DRG4 FOOD

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Value Chain Analysis

Cacao-Tech

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Summary

The Cacao-Tech project intends to provide a contribution to the transformation of the Cacao Value Chain in Latin America by enhancing transparency and quality with NIRS (Near Infrared Spectroscopy) technology and whole pod automated processing.

The objective of this value chain analysis is to identify, describe, and engage the primary actors in the cacao pulp value chain. Cacao pulp is a side stream of cacao bean production and an upcoming area for new product development such as sugars, drinks and syrups.

The cacao value chain is a disaggregated complex global value chain with many different players. It is predominantly populated by smallholders, depending on the country. These cultivate 70-90% of the total cacao production. It is characterised by largely informal relationships between producers and buyers with on-the-spot single purchases and a lack of trust and collaboration between actors. Multiple actors interact in small direct sales, such as producers, cooperatives, associations, off-takers, traders, other intermediaries, transportation companies, warehousing and chocolate makers. The value chain is mainly focused on trading cacao beans for chocolate making, but knows many side streams such as cacao butter, cacao powder, nibs and liquor and can also include parts of the cosmetic industry.

Cacao-Tech offers 3 solutions for an enhanced cacao value chain. It offers a traceability solution, a cacao quality control solution and a solution for whole pod processing of circular cacao. These can be applied in combination with each other or separately.

Regarding the ***traceability*** components that enable the circular and fair use of cacao, different value chain partners do not always value the same attributes in the value chain and trust is not necessarily defined by digital tools and responsibility goals. However, all partners in the value chain would benefit from more trust and traceability through digital enablers. Developing Cacao-Tech solutions could bring value to the Ecuadorian industry and enhance the position of European traceability-based business models enhancing ethical and sustainable cacao production. There are many tracks in which digital data sharing could enhance the value chain.

For digitally enhanced ***quality control***, the detection and visualization of key quality aspects of cacao by-products can enhance collaboration in the value chain and make the value chain more cost efficient and transparent for other users of cacao products, too. The direct cost benefits of addressing quality control at key points in the value chain alone might save millions in costs in the industry. The digital enablers also enhance trust and traceability through less cumbersome data collection and higher data quality, resulting from scanned information compared to manual data entry in other solutions.

Introducing new products from the cacao fruit enhances the industry's sustainability and provides additional income sources for farmers, in particular smallholder farmers, while also reducing waste. Therefore, in this project we are working towards ***whole-pod processing*** of cacao, introducing new by-products from the pulp. The pilot has shown that whole-pod processing is feasible and can substantially contribute to farmer income (Desczka, 2022), if cost implications of the new logistics are managed well. In the case of pulp the logistics are not largely changed, but harvesting whole pods will require further research on how to

develop the logistics well in the case of smallholders. Cacao-Tech can be a solution for systemic problems that the industry has to overcome, such as lack of trust and transparency, lack of circularity and income from cacao. Cacao-Tech solutions therefore have the potential to transform the cacao industry into a modern, growth-oriented, and data-driven industry, bringing new innovation to an old trade and offering exciting opportunities for young people.

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Abbreviations

Abbreviations	Full
AI	Artificial intelligence
B2B	Business to business sales
B2C	Business to consumer sales
BRiAPI	The Breeding API
CCN-51	An industrial breed of cacao largely used in Ecuador
CSDDD	Corporate Sustainability Due Diligence Directive
CSRD	Corporate Responsibility Directive
DRG	Digital Responsibility Goals
ESG	Environmental. Social and Governance effects
EUDR	EU Regulation on Deforestation-Free Supply Chains
FGD	Focus Group Discussion
GHG	Greenhouse Gas (emissions)
ha	Hectare
MIAPPE	Standard for phenotyping platforms
MPL	Multiprogramming languages
MT	In this report, MT stands for mega ton, defined as 1 million tons. Please note: this differs from the more common use of MT to mean metric ton (1,000 kg).
NGO	Non governmental organisation
NYSE	New York Stock Exchange
QR code	Quick responds code
USD	US Dollar (also currency in Ecuador)
VC	Value Chain
VCA	Value Chain Analysis

1 Introduction

Cacao-Tech implements new technology to the cacao value chain to improve cacao quality. It introduces tracking and tracing of products and valorises additional products from cacao pods, while reducing waste. The lack of control and incentives for quality separation has long frustrated the chocolate industry. With 85% of cacao produced by smallholder farmers and passing through numerous intermediaries before reaching exporters, ensuring quality and traceability is complex. Certification, which typically only extends to the cooperative level, fails to fully address the issues. The industry's need for traceability is further intensified by the European Deforestation Regulation (EUDR). The challenge is further aggravated by the current cacao crisis, characterised by a significant demand shortage, which means that farmers mix cacao with low-quality or discarded pods. Introducing traceability and valorising waste streams creates a much-needed win-win situation for all value chain (VC) partners.

The project develops a circular traceable quality enhanced model for cacao products using whole cacao pods, valorising waste streams such as pulp and husks. Farmer-specific traceable quality information from NIR (Near Infrared Spectroscopy) technologies creates a circular value chain (VC) with high quality products. This pilot detects two key cacao quality parameters that are important to buyers: sugar content of cacao pulp and fatty acids for beans. The quality data will be combined with a traceability system including time and geo-location resulting from NIR scans of produce to trace the cacao ingredient, including its quality parameters, back to its origin. Cacao-Tech piloted these technologies in cacao-producing regions and developed the design for a global tracing open-source licensing model that can be scaled. Over time, the collected data can be used to predict cacao quality, direct cacao components towards their best application in the circular value chain and advise on smart farming practices using AI. This report provides the analysis of the current state of the art of the cacao value chain regarding the relationships of value chain partners, the trust and transparency established in the industry and the current use of traceability and quality control tools applied to ensure premium cacao prices can be paid and farmers receive a fair income. The report documents the findings of the pilot implementation.

