an increase in production. Because of these factors, it is an ecosystem that moves political, cultural and social aspects (Boaventura *et al.*, 2018). Several companies join this ecosystem to leverage and improve the systems, such as machinery manufacturers, consultants, and logistics companies (Siqueira, 2005). Coffee production in Brazil covers different regions of the country and has different institutions that help support the chain and serve as integration agents. Examples include the Brazilian Specialty Coffee Association (BSCA) and the Brazilian Coffee Industry Association (ABIC), which promote events, training, championships and so on, including at an international level (Volsi *et al.*, 2019).

| **Year** | **Brazil** | **Vietnam** | **Colombia** | **Indonesia** | **Ethiopia** |
|---|---|---|---|---|---|
| 2020/2021 | 69,9 | 29 | 13,4 | 10,7 | 7,6 |
| 2021/2022 | 58,1 | 31,58 | 11,8 | 10,58 | 8,15 |
| 2022/2023 | 62,6 | 29,75 | 11,3 | 11,85 | 8,27 |
| 2023/2024* | 66,4 | 31,3 | 11,6 | 9,7 | 8,35 |

Table I: Coffee production in the top five producing countries in millions of 60 kg bags, * being an estimate. Source: United States Department of Agriculture (USDA), 2023

As this is a complex chain with multiple layers and different actors, and also considering the importance of the activity on different scales, it is necessary to promote continuous improvement in processes and facilitate integration within the chain, in order to add even more value to the final product. In this scenario, the blockchain technology emerges as an important alternative for this purpose (Thiruchelvam *et al.*, 2018). It is known for its aspects of security, transparency, efficiency, and cost reduction (Habib *et al.*, 2022). This technology has been widely used in value chain work in different areas and has shown good results (Gurtu and Johny, 2019; Rana *et al.*, 2021; Rocha *et al.*, 2021).

The implementation of blockchain in coffee value chains more broadly offers significant potential benefits: it can enhance transparency and traceability, enabling producers to track their beans' journey to the end consumer—a feature valued as recognition and appreciation of their production (Singh *et al.*, 2022). Additionally, blockchain-enabled access to detailed information on quality practices and market preferences provides opportunities for productive improvement through direct feedback, potentially leading to economic gains.

In this research, we are going to present the value chain of a farm located in the interior of São Paulo, in order to investigate the actors involved and the interactions between them, demonstrating the main activities and resources that are understood in the context analyzed. Alongside this, we also present a deep bibliometric review, in order to compare the value chain presented and those being studied in different countries and contexts. Given the potential of blockchain to transform agro-industrial chains – evidenced by transparency, traceability and efficiency –, and considering the need for adaptations to specific local contexts, a central question arises for this research:

**How can blockchain implementation optimize processes, add value and overcome challenges in the Brazilian coffee production chain, considering local empirical evidence and international benchmarking?**

The paper is divided into five sections, which the first one provides a general understanding of the coffee market and the structure of this ecosystem in Brazil, especially with regard to the value chain. A link is also made to Blockchain technology to justify its use. Section 2 lists and elucidates some contributions that discuss the coffee value chain and also link it to Blockchain technology. The works shown in this section are part of the bibliometric review. Section 3 presents the research terms used for the review, details of the farm studied in terms of geography and operation, and how the research was conducted to arrive at the results. The main contributions are listed in

Section 4, where the value chain is shown and correlations with the literature are explored. Also based on the literature, blockchain technology is presented as a solution to fill gaps and overcome challenges. Section 5 closes the paper, highlighting the contributions and main results. We also present an outlook for future work that could complement this study.

## 2 LITERATURE REVIEW

Value chain modernization strategies for the integration of coffee growers require structural interventions to mitigate information asymmetries, production fragmentation, and market access barriers (Babu *et al.*, 2019). The adoption of digital technologies, notably blockchain, emerges as a critical mechanism to establish transactional transparency and traceability, enabling disintermediation and direct connections between producers and premium markets. Complementarily, product differentiation strategies—through quality certifications, geographical indications, and eco-sustainable processes—are fundamental for capturing added value in specialized markets. Finally, vertical integration via digital trading platforms and agricultural information systems enables efficient coordination across chain segments, reducing transaction costs and optimizing production flows.

Based on the results obtained from our bibliometric analysis, in this section we mention some articles that support the need to promote studies on the coffee value chain and also on the intersection of this literature with blockchain technology. In addition to a theoretical basis, the articles discussed also provide practical applications and visions of the future for this important topic. Different perspectives have been raised and explained, from economic to political factors, from small produce to large coffee farms. The idea is to promote a general perception of studies in this field of research through important works developed over the years.

### 2.1 Defining value chain

A product or service is rarely produced entirely within a single sector, especially high value-added goods like cars, houses, appliances, and similar products. Usually, each industry specializes and offers small parts of a whole that is ultimately manufactured and made available to the trade to reach the end customer, which means that industries interact in the purchase/sale of materials or services that add value until the final work, hence the name value chain. This dynamic was recognized and conceptualized by Porter (1985). Understanding parts or all of the chains is essential for generating value and improving processes.

Mapping the chain is essential for identifying the players involved and their activities and collaborations. This allows influences and barriers to be extracted in a given market, promoting a general understanding that is useful in decision-making and strategic definitions, for example, where investments are needed or in identifying risks and opportunities (Hellin and Meijer, 2006). This general analysis allows specific actors to be elevated in order to determine the flows and drivers of a chain. It's like a puzzle, without a piece you can't complete the project.

When looking at it from this perspective, challenges and paradigms naturally arise that need to be explored, such as how to manage stock, efficient logistics, exports, and imports and so on. Chain analysis also allows us to capture aspects related to sustainable and social practices, in how the chain behaves in relation to evolution and changes related to cultural, environmental and political issues (Mol, 2015).

Niri *et al.*, (2024) demonstrate a practical and super-current situation in the electric vehicle battery scenario. The authors map the risks and challenges, including political and legal approaches, and present the chain of this segment, mapping the main materials and actors that consume them. The work is an important basis for other studies to develop frameworks and models on this chain, providing valuable and in-depth insights on the functioning and complexity of this chain.

The variety of studies on value chains, at a global level, can be seen, for example, in the mapping of a fungal chain, more specifically *Ophiocordyceps sinensis*, where Fan and He (2024) maps the functioning of this chain, demonstrating aspects of profitability, actors, geographies, social institutions and marketing. It is a holistic analysis of different aspects that demonstrate the functioning of an ecosystem for a very specific product. The functioning of the processes that interact within this chain can be useful in drawing parallels with the functioning of other chains, and thus determining generic processes that can help different segments. The work presents the context of the chain in China, and is also useful for expanding the exploration of the same (or similar) segments in other regions.

Another example of a chain, in another market in another country, is the analysis of the beekeeping chain in Ethiopia. Bayissa *et al.*, (2024) demonstrate how the chain can be explored through techniques such as the SWOT and PESTEL matrix, as well as through the use of statistical data and mapping systems. These approaches promote the challenges and opportunities of the chain and the mapping of production issues in terms of impact, giving suggestions for paths that tend to favor the chain.

The works cited above support the need and usefulness of studying value chains and making contributions to different sectors. This work, although focused on the coffee market, uses ideas and methodologies applied

to analyzing different sectors. The knowledge obtained through the integration of different areas and markets is essential for the evolution of the subject and the creation of a solid base that allows for the development of specific frameworks.

## 2.2 The coffee ecosystem

Research on coffee is diverse. The importance of this product, both in a historical context and in economic terms applied to the present day, favors the development of research aimed at collaborating with the coffee ecosystem. This scope is also reflected in the areas of knowledge that study the phenomenon, such as: (1) health, since coffee has characteristics allied to the fight against some types of (Melo Pereira *et al.*, 2020) diseases, (2) tourism, in view of the potential to attract tourists who like the product and/or farms that promote educational content, entertainment and/or explore aspects related to nature and the coffee trail, exploring the whole process from production to consumption (Nono *et al.*, 2024; Setiawati *et al.*, 2024; Dewi *et al.*, 2024) and above all (3) administration and its various ramifications such as marketing (Basha *et al.*, 2023), economics (Paull, 2024), entrepreneurship (Fang *et al.*, 2024), among others.

