TRADE, DEVELOPMENT & THE ENVIRONMENT HUB

TRACEABILITY IN FOOD SUPPLY CHAINS

CURRENT LANDSCAPE, MECHANISMS FOR IMPLEMENTATION AND POTENTIAL SUCCESS FACTORS

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The UK Research and Innovation Global Challenges Research Fund (UKRI GCRF) Trade, Development and the Environment Hub is working with over 50 partner organisations from 15 different countries. The project aims to make sustainable trade a positive force in the world by focusing on the impact of the trade of specific goods and seeking solutions to these impacts.

This report sheds light on further understanding the concepts underlying traceability in supply chains. Based on a literature review and interviews with participants from different sectors, the aim is to explore aspects of traceability to identify potential success factors for effective traceability in agricultural supply chains and provide recommendations to enable greater uptake.

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APIs	Application programming interfaces
BSR	Business for Social Responsibility
CTEs	Critical Tracking Events
DLT	Distributed ledger technology
ESG	Environmental, Social, and Governance
EU	The European Union
FTS	food traceability system
GDPR	General Data Protection Regulation
GMA	Grocery Manufacturers Association
GS1	Global Standards 1
ISEAL	International Social and Environmental Accreditation and Labeling
ISO	International Organization for Standardization
IT	Information technology
ITC	International Trade Centre
KDEs	Key Data Elements
NGO	Non-governmental organization
QR	Quick response (codes)
R&D	Research and development
RFID	Radio-frequency identification
RSPO	The Roundtable on Sustainable Palm Oil
RTRS	Round Table on Responsible Soy Association
SME	Small and medium-sized enterprises
UNGC	United Nations Global Compact
US	The United States
WEF	World Economic Forum

1. SUMMARY: KEY FINDINGS TO IMPROVE TRACEABILITY

Enforcement: There is a need for more concrete and strict enforcement from both markets and governments, making noticeably clear what specific metrics and indicators must be measured and reported as well as the required level of assurance. Financial institutions have a role to play too by requiring their clients to meet specific traceability requirements. All three actors should also invest resources in mechanisms that guarantee effective verification and the establishment of corrective actions where necessary.

Clear measurement of benefits: The literature review and some of the interviewees mentioned that strategic traceability data can grant companies a competitive advantage (by opening new and greater markets) and enable resource optimisation (which results in economic savings). Providing more examples with quantitative evidence of the potential benefits that companies can attain from traceability data would encourage further investment.

Collaboration, harmonisation and incentivisation: The literature review suggested an independent body would play a key role in convening different stakeholders for the development of harmonized standards for traceability data collection, storage and sharing. Several interviewees suggested that such a role could be adopted by governmental agencies. This independent body should also take care of managing any unintended consequences of regulatory and market policies to make sure vulnerable farmers are supported and rewarded.

Multidisciplinary leadership at the corporate level: While the leading team for traceability implementation most often mentioned was the sourcing department, the involvement of many other departments was considered key (e.g., business development and marketing, IT, sustainability, finance, legal, public affairs, operations, strategy, food safety, research and development, monitoring and evaluation) ideally with the support and leadership of top management. Creating an internal working group that involves relevant stakeholders from these departments can be a key enabler for traceability implementation.

2. INTRODUCTION AND METHODOLOGY

Supply chain traceability is widely recognised as a key enabler for sustainable trade of agricultural commodities. However, there are a range of concepts, definitions, tools and experiences around implementation that are not fully understood. This research study therefore aims to explore these aspects of traceability to understand potential success factors for effective traceability in agricultural supply chains and provide recommendations to enable greater uptake. Additionally, it aims to identify potential research gaps that could be addressed through specific research questions. This study is based on a literature review and expert interviews as follows:

First, a short literature review (Section 3) was undertaken to understand concepts related to traceability in supply chains. This included the main drivers, barriers, and potential benefits associated with adopting traceability. Additionally, the review outlined recommended implementation processes, identified key success factors, best practices, and discussed available tools and solutions for traceability.

Second, several traceability experts working in companies involved in agricultural supply chains were engaged to discuss aspects around drivers for implementation, governance, stakeholder engagement, collaboration, benefits, and best practice recommendations (Section 4). Expert consultations provided additional context from a practitioner's perspective, allowing us to contrast and complement the insights from the initial literature review. A qualitative and exploratory semi-structured interview technique was chosen as the method of data collection, with the interview audience selected through non-random, purposive sampling. This sampling method consists of selecting individuals who are particularly knowledgeable about the subject matter and able to communicate their experiences and opinions in a reflective manner. Key insights and quotes illustrating the interviewees' opinions were selected to help fulfill the objectives of this study.

Finally, Section 5 includes observations on potential limitations of this study, and proposed topics for future research.

Additionally, Annex A contains the questions used in the interview questionnaire; Annex B lists the best practices for implementing traceability, as mentioned by the interviewees; Annex C outlines the benefits of traceability adoption identified by the interviewees; and Annex D provides an aggregation of additional statements from interviewees on topics such as implementation, governance, approach, gaps, weaknesses, barriers, and others.

3. AN OVERVIEW OF TRACEABILITY

The literature was reviewed and consolidated along the key themes of 1) definition and key concepts, 2) success factors in implementation, 3) drivers and barriers, 4) traceability tools and services.

3.1. Traceability: definition and key concepts

Multiple definitions of traceability were found in different academic papers, reports, standards and regulations. Particularly relevant to the context of this study, is the one suggested by the United Nations Global Compact (UNGC) and the Business for Social Responsibility (BSR), a hybrid definition of the widely accepted definition from the International Organization for Standardization (ISO), with the added key component of a sustainability focus. They defined **traceability** as "the ability to identify and trace the history, distribution, location and application of products, parts and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labour, the environment and anti-corruption" [1].

The literature differentiates among diverse kinds of traceability:

- **Client traceability**, also known as **tracking** (forward), is the ability to follow the downstream path of a particular trade unit in the supply chain. Is a top-down approach [2].
- **Supplier traceability**, also known as **tracing** (backward), is the ability to identify the origin of the products used in a particular trade unit. Is a bottom-up approach [2].
- **Chain traceability** refers to the capability of tracing over the whole supply chain between all supply chain actors [3].
- **Internal traceability** refers to the traceability of the internal processes of a specific supply chain participant. Processed, reconfigured, or repacked products must have their own Unique Product Identifier and processes must link the identifiers of raw materials to those of finished goods [4].
- **External traceability** refers to the traceability between two participants in the supply chain. This requires products to be uniquely identified, and information to be shared between participants [4].

While traceability is the main concept of this study, the principal objects of exploration are the traceability systems that should be deployed both individually at the corporate level and collectively at the food industry level. Traceability systems are record-keeping systems that trace the path of a particular product from suppliers through intermediate steps to consumers. The basic characteristics of traceability systems, irrespective of the process or product involved, include the following points [4] [5]:

- Identification of units or batches of all ingredients and products.
- Registration of information, including Key Data Elements (KDEs) which record the who, what, where, and when at each step of the chain, and Critical Tracking Events (CTEs) that record the completion of a step in the supply chain.
- A system that links these data and transfers all relevant traceability information with the product to the next stage or processing step.

A traceability system is characterized by three main parameters:

- Its breadth, which refers to the amount of information collected and recorded.
- Its depth, which denotes how far relevant information can be tracked forward and backward.