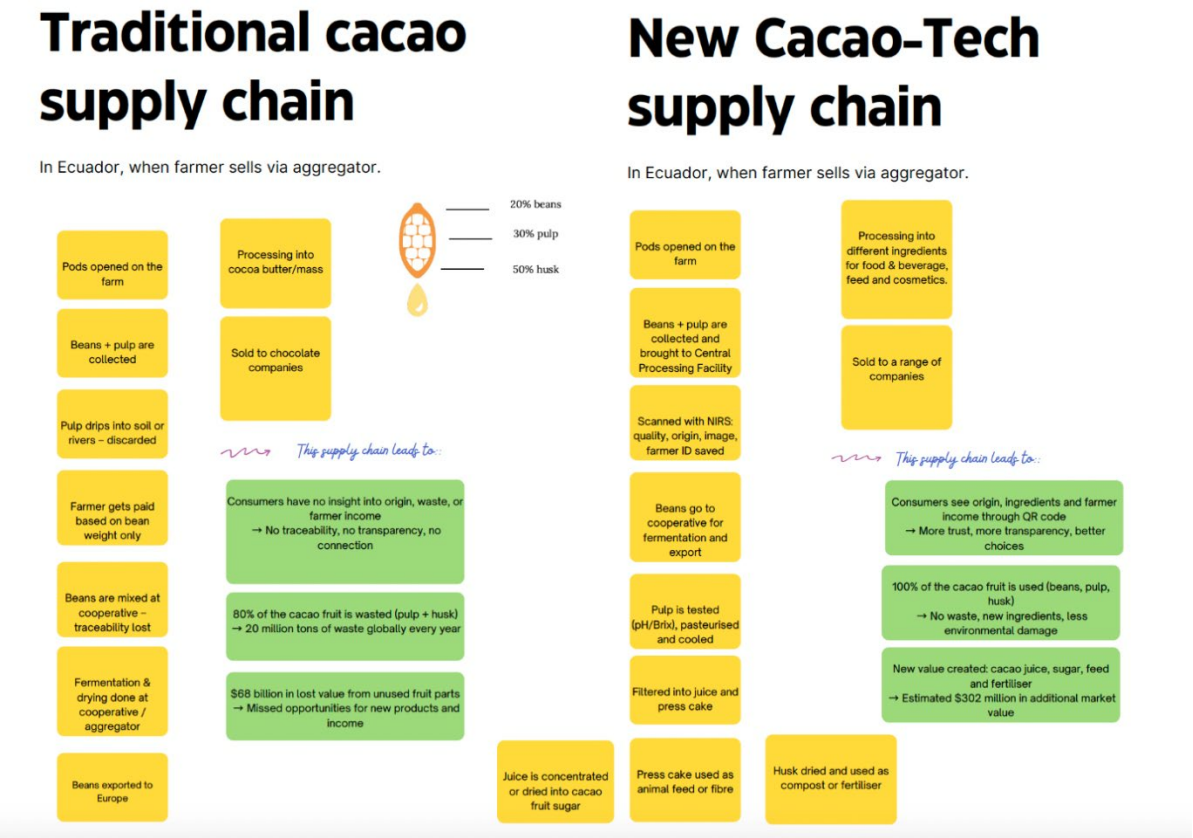

Figure 1-1 Traditional supply chain versus new proposed Cacao-Tech supply chain for cacao fruit processing.

2 Approach to Research

This report is the result of literature research, B2B and B2C surveys, Focus Group Discussions (FGD) and interviews into the cacao value chain and industry in Ecuador, with a specific focus on cacao pulp, traceability and digital quality control. We focus on the Ecuadorian cacao value chain, its actors, its current status regarding circular business models, in particular cacao pulp and how cacao pulp can become a second value stream for cacao producers.

The objective of this value chain analysis is to identify, describe, and engage the partners in the cacao pulp value chain and to determine the state of traceability and quality control implemented. Cacao pulp is a side stream of cacao bean production and an upcoming area for new product development such as sugars, drinks and syrups. The insights, conclusions, and recommendations will guide further activities of the participating VC partners in developing the cacao pulp value chain.

2.1 Approach to Value Chain Analysis

A value chain is a sequence of interlinked agents and markets. The actors transform inputs and services into products and deliver them to consumers. (Devaux et al. 2018; Miller and da Silva 2007). The chains' main function is to connect agricultural producers to markets (Van Vuuren, 2014). Agricultural value chains differ in length, scope, quality attributes, bargaining power, transition stages, relational and market governance (Marsden et al., 2000; Renting et al., 2003).

This analysis is a participatory value chain analysis (FAO 2020). This implies that value chain partners support the research by identifying ways to add value to the cacao supply chain and describing their needs. Identifying key points for technology use, where data can bring the most benefits and secure information, can help to improve trust within the value chain. We collect primary data from the participating partners in the value chain, as there is no other data source for cacao pulp available.

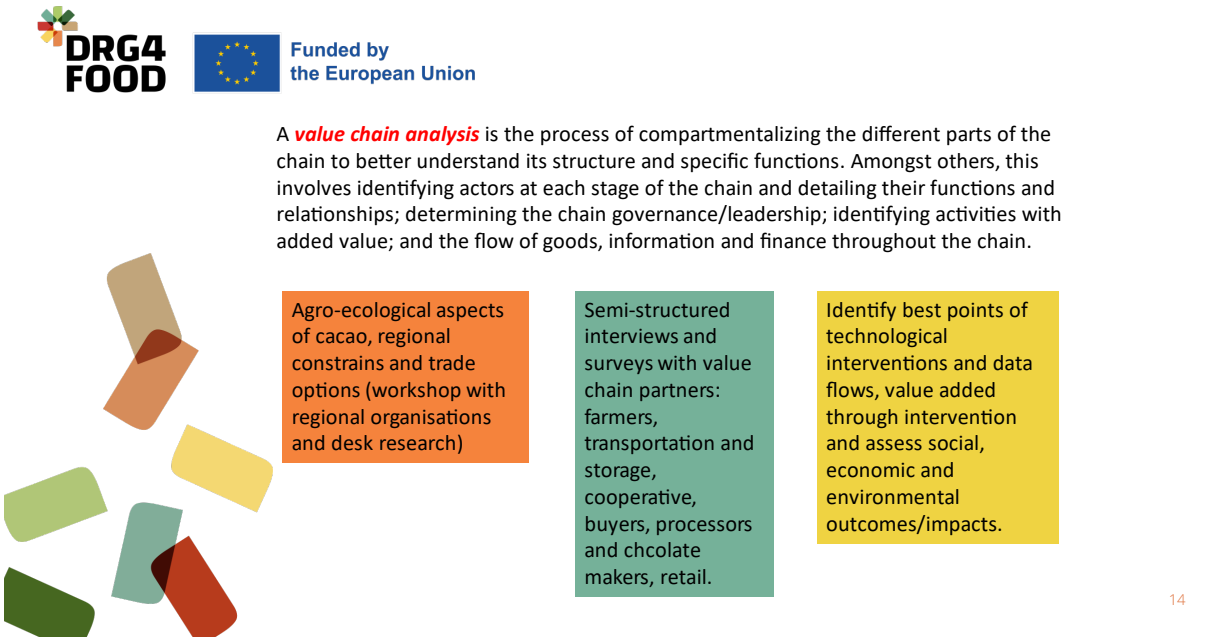

Figure 2-1 Approach to value chain analysis.

2.2 Research Question

The analysis explores the market potential for valorising pulp and improving traceability and quality control with NIR technology. The analysis focuses on the relationships between value chain partners and their trust, non-monetary values, and opportunities for operational efficiency and transparency in the cacao industry. The three main research questions are:

(1) Roles and relationships in the cacao pulp value chain:

1.1 Who is actively engaged in the value chain for cacao pulp production?
1.2 Who supplies materials such as machinery for pulp extraction and collection/ products such as (cacao beans, pulp) in the value chain?
1.3 How do producers, cooperatives, traders, buyers, transporters, and other partners in the supply chain work together?
1.4 What is the level of trust between value chain partners, what is it based on and how can it be improved?