The global coffee ecosystem is characterized by fragmented and geographically dispersed value chains, with high informality in transactions and labor contracts. This complexity creates opacity regarding production conditions, hindering sustainability assessment (Singh *et al.*, 2022). Despite generating approximately US$200 billion annually, only 10% of the value remains in producing regions, where smallholders often operate at a loss due to international price volatility. This economic pressure has incentivized a transition to full-sun monoculture plantations, increasing dependence on agrochemicals and contributing to greenhouse gas emissions and deforestation. Voluntary sustainability standards (such as Fairtrade) have emerged to mitigate these impacts but face limitations in equitable benefit distribution, potentially causing ”supplier squeeze” where producers bear certification costs while downstream companies capture most added value through branding.

With regard to the value chain, the studies seek to value the coffee ecosystem, integrating the players and promoting efficient processes from production to final consumption. Gurmessa *et al.*, (2022) analyzes the coffee chain from a sustainable and social perspective, through gender dynamics in Ethiopia. The study pointed out technological practices and adaptations that have been necessary in view of technical, institutional and socio-economic factors, and also how these factors affect quality issues, market access and financial aspects. They highlight the importance of gender analysis in the context of the value chain and the need for fair and equitable representation for women, and reinforce the influence these factors have on the efficiency and sustainability of the chain.

Another approach is offered by Fauzi *et al.*, (2023), who analyzed the coffee context in Indonesia, from the local perspective of small-scale robusta coffee producers. They highlight product price relationships and how this affects the chain, the integration between producers and traders. According to the authors, economic aspects dominate the relationship between the actors, given the weak social capital in the context studied. The study also contributes to the identification of cultural and historical factors in the development of coffee production and how this impacts the relationships in the chain. The result is the identification of the main and most influential actors in the chain and how they shape relationships.

Research into coffee, especially value chain analysis, underpins the need to continue applying efforts to identifying and analyzing different scenarios, regions, and cultures. The development of this study provides a holistic and empirical view of a farm in the interior of São Paulo, correlating with studies in different regions such as Ethiopia and Indonesia. The analysis that highlights the main players and their relationships is essential for creating value and how this ecosystem generates results in financial, cultural and social terms.

## 2.3 Blockchain technology: enabling transparency and traceability

Blockchain technology is considered disruptive given its potential for impact and transformation. It offers aspects such as decentralization, distribution of records (distributed ledger), transparency and being tamper-proof, since once the information is saved, it cannot be altered (systematic). The technology comes from the concept of Merkle trees, also known as scatter trees, which was created in the 1970s and first implemented in the 1990s for a stamp use case by Stuart Haber and W. Scott Stornetta (Haber and Stornetta, 1991). Despite its ancient origins, the technology only became widespread and popularized when (Nakamoto, 2008) published an electronic currency system peer-to-peer, the famous bitcoin. From that moment on, numerous research projects began to emerge in different areas to explore the potential of this technology and add value.

The blockchain is a combination of two concepts: a peer-to-peer network (popularly known as chains) and a distributed database based on the storage of records in blocks. Transactions take place and are validated in the chains and are saved in these databases, which can be open (accessible to everyone) or private (only for authorized people). In a simple analogy, it’s similar to a ledger. Upon entering the network, a root block is created, containing

information on the rules and instructions for the blocks to come. When new operations or transactions are made, new blocks are created and connected from a hash. It is through this hash that it is possible to synchronize and view all connected blocks (Sarmah, 2018).

Considering these features and aspects, blockchain has been used in different areas for different purposes. In the financial sector, technology has brought about many changes. In addition to bitcoin, numerous companies have seen this system as a possibility for new forms of monetization and gamification. Many cryptocurrencies have emerged, emphasizing a new financial system. It also favors the creation and development of Decentralized Autonomous Organizations (DAOs), which see this system as an opportunity to practice new forms of governance, processes, and dynamics (Wüst and Gervais, 2018). As pointed out by Al-Jaroodi and Mohamed (2019), companies from different sectors are benefiting from the technology, such as health, logistics, manufacturing, energy, agriculture, robotics, entertainment, construction and telecommunications, although the benefits come with challenges to overcome, such as regulatory issues, privacy, skilled labor, scalability, and security. The blockchain also manages to serve as a lever for recent topics such as the meta-verse, also promoting impacts on how users use and interact in (Gadekallu *et al.*, 2022) networks.

In the context of the value chain, the blockchain is associated with the potential to promote process improvements and integrations. Thiruchelvam *et al.*, (2018) presented a case study of coffee cooperatives in Colombia, listing seven main nodes of the chain: Farm, Buyer, Processor, Export, Import, Roaster, and Consumer and for each node implemented a pilot model of the use of blockchain, demonstrating use cases and forms of interaction. The results were analyzed from two angles: traceability and transparency, presenting the opportunities offered by blockchain in these respects, but also the challenges posed by the technology. Factors such as fraud reduction, pricing, quality and sustainability can be improved with blockchain, but, on the other hand, they can represent an increase in complexity and costs.

According to (Singh *et al.*, 2022), blockchain implementation in the coffee value chain offers significant benefits, particularly in enhancing transparency and traceability. The technology enables the immutable recording of events such as harvesting, processing, and transactions, facilitating end-to-end tracking of coffee's journey "from farm to cup" by both producers and consumers. This visibility not only addresses the historical opacity of global chains, which is often criticized by producers, but also creates opportunities for commercial valorization by linking products to specific origins and sustainable practices, generating potential market differentiation. Additionally, by providing access to information on final prices and quality preferences, blockchain can empower producers in negotiations and practice adjustments, reducing information asymmetries. However, the authors emphasize that these benefits depend on equitable design, avoiding "data squeeze," the unilateral appropriation of data by large corporations, and ensuring fair distribution of operational costs along the chain.

Chain governance is also directly affected by increased integration and consequently easy and fast access to more data and information. Another case study promoted by Tharatipyakul *et al.*, (2022), this time in Thailand, evaluated the use of blockchain through user-centered applications to measure the impacts on the chain. The results obtained demonstrate the viability of blockchain in the context studied, with 67% of participants positively evaluating the technology, highlighting the increase in product reliability and ease of identifying origin. Although the results endorse the use of technology to amplify value in the chain, the authors also suggest further research to shed light on the challenges that need to be overcome, such as providing education and motivation to producers to implement the technology and ensuring that there are no loose ends when it comes to the security (integrity and privacy) of the information, especially confidential information, that passes through the chain.

Mapping and detailing a coffee value chain, which is one of the objectives of this research, makes it possible to suggest and assess the feasibility of applying blockchain. By identifying the actors present, taking into account their duties and responsibilities in the chain, it is possible to estimate how the use of technology can bring benefits, individually and also collectively, in terms of integration between links.

## 3 METHODOLOGY

This section delineates the methodological framework used to extract and analyze data to achieve research objectives. The bibliometric review was conducted using different keywords, holistic observations were made to understand the workings of the farm studied, and secondary databases were also used to complement and give meaning to the results found. Furthermore, this section details the processes for carrying out the case study and also the list of materials and secondary sources used to support the research.

We carried out the bibliometric review in four stages, the first being responsible for mapping articles that talk about the coffee value chain in general and the other stages refining the results more and more, focusing on the Brazilian context and the use of blockchain technology. Table II describes the searches in detail in each of the four stages. The platform used to enter the search criteria was Scopus, one of the largest databases of academic papers with various resources that help with bibliometric analysis. Scopus covers works from different areas of

knowledge and is widely used by the academic community for literature review and theoretical reference purposes (Burnham, 2006).

| Keywords | Search field | Publication period | Languages | Knowledge area | Document type |
|---|---|---|---|---|---|
| (”chain value” OR ”value chain” OR ”cadeia de valor”) AND (coffee OR café) | Doc Title, Abstract, Keyword (TITLE-ABS-KEY) | All the time | English and Portuguese | Social Sciences & Economics, Econometrics and Finance & Agricultural and Biological Sciences & Business, Management and Accounting & Computer Science | Only articles published in scientific journals (excluding conference abstracts, proceedings, etc.) |
| (”chain value” OR ”value chain” OR ”cadeia de valor”) AND (coffee OR café) AND blockchain | Doc Title, Abstract, Keyword (TITLE-ABS-KEY) | All the time | English and Portuguese | Social Sciences & Economics, Econometrics and Finance & Agricultural and Biological Sciences & Business, Management and Accounting & Computer Science | Only articles published in scientific journals (excluding conference abstracts, proceedings, etc.) |
| (”chain value” OR ”value chain” OR ”cadeia de valor”) AND (coffee OR café) AND (brazil OR brasil) | Doc Title, Abstract, Keyword (TITLE-ABS-KEY) | All the time | English and Portuguese | Social Sciences & Economics, Econometrics and Finance & Agricultural and Biological Sciences & Business, Management and Accounting & Computer Science | Only articles published in scientific journals (excluding conference abstracts, proceedings, etc.) |
| (”chain value” OR ”value chain” OR ”cadeia de valor”) AND (coffee OR café) AND (brazil OR brasil) AND blockchain | Doc Title, Abstract, Keyword (TITLE-ABS-KEY) | All the time | English and Portuguese | Social Sciences & Economics, Econometrics and Finance & Agricultural and Biological Sciences & Business, Management and Accounting & Computer Science | Only articles published in scientific journals (excluding conference abstracts, proceedings, etc.) |

Table II: Search criteria. Source: developed by the authors.