Its precision, defined as the degree of assurance to pinpoint a particular food product and its movement. Precision is influenced by granularity, which involves the size and number of units identified, as noted in [6]."

3.2. Success factors for effective traceability in food supply chains

3.2.1. Enabling factors for effective end-to-end traceability

Effective end-to-end traceability requires all participants in the supply chain to be capable of performing both tracking and tracing functions by implementing internal and chain traceability [7][4]. To facilitate an enabling context, there is a need for an implementation framework that establishes systematic guidelines based on aligned standards and best practices, while also considering the particular needs of small and medium-sized enterprises (SMEs) and smallholders [7]. Additionally, alignment around tools would help reduce implementation and maintenance costs of individual supply chain participants [1].

The enablers required to facilitate traceability can be grouped in four main dimensions [5]:

- **Incentives** (e.g., market access, premium pricing, or preferential financing conditional upon demonstrating compliance with mandatory regulations or adherence to voluntary standards).
- **Capacity** (e.g., financial resources, knowledge, and skills).
- **Access to technology** (e.g., local availability of infrastructure that provides the required connectivity, reliability, and speed levels).

- **Coordination** (e.g., willingness and ability of suppliers and buyers along the chain to implement traceability, adopt common standards and share information).

Beyond the food supply chain, the support of stakeholders such as governments, civil society, technology firms, and financial institutions is essential. According to a comprehensive report by the World Economic Forum (WEF), a series of support mechanisms from stakeholders not directly engaged in food supply chains is necessary [8]:

- **Governments** could incentivize and support the adoption of traceability systems.
- **Civil society and system leaders** could ensure all stakeholders have the opportunity to provide input when creating standards and requirements.
- **Technology companies** could further develop transformative traceability technologies that bridge infrastructure gaps, reduce costs, improve delivery, and maximize efficacy. Specific technological considerations that would support a more efficient adoption of traceability solutions include:
    - Enhanced digital identifiers that eliminate the need to relabel products.
    - Low-cost, robust food-sensing technologies accessible to consumers as well as to supply chain participants.
    - Low-cost advanced sensors, including satellite or drone technologies, that automate information capture with limited work required from producers.
    - Technological infrastructure based on open-source software standards that facilitate access to electricity, the internet, cloud computing, and satellite data.

Additionally, it is argued that **banks, particularly trade finance**, can play a central role in [9]:

- Supporting traceability efforts, in partnership with data providers.
- Raising sustainability standards and requiring traceability and transparency as conditions for accessing finance.
- Mobilising funds that channel finance and incentives toward sustainable practices in agricultural supply chains.

At the collaborative level, several sources suggest that a well-governed, independent body focused on one or related commodities would play a key role in convening different stakeholders to **develop harmonized standards for data collection, governance and sharing** [1][8]. Priority areas for alignment include:

- **Data-collection requirements.** Global players should align on the data that needs to be collected, the platforms used, the types of technology required to store the data, and the methods of data collection.
- **Data-governance and ownership standards**. As participants might have concerns about data ownership, access and usage, it is crucial to develop standards that regulate these aspects.
- **Data sharing.** It is also important to consider strategies for "packaging" a large volume of new data to inform decisions across the system, such as how information is communicated to governments as opposed to consumers or producers).

A trusted independent body should be responsible for providing guidance, storing relevant data, facilitating data sharing, managing labeling requirements and sustainability claims, as well as verifying and auditing data linked to claims at every step in the supply chain. An example is the Better Cotton Initiative, which aims to adopt such responsibilities in the cotton industry [10].

3.2.2. Step-by-step process for effective implementation

To develop **internal traceability**, each supply chain participant should have an internal record-keeping system that enables them to trace back their ingredients and track forward their products (at least based on a one-up and one-down basis). Steps for implementation include:

- **Identify key commodities, supply chains, and/or target markets** to be traced [1][5].
- **Determine a traceability plan** in the form of a traceability manual that includes what data needs to be recorded and shared with other participants, what precision is required, and how success will be measured. The plan should be defined according to the specific aspects the traceability system aims to inform (e.g., compliance with specific regulations, standards, sustainability certifications or consumer claims) [5][2]. Processes and methods should be clearly defined, repeated over time in a stable manner, and documented [4]. Resources required to fulfill this step include:
    - **A multidisciplinary team comprising individuals from different backgrounds and departments** within the company, such as purchasing, distribution, logistics, and food safety and quality teams, to drive the implementation of traceability [11]. The traceability team should have its own administrator, working methodology, schedule, budget and reporting responsibilities [2].
    - **Deep knowledge and understanding of the supply chain**, its strategy and processes [12].
- **Implement the traceability plan** through the specific actions defined in the traceability manual, which should include actions such as 1) setting up a relational database management system; 2) recording data on incoming material lots, internal lot activities (material movements within the elevator and blending for customer shipments), quality, and outgoing material lots; and 3) generating a traceability report with a detailed description of the database system and its use [2]. The implementation plan should be tested on a "pilot" basis to improve/adjust it as necessary [4].
- **Train internal (employees) and external (suppliers) stakeholders** on the new traceability requirements and associated task obligations [4][13].
- **Evaluate the system's performance** (e.g., whether it reacts rapidly in a food safety crisis, whether it is effective in informing real-time decision-making processes, or whether it provides the required information to validate a participant's compliance with specific requirements) by generating performance and audit reports [2]. It is also necessary to periodically review the system with changes in context, clientele, suppliers, processes, products, and/or regulations [4].
- **Validate the traceability system** by employing the performance and audit reports to check the achievement of the traceability objectives. This process should result in periodical validation reports, enhanced production practices and validation certificates, among other documents [2].
- **Maintain the traceability system** according to new requirements or best practices identified [2].
- **Measure and incentivise internal stakeholders' progress** on implementing traceability.

To develop **chain traceability**, apart from the information mentioned as part of the internal traceability (which should be recorded by all individual supply chain participants, whether in their own database or in a joint platform) it is necessary to capture details on activities such as movement (from one participant to another), aggregation (a grain lot coming from different storage bins), segregation (a lot divided into different lots), storage, transformation, and destruction [2]. The main mechanisms all supply chain participants should adopt for effective chain traceability include:

- **Close collaboration** with all supply chain participants [12].
- **Aligning commercial terms and buying practices with the traceability objectives** by including traceability requirements into supplier codes of conduct. For example, mandating suppliers and distributors to employ specific standards to identify products and their physical locations, and setting deadlines for compliance) [4] [11] [12].

- **Guiding new suppliers on how to implement traceability standards**, engaging their technical teams, labeling staff, and other relevant teams [11][12].
- **Measuring suppliers' progress, for instance, by** publishing a scorecard that represents supplier's traceability progress in terms of data completeness and accuracy [11].

3.2.3. Best practices for effective traceability

The literature review revealed a comprehensive list of best practice recommendations for supply chain actors. These practices encompass industry alignment, technological advancements, effective communication and mechanisms, and collaborative efforts among supply chain participants. This section provides an overview of the best practices at both the food industry level and the individual supply chain participant level.