(2) Economic conditions, adding value and changing processes:

2.1 What values do value chain partners in the cacao industry consider important? What adds value to their business model?
2.2 What attributes of cacao are important for buyers and add value?

(3) Data use and digital tools:

3.1 What data is collected in the cacao pulp value chain and to what end?
3.2 What data entry points are there in the cacao pulp value chain to add traceability?
3.3 What type of data is most useful to improve the flow of activities in the cacao pulp supply chain?
3.4 What (digital) tools are currently in use and what do they help the industry with?

These questions will be answered in this document.

2.3 Data Collection

Information for this analysis results from hybrid semi-structured interviews, observations from farm visits and workshops with Rikolto, ANECACAO, ESPOL, TRIAS, ESPOCH and UNOCACE in Ecuador, and with partners and value chain actors in the Netherlands. In 33 interviews we collect information on (1) processing of cacao pulp, (2) Market aspects, trends and governance, (3) standards and certifications, (3) technology and product development, (4) management and organisation, (5) input supply and financing of inputs, and (6) digital infrastructure. (ANNEX 1 Questionnaires.) Another survey concentrated on consumer needs, which we further elaborated on in focus group discussions. Additional insights come from a series of short interviews at the Chocoa event (Amsterdam, 4-7 February 2025) with industry professionals (n=22).

Type of actor	Nr. of respondents	Collection of information through
Farmers	N=3 large farms N=3 smallholder farms	Semi-structured interviews, meetings and workshops,
Associations/ cooperatives	1 Ecuadorian cacao industry association, 1 cacao farmer association of cooperatives	Semi-structured interviews
Processors/ mainly chocolate makers/ juice producers	N=4 1 large chocolate maker, 1 large farm, 2 processors, 5 manufacturers at Chocoa, 1 juice producer at Chocoa, 1 juice producer in the project Chocoa survey (5 manufacturers, 12 producers, 1 consultant, 4 not specified)	Open and semi-structured interviews, B2B survey at Chocoa n=22
Trading houses/Traders	1 Trading house in the Netherlands. 2 Trading house in Germany. German Trader.	Semi-structured interviews
Input providers	3 Digital application providers: ICE, Satelligence, Koltivo at Chocoa	Unstructured questions, separate landscape analysis
Academia	3 departments, agriculture, product technology, soil.	Workshop ESPOL, conference ESPOCH, Q&A, results from CREA project, presentation Univ. of Applied Sciences Bern, and CIAT/WU soil group.
NGOs	4 Jocotoco, Rikolto, Pro-Ecuador, TRIAS, 2 former employees from NGO's now independent cacao experts.	Workshop, presentations Q&A, results from CREA project
Consumers	Survey n=55; FGD n=5	Survey, Focus Group Discussion

Table 2-1 Summary of Data Collection

The interviews were conducted via direct conversations at exhibitor booths. Responses were analysed with Qualtrics to identify common themes, concerns, and opportunities for the future of cacao by-product utilisation. The objective was to get a better picture of the size of the cacao pulp market and the importance of monetary and non-monetary attributes of cacao for consumers.

2.4 Building on earlier work

Initial data on the cost components and willingness to collect pulp for different cacao pulp processing systems in Ecuador was collected through a farmer survey as part of the CREA project. The project is running from 2022 to 2026. The survey inquired about farm systems, size of farms, sustainable practices adopted, production costs, income, means and frequency of transportation, motivations for establishing and maintaining new extraction practices, barriers to implementation, and willingness to adopt to whole cacao-pod processing. It examined production costs for each system and cacao sale prices within the UNOCACE cooperative.

The survey targeted 100 smallholder farmers in 3 regions in Ecuador—Los Rios, Esmeraldas and Guayas. It was conducted between February and April 2022. The results were then analysed to identify the profitability of cacao pulp extraction at current market prices (SMP, 2022).

3 Characteristics of the Cacao Value Chain

The cacao value chain is a disaggregated complex global value chain with long distances, low trust and loose informal relationships. It is predominantly populated by smallholders. Depending on the country, these cultivate 70-90% of the total cacao produce. It is characterised by largely informal relationships between producers and buyers with on-the-spot single purchases and a lack of trust and collaboration between actors. Multiple actors interact in small direct sales, such as producers, cooperatives, associations, off-takers, traders, other intermediaries, transportation companies, warehousing and chocolate makers. The value chain is mainly focused on trading cacao beans for chocolate making (fine cacao), but knows many side streams such as cacao butter, cacao powder, nibs and liquor and can also include parts of the cosmetic industry.

Only 20% of the cacao fruit is used (the beans). The pulp usually leaks away during overnight drying processes and the husks are left on the fields, possibly leading to environmental pollution or in the most positive case, providing organic fertiliser. On large farms using CCN-51 cacao, an industrial variety of cacao, the excess cacao pulp is first removed and then discarded either in the ground or the sewage systemin the best case. The Cacao-Tech project stimulates the use of more parts from the cacao fruit. We are adding separation of materials, pulp extractors and processors, beverage markets, sugar markets, and new consumers to the value chain. This section provides the context of the Ecuadorian cacao value chain in which the idea of whole pod processing in Ecuador is implemented, the regional aspects, some specific characteristics of pulp extraction and the local area within which we implemented the pilot.

3.1 The Global Cacao Value Chain

Cacao is a global value chain. The cacao value chain is traditionally oriented towards bulk production of cacao beans with a few large multinationals dominating the B2B (business to business) market and small and large chocolate makers, and cacao juice makers that provide to consumers in the B2C (business to consumer) market. Small fine chocolate makers in Europe, the US or Asia buy cacao from traders or B2B ingredients manufacturers to develop high quality chocolate. It becomes more common to offer under the label “bean to bar”, meaning that they are producing their own chocolate from beans, not using cacao powder or other semi-processed ingredients. New developments induced by European or US regulations require the industry to become more sustainable or organic. When exporting to Europe, producers need to demonstrate that cacao comes from deforestation-free land, eliminating traditional practices of cacao farming and introducing new low-emission cacao farming methods. The most common problems in the cacao industry are unsafe harvesting and fermentation processes and deforestation. Child labour is less prominent in Ecuador than in Africa and Indonesia. Other problems persist such as mixing of beans of different quality, adding water to pulp and beans to increase weight, climate change induced drought or flooding (or both) and exclusion or exploitation of smallholder farmers with unfair data and trading practices. Cacao pulp as a product is new, although used on cacao farms; markets are nascent and not fully developed. Evaluating cacao pulp potential is difficult as all data and trading experiences on cacao usually refer to cacao beans.