As expected, the number of articles found decreases as the searches are refined: 234 articles were found for the first combination of keywords, 5 for the second, 17 for the third and 0 for the last, highlighting the gap in the literature regarding research exploring the potential use of blockchain technology in the value chains of coffee farms in Brazil. Research considering these factors is necessary, given Brazil's importance in the global coffee production and export scenario. Mapping the coffee value chain, as well as the relationship with technologies such as blockchain, helps build knowledge for more efficient management of this sector.

The results were analyzed with the help of the VosViewer software, which enabled the creation of maps and relationships based on the data extracted, making it possible to visually identify patterns and common characteristics of the works in the literature (Van Eck and Waltman, 2010). The main articles found are detailed in Section 2, while the tables and graphs of the bibliometric review are shown in Section 4. A thesaurus file was created to group similar words, both semantically and syntactically. This file has 234 entries that aim to bring more clarity to the results found in terms of keyword analysis.

Given the scarcity of scientific literature on the topic (based on the search criteria applied in the Scopus database), the study was also supplemented with a review of secondary sources. This included documents, news clippings, institutional websites, and secondary databases from specialized coffee repositories. Data pertaining to exports, production, labor, and related metrics were utilized to contextualize and underscore the significance of

coffee production, particularly within Brazil.

In contrast to the bibliometric review, a single-case study was conducted on a coffee farm in the interior of São Paulo, in the Intermediate Geographic Region of Campinas. The case was selected by convenience sampling, given our direct access to both the farm owner and a coffee market specialist, in addition to the farm's location. Prior to data collection, each participant received and signed a Term of Free and Informed Consent (TCLE). Data were gathered through two semi-structured interviews (one with the farm owner and one with the specialist) and systematic field observations covering all stages of the coffee production chain—from planting through processing to final distribution. Finally, we mapped the multi-layered network of value-chain actors interacting with the farm and examined how blockchain technology could further enhance transparency, traceability, and value creation for coffee producers.

The case study was conducted following the model suggested by Yin (Yin, 2009): in the first stage the research question and the theoretical framework are defined, followed by data collection, analysis, and reporting of findings. In our case, the study was carried out on a fully integrated coffee farm, covering all production activities and processes. Figure 2 illustrates the steps described.

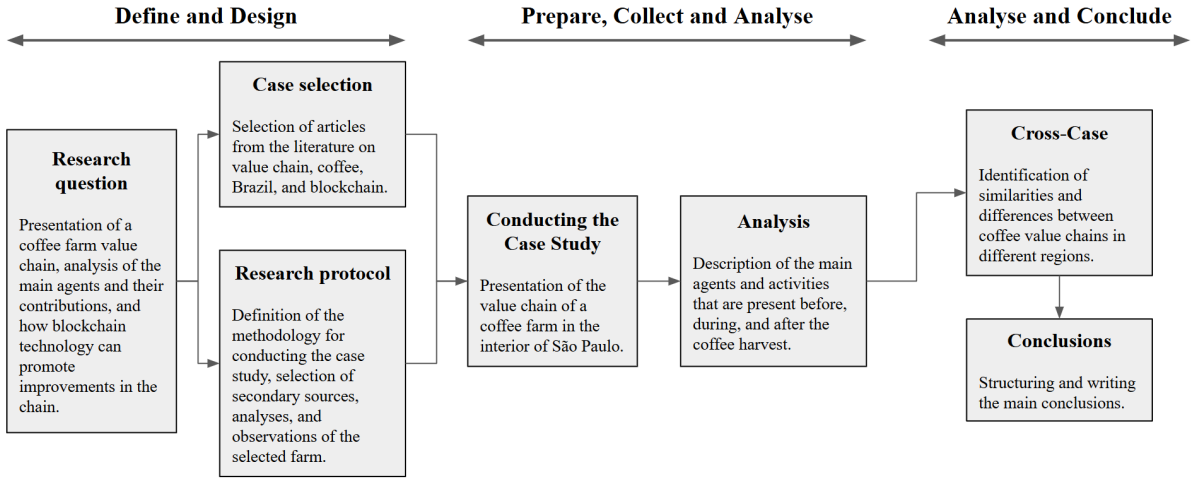


Figure 2: Modeling the case study following the structure proposed by Yin (Yin, 2009).

Interview transcripts and field notes were then organized and coded in line with content-analysis principles, enabling systematic identification of core categories and patterns. Once the data were collected, it was necessary to identify a method capable of providing a systematic and rigorous analysis of the interview material. To this end, we chose to apply content analysis as conceptualized by Bardin (Bardin, 2011), given its well-established procedures for organizing, coding, and interpreting qualitative data. This technique enabled us to define clear units of analysis, develop thematic categories through iterative reading, and derive analytical inferences that support a transparent mapping of the coffee farm's value-chain processes. The Figure 3 illustrates the three core phases—pre-analysis, exploration, and treatment of results—adapted from Bardin's original framework.

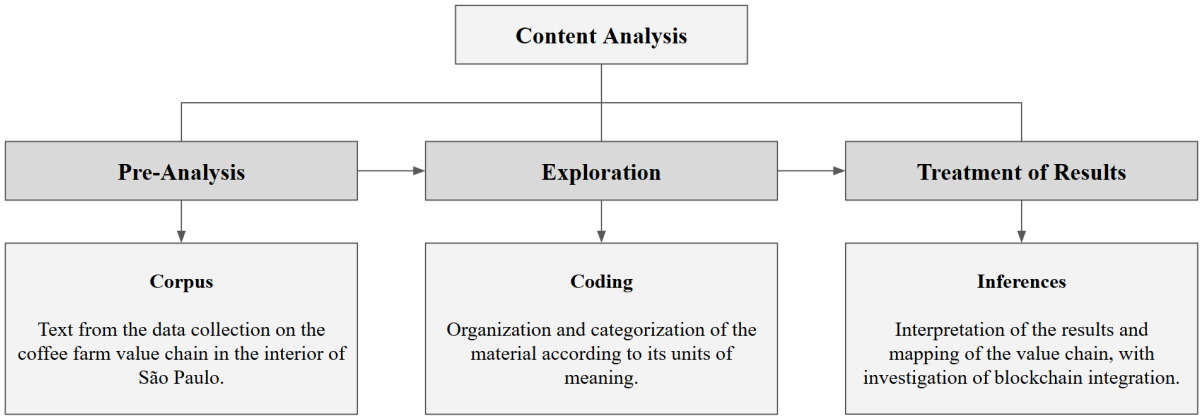


Figure 3: Phases of Content Analysis Applied to the Coffee Farm Value Chain Study. Adapted from Bardin (2011).

In the pre-analysis phase, the corpus—comprising interview transcripts, field reports, and internal documents related to the coffee farm value chain in the interior of São Paulo—was systematized to enable initial familiarization and the definition of recording units. During the exploration phase, coding was performed through floating readings of the material, the establishment of thematic categories, and the grouping of meaning units according to their relevance to the study's objectives. Finally, in the treatment of results phase, analytical inferences were drawn from the interpretation of the generated categories, aiming at a detailed mapping of the value-chain activities and the identification of opportunities for blockchain integration to enhance process efficiency.

# 4 RESULTS

The results are divided into three subsections, each representing a collaborative aspect of this study. The first subsection presents the results of the bibliometric review, where we analyzed the keyword clusters obtained through the VOSviewer software. The second subsection shows the case study of the farm studied in detail, also presenting a visualization of the chain with the actors detailed in different categories. The farm is also in contrast with the information collected from the literature, pointing out similarities and differences. Finally, the third subsection complements the research with important secondary sources, in order to better understand the current scenario. During all these subsections, correlations are made with blockchain technology in order to highlight its qualities and how it could add value to coffee production, considering its entire life cycle.