At the food industry level:

CATEGORY	BEST PRACTICE	SOURCE
INDUSTRY ALIGNMENT	Address traceability through a sector-encompassing systems approach.	[13][14]
	Establish a trusted independent body that brings stakeholders together to align on clear, consistent and harmonized standards, provide guidance, record and share traceability data, and verify and audit traceability processes.	[1][8]
	Devote time, effort and resources to industry collaboration to establish joint traceability standards and best practices, communicated through a common and agreed-upon language.	[1][11] [12][13] [14]
	Define and adopt clear, consistent and globally harmonized standards for traceability processes, interfaces, tools, data collection, data governance, data ownership and data sharing.	[1][11] [8][3]
COMMUNICATION	Communicate effectively the agreed-upon aligned standards are their implementation methods.	[8]
TECHNOLOGY	Identify cost-effective traceability techniques that are easily applicable to the target supply chain.	[13]
	Collaborate with technology providers, users, government and civil society to bridge infrastructure gaps and develop more robust and lower-cost technology solutions.	[8]
COLLABORATION	Engage in supply chain collaborative solutions to scale viable traceability options with catalytic financing and policy incentives that support small-scale producers in complying with traceability requirements and accessing advisory services.	[8]
	Develop a joint end-to-end supply chain traceability platform.	[13][3]

Table 1- Best practices for traceability implementation at the food industry level.

At the individual supply chain participant level:

CATEGORY	BEST PRACTICES	SOURCE
BUSINESS BUY IN AND GOVERNANCE	Develop a business case for traceability adoption with a long-term vision.	[1]
	Ensure top management support to make traceability implementation a top priority	[11]
	Create an internal multidisciplinary team comprising individuals from diverse backgrounds and departments to develop robust practices and processes.	[1][11]
	Implement mechanisms for effective traceability governance and management by following the methodology outlined in Section 1.1.	[12]
	Set internal traceability progress goals, and measure and monitor internal traceability progress indicators	[11]
CREATE EXPERTISE	Develop internal expertise or contract external expertise	[13]
	Train front-line workers and administrative staff	[4][13][8]
APPLY SUITABLE MECHANISMS AND DATA	Build a corporate culture that emphasizes data management and quality	[11]
	Implement both tracking and tracing through internal and external traceability mechanisms.	[7][4]
	Guarantee access to traceability data at any moment	[13]
REPORTING AND PROGRESS	Periodically generate reports on traceability progress and effectiveness	[12][13]
	Regularly review and improve traceability processes	[4][2] [13]
	Set external traceability progress goals, and measure and monitor external traceability progress indicators	[11]
	Measure suppliers' progress (e.g., in data completeness and accuracy)	[11]
	Conduct physical audits of product data for validation purposes	[11]
	Celebrate progress and small wins to maintain momentum	[11]
COMMUNICATION	Engage and guide suppliers through strong relationships and effective communication.	[1][11] [12]
	Define effective strategies to communicate traceability progress and outcomes to buyers and consumers	[8]

Table 2- - Best practices for traceability implementation at the individual supply chain participant level

3.3. Drivers, benefits and barriers

As traceability systems have emerged as indispensable tools, they offer a varied range of benefits, including efficiency improvements, better decision-making, and long-term profitability. This section summarizes the drivers and benefits of implementing traceability within the private sector, as well as the barriers identified in the literature.

3.3.1. Drivers for traceability implementation

A number of drivers that create the incentives for companies to implement traceability were identified. These can be clustered into four categories: transparency, compliance, accountability and reputation; efficiency, better decision-making and license to operate.

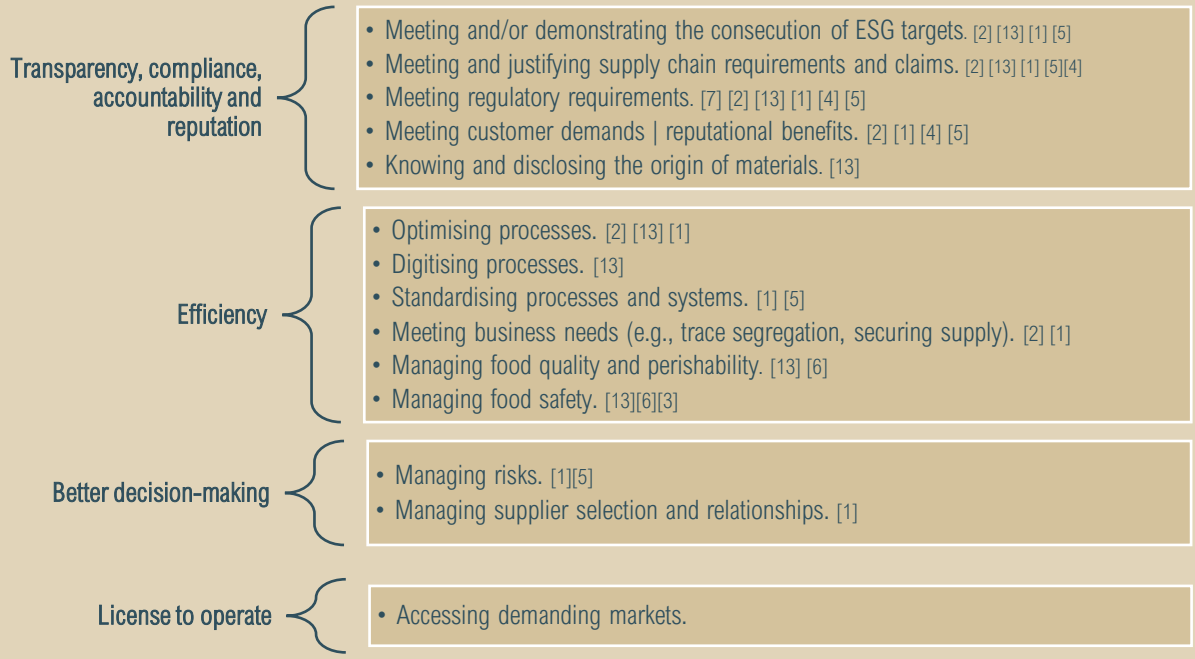

Diagram 1-Drivers for traceability implementation

3.3.2. Potential benefits from traceability

The World Economic Forum (WEF) and the International Trade Centre (ITC) support the notion that traceability data enable businesses to **enhance their long-term profitability** by:

- Employing resources and processes **more efficiently**, which results in:
  - Increased supply chain automation and hours saved in processing [8].
  - Faster **real-time** information collection, enabling rapid and informed decisions [8].
  - Improved product scanning, resulting in quicker ordering [8].
  - Reduced losses from outdated products [4].
  - Lower inventory levels [4].
  - Quicker identification of process and supplier difficulties [4].
  - Greater effectiveness of logistics and distribution operations [4]
- Enhancing customer confidence and, consequently, improving brand equity and reputation [4].

Additionally, expanding market access [5] [4] [12], reducing distribution costs, decreasing recall expenses, and minimizing food contribute to maximizing economic gains [7] [2] [5] [8] [4].

In terms of efficiency and cost savings, Sparling and Sterling confirmed in 2004 that traceability could reduce the scope of recalls by between 50% and 95%, thereby reducing the amount of **product wasted** [15]. In 2014 interviews-based study by BSR highlighted that the long-term perspective from those involved in traceability is that it ultimately pays off. More recently, in 2021, a case study quantified Subway's annual **cost avoidance** due to their traceability system at approximately US $1.3 million (€1.064 million) [11], confirming that standardised product data drove operational efficiencies, **reduced supply chain costs, and saved time and labour costs** [11].