3.2 The Ecuadorian Cacao Value Chain

This pilot focuses on the Guayaquil area in Ecuador, located in the southwest part of the country near the Pacific coast. Dry grassland primarily characterises Guayaquil. A study analysing cacao production systems in Guayas identified four types of farming systems: traditional, semi-intensive, intensive, and organic. Guayas is the heart of the cacao industry in Ecuador. Several thousands of cacao-producing families are in the area, most of them smallholders with under 4 hectares (Solidaridad 2023). Compared to other regions in Ecuador, Guayaquil has more larger farms, partly supporting the smallholders in the area through aggregation of produce with neighbouring farmers. Guayaquil has good access to ports and oversees destinations, and the relatively flat area allows for low-cost easy transportation. The area is largely industrialised with technology providers close by. Most farmers produce CCN- 51 cacao, a fast-growing, high-yield, industrially bred variety with larger beans and more pulp. This variety differs from the "Nacional Arriba" types, which are indigenous and regarded as some of the best fine-flavour cacao, with more different flavours. Some very small amounts of Criollo and white cacao are present, but they are usually mixed with the other varieties as it is too costly to exploit these separately.

Cacao production faces some different challenges in each region. Guayaquil faces climate change, water scarcity, drought and common power outages, which creates significant problems for irrigation. Recently, also flooding has occurred in the area, causing significant damage to some farms in the region. However, the distance to the city and the ports is small and infrastructure is well developed compared to other regions in Ecuador, such as Esmeraldas. These factors are particularly important for cacao pulp, which is a highly perishable product and requires rapid processing.

The region struggles with limited access to premium markets. The region mainly produces the CCN-51 variety, a high-yield cacao type that is relatively flat in taste and therefore usually typically not used for fine-flavour cacao. Certification is not very strongly implemented yet, due to its high costs for farmers. However, the Swiss, European and American markets are increasingly demanding sustainable or organic certification and efforts are progressing to avoid being locked out of these markets. Certification of organic production and fair trade seems to be in particular a pathway for smallholder farmers to achieve higher prices on international markets. Alternative markets in Asia and large-scale B2B processing companies rely more on quality control and quality consistency. CCN cacao includes more moisture and is therefore better for pulp extraction.

Early-stage companies in Quito and Mindo explore freeze drying, canning and concentration of cacao pulp for the local market. At least two larger companies are also exploring cacao pulp products for export.

Ecuador produced around 0,4 MT of cacao in 2024, with projections indicating this could rise to 0,6 MT within the next two years (Anecacao, 2024). It will then become the third largest producing country in the world (now the fourth largest, after Ivory Coast, Ghana, Indonesia). This is very different from the size of the cacao pulp market, which produces globally maybe 1,000 to 1,200 *metric* tons, although the pulp to bean ratio is 3/2 (interview processor), which makes it many times smaller than the cacao bean market, around 4.3 million MT globally in 2023 (ICCO, Quarterly Bulletin of Cacao Statistics, Vol. L -No.3 -Cacao year 2023/2024.) However, many cacao producers expect the market to develop more (The Chocolate Journalist, 2021).

The Ecuadorian cacao industry, as the entire sector, grapples with outdated practices, social issues and poverty, mistrust between value chain actors, and significant environmental challenges. Issues such as water management, excessive chemical use and deforestation persist, though differ per country and to a lesser extend experienced in Ecuador. Moreover, innovations are rare, and business decisions are often based on perceived value rather than solid data. This lack of modernisation leaves room for efficiency improvements, but resistance to change remains a significant barrier.

Climate change is severely impacting cacao yields, particularly in West Africa, contributing to a global cacao shortage. This shortage has already driven up cacao prices; a trend expected to continue. For Ecuador, this has serious implications for both production levels and the stability of supply chain relationships, creating additional risks and uncertainties within the sector. In the regions where most cacao grows, rainfall has diminished, and the farms are highly dependent on irrigation systems. This also gives rise to disease and pests with Cadmium being the largest problem in cacao and black pod also affecting the quality of cacao pulp.

The Malaysian Cacao Board (2007) identified about 32 uses for cacao, most for cacao pulp. A study from the Fachhochschule Bern also confirmed that most by-products might use pulp (to be published in Franco, 2025). Fraunhofer institute investigated by-products in a large research project with industry partners in 2019-2022. The complicated knowledge-intensive processing of pulp, the perishable product, food safety concerns and the fear of damaging the cacao beans are barriers to market entry. Many cacao producers are also missing “buy-in” of the corporate leadership for developing cacao pulp products. Outside the cacao bean industry, sweeteners, juices, jams, gels or alcoholic beverages seem to be the most common uses of cacao pulp. Canning or concentrating are also options. Cacao pulp is either pasteurised and frozen, freeze dried or powdered in Ecuador and can be transported in this way, although the distance to Europe is long.

4 Trust and Relationships in the Value Chain

The purpose of this chapter is to demonstrate how new measures based on digital data can enhance trust, collaboration, circularity and value chain development in the industry. Together with the participating partners in the cacao pulp value chain, we are describing processes and identifying entrance points for data collection that might benefit the development of the industry.

4.1 Consortium relationships in the participatory value chain analysis

In December 2024, two promising pilot partners joint the efforts. A large industrial farm working with smallholder farmers, managing approximately 450 hectares of cacao with an average yield of 2,000 kg per hectare. More than half of their output of beans comes from smallholder farmers in the region, the other part is grown on own land. The farm also has banana plantations, leveraging the technology of pulp extraction that is (more) commonly used for banana production for cacao. The other partner is a large association, one of Ecuador's largest and most organised associations of cooperatives, representing about 2,500 members in different cacao-growing regions. They are organic certified and work with small holder farmers. Most of their customers are premium chocolate manufacturers in Europe. One of their main customers onboarded in the project: a prominent Swiss chocolate manufacturer. This is accompanied by Pacha de Cacao, a cacao beverage startup in Amsterdam importing cacao pulp and cacao ingredients, and VanillaGorilla.ai, a company specialised in delivering customised AI solutions designed to enhance efficiency, automate processes, and drive innovation. These partnerships provide us with valuable insights and opportunities to test our assumptions and build scalable solutions in the Ecuadorian cacao sector.

These companies work together with Wageningen Research and The Czech University of Life Sciences to identify and trace quality aspects of cacao and production metrics that will enhance the traceability components of the project. Other cacao processors collaborate and provide us with insights into the quality aspects and key entrance points for data collection in the value chain on a friendly collaborative basis.

4.1.1 Farmers

For the purpose of this study, we differentiate between smallholder farmers, large farms, and aggregating organisations.