## 4.1 Keyword clusters from bibliometric review

The keyword cloud analysis, Figure 4, reveals a clear thematic structure in studies on the coffee value chain, organized into three interrelated main clusters. The first cluster, centered on sustainability and governance concepts, aggregates terms such as fair trade, certification, voluntary sustainability stand, deforestation, social impact, gender, equity, and livelihood. This grouping highlights the centrality of socio-environmental dimensions in contemporary literature. The strong presence of certification and fair trade underscores the role of voluntary standards as mechanisms of transnational governance, aiming to mitigate negative impacts (such as deforestation), promote responsible practices, and ensure greater equity and improved livelihood conditions (subsistence and well-being), especially for smallholders, who form the foundation of production in many countries. The occurrence of gender reinforces the attention to gender dynamics within this chain.

A second cluster, focused on the structure, operation, and competitive dynamics of the value chain, encompasses fundamental terms like value chain, supply chain, global production networks, coffee value chain, upgrading, innovation, knowledge management, standards, trade, international business, marketing, commodity, and specialty coffee. This core describes the complex global architecture of coffee, from agricultural production (agricultural production) to final markets. The dichotomy between commodity (coffee as a primary good) and specialty coffee is striking, pointing towards differentiation strategies and the pursuit of higher added value. Concepts like upgrading (moving up the chain) and innovation are crucial, indicating the need for actors, including cooperatives, to enhance their capabilities and positioning within global production networks. The presence of international business and trade underscores the deeply globalized nature of this sector.

The third cluster emphasizes the geographical, productive, and developmental context of coffee farming, bringing together coffee, coffee production, agricultural production, agriculture, agroindustry, smallholder, rural development, developing world, and the main producing countries: Brazil (highlighted by the study context), Indonesia, Ethiopia, Vietnam, Uganda, Mexico, and Africa. This grouping confirms that coffee production is predominantly anchored in the developing world, being vital for the rural development of various tropical regions. The emphasis on smallholder highlights the predominant profile of many producers, for whom coffee is often essential for livelihood (survival and sustenance), even within a gigantic global food market. The recurrence of countries like Brazil (the world's largest producer), Vietnam (a leader in Robusta), Ethiopia (the birthplace of Arabica), Indonesia, Colombia (implicitly associated), Uganda, and Mexico illustrates the central geographical distribution of the phenomenon under study.

High-frequency and cross-cutting keywords, such as sustainability and certification, act as integrating concepts between the clusters. Certification emerges as a key governance tool for promoting sustainability along the chain, influencing standards and seeking positive social (social impact, gender, equity) and environmental impacts. Meanwhile, trade and international business permeate the analysis, reflecting the intrinsic connection between local production in developing countries and global consumer markets. This thematic structure demonstrates that understanding the coffee value chain, particularly in the focused Brazilian and São Paulo context, requires a holistic approach that simultaneously considers its complex economic-logistical organization, its productive and geographical challenges, and the imperative integration of socio-environmental sustainability across all its stages – dimensions where technological innovation, such as blockchain, can offer significant contributions.

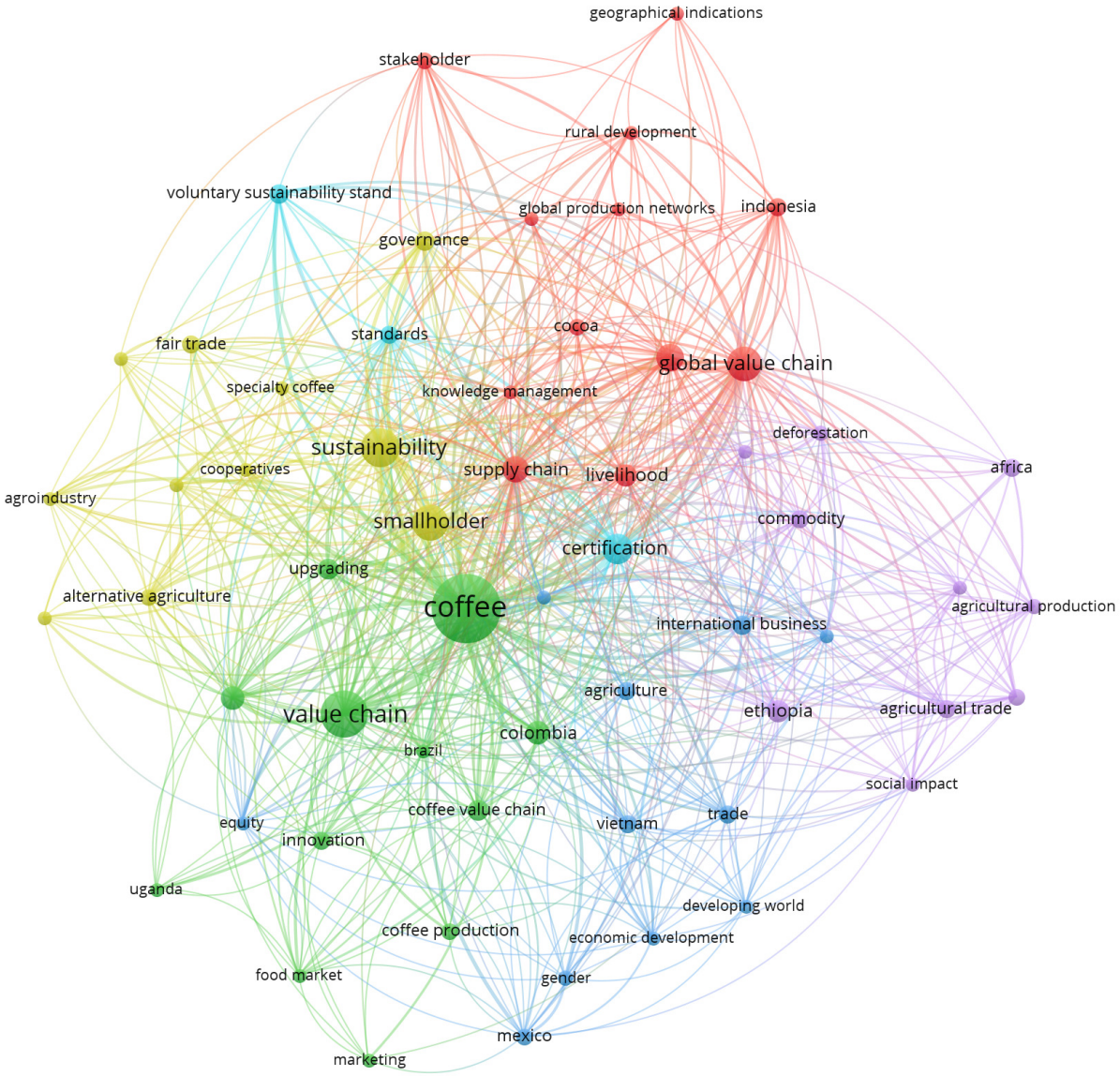


Figure 4: Keyword clusters

In terms of the distribution of documents by country, the United States stands out as the leading contributor, despite not being among the world's largest coffee producers or consumers. It is followed by Germany and the United Kingdom—countries that, although not major coffee references, frequently appear well ranked in diverse research fields. This highlights their strong collaborative potential and serves as evidence that there is no strict correlation between local scientific production and a country's prominence in developing a specific product or service.

Brazil ranks fifth in terms of the number of published documents (18 indexed in Scopus). However, this relatively high volume of publications does not translate into widespread dissemination of its research, especially when considering the number of citations as a metric. Notably, Mexico, with fewer than half the number of documents (6), has accumulated more citations, challenging any notion of a Latin American barrier in research dissemination. One possible explanation is that Brazilian research often focuses on highly specific topics with limited generalizability. Additionally, aspects related to globalization, particularly in the coffee sector, remain underexplored in Brazilian studies.

It is important to note that citation count alone cannot be used as an absolute measure of research quality. Nevertheless, these figures underscore the need for coffee value chain research in Brazil to develop more broadly applicable concepts, with greater potential for international dissemination and, consequently, a wider diffusion of knowledge.