Traceability technologies that **enable automated data collection significantly** reduce the time and expense required for data processing and maintenance. Manually gathering information is not only time-consuming but also prone to recording errors, inventory inaccuracies, and stock shortages. According to the Grocery Manufacturers Association (GMA) in the United States, errors occur in 36% of packaged goods orders [4]. The use of technology for product identification, information capture, analysis, storage and transmission of

data markedly decreases these risks and allows for data capture at minimal operational cost. For example, barcodes and RFID systems, which are exceptionally accurate (>99%), contribute to better information management and improved inventory management [10] [6] [14], enhancing precision and thereby the decision-making process [7] [4] [12].

Traceability also serves as a critical **risk-management tool** for food business operators and governments [4]. For instance, effective traceability could have mitigated incidents like the 2008 Melamine-contaminated infant milk powder scandal in China, which resulted in tragic fatalities, the incarceration of business managers, and the subsequent market collapse and bankruptcy of the milk powder supplier, by reinforcing preventative measures and enabling businesses to monitor and defend against risks in real-time.

Furthermore, traceability can generate **new revenue streams from increased sales and/or premium pricing**. Traceability holds value for consumers when associated with origin, quality or sustainability-related labeling or certification. An EU survey indicated that most consumers are willing to pay more for higher-quality food products and would trust them more if there is a guarantee of origin and production practices [4]. This consumer trust and satisfaction can enhance transparency [7] [10] [6] [4] [12], potentially leading to revenue growth of over 3% [16].

The integration of traceability systems across various points in the supply chain yields multifaceted benefits. From input providers and producers to trading entities, brands, retailers, and ultimately consumers, the adoption of traceability measures enhances operational efficiency, profitability, market access and consumer confidence. This paradigm shift towards traceability not only validates the legitimacy and quality of products but also fosters a more transparent value chain. The potential benefits for each supply chain participant are detailed below[8] [11]:

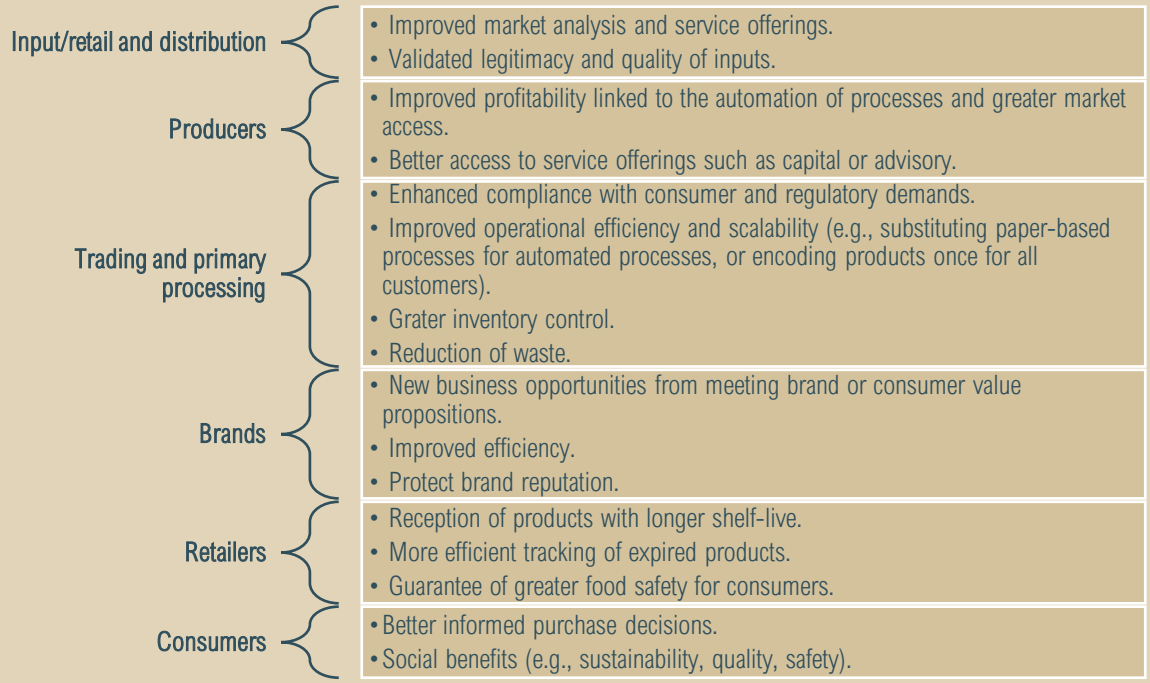

Diagram 2-Potential benefits from traceability implementation

3.3.3. Barriers and challenges for traceability implementation

Although achieving traceability in supply chain has been highlighted as crucial, the journey towards comprehensive traceability faces numerous challenges. This overview explores the main challenges and barriers to the implementation of traceability systems.

CATEGORY	MENTIONED BARRIER OR CHALLENGE	SOURCE
BUSINESS BUY IN AND GOVERNANCE	Food safety and animal welfare are often prioritized over traceability	[4]
	Inconclusive business case	[7] [8]
	Associated bureaucracy	[7] [8]
	Participants' reluctancy to share information	[7][3] [8]
	Perceived loss of autonomy	[7]
REQUIRED RESOURCES	Implementation costs (especially for SMEs and farmers)	[7][1] [4][8]
	Lack of expert technicians in companies	[7]
	Language, skills and access barriers for smallholders	[1][8]
	Not all support associations have the capacity to train smallholders on traceability processes, systems and documentation	[4]
LACK OF INDUSTRY ALIGNMENT	Multiple traceability terminologies, numbering systems and data formatting	[13] [4]
	Multiple requirements from different buyers (resulting in duplicated efforts for suppliers).	[4]
	Participants having different interests	[3]
	Potential technical incompatibilities	[7]
COMPLEXITY	Difficulties to meet the required granularity | The mixing of products	[7] [4]

Table 3-Barriers and challenges for traceability implementation

In addition to the barriers highlighted above, costs also pose a significant great challenge. The costs associated with traceability depend on various factors, including the regulatory environment, firm size, firm strategy and culture, technology adopted, characteristics of products and production processes, structure and complexity of the supply chain, and the volume of information to be stored [6].

A report by the WEF [8] specified which barriers are particularly relevant for each participant in food supply chains:

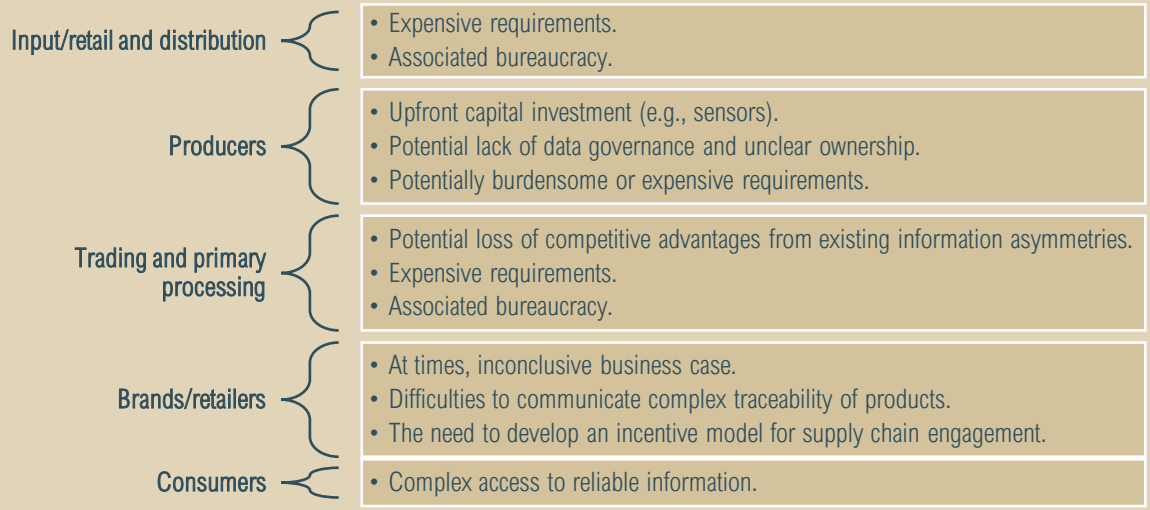

Diagram 3-Barriers particularly relevant for each participant in food supply chains

3.4. Traceability tools and services

Multiple options exist for selecting technologies and services for traceability implementation. This section introduces the components of a traceability system, the different levels of complexity a traceability system can adopt, and the types of commercial offerings available in the market.