4.1.1.1 Large Farms

Large farms have a production of around 2,000 kg per hectare. Farms have a direct relationship with pulp and bean clients, mostly chocolate makers. They ship directly to clients. Farmers visit clients in the beginning of the harvest season to agree on a price, volumes and delivery scheme. Many clients visit the plantation at least once a year. Many farms also receive local orders, which are more spontaneous following a phone call and pick-up arrangement. None of these sales entail contractual multi-year contracts or off-take guarantees, or even investments in farms such as usual with value chain finance in

integrated value chains. There are no repercussions for buyers if they do not buy from farmers in one year or change farms. It is a buyer's market. Buyers all have bargaining power. The buyer power is under pressure due to supply shortages, still many farmers cannot afford to not sell immediately to the first buyer offering a price.

Large farms have very different business models ranging from buying cacao from smallholder farmers to increase sales volumes and decrease costs (economies of scale), specialising on the client experience with high-end and consistent flavour pallets accustomed to clients' tastes, curing specialty cacao breeds and tweaking the fermentation and drying process, high yield monocultures of CCN-51 or research farms.

Contact with other value chain partners is mainly based on personal contact, phone calls, and WhatsApp. Apart from prices and agreed volumes, buyers receive the cut test results for quality assurance. A cut test is traditionally performed at various exchange moments in time: on farm in the fermentation process, now for sale, during farm visits, or before shipping and after receiving a batch. The cut test results are transmitted by e-mail ahead of the sale. Cut tests are highly subjective to the expert and can be performed by farm experts or independent experts. In many cases when shipped overseas, the buyer hires an independent expert to do the cut test, Brix and Ph-level tests, micro test and visual inspections. Each of these checks usually means that a bag is opened, beans are extracted, and the rest of the beans are wasted.

4.1.1.2 Smallholder Farmers

This information is based on the 2022 farmer survey among 100 small-scale farmers (SMP 2022). Smallholder farmers have usually between 2-5 ha cacao plantations and can have up to 20 ha. 75,5 per cent of cacao farmers are smallholders in Ecuador with less than 5 ha (Franco, 2025). The overall size of the farm can deviate and include mixed farming and other produce. Information resulting from the 2022 farmer survey under 100 smallholder farmers in Ecuador in 3 regions resulted in the following insights:

The survey conducted among cacao farmers reveals a mixed but generally positive attitude towards the transition to whole pod processing. Many farmers recognise the potential benefits, such as reducing waste and increasing income by utilising the cacao pulp, which is currently discarded during fermentation. The idea of on-farm pod processing using a Mobile Processing Facility (MPC) is particularly appealing to some, as it allows for immediate processing and quality control of the pulp and juice. However, concerns about the costs and logistics of implementing such a system, including the need for additional labour and equipment, are significant considerations for farmers.

The option of transporting pods to a central processing centre is seen as less favourable due to the potential increase in transportation costs and the logistical challenges it presents, although it could potentially reduce labour on farm. Farmers are also wary of the impact on their current sales channels and the need to adapt to new business models. Despite these concerns, there is a willingness among many farmers to explore these new methods, provided they receive adequate support and incentives

The pulp extraction needs to happen in a very small window of 8 hours. This might mean farmers would have to hire 1-5 additional labourers. One labourer can extract pulp from 1 hectare in approximately 6 hours to meet this time requirement (Interview with smallholder farmers UNOCACE 7-3-2025). The survey highlights the importance of

addressing these logistical, social and financial concerns to ensure a smooth transition to pulp processing and/or whole pod processing and investigate alternative processing methods.

The main challenge for smallholder farmers is connecting to the cacao pulp value chain to achieve sufficient cacao pulp production volumes that enable economies of scale and meeting transportation standards (e.g. a container). The pulp production processors need to find a way to either keep transportation costs to a minimum by placing the processing facility as close as possible to the farmer or collection point, or it needs to increase payments for produce that allows for hiring a vehicle (beans and pulp, plus other separated resources) to a level that extra transportation cost and time investments are covered. To receive sufficient buy-in from farmers (and chocolate makers), this aspect requires further research and possibly proof of concept. Cacao farmers could learn from dairy farmers that deal with similar problems.

Smallholder farmers with UNOCACE are moving towards more CCN cacao. This is the result of the field analysis of UNOCACE. The reason is that CCN grows faster and can therefore be a solution to current supply shortages. Because of the high prices farmers have also increased the number of hectares and planted more cacao. This will, however, only influence production volumes in 2-3 years. Some farmers improved their harvests already from 12-18 quintales (about 45 kg) which is an increase from 540 to 810 kg, as higher prices make them take more care of cacao trees. This is positive for pulp production as the CCN variety contains more pulp. Also, the need to increase income with farmers producing CCN is higher as CCN is traded at lower prices than Ariba varieties, although the price difference has decreased due to the shortage of cacao, which makes buyers less picky (interview chocolate maker).[1]

4.2 Associations and cooperatives

The largest association for cacao in Ecuador (UNOCACE) comprises a total of 2,500 smallholder farmers on 6,340 ha of cacao plantations in 2023. They are organised in 24 cooperatives, each comprising about 65-85 producers in 10 provinces of Ecuador. Each cooperation has its own collection point. At the collection points, the fermentation and drying of the beans is done by experts from the association. The association also provides technical assistance on other aspects of cacao, such as productivity, organic certification, managing pests and diseases, and providing better agricultural practices in agroforestry. Each farmer provides on average 1.5 quintales (68 kg) cacao per week on an agreed day of the week (some twice a week).

To maintain good relationships and loyalty with farmers, UNOCACE develops projects for farmers to increase their productivity, farming methods and income. The current project FINCA, financed by a chocolate manufacturer and a development agency, focuses on

[1] The current price of US$8,170 per metric ton is equivalent to US$817 per quintal, since 1 metric ton equals 10 quintals. National has a 3% higher price, US$2,000-3,000 per quintal, but earlier it was almost 20%: US$360 per quintal for CCN.

agroforestry intensification, intercropping and biodiversity. This will lead to a *Gold Standard certification* for carbon dioxide emissions. The organisation envisages a contract of 510 ha certified carbon, an increase of 100 ha per year (360,000 tons of carbon up to 2030) to be sold on the Swiss carbon market.

Their biggest client buys 75% of the yearly production and is very engaged with financing the projects, inputs and machinery and visits at least 4 times a year to track progress and evaluate needs for innovation and productivity. They are pushing for organic production, which is important for the Swiss market. Switzerland protects its local market with strict import regulations and taxation of non-sustainable foods with strong support of citizens. In a 2018 vote, almost 70% of voters planned to say yes to import taxation of non-organic foods, but did not do so in the end because the right business models were not in place then (Gillman 2020) Also the new EU regulation on organic production increases pressure on cacao imports.

First companies and organisations appear in the market that buy cacao pulp, and more initiatives are emerging for circular cacao, supported by NGOs such as TRIAS or Producer Plus. First retailers are also planning to buy whole pods, already available in Spanish and British supermarkets. When whole pods are traded, it is visually possible to distinguish the different cacao varieties and mixing of beans will be impossible (Interview Rikolto 6-12-2024).