Table III shows the countries with more than five documents, alongside their respective citation counts. It is also worth highlighting the presence of several African countries, reflecting the cultural and economic significance

of coffee across the continent.

| Country | Number of Documents | Number of citations | Total link strength |
|---|---|---|---|
| United States | 40 | 982 | 42 |
| Germany | 36 | 863 | 38 |
| United Kingdom | 24 | 695 | 36 |
| Netherlands | 20 | 591 | 20 |
| Brazil | 18 | 236 | 16 |
| Ethiopia | 18 | 247 | 18 |
| Indonesia | 18 | 275 | 14 |
| Switzerland | 14 | 352 | 21 |
| Australia | 13 | 441 | 10 |
| Italy | 13 | 454 | 13 |
| Belgium | 12 | 394 | 15 |
| Colombia | 11 | 168 | 7 |
| Denmark | 10 | 270 | 11 |
| Costa Rica | 9 | 312 | 12 |
| Vietnam | 8 | 33 | 10 |
| France | 8 | 332 | 14 |
| Austria | 7 | 84 | 4 |
| India | 7 | 25 | 0 |
| Uganda | 7 | 72 | 5 |
| Canada | 6 | 56 | 2 |
| Mexico | 6 | 248 | 6 |
| South Africa | 6 | 48 | 4 |
| Spain | 6 | 181 | 12 |
| China | 5 | 13 | 4 |
| Kenya | 5 | 43 | 5 |
| Peru | 5 | 9 | 4 |
| Thailand | 5 | 16 | 3 |

Table III: Number of Documents and Citations by Country

The bibliometric analysis revealed the most influential journals in the literature on agricultural value chains, sustainability, and topics related to this study, as summarized in Table IV. Identifying these key sources is crucial for two strategic reasons: first, it serves as an essential guide for locating the most relevant and impactful publications in the field, directing the search for a robust theoretical framework; second, it highlights the most suitable and promising outlets for future publications derived from this research, considering their thematic alignment and specialized audience. Journals such as World Development (notable for citations and link strength), Sustainability (leading in document volume), and Ecological Economics (consistent metrics) emerge as critical references for our case study on integrating blockchain into the coffee chain in São Paulo's countryside, also signaling potential channels for disseminating subsequent findings.

| Source | Number of Documents | Number of Citations | Total link strength |
|---|---|---|---|
| Sustainability (Switzerland) | 14 | 182 | 8 |
| World Development | 8 | 665 | 27 |
| Journal of Agribusiness in Developing and Emerging Economies | 8 | 85 | 7 |
| Journal of Cleaner Production | 7 | 265 | 4 |
| Ecological Economics | 6 | 331 | 14 |
| Journal of Rural Studies | 4 | 147 | 9 |
| Sustainable Development | 4 | 26 | 7 |
| Emerald Emerging Markets Case Studies | 4 | 6 | 0 |
| Food Policy | 3 | 33 | 0 |
| Enterprise Development and Microfinance | 3 | 23 | 0 |
| Frontiers in Sustainable Food Systems | 3 | 23 | 1 |
| International Food and Agribusiness Management Review | 3 | 48 | 3 |
| International Journal of Agricultural Sustainability | 3 | 47 | 4 |
| Journal of Development Studies | 3 | 44 | 10 |
| Review of International Political Economy | 3 | 133 | 16 |
| World Development Perspectives | 3 | 21 | 4 |
| Coffee Science | 3 | 3 | 2 |

Table IV: Sources distribution

## 4.2 Coffee Farm Case Study

The coffee farm studied is located in a privileged territory, at an altitude of 1200 meters. It covers a total of 125 hectares, 72 hectares dedicated to planting and 40% preserved, including more than 20 water springs. It is considered a historic property, which helps to add value to the coffee produced. Its owner is an agronomist and is at the forefront of adopting modern techniques to guarantee better quality and performance in coffee cultivation.

Throughout the subsequent subsections, we will delve into each phase of this coffee farm value chain based on the insights gathered from the interviews. We will systematically detail the processes, stakeholders, challenges, and opportunities identified at every stage—from cultivation and harvesting at the farm level through processing, distribution, and eventual market integration. This granular examination, grounded directly in the empirical data collected from key actors within the São Paulo coffee sector, will provide the foundational context necessary to later evaluate the specific integration points and potential impacts of blockchain technology across the chain.

### 4.2.1 Value chain modeling

To demonstrate the chain, a model was made using references from Bamber *et al.*, (2014) that present a chain design in 6 spheres: Input, Production, Processing, Negotiations, Roast Types and Marketing. A more recent model, which follows the same line of reasoning but with four levels, is that of Tan (2021). It presents the chain in four categories: production, primary and secondary processing and the market. We have chosen to also use four levels, but with different names for the categories: (1) Pre-planting, the preparatory stage for cultivation, (2) Cultivation, where the coffee tree is cared for and managed so that the fruit grows as expected, (3) Harvesting, where the fruit is removed from the trees and prepared for the following processes and (4) post-harvesting, where the processes are carried out to follow on to more specific processes and/or distribution for final marketing. All the stages of both models are included in the design of the chain at the farm studied. The actors have been grouped into business sectors. A sector can be represented by one or more companies that sell products or provide services. No names have been given so as not to provide any commercial bias.

Figure 5 visually shows the value chain in which this farm is inserted. The figure shows that most of the actors have a general influence on the entire ecosystem and on all stages of coffee cultivation. The actors considered to be sources of indirect services and basic resources are outside the internal chain, but still exert a direct influence. The following paragraphs are dedicated to explaining the 4 dimensions proposed in the figure, and then the main actors and resources used are listed and explained.

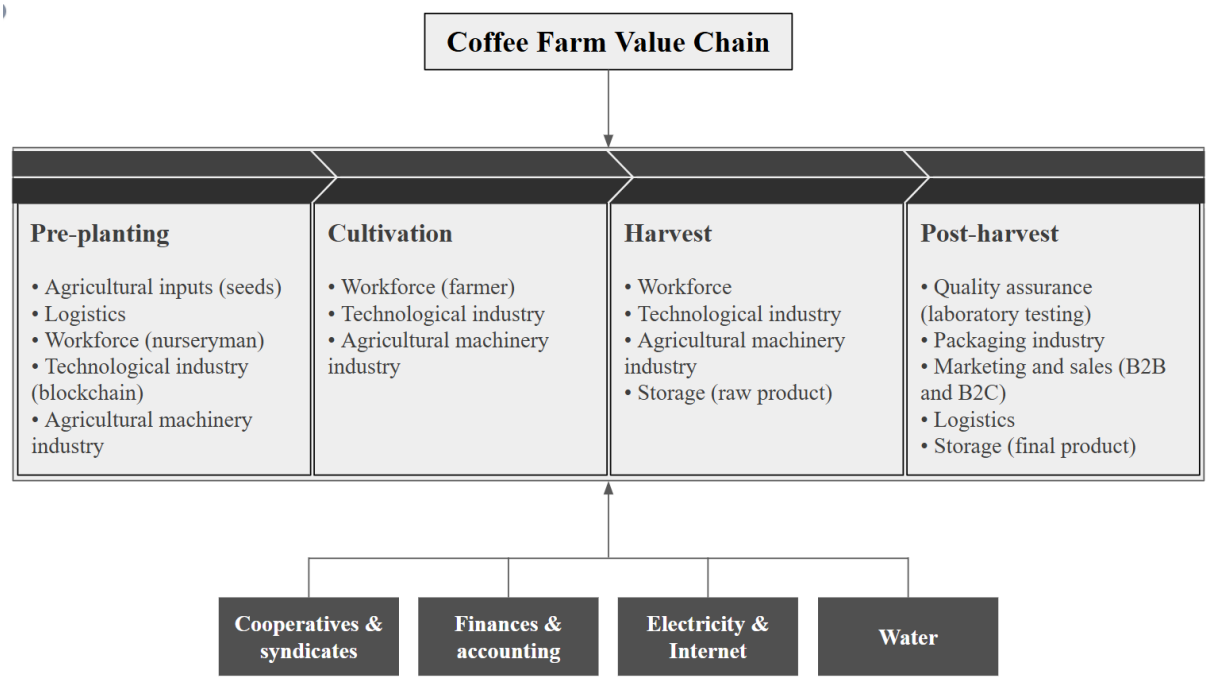


Figure 5: Value chain of a coffee farm in the interior of São Paulo.