3.4.1. Components of a traceability system

A traceability system typically includes the following components:

- **Data elements:** specific data to be captured (e.g., farm location, product volumes and product origin) in a designated format.
- **Unique identifiers:** unique identifiers that are assigned to units or batches of food products (e.g., RFID tags, QRs codes or barcodes).
- **Sensor technology:** devices that read the unique identifiers and associated data.
- **Relational databases:** ledgers to store and link traceability-related data.
- **Software:** Software that facilitates the capture, aggregation, integration, analysis and sharing of data.
- **User interface:** interfaces for displaying and capturing data, which can be a computer, mobile or tablet app, or any other application developed for devices with a display or screen.
- **Sharing interfaces:** Interfaces that facilitate data exchange between databases or software applications, both internally and externally. These are also known as application programming interfaces (APIs), which are software intermediaries that allow two applications to communicate.

3.4.2. Complexity levels of a traceability system

Traceability systems can be very complex. The process can begin with the manual entry of traceability data into an Excel file, which is then shared by email for manual reading and analysis, or data storage can be automated. Automated data capture can be done by using sensors, storing data in a distributed ledger, encrypting, validating, verifying, analysing using tailored software and sharing data with predefined stakeholders in real-time.

The following figures illustrate the different levels of complexity a food traceability system (FTS) could adopt:

Figure 1 represents the four dimensions that determine the level of complexity of an FTS:

1. **Data granularity:** depending on whether the identification is made per unit or per lot.
2. **Data entry method:** depending on whether the data input is manual or automatic.
3. **Data storage:** depending on whether traceability data is recorded on paper, in a centralised database, or in one based on distributed ledger technology (DLT).
4. **Distance data travels:** depending on the number of steps back and forward the traceability data is transferred between supply chain actors.

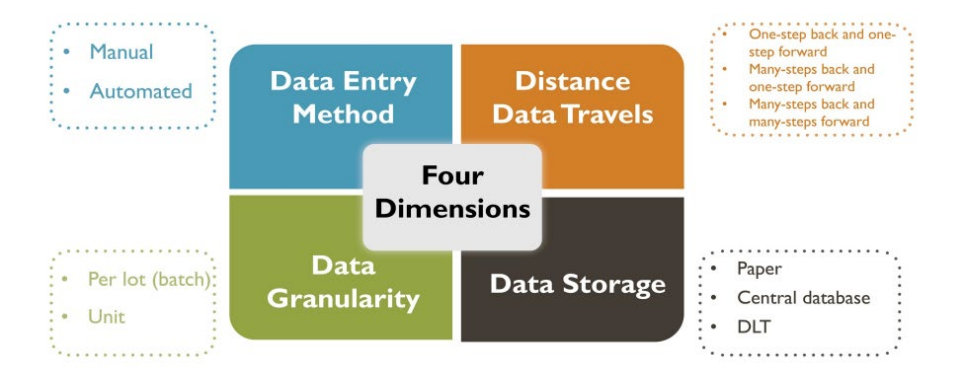

Figure 1- Four main dimensions that can determine the complexity of a food traceability system[5].

Figure 2 represents three potential levels of complexity an FTS could adopt, depending on the options chosen for each of the dimensions introduced in Figure 1.

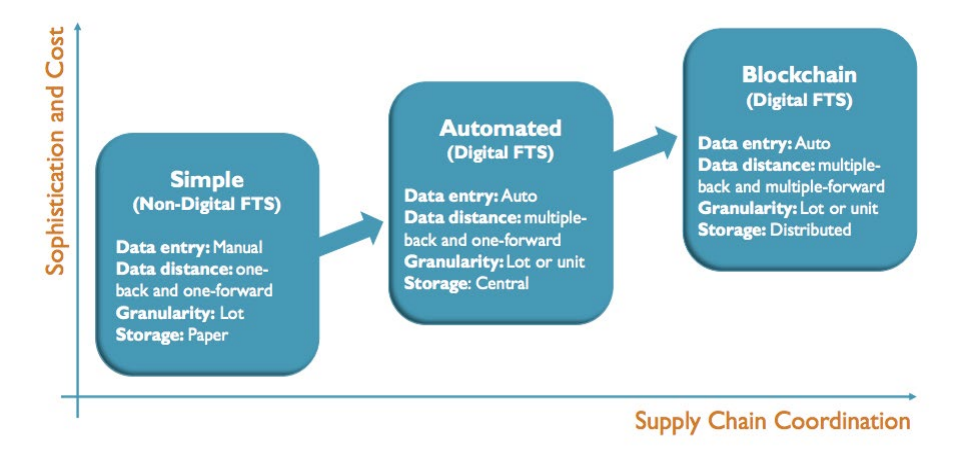

Figure 2- Examples of potential levels of complexity of a food traceability system [5]

3.4.3. Types of traceability tools and services

This section explores various approaches to traceability data storage and management. When deciding on the type of traceability system to adopt, it is crucial to consider several aspects including technology, components and maintenance:

Internally deployed traceability system

Internal systems involve setting up a database, associated software and interfaces within the company's data warehouses and devices. Maintenance is typically handled by the company's IT department or by a contracted service provider. This approach requires a significant initial investment and a certain level of internal expertise at both the maintenance and user levels. The company owns the data. Design and deployment can range from months to years, depending on the company size and the scope of the traceability strategy.

An example of commercially available software for traceability purposes is FoodLogiQ [17], a GS1-based solution that facilitates the creation of tailored dashboards and reports to monitor how many of the company's suppliers and distributors are scanning deliveries, the percentage of products being scanned and more. These dashboards enhance transparency and help identify gaps across the entire supply chain.

Externally contracted traceability system

Some providers offer traceability as a service by hosting and maintaining the platform externally. The supply chain participant connects to a third-party traceability platform (either through a secure internet browser or a dedicated software on the company's devices) to upload and access traceability data.

This model involves a low or no upfront investment and requires minimal internal expertise (some at the user level but none at the maintenance level). Supply chain participants can begin using the traceability platform immediately with minimal process adaptation and capacity building at the user level. Data ownership and access terms can vary by tool but are generally defined by the service provider.

Examples of tools offering traceability as a service include:

- HARA: a blockchain-based ecosystem that allows Indonesian farmers to enter data related to their farming production via mobile phones. Participants, including farmers and others (e.g., cooperatives, NGOs), earn HARA loyalty points for their contributions, which can be redeemed for services and products like phone credits and discounts on agricultural and educational supplies.