The association makes predictions on harvests of CCN and Arriba for all farmers, based on the field information and compares those with the received amounts of each variety. Extension workers meet farmers weekly on their farms and help distinguish diseased pods that need to be cut, help with fertilisation and developing organic fertiliser and GHG reducing farm practices. The farm harvest predictions and volumes of produce bought together are also used to estimate the on-farm amounts of Arriba (higher price) and CCN-51 (lower prices). This should discourage farmers from mixing beans and being dishonest about the type of beans provided, which is common in the industry. The estimations help to estimate the risks, but they do not contain the risk of mixing beans. There are also other practices used to increase weight and therefore income, such as adding water or other stuff to the buckets of produce delivered to the associations of which the associations need to be aware of.

UNOCACE has yearly contracts with clients with a negotiated price for cacao (organic/bulk). A quart of this price goes to the association, the rest to the farmer. These prices are developed following commodity prices on the NYSE and a commission for transaction costs of US$1,100 paid by the buyer. Because these prices are linked to the NYSE, there is transparency for farmers on the prices they get, and therefore trust. However, the currently high market prices lead to additional price negotiations that need to be explained to farmers. Other buyers use an average of national market prices for cacao. Fair trade organisations have different price constellations as well which include either a fixed amount premium or a percentage on top of the market price (Cacao Barometer 2023). Fair trade prices vary per season and between varieties and have different margins between wet and dry cacao. Dry cacao prices are about 35% higher than wet cacao prices. Since pulp is removed during the conversion from wet to dry cacao, pulp prices for producers should reflect this margin as well as the additional efforts undertaken by the association (Interview UNOCACE, 7-3-2025). Consequently, payments for pulp would amount to 44 cents per dollar for a

whole pod. These prices need to be recalculated, taking into account the strong price increase for beans.

Farmers receive cash payments according to the daily price and a paper receipt. However, this information is entered into the association's program at the end of the day or continuously transferred through WhatsApp to the association's accounting system. UNOCACE will start with a new program that automatically puts this information in the cloud.

Within UNOCACE only 'clean' cacao is collected. Experts inspect the fields every week and farmers need to cut bad fruits immediately. The current high prices do not affect strict quality control measures. They have not been relaxed to achieve higher yields under the pressure of demand. The primary goal is to become organic and that requires maintaining high standards. The risk is that becoming organic is not so much in the interest of farmers now as selling cacao fast. The high prices also cause loyalty problems. While earlier 70% of cacao was sold through the associations, now this applies to only about 10% of cacao. The association is more in need to prove its value by being innovative, providing farmers with projects or tools to improve cultivation methods, farm management, phytosanitary practices on farms. They also make and provide biol fertiliser free of charge to farmers, offering additional incentives for them to adopt organic practices. They are also investigating diversifying markets into banana pulp, yuca and lemons and help commercialise new products such as combined cacao and banana pulp or snacks from banana and yuca.

4.3 Transportation, Storage and Warehousing

The transport is typically handled by a local transport company, which delivers cacao to the port in container trucks. The customer usually arranges the transport, using a local Ecuadorian company they cooperate with, and they have met on earlier country visits. UNOCACE also sometimes organises transport. Both ways are possible. Before transportation, a simple cutting test is done, and cadmium is measured to reassure the customer. The results are captured in the FCC protocol. The FCC protocol is mailed to the buyer. Another test set is done at the port before shipping. The buyer will want to see the FCC protocol before shipment. A sample analysis contains 100 cacao beans, a bean count (20 beans), estimates how much over- or under referenced cacao is present, and a check for fungus. Cadmium is not stable, and values can differ per test. Also, the manual tests (bean count) are not very precise. The delivery can be insured. Transport companies are only responsible for secure storage and transportation to the destination, not the quality of the batches.

In the current situation, cacao pulp is pasteurised and/or frozen at the collection point. Only larger farms have the right equipment for extraction and cooling, and the generators to be proof against power outages. Pulp is transported, stored and shipped cooled to the processor for freeze drying, powder, canning or concentrate to Europe. On arrival, it is collected, pasteurised again and bottled or used as an ingredient for other food processes. The form cacao is transported also defines the storage and packaging material. Cacao pulp is tested initially for Brix and Ph values to ensure food safety and taste.

4.4 Processing, Chocolate Buyers, Beverage Companies, B2B Products

Cacao pulp is mostly traded as a side product of and for the chocolate industry. Processors make sweeteners, concentrates or other products for business-to-business purposes (B2B) and it is sold as a drink, e.g. by Pacha de Cacao.

4.4.1 Pulp Buyers (drink manufacturers, sugar manufacturers)

Pulp buyers are mainly small start-up companies in Europe producing drinks and sugars from cacao pulp (interview Pacha de Cacao 5-11-2024, Kumasi, 17-04-2025, Cacao Latitudes, 6-6-2025) in Ecuador. Pulp is imported to Europe as pasteurized frozen pulp. Local processing companies freeze-dry cacao pulp and transform it into a sweetener/sugar granulate for various buyers. In Latin America and African countries cacao juice is also introduced into local markets. Not much is known on the different uses yet: within the Guayas area 2 companies work with pulp, within Ecuador some processors are known in Quito and Mindo. In Latin America a company in Colombia works with pulp and a chocolate maker from Peru requested a larger party of pulp products, but did not pursue the buy in the end. There is also a lot of interest in using cacao mucilage as fermented drinks such as Kombucha.

Bio-innovation companies have been proven valuable additions to the cacao vale chain, providing processing parameters and identifying optimal processing conditions. Pulp is a new material, which is why no existing value chain relation structures can be identified. Alignment of objectives is the main basis for collaboration. There is no fixed model for how processors in Ecuador organize their relationships in the cacao value chain—it largely depends on the company's size, risk exposure, and the dynamics of the partnership. Larger production companies typically work with formal contracts, especially when technical processes, machinery, or food safety are involved. Smaller processors may start with informal agreements for early-stage projects, but once production begins, a contract is almost always in place to manage responsibilities and risks. Given the complexity of food production, consistent communication, clear documentation, and regular feedback rounds are essential usually based on in person visits in Ecuador or on international fairs. Trust is based on professional behavior, respecting timelines, showing up in person and paying on time. The role of the production partner, such as NunaLabs, is frequently overlooked in outward communication, as companies tend to treat processing capabilities as confidential or intellectual property. Instead, actively acknowledging and showcasing the production partner's role—for example, in communications or product storytelling—would be seen as a strong gesture of trust and respect, as it will have a positive effect on how others view them. Also engaging in co-creation processes rather than purchasing is a sign of trust. Trust is enhanced with informal gestures such as sharing lunches, extending invitations and open reflection and information sharing.