#### 4.2.2 Pre-planting

Pre-harvest soil preparation is carried out, both manually and mechanically, pest and disease control, all equipment is checked and maintenance is carried out if necessary. Strategic planning in general, such as investment definitions and hiring, are also part of this first stage. With regard to the soil, the main products used for correction are lime and gypsum. Fertilization is also part of this stage, using organic materials (animal or vegetable), minerals and organomineral. In addition, it is also necessary to prepare the infrastructure to receive the employees and provide the necessary materials that will be used during the process, such as personal protective equipment (PPE). This is an extremely important stage, as all activities must be conducted carefully to avoid harming the soil, requiring specialized management.

#### 4.2.3 Cultivation

The cultivation stage begins with planting the seedlings and taking care that they germinate and flower. Planting is done in a georeferenced, mapped and mechanized area. The planting is done using specific spacing between seedlings, already thinking about the next activities that will be necessary. During the growing period, phytosanitary treatment is carried out to keep the plant healthy, as well as biological control of pests and diseases and nutrition. Generally, after 2.5 to 3.5 years, the harvesting stage can begin.

#### 4.2.4 Harvest

There are different ways to harvest coffee. It can be fully mechanized, with the hiring of a specialized service that uses machines to remove the fruit from the coffee plant, fully manual, where the employee removes the fruit with his own hands, or a mixed, semi-mechanized approach, where an employee uses suitable agricultural equipment such as stripping machines. Each approach has its advantages and disadvantages. The first increases the speed of harvesting, consequently shortens the plant's recovery period, leading to greater future productivity. It also reduces operating costs, where often the coffee itself is used as a form of payment.

On the other hand, the use of machines requires training, qualification and extreme care, since improper use represents damage to the soil and/or the plants. The use of machines also does not offer ways of harvesting based on selection, in which case the greatest benefit of manual use comes in, as it is possible to select the cherries that are already more ripe and suitable for harvesting, which represents greater quality and less impact on the plant. However, the disadvantage is the higher operating cost and naturally a lower yield.

A mitigating factor against manual harvesting is the lack of skilled labor; it is difficult to find people interested and qualified for the task. Finally, semi-mechanized harvesting is a mix of both. It offers higher throughput/efficiency, but has a greater impact on the plant and also requires skilled labor. The harvest period is part of the

farm's strategic planning; it usually starts in July and ends in September, but it can vary depending on the type of coffee and natural conditions.

#### 4.2.5 Post-harvest

After the coffee is harvested, the cherries are taken to begin processing: separation, washing, drying, processing and re-processing. Some cherries are pre-selected for the classification stage, carried out by professional classifiers, who determine the quality of the coffee according to parameters previously established by competent bodies. From there, multiple paths are possible, depending on the producer's strategy, which may be storage or manufacturing. In the first, the cherries are appropriately stored awaiting the best time for sale. In the second, the beans are processed to become powder or capsules. The farm sells its own coffee and also licenses the product to other brands. This is where intermediaries come in to sell the coffee and send it to suitable locations (retailers, local businesses or export). In quantitative terms, although industrial coffee generates more profitability, the main product sold is the processed beans.

#### 4.2.6 Actors, Tools and Machines

Tables V, VI, VII, VIII and IX demonstrate the role of each actor or activity/resource promoted by the actors and explain how it works, demonstrating how this adds value to the chain as a whole. Respectively, the tables refer to (1) basic, primary or indirect services, (2) general infrastructure, (3) technological services (such services promote the possibility of practicing precision agriculture), (4) agricultural machinery and (5) storage methods.

| **Category or Actor** | **Description** |
|---|---|
| Cooperatives | Acts as an intermediary between large agents, promotes events, provides consultancy and also sells some agricultural products |
| Syndicates | Offers several courses and training in addition to having partnerships with several actors in the chain. It is also an important institution that works on protectionist guarantees for workers |
| Finances & Accounting | Outsourced and specialized accounting office that manages all hiring and other tax issues for the farm |
| Agricultural inputs | Some inputs, such as seeds, are fundamental raw materials for coffee cultivation |
| Workforce | Nurseryman acquires the seeds and produces the coffee seedlings that will be planted |
| Logistics | Transportation of coffee to the appropriate agents, done by trucks |
| Packaging | Final husk of the product, which can take various forms, such as capsules or packages. It has integration with printing companies to customize the packaging. The capsules used by the farm are compostable and biodegradable |
| Marketing & Sales | Time of sale of coffee: studies are carried out to find the best time to sell, in line with market expectations, developing the best marketing strategies to reach the end consumer. Coffee has a biennial characteristic, if well stored, there are no losses, and therefore, the producer can deal with price variations and sell at the right time (high). There are different forms of negotiation, giving the producer flexibility. There are also different intermediaries, such as cooperatives and exporters, who facilitate the sales process. Coffee is sold in 3 forms: roasted beans, coffee powder and capsules. Technology also helps in this stage, with applications such as Olam Direct that connect actors and facilitate negotiations |

Table V: Description of activities carried out on the Farm provided by agents in the chain - basic, primary or indirect services

In this scenario, cooperatives function as vital intermediaries, expanding market access by connecting the farm with large buyers, facilitating event promotion, providing consultancy services, and marketing products, thereby enhancing market reach and knowledge transfer. Syndicates contribute substantially by upskilling the workforce through specialized courses and training programs, establishing strategic partnerships across the chain, and ensuring robust worker protection, resulting in a more qualified, stable, and secure labor force. Outsourced Finance & Accounting ensures strict tax compliance and operational efficiency in hiring and fiscal management, effectively mitigating legal and financial risks. The reliable procurement of essential Agricultural Inputs, particularly quality seeds, underpins the Nurseryman's production of robust coffee seedlings, securing successful crop establishment. Efficient Logistics, primarily via truck transportation, enables the physical movement of coffee to

processing or sales points. Finally, Packaging integrates with printing firms for customization and utilizes compostable, biodegradable capsules, adding tangible value to the final product and directly addressing contemporary consumer and environmental demands for sustainability.

Marketing & Sales emerges as a critical phase within this interconnected chain, characterized by sophisticated market timing and diverse negotiation strategies. Targeted market studies identify optimal sales windows, aligning with price forecasts to maximize financial returns – an advantage afforded by coffee's biennial nature and quality preservation under proper storage, enabling producers to strategically navigate price volatility. The process leverages flexibility through multiple negotiation channels and intermediaries (including cooperatives and exporters) to streamline transactions. Commercialization occurs in three primary value-added formats: roasted beans, ground coffee, and sustainable capsules. Digital platforms, notably Olam Direct, further enhance results by efficiently connecting actors and optimizing the sales process, strengthening the farm's capacity to develop consumer-centric strategies and adapt dynamically to evolving market requirements.

| **Category** | **Description** |
|---|---|
| Energy | Transmission of electrical energy for farms. Even though there are already solar projects, they do not supply 100% of demand, still requiring conventional means |
| Internet | Wired transmission provided by local companies that serve rural areas |
| Water | Fully managed by the farm itself, with artesian and semi-artesian wells and water mines |
| Cement patio | Physical structure for drying coffee |
| Suspended patio | Structure of fine mesh screen, shade-type, supported by smooth wire stretched over cement and wood pillars, and its main purpose is to dry the coffee slowly, without contact with the ground. Used in the production of specialty coffees |
| Laboratory | Location where coffee is classified to determine the characteristics of the bean |

Table VI: Description of activities carried out on the Farm provided by the chain actors - general infrastructure.

The farm's general infrastructure provides the foundational support necessary for consistent operations. Critical utilities include hybrid energy systems (solar supplemented by conventional sources), dedicated rural internet connectivity, and autonomous water management through artesian wells and water mines. Physical assets like cement patios enable efficient coffee drying, while specialized suspended patios facilitate premium specialty coffee production through controlled airflow and ground separation. An on-site laboratory further ensures quality control through rigorous bean classification. This integrated infrastructure establishes the baseline operational resilience and product differentiation capabilities of the value chain.

| **Technology** | **Description** |
|---|---|
| Global Positioning System - GPS | Allows for the precise identification of the geographic coordinates of each point in the agricultural area, which facilitates detailed mapping of the crop |
| Remote Sensing and Monitoring | Provides a detailed view of soil and plant conditions in real time. These devices collect nutritional information about the soil, humidity, temperature, pest and disease levels, and even crop growth. With the data obtained, it is possible to identify problems dynamically and quickly implement corrective measures, avoiding significant losses |
| Drones and UAVs | Used to perform aerial surveys of crops, capturing high-resolution images that, after being processed, generate detailed maps of the vegetation, which makes it possible to detect plant weaknesses in advance, such as water stress, nutritional deficiency, pest infestation, and others. They are also used to apply products autonomously, such as agrochemicals, foliar applications, adjuvants, fertilizers, and others |
| Geographic Information Systems (GIS) | Software that allows the analysis and interpretation of geospatial data collected by different technologies. They facilitate the integration of information and enable the creation of productivity maps, crop zoning and identification of patterns in a data set |

Table VII: Description of activities performed on the Farm provided by chain actors - technological services.