The system also involves the participation of data qualifiers, who help validate the quality of data in exchange for loyalty points.

- **IBM Food Trust**: a blockchain distributed ledger that enables secure management and access to transactional data for all supply chain participants. It allows upstream and downstream tracing of food products, sharing of inspections, quality certifications, and registrations. It uses permissioned networks and smart contracts to ensure data privacy and automate contract execution. IBM developed an online tool to estimate the potential financial benefits from adopting of Food Trust (recalls, spoilage and certificates).
- **Koltiva** implements traceability through an integrated technology platform comprising web, mobile, GIS, and IoT solutions, enhancing supply chain visibility from producers to consumers. The platform uses real-time data to monitor and manage supply chain activities and incentivizes stakeholder participation by offering field support, increasing productivity, and facilitating carbon monitoring. Additionally, it provides improved market access, financial incentives, and it tracks environmental and social impacts, ensuring compliance with sustainability standards.
- **SafeTrace** offers the miniDART®, an on-product traceability and authentication tool that uses unique, edible DNA-based tags. These flavorless tags are applied directly to products to enhance transparency and reduce risks associated to product fraud and adulteration, supporting downstream partners in verifying product authenticity and quality.

3.4.4. Blockchain

Blockchain [18] is a database shared and synchronized across multiple parties on a distributed ledger (DL) network, where data is encrypted, and blocks of information cannot be altered once created. In a blockchain, multiple participants co-agree and co-process the appending of new transactions, thus democratizing governance and data ownership. Most traceability-as-a-service tools are consortium blockchains, where participants are assigned different levels of permissions based on their roles [19], requiring effective governance and coordination. Blockchain can complement conventional databases, recording only data needing higher trust and safety, like that used in blockchain-enabled smart contracts. However, as blockchain records are immutable, personal details should not be recorded to comply with GDPR legislation, which requires the possibility of rectification and deletion.

4. PERCEPTIONS OF SUPPLY CHAIN ACTORS ON TRACEABILITY

Interviews were conducted with supply chain actors to acquire a nuanced understanding of the implementation, impact, and potential barriers to effective traceability measures (see Annex A for further details on the questions included in the interview questionnaire). These interviews were vital for gathering firsthand perspectives, uncovering hidden nuances, and identifying practical strategies for enhancing traceability practices. This section highlights the key findings from these interviews. Annex D provides a more detailed record of the statements made by the interviewees.

4.1. Overview of supply chain actors interviewed and general observations

Eleven traceability experts working in agricultural supply chains were consulted:

- **Retail industry:** 2 experts
- **Manufacturing industry:** 3 experts
- **Brand company:** 1 expert
- **Major trading companies:** 3 experts

- **Sectorial multistakeholder initiatives:** 2 experts

Most food supply chain actors were attempting some degree of traceability. Examples of different traceability scopes developed by the organisations interviewed include:

- **Chain of restaurants:** they traced their main supply chains using various technologies and, in some cases, had traceability data at the chain of custody level, mainly for food safety, reputation and efficiency purposes.
- **Supermarket:** primarily recipients of traceability data from suppliers, they gathered this data in different systems based on the business area and its use. They confirmed having full traceability for meat products (beef and chicken), primarily for food safety and reputational purposes.
- **Cocoa manufacturer:** they captured data at the farm level and maintained a system to record data on farms, farmers, materials, agreements, contracts and movement of volumes up to their manufacturers. They used traceability data to demonstrate compliance with regulations (e.g., on child labour), corporate commitments and certifications schemes. Farms directly supplying were geolocated, though volumes may not necessarily be associated with specific farm polygons.
- **Soy trader:** they captured data at the farm level and maintained a system to record data on farms, farmers, materials, agreements, contracts, and movement of volumes up to the importing port. They also captured data from official databases and third-party data providers, using traceability data to justify compliance with regulations (e.g., labour and conservation of natural reserves), corporate commitments (e.g., deforestation), certifications schemes (e.g., Proterra and RTRS), and to reward farmers (e.g., through premium prices or for ecosystem services).
- **Palm Oil trader:** implemented strict enforcement measures to trace palm oil at the mill level, as the mill location indicated sourcing within a 15 km radius. This origin data was compiled in an Excel file and attached to trading contracts until the material reached the EU market, primarily for reputation purposes and to prove compliance with deforestation regulations and commitments.

Not all actors employed all system components described in the review section:

- Retailers (the restaurant chain and the supermarket) seemed to use most components (data elements, unique identifiers, sensor technology, relational databases, software and user interface) but did not seem to use sharing interfaces. However, unique identifiers were not necessarily tracing all raw materials, as applied at the manufacturing stage.
- Interviewed traders and manufacturers used data elements, relational databases, software and user interfaces but did not use unique identifiers or sensor technology to trace volumes from the farm to the manufacturer. Only one trader mentioned using sharing interfaces with public databases and third-party data providers.

4.2. Main drivers for traceability

Interviewees mentioned several key drivers for adopting traceability systems, with the most frequently cited factors being:

- Meeting and/or demonstrating ESG targets (mentioned 7 times).
- Regulatory compliance (6 times).
    - Knowing and disclosing the origin of materials (6 times).
    - Meeting market requests (6 times).

A significant portion of traceability efforts was driven by commitments or requirements to avoid deforestation. In the future, these efforts may be driven by the need to more accurately measure the carbon footprint of products and initiatives linked to circular economy.

While most organisations interviewed primarily considered their own policies or those imposed by their clients when defining their traceability strategies, four of them acknowledged that their traceability efforts are tailored to meet regulatory demands, and three to meet certification or standard requirements.

Most interviewees believed that there is no need for specific incentives to engage internal stakeholders in implementing traceability, as in most cases, traceability is linked to policies mandated by top management or the need for regulatory compliance.

Most interviewees emphasized the importance of raising awareness of the need and benefits of traceability through specific training.

Other mechanisms mentioned in particular cases included:

- Adopting efficiency-related win-win approaches.
- Linking management bonuses to targets involving traceability.
- Celebrating good performance.

4.3. Thoughts of the interviewees on specific topics

4.3.1. Involvement in traceability-focused multistakeholder initiatives

The interviewees mentioned various traceability-focused initiatives their companies have joined:

- Global Standards 1 (GIS's) working groups
- An initiative convened by major cocoa brands
- A cocoa traceability platform at the EU level
- An initiative convened at the palm oil industry level (not in the public domain)
- Covantis (initially focused on spot-trade)
- Certifications (therefore sustainability-focused but involving a degree of traceability): RSPO, Rainforest Alliance, RTRS, ISEAL, Proterra, Global Gap
- Eco-labels: Planet Score

4.3.2. Corporate department leading the implementation

In most cases, the team in charge for leading the traceability efforts was part of the sourcing department (noted in 7 cases). Five of these had a specific team or individual focused on traceability. In three other cases, the sustainability team primarily handled traceability tasks. Only one interviewee indicated that their organisation does not have a specific team dedicated to traceability; instead, various functions utilize different traceability data provided by suppliers.

It is important to note that the need to implement traceability varies depending on the supply chain actor (e.g., retailers primarily use traceability data but do not conduct traceability activities themselves; instead, they require brands to do so, who then pass the responsibility onto manufacturers or traders). Manufacturers and traders are the ones required to trace upstream the materials they purchase by engaging with farmers, cooperatives, mills, or intermediaries.