4.4.2 Cacao Bean Buyers

Large buyers are usually interested in overall consistency and quality of the product, while smaller buyers tend to be more interested in sustainability attributes. Thus, trust in the industry is related to a (1) consistent quality, good agricultural practice, (2) avoidance of pests and diseases, (3) avoiding overfermentation or underfermentation in cacao beans, and

(4) cost-effective aggregation of produce. Traceability can enhance most of these aspects and go beyond quality control with detection of food adulteration (selling more than one can have produced as their own produce), improved fermentation for beans and more consistency in taste. Large buyers, who compete on international global markets, are more aware of the prices of alternative ingredients and less likely to change their products.

Large buyers prefer to buy from larger farms that can guarantee quality of produce and have better measures and knowledge in place to control the fermentation process for beans. Consistency of delivery and fulfilling volumes of the contract is a real important value for buyers and got more challenging during this "cacao crisis" (interview 1 chocolate maker). For pulp, buyers also prefer to buy from larger farms, due to the small-time frame for refrigerating the pulp and the complications this implies for collection of pulp from smallholders.

The most named sustainability attributes for smaller buyers were (1) country of origin, (2) buying from smallholders, (3) increasing smallholder income, (4) specialty cacao from national (indigenous) varieties, (5) organic production and (6) circularity, waste reduction and environmental concerns. The EUDR adds to these attributes with the requirement that all produce exported or imported to the EU needs to be guaranteed deforestation free. Swiss companies importing and exporting are almost exclusively interested in organic produce that is sustainable. All these attributes are related to new business models that could be enhanced by more traceability and are based on a more individual story that is marketed and protected, which would increase in trustworthiness if traceability can show all these attributes up to the consumer.

Because of the introduction of the CSDDD/EUDR directives, all companies in Europe or trading with Europe have to ensure sustainability at all levels of the supply chain and establish a trusted traceable system, in a fair way. Current systems seem to lay the burden on small scale producers, that need to fill in multiple traceability tools and provide verified and certified information on their farms, even when a sale is not going through. These practices raise a number of questions about fair and equal trade responsibilities, with farmers looking for buyers' elders in the world.

The most common use of cacao pulp is to include cacao sugar or snips in chocolate to make chocolate exclusively from cacao. Local high-end producers such as Kamm, Paccari and others have all been experimenting with this technique. Also, European chocolate makers use pulp in their products as observed in the assortment of Lindt or Rittersport. These companies have been exploring by-products since 2019 (Fraunhofer, 2019).

4.4.3 Retailers and Hospitality Sector

Large retail companies and the hospitality sector are crucial partners in the cacao value chain as the final link between producers and consumers selling cacao products through supermarkets, specialty stores, online platforms, and cafes. Their closeness to consumers gives them substantial bargaining power in influencing consumer demand, shaping market trends, and determining pricing strategies. Retailers such as Lidl or Ecoplaza have used this influence to educate consumers on sustainability, while also providing a platform for new innovative products.

Given the size of most supermarket chains and their position in the market, supermarkets are vulnerable to consumer criticism and inflation and have recently increased their efforts to become more sustainable with many national extensive agreements for circularity. Supermarkets in Spain and the UK started to sell whole cacao pods as a specialty and novelty to address the more advantageous consumer segment.

While large retailers have the power to demand sustainably sourced cacao, recent cacao shortages have made them reluctant to do so. However, some major retailers are known for going beyond exercising pressure through purchasing policies and have committed themselves to providing training, research and making long-term buy-in commitments.

Pioneers in retail and selling cacao by-product in Europe are integrating fruit bits from cacao pulp in some of their products (CAPao, Nestle Incoa, BC and Lind Sprungli), but have not replaced other ingredients in their regular chocolate lines.

4.4.4 Consumers

From a survey among 55 consumers visiting the Chocoa event in Amsterdam in 2025, it resulted consumers are largely unfamiliar with cacao pulp and often refer to their experience and knowledge of chocolate when being ask on the information they require for a product. While most consumers state they want to be fully informed on all aspects of cacao when buying cacao products, they admit that the time spend on buying cacao products limits their ability to be fully informed. QR codes that have the potential to provide more information, add to the trust in cacao products, while a lack of information creates distrust among consumers. When the quality of cacao is not well communicated, consumers are more price sensitive. Thus, enabling a more data-driven consumer choice option through traceability of cacao can increase consumer trust.

Cacao pulp might be interesting for consumers given it has the potential health benefits that could result from replacing traditional sweeteners. Also environmental benefits from replacing other products with cacao products could be an incentive to include more cacao by-products in their diets. While it would be important to test consumer trust and attitudes towards cacao pulp in particular, this cannot be done in a trusted way as consumers are largely unfamiliar with cacao pulp.

4.5 Conclusion

While different value chain partners do not always value the same attributes in the value chain and trust is not necessarily defined by digital tools and responsibility goals, all partners in the value chain could incur potential benefits from more trust and traceability, pending further research into how the costs would be distributed and the cost-benefit calculation works out for individual cases.

The detection and visualization of key quality aspects of cacao beans and by-products can enhance collaboration in the value chain and make the value chain more cost efficient and transparent for other users of cacao products, too.

The cacao bean value chain can profit from more cost-effectiveness and data driven decision making, while the cacao by-product industry can profit from increased incomes and awareness of its qualities, best fit solutions for the use of cacao by-products and market development through increased access and availability of cacao products with trusted characteristics necessary for new processing methods.

Traceability increases transparency and can add to a more informed cacao value chain which enhances trust with consumers and other value chain relationships, while also enabling cacao buyers to provide relevant information for consumers.

Enhanced insights into the quality of cacao can unlock premium prices for farmers and chocolate and by-product makers alike, making them less sensitive to price comparisons among consumers.

5 Economics of Whole-Pod Processing, Values added, Prices, Volumes, Adoption of new Technology and Sustainability

While the previous section was mainly looking into what defines trust in the value chain and focused on disaggregating the different partners in the cacao value chain and their particular interests in enhancing cacao production, this section focuses on the different values that can be marketed and enhanced through traceability, whole pod processing and identification of quality aspects of cacao. We make a distinction in direct value aspects of cacao by-products, such as price and risk, and indirect values of cacao quality tracing, including the opportunity to communicate additional values and farm/farmer aspects through the digital data flow from farmer to consumer and back. Section 4.1 focuses on direct monetary aspects such as prices, market effects, operational costs, and market dynamics. Section 4.2 focuses on possible impacts that cacao whole pod processing can have on different partners in the value chain and beyond.

5.1 Identified Values in the Cacao Value Chain

In the cacao value chain, values play a crucial role in shaping sustainable and ethical business practices that go beyond mere profit generation. Stakeholders in this sector—ranging from smallholder farmers to multinational chocolate companies—often identify values such as fairness, transparency, environmental stewardship, community empowerment, and quality. These values help ensure that the benefits of cacao production are equitably distributed, ecosystems are preserved, and local communities thrive. Unlike profits, which are short-term financial gains, values guide long-term decision-making and foster trust, resilience, and reputation. To identify core values, businesses can engage in stakeholder consultations, conduct ethical audits, and reflect on their mission and impact. This process helps align operations with principles that support both people and the planet, ultimately creating a more resilient and respected cacao industry.