Complementing these physical assets, advanced technologies drive precision agriculture and data-driven optimization. GPS enables exact geolocation mapping of crops, while remote sensing systems deliver real-time analytics on soil nutrition, moisture, pests, and crop health for proactive interventions. Drones/UAVs perform dual roles: capturing high-resolution aerial imagery to detect plant stress and autonomously applying agrochemicals with targeted efficiency. These inputs are synthesized through Geographic Information Systems (GIS), which generate actionable intelligence such as productivity maps and crop zoning strategies. Together, these technologies transform field data into operational foresight, minimizing resource waste and maximizing yield quality.

| **Agricultural Machinery** | **Description** |
|---|---|
| Coffee Washer | Equipment used to wash coffee after harvesting |
| Coffee Dryer | Equipment used to finish drying coffee after the drying stage in the yards |
| Harvester | Equipment used to remove the coffee fruit from the coffee plant |
| Brushcutter | Equipment used to clean the land, a process where the weeds are removed and thrown under the coffee plant's skirt, serving as organic matter for fertilizer |
| Coffee Shaker | Equipment used to remove leaves, branches, sticks and stones |
| Processing Machine | Equipment used to remove the coffee husk. The residue generated by this machine, called coffee straw, is later used as fertilizer due to its nutrients. It can also be used as a substitute for wood in furnace fuel |
| General Equipment | Equipment used for general needs on the farm, such as tractors, trailers, road tractors and the like |

Table VIII: Description of activities carried out on the Farm provided by actors in the chain - agricultural machinery

The Table VIII summarizes key agricultural machinery used in the coffee production of this farm, as reported by chain actors. The equipment spans critical stages: harvesting (Harvester), post-harvest processing (Coffee Washer, Coffee Dryer), and waste valorization (Processing Machine converts husks into fertilizer/fuel). Notably, the Brusheutter integrates land cleaning with organic fertilization, while general machinery (e.g., tractors) supports logistical operations. This reflects operational efficiency coupled with circular resource use.

| **Storage** | **Description** |
|---|---|
| Silos | Fixed or mobile structures, usually made of metal, for storing coffee. It has an average operating cost and does not require a complex structure, representing a good cost-benefit option |
| Bins | Fixed structures for storing coffee, which can be made of masonry or metal. It is most commonly used in wood, since this material helps better in preserving the coffee. They are located on dry land, with plenty of exposure to the sun and far from the ground |
| General Warehouses | When there is no structure to accommodate silos or bins, it is possible to resort to companies specialized in coffee storage |

Table IX: Description of activities carried out on the Farm provided by chain actors - storage methods

Some of the main coffee storage solutions used are highlighted in the table above. Cost-effective metal Silos (fixed/mobile) offer balanced benefits, while wooden Bins—positioned on dry, elevated ground—optimize preservation. Specialized General Warehouses address infrastructure gaps. Together, these methods demonstrate adaptive strategies to safeguard quality under varying technical and economic constraints.

#### 4.2.7 Extra activities details

It is worth highlighting some more generic activities, which add value to the producer and the entire chain. One example is the use of regenerative agriculture. It is a process that aims to restore and revitalize plantations, ensuring that natural resources are preserved and respected. The goal is to preserve the soil, increase biodiversity and reduce environmental impact. These practices allow the land to recover while being cultivated, maintaining a sustainable cycle. The impacts are practically the reduction of agrochemical products, minimization of soil degradation and mitigation of climate effects. To achieve these goals, plant cover such as brachiaria is used. Waste such as coffee husks are also reused, creating Biochar. This product allows carbon to be stored in the soil, reducing greenhouse gas emissions. Other players in the chain, such as manufacturers of agricultural machinery, are also committed to

sustainable actions, such as the implementation of the PA-REDUX system, which aims to reduce carbon emissions, and also of machines that allow coffee pulping without the need for water. In addition to the sustainable aspects, the chain, especially at harvest time, manages to employ many people, being a source of income for many families. This fact is in line with data from the Federação das Indústrias do Estado de São Paulo (FIESP) (2024) portal, where approximately 585 thousand people were employed due to activities related to coffee.

#### 4.2.8 Challenges, issues and risks

Even with major investments in technology and practices to ensure coffee quality, the farm is not free from problems and challenges. The first of these is access to qualified labor. Currently, manual resources with the capacity and motivation to work on farms are becoming scarce. Another problem is logistics. Being in the interior of São Paulo has advantages for production, but post-harvest is hampered, requiring more resources to ensure the transportation of coffee and dealing with poor roads. Political issues are also a problem. In addition to there being no incentives, producers face high interest rates and lack of access to rural credit. Finally, we are talking about a farm that practices monoculture, dedicated to coffee. On the one hand, this is good in terms of resource allocation, but on the other, it is a great risk to depend on a single product, even if it offers stability and flexibility.

The market demands that farms be constantly updated, seeking ways to optimize production and improve margins, while maintaining sustainable prospects. One example is investing in a machine to use for harvesting. Even though it may be a high investment in the short term (approximately 1 million and 200 thousand), in the long term it is a lower cost, eliminating the need for outsourcing at the time of harvesting. Another future investment is the issue of automatic irrigation, integrated with intelligent systems, which has the function of optimizing processes and facilitating climate problems. Another factor is the continued investment in solar energy, promoting even greater sustainability, in addition to greater autonomy. There is also a shortage of intelligent services through applications that connect the entire chain and promote better communications and relevant information for decision-making. Above all, blockchain technology is very little known and consequently not used. Exporting is also something that has been little explored and has great potential for returns, especially when done directly, without specialized agents that add a layer of intermediation. This is attenuated when we look at the countries that consume the most coffee in the world, shown in Table 5. Brazil occupies only fourteenth position.

| Position | Country | Consumption (kg/inhabitant/year) |
|---|---|---|
| 1 | Finland | 12 |
| 2 | Norway | 9.9 |
| 3 | Iceland | 9 |
| 4 | Denmark | 8.7 |
| 5 | Netherlands | 8.4 |
| 6 | Sweden | 8.1 |
| 7 | Switzerland | 7.9 |
| 8 | Belgium | 6.8 |
| 9 | Luxembourg | 6.5 |
| 10 | Canada | 6.5 |

Table X: Countries with the highest coffee consumption (kg per inhabitant/year). Source: International Coffee Organization

Unlike some trends, the coffee trade has not taken off in e-commerce. The number of online sales represents only a little over 10% (Statista, 2024). This shows that there is still room for exploring different sales channels, especially in the digital environment. Although there are challenges, as with other food products, where sensory and olfactory characteristics are essential for consumer decision-making, there are spaces, especially for high-quality coffees, for sale in specific channels and in specific models, such as, for example, in the coffee club format, where in addition to the powder/capsule/roasted beans, the customer has other advantages.

These challenges and possible solutions are in line with what we have seen among the most frequently studied topics. The sustainable aspect is a priority, both practical and theoretical, and technologies such as blockchain and the Internet of Things also add value and tend to solve problems and/or remove obstacles. The need for human labor and how to capitalize on and provide good conditions, in addition to ensuring equal conditions for different sexes, are also similarities.

#### 4.2.9 Chain value similarities and differences

It is possible to compare coffee value chains in different countries and note similarities and good practices that can be inserted into the chain studied in Brazil. For example, in Colombia there is a strong focus on quality

and certifications, which produces smooth and balanced coffees that please consumers' palates. This is possible due to the country's geographical and climatic advantages, as well as investments in the sector (Samoggia and Fantini, 2023). Another country that also presents similarities in terms of the coffee value chain is Ethiopia, where there is a focus on sustainability, instigated by climate impacts, in addition to production based on small producers, which encourages aspects of chain integration (Minten *et al.*, 2019). In Indonesia, one challenge is to maintain equality in the supply chain, ensuring that all actors are rewarded accordingly and do not suffer from market-imposed dependencies. These challenges make government policies essential to ensure balance and social guarantees (Vicol *et al.*, 2018).