Other departments or teams also considered key for effective traceability include Business Development and Marketing (7 mentions), IT department (6), and Sustainability (5).

4.3.3. Traceability scope, indicators and technology

Only one organisation interviewed (a retailer) had an end-to-end vision of some of their supply chains. Other actors, such as traders and manufacturers, only had partial visibility of material movements. Two other organisations were still in the process of deciding on the tools to be employed in the future.

Those collecting data at the farm level (typically traders or brands) often had personnel visiting farms to collect data, either by using mobile apps or by filling out paper-based forms and then uploading a picture to the system. However, in some instances, traceability was not performed at the farm level but at the regional level (e.g., at the mill level for palm oil).

Only two interviewees mentioned using indicators to measure the quality of traceability data, such as fidelity, usage and completeness. One of them also measured performance based on the speed at which data was made available after an event occurs, arguing that delays in uploading documents post-event increase the likelihood of data inaccuracies.

Although "blockchain" was not included in the initial discussion, several interviewees identified it as a key technological reference for achieving full traceability, with some stating that they are exploring its potential. They noted that the leading actors in traceability were already implementing blockchain technologies.

4.4. Best practices and benefits recognized by the interviewed actors

The suggested best practices for traceability varied significantly among actors, with the most common recommendation being "the need for collaboration and harmonization," closely followed by "rewarding farmers for traceability data and demonstrated impact". (For a full list, refer to Annex B). Additionally, a range of benefits was identified, including better regulatory compliance and improved risk management. (Full list in Annex C).

> *"What's the strategy for change? You need data. To be a responsible business you need to understand your supply chain to then know how you can change things for the better. There is increasing demand for data and transparency which will involve further traceability. As a result, data is very valuable. If you have good traceability data you can explore multiple benefits such as efficiency, speed, and cheaper processes."*
>
> Supermarket Sustainability Manager

It is also important to note that perceptions of traceability differed between those who have already implemented some traceability measures (these participants were generally more optimistic due to experiencing the benefits firsthand) and those who were still in the assessment phases or not directly involved in implementation, who tended to be less optimistic.

While large farmers in developed countries typically have access to the technology needed for traceability and may not require additional support, small farmers in developing countries often lack the resources to commit to traceability efforts. However, it was noted that small farmers are not usually required to collect traceability data themselves, as other stakeholders (traders, major manufacturers) often arrange for the collection of farm data through local third parties. Two interviewees highlighted the need to find mechanisms to convert traceability data into new opportunities that benefit farmers. Only one interviewee confirmed that they offer premium prices for additional work required from farmers and inform non-compliant farmers about the necessary corrective actions to become eligible suppliers.

Several interviewees discussed mechanisms to reward farmers for traceability data or ecosystem services through supply chain mechanisms. Two specifically mentioned the potential of carbon credits (either stored in preserved forests or captured in soils) as a reward mechanism. Two interviewees emphasized the importance of traceability in justifying claims on soil carbon capture, a topic gaining increasing attention. They argued that data on soil carbon capture and associated carbon credits do not present competitive issues, suggesting that this area could foster collaborative efforts on traceability across agricultural commodity supply chain actors.

5. FINAL OBSERVATIONS

5.1. Progress on traceability so far

Overall, the greatest progress on traceability seems to have been made with certified materials. The palm oil industry appears to be the only one tracing significant volumes of sourced materials (at the mill level rather than the farm level). In the cocoa and soy industries, traceable volumes are mainly either certified or directly sourced by traders. This means that, except in the case of palm oil, a major proportion of sourced volumes (up to 75% in some cases) are not traceable, yet. This, in turn, means that the idealistic concept of traceability (where any materials produced and exchanged between supply chain actors should be recorded and traced) is far from reality for some of the major commodities and actors interviewed.

Most food chain actors interviewed for this study limited the concept of traceability to knowing the origin of products (in a few cases capturing farm and farmer data too) rather than knowing the full chain of custody. Therefore, the market's concept of "traceable to the farm" might not always be technically accurate. Traceability to the farm should involve knowing the chain of custody from one point of the supply chain to the farm. Only one organisation interviewed (a retailer) had an end-to-end vision of some of their supply chains, while other actors (e.g., traders, manufacturers) had only partial visibility of material movements. Progress is slow, and in the cases where actors claim almost 100% traceability, they do not even trace to the farm level but to the region level (e.g., palm oil industry tracing to mills). Furthermore, in most cases, traceability was mainly provided for certified products or sustainability compliance rather than applied to all product volumes by default.

The palm oil industry, which employs a basic traceability mechanism (the exchange of Excel templates that are manually processed), reports significant progress in deforestation reduction [20] compared to other industries like the cocoa or soy, which seem to be employing more sophisticated technologies. It appears that the palm oil industry has been stricter in requiring compliance as a condition for market access. Moreover, market, consumer and media pressures have been heavier and for a longer duration. For some use cases, the effectiveness of traceability might depend more on market enforcement and strict market access policies than on technology. Regardless of the sophistication of a traceability system, without strict enforcement, traceability may not be effective enough.

5.2. Limitations of this study

While participants were relevant both in terms of professional roles and their organisations' market volumes, the number of interviewees is relatively small compared to the total number of actors involved in the agricultural supply chain. This limited sample size makes it difficult to draw general conclusions from the information gathered.

Participants primarily represented retail, manufacturing and trade companies, as well as standard organisations. It would have been beneficial to include the views from producers, mills and processors as well. However, these actors rarely have dedicated sustainability or traceability teams, making it challenging to identify and engage suitable interviewees from these sectors within the timeframe of this study.

Although the interviewee sample approximately represented the targeted audience, the varying roles of the interviewees and the broad range of themes discussed might introduce some bias in the results. Additionally, a few interviewees were unable to answer all questions posed.

5.3. Potential new research

Based on the literature review and interview findings reported here, further studies could help promote the adoption of effective traceability systems that contribute to sustainable trade outcomes. Potential research proposals could include:

- Developing a framework to quantify the benefits of traceability data for different supply chain actors, including specific indicators and metrics.
- Investigating mechanisms beyond existing regulations that governments could implement to support private sector action on traceability. This could involve leading the creation of an enabling environment for data sharing, management and verification.
- Defining and promoting mechanisms to ensure traceability data accurately reflect the link between the volumes of raw materials and the polygons of the farms where they were produced.
- Conducting a comparative analysis of the potential positive impacts (e.g., preventing of deforestation or labour crimes) achieved through different levels of traceability (e.g., farm-level vs. region-level) for key commodities such as soy, cocoa, and palm oil.

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ANNEX A. Questionnaire

Why

- What are the main drivers that encouraged you to implement traceability?
- What are the main objectives of your existing traceability system?

How

- What tools are you deploying to achieve traceability?
- Which traceability standards or regulatory frameworks do you follow?
- Why these?

With whom

Internally:

- Which department in your organisation takes the lead and covers the costs of designing, implementing, and maintaining the traceability system?
- Which other departments and internal stakeholders are involved?
- How do you engage or incentivise them?
- How do you measure traceability progress internally?