In terms of technology adoption, we have seen the potential that technology has to guarantee traceability and reliability in the chain. Although the initial costs may be high, in the long term the tendency is to generate cost reductions, while maintaining quality and continuous data that can be used to assist in decision-making. Not only in economic and strategic terms, technologies also help to improve sustainable practices. And perhaps one of the most important collaborations is in operational aspects, with regard to logistics, loss reduction and increased quality. All of these points add value to the chain (Hidalgo *et al.*, 2023).

#### 4.2.10 Content analysis

To empirically substantiate the coffee value chain dynamics under study, interview data underwent rigorous content analysis following Bardin's (Bardin, 2011) framework. This process yielded five core codes, synthesized in Table XI, which encapsulate critical operational and strategic dimensions articulated by stakeholders.

The analysis commenced with comprehensive familiarization and unitization of interview transcripts. Transcript segments expressing similar core ideas were clustered into broader conceptual categories (codes). Redundant codes were systematically eliminated to ensure conceptual distinctiveness. The resultant five codes reflect thematic saturation and recurrence across the dataset: (1) Production Practices captures adaptive on-farm management strategies in response to climatic variability and biological cycles, exemplified by nuanced irrigation protocols during drought and flowering phases; (2) Quality Control underscores mounting market-driven pressures for standardization and certification; (3) Traceability Requirements highlights demands for supply-chain transparency, with digital tools increasingly deployed for origin verification; (4) Blockchain Integration reveals tensions between technological potential and implementation barriers, where awareness exists but adoption remains nascent; (5) Process Optimization demonstrates efficiency gains from digitizing manual workflows, particularly in data synchronization.

| Code | Definition | Interview Excerpt |
|---|---|---|
| Production Practices | Descriptions of on-farm activities, techniques, and decision points throughout the cultivation cycle. | "During the dry season, we irrigate more, and during periods with more rain, we irrigate less. Nowadays, it has been proven that we need to continue irrigating, even when it rains. We have also come out of a period of stress during the dry season, where we cannot irrigate to stimulate flowering." |
| Quality Control | References to grading, sampling, and standards applied to ensure bean quality prior to processing. | "The future is certified coffees, there is no turning back. The market is increasingly demanding. Here we use applications and spreadsheets to ensure the traceability of coffee origins (G3 Platform)." |
| Traceability Requirements | Needs and expectations regarding the tracking of beans from farm to final consumer. | "Buyers increasingly ask for origin certificates and time-stamp logs of each shipment." |
| Blockchain Integration | Perceptions of benefits and challenges related to implementing blockchain for record-keeping. | "I know about blockchain technology and I receive some information and suggestions to use some applications... We use this concept manually, synchronizing year by year, trying to project the future." |
| Process Optimization | Suggestions and insights on streamlining workflows, reducing delays, or cutting costs. | "Digitization certainly helps a lot. We are in the transition phase, before everything was manual. Now, it is much easier to synchronize, search and compare information from all years. I already do this for soil analysis." |

Table XI: Main Codes, Definitions, and Interview Excerpts

To enhance methodological transparency, these five codes were derived through iterative floating readings and grouped according to their relevance for mapping the coffee farm's value chain processes and blockchain integration potential. Collectively, these codes demonstrate how environmental adaptation, market standards, technological innovation, and operational efficiency intersect to shape contemporary coffee production and distribution.

## 4.3 Secondary sources

Since there is a lack of academic literature on blockchain applications in Brazilian coffee value chains, this study also extensively analyzed non-academic sources to map current implementations. These sources—including industry reports, verified news platforms, and institutional documents—reveal concentrated efforts to integrate blockchain for traceability, sustainability, and financial innovation, though significant operational and structural challenges persist.

An analysis of reports from major Brazilian media outlets and specialized sources reveals that blockchain applications in the coffee sector began receiving significant public attention only recently. Most of the news coverage on this subject emerged from 2020 onwards—a period that notably coincides with the technological surge driven by the COVID-19 pandemic. This global crisis accelerated the adoption of digital innovations across various sectors, including agriculture and the broader agri-food industry, as stakeholders sought to enhance supply chain transparency, sustainability, and resilience. As highlighted by Hassoun (Hassoun *et al.*, 2023), the pandemic played a crucial role in prompting the adoption of emerging technologies—such as blockchain—to address challenges in food traceability, quality assurance, and consumer trust.

In 2019, Syngenta (Syngenta, 2023) declared itself the pioneer in Brazil in coffee traceability with blockchain technology, with the project being the result of a partnership between the Nucoffee platform and startup Arabyka. A year later, in 2020, CCCMG (CCCMG, 2023) reported that a Swiss company, Farmer Connect, had tracked more than 100,000 bags of coffee. According to the source, the aim was to use blockchain-based traceability to securely share this information with consumers and other parts of the coffee supply chain.

In addition, in 2021, a stablecoin called Coffee Coin was launched by a cooperative with more than 60 years of tradition in Brazil's coffee market, Minasul. According to Microsoft's news portal (Microsoft News Center Brasil, 2022), the management is supported by Dynamics, Microsoft's ERP. In a simplified explanation, the cooperative members' coffee is converted into a monetized standard that makes it possible to exchange stored coffee for various goods in Minasul's stores, and products of various values can be purchased, from a hat to a tractor.

One year later, in 2022, Brazilian coffee was exported to Japan with blockchain traceability for the first time, according to Forbes Brasil (Forbes Brasil, 2022). The startup Arabyka was responsible for implementing this technology in a batch of organic coffee from the Minamihara brand. This marked the first instance of Brazil exporting blockchain-traced coffee to that market, enabling detailed tracking of harvest timing, processing methods, exportation dates, and end-to-end chain-of-custody data.

An editorial published in 2023 on one of the websites of the Regional Cooperative of Coffee Growers in Guaxupé (Cooxupé) (Cooxupé, 2023) talks about how the use of technologies, such as blockchain, can help improve transparency and fairness in coffee production. According to the article, by attaching a digital record of a product's origin and journey to each shipment of coffee beans, blockchain can provide unprecedented levels of optimization, allowing stakeholders to identify problems, such as unethical labor practices or environmental damage, and resolve them quickly before they become bigger problems.

Despite growing attention in recent years, the frequency of news items between 2024 and 2025 has substantially declined, suggesting a slowdown in publicly visible blockchain initiatives within this sector. While early-phase innovations—ranging from Syngenta and Arabyka's traceability solutions to Farmer Connect's supply chain tracking—captured attention, coverage in recent years has shifted toward broader agricultural and fintech applications.

## 5 CONCLUSIONS AND DISCUSSIONS

This study presented a holistic and empirical view of the value chain of a coffee farm in the interior of São Paulo, highlighting the main actors and how the farm uses the resources from the chain to achieve good results. The description of the farm, located in Brazil, shows that the processes and methods used are in line with the literature studied on the coffee value chain, especially with regard to sustainable production. Mapping this chain can assist other studies that aim to understand the coffee market, regardless of geographic location, and also help in understanding how to add value in this market. The actors identified play a fundamental role in the balance of the chain, from the pre-harvest moment until the coffee reaches the final consumer, managing to attract different audiences. Even with large investments and resources, there are still challenges, such as qualified labor, logistics, access to credit, high interest rates and dependence on a single product (monoculture).

The results presented in terms of the bibliometric review show relevant information for the development of new research. This is possible through the identification of keywords that indicated some gaps, such as, for example, the lack of studies on blockchain, and technologies in general, in the Brazilian context. It also helped to identify the geographic context of the development of research on the topic and also provided an analysis of the main journals of research published on the topic.

Blockchain technology has proven to be useful for adding even more value to the chain, helping with aspects such as traceability and marketing targeting. In addition, it can integrate all actors in the chain, facilitating communication and assisting in data collection, which, when analyzed, provides information that can help in decision-making at different stages of planning. However, its implementation is not trivial, requiring skilled labor and initial investments, in addition to employee education about the technology. In the chain studied, there is a need for disruptive technologies and blockchain has the potential to meet the needs of actors.

For future research, we suggest implementing blockchain technology in the context of a coffee value chain and validating it with the chain's stakeholders, using a mixed qualitative and quantitative approach. Furthermore, a more in-depth comparison between chains could help identify different barriers and opportunities that may favor coffee production and that are difficult to observe when analyzing a single property. Another aspect that could be further explored is the inclusion of the global value chain theme following the logic of this work, where it would be possible to see the collaborations between countries, as well as which barriers still exist.

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