Externally:

- How do you influence your suppliers to engage with your traceability requirements?
- How do you measure traceability progress externally?
- Are your traceability requirements aligned with those of other supply chain participants? How?
- Are you involved in any multi-stakeholder initiative focused on end-to-end supply chain traceability? Which one and who is involved in it?
- How do you enhance farmers' participation in traceability activities?
- Do you think the public policies in the countries where you are present support and value your traceability efforts? How could the regulatory context change for the better?

Outcomes

- What progress have you made against traceability goals?
- What economic benefits (e.g., resource optimization) are you seeing from employing your traceability system?
    - What other benefits are being observed?
    - Were these expected?
    - Are they providing new opportunities for action?
- What are the best practices and wider learnings you would share with others on traceability?

ANNEX B. Full list of best practices for implementation mentioned by the interviewees

Suggested best practices highlighted: (in order of occurrence):

- the need for collaboration and harmonisation (4 times)
- reward farmers for traceability data and demonstrated impact (3 times)
- start small and aim big (2 times)
- build capacity (2 times)

All the rest were mentioned just once:

AREA	SUGGESTED BEST PRACTICE
Leadership and collaboration	Brands and retailers should: • be more specific on what they want and more proactive in setting solutions. • lead the process by demanding traceability for the majority of volumes (rather than a small proportion of certified traceable products)
	Convene industry-wide collaboration to define methodologies (e.g., data collection)
	Collective action and good coordination at the landscape level too
	Involve stakeholders from the begging
	Recognise that traceability implementation is a long journey
	Set clear expectations
Defining the objectives	Define the goals and value you want to get from traceability
	Adopt an opportunities-focused approach
	Build a business case
	Think like a farmer to understand what you can and what you cannot do
Scope and pace	Start with baby steps and take faster decisions
	Adopt an approach that is feasible and stepwise to avoid business disruption
	Prioritise a specific supply chain to start and then escalate
	Be ambitious and bold
Defining which data should be collected	Prioritise good data management and analytics
	Understand what data you need and make sure you have the resources to extract the aimed value from it
	Understand what's the data granularity required to have a competitive advantage
	Understand well the supply chains and who you are gathering data from
	Be bidirectional (deliver value to producers from traceability data)
Technological approach	Prioritise digitalisation (considered key and cost-effective) to optimise resources and minimise error-risks
	Implement as much automation as possible (e.g, blockchain-enabled smart contracts)
	Do not reinvent the wheel by developing something from scratch, check what's already available to make it better

	Do not start by focusing on a tool, define the process and then look for a suitable tool
	Integrate product identity across the business system
Operational aspects	Build capacity to have quality data and avoid mistakes
	Assess the effectiveness of traceability outcomes
	Share as much as possible, be as open as possible
Supplier engagement	Have an open discussion with suppliers
	Include traceability requirements in suppliers' contract
	Set contracts that effectively reward suppliers meeting traceability requirements as opposite to those not meeting them

ANNEX C. Full list of benefits from traceability adoption mentioned by the interviewees

The benefits mentioned were very varied and there were not many coincidences (in order of occurrence):

- better regulatory compliance (4)
- better risk-management (3)
- more replicable |efficient |cheaper processes (2)
- meeting new requirements in a cheaper and easier way *as the base system is ready (2)
- origin-linked quality (2)
- better resilience (1)
- better integrations (1)
- business continuity (1)
- competitive advantage (1)
- prove of origin (1)
- standard/certification compliance (1)
- more convincing justification of premium prices to end-consumers (1)
- enhanced reputation and better access to financial services (1)

Not all interviewees answered this question as a couple of them are still in the early stages.

ANNEX D. Statements made by the interviewees

For traceability implementation:

- "If you improve traceability, you improve your business" (B)
- To be a responsible business you need to understand your supply chain to then know how you can change things for the better. What's the strategy for change? You need data. (H)
- There is increasing demand for data and transparency which will involve further traceability. (H)
- Data is very valuable. If you have good traceability data you can explore multiple benefits such as efficiency, speed, and cheaper processes. (H)
- Traceability is an opportunity for farmers, as farmer data could be turned into new opportunities for them (business, premium). (J)
- Customers make decisions based on price. However, making a product sustainable has a cost. When you raise the price of a product customers tend to buy an alternative product. If customers do not see the value of sustainable products, the market just stops selling them. Creating high-quality comparative info about products (e.g., sustainable vs non-sustainable) for customers would help change this. This could be enabled through traceability data. (H)

About traceability governance:

- "If you don't measure traceability progress you can't drive compliance" (B)
- Big manufacturers such as Unilever tried to put in place a very complex platform to capture the chain of custody data, but it was too complicated and non-effective. Excel templates have been more effective, and their impact has been recognised. (C)
- Being one of the most complex SC we found a very simple and effective solution: enforcement. The soy industry could be applying the same methodology, but they do not. (C)
- It is very important to share one's traceability data in order to receive others' traceability data (C)
- Traceability is only good if you input quality data into the system. You need to train people. (H)
- "Traceability data should be used to reward farmers" (I)
- Farmers should be rewarded for the crop, the data and the positive impact traceability data demonstrates. (D)
- Today traceability compliance is based on mandatory requirements for suppliers and these do the minimum required because traceability has a cost. A better system would benefit suppliers performing well. (H)

About the scope and approach to be adopted:

- Traceability does not always need to be end-to-end. Depending on the purpose you might not even need to know which farm it comes from. (H)
- It is hard to be pure but it's important to be practical. Practicality over perfection and philosophy of continuous improvement. (K)

About existing gaps in the traceability space:

- "There are no good training tools out there on traceability" (B)

Weaknesses of existing traceability approaches:

- While farms are identified and geolocated through polygon coordinates, volumes of product are not linked to specific polygons and therefore there is no guarantee that purchased volumes come from the registered and monitored polygons. (E)
- nowadays "traceability" can be claimed based on different levels of ambition, accuracy and validation. (E)
- traceability might not be the solution if it does not necessarily guarantee accountability. (E)
- Traceability provides dangerous content because when there is an issue whether they invest in changing things or they directly change suppliers. They can just buy from someone else or a different region considered less risky. Or even, when very difficult and costly to solve the issue, stop producing the product containing problematic materials. Alternatively, they might even decide to buy the farms and become vertically integrated. Traceability provides knowledge but sometimes leads to difficult decisions (exit farmer, exit region, exit product). There might be unintended consequences. (K)
- Access and usability of traceability data for analysis purposes are strategic to better understand and manage supply chains. Transparency and data exchange on top of traceability are key as the process of manually gathering and analysing data spread in different systems is slow and resource-intensive and, therefore, limits the number of products you can focus on. (H)

Major barriers:

- The industry does not want harmonisation as this would compromise the competitive advantage of a few. (G)
- There is a gap between what occident requires and what is feasible on the field. (I)

About blockchain:

- "We don't have anything fancy like blockchain". (H)
- XX companies are trying blockchain and there is huge potential to obtain more granular and auditable data. Company X has done a lot on traceability with tech companies for many products and is considered the ones more advanced in traceability. (H)
- Implement as much automation as possible (reduce manual work). For instance, blockchain allows smart contracts that can dramatically reduce the time required to sign contracts and you can automatically execute restrictions when no compliance is detected. (I)

About standards and certifications:

- If you have a robust enough traceability system that enables you to trace your supply chains and where products come from, standards do not add much value to that (K)
- there is no benefit from standardisation of data because having a unique approach grants a competitive advantage. (J)
- Company X and Y are particularly good at sustainable sourcing. They are very big in volumes. (I)