In the cacao value chain, the motivation for using Cacao-Tech technologies varies greatly between the different value chain partners and also per cacao product, beans or pulp. The project aims to contribute to three objectives:

1. The Cacao-Tech solutions should contribute to operational efficiency and better communication in the cacao value chain through enhanced technologies and more and better use of resources and data for forecasting, and inventory management.
2. The Cacao-Tech solutions should increase sustainability through circularity, the reduction of GHG, improvements in smallholder farmer resilience, and reduced risks of deforestation and contamination of soil and water.
3. Cacao-Tech should contribute to brand reputation of the value chain partners by turning an old-fashioned industry into an innovative data driven market-oriented value chain with a much higher earning potential for farmers and more attractive jobs for young people.

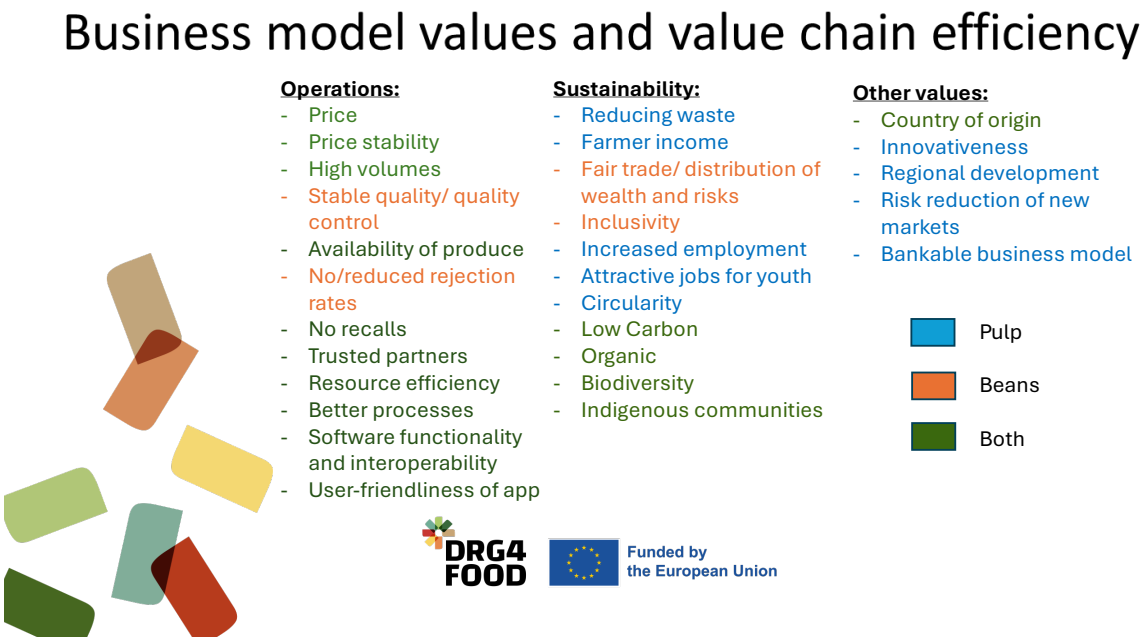

Figure 5-1 Values and value chain efficiency.

5.1.1 Insights into Prices, Price Stability and Volumes Traded

The current market dynamics present both opportunities and challenges for investment in cacao pulp exploration. The increased profitability of cacao farming may encourage diversification into cacao pulp products and provide valuable incentives for a long-forgotten industry. However, the volatility in cacao prices and the associated risks and uncertainties may deter investment in new ventures. Moreover, the lack of a national mapping and traceability system in Ecuador, as required by upcoming European Union regulations, could hinder market access for new cacao-derived products.

Ecuador's cacao sector has experienced unprecedented price surges in 2024, driven by global supply constraints and market speculation. While these developments have provided farmers with higher incomes and export revenues, they have also introduced significant challenges, including market volatility, investment uncertainties, and heightened industry risks.

In 2024, Ecuador experienced unprecedented high cacao prices, with peaks reaching up to US$12,000 per metric ton in April, a substantial increase from the typical US$2,000–US$4,000 and even premium prices usually in the range of US$10,000. This surge is primarily attributed to a decreased production in major cacao-producing countries such as Ivory Coast and Ghana due to adverse weather and disease. (Avadi, 2023). Ecuadorian farmers have benefited significantly, realising between 80% and 90% of the world market price increase. This has led to increased investments in cacao cultivation, with projections of annual production reaching 0.5 MT in the next two years (Anecacao, interview 06-03-2025). This will potentially position Ecuador as the world's second-largest cacao producer. The high cacao prices however cause input sourcing, quality, certification, and loyalty issues. Price volatility impacts trust within the supply chain, with some cooperatives reporting decreases

in production volumes due to drought or flooding by 70%. Most farmers sell directly to any buyer who comes by and pays in cash as they cannot afford to wait to fulfil agreements and loyalty obligations.

While cacao prices increased farmer income, exporters face liquidity challenges due to the increased costs of purchasing cacao at elevated prices, impacting their ability to fulfil contracts. Additionally, the high prices have led to increased costs for chocolate manufacturers, resulting in higher consumer prices and production reductions. Many chocolate makers are concentrating on key markets (interview chocolate maker, 06-02-2025, 10-12-2024) and effectuate major cost cuts to counter high prices and liquidity challenges.

Speculation in the cacao market has further exacerbated price volatility, with speculative funds entering the market and driving prices to unprecedented levels (Guardian, 2024). This volatility poses risks to all stakeholders in the cacao supply chain including the need for larger amounts of liquidity at all levels in the value chain, leading to increased uncertainty in the sector and new unaccounted risks. In addition, the high level of liquidity does pose additional security risks to large farms, aggregators, and transporters as criminal activities increase.

Value chain partners would benefit from increased insights into market prices and traded volumes to make better predictions on their income and investment capacity and to better manage liquidity risks in the value chain. Understanding price developments and quality aspects of cacao traded on markets will also help farmers to align with each other on prices in cooperatives and other forms of sales. Tracking and traceability of produce, more insights into local amounts of cacao produced, having information on cacao prices at international markets and being able to follow cacao produce from farm to buyer - and receiving feedback on the quality of their produce form buyers - will provide the much-needed transparency in the market to secure income, invest and be able to take calculated risks.

5.1.2 Consistent Cacao Quality

Cacao's quality is influenced by a range of agroeconomic, post-harvest and environmental factors. The cultivar or variety of cacao produces different flavours with the National/Arriba variety being used for fine cacao and the hybrid variety of CCN-51 being more resilient, producing more cacao and growing faster. Other less common varieties, such as Criollo or even the rare white cacao are, despite their better quality and flavour usually just added to other cacao batches, because it is too expensive to collect them separately. Weather conditions such as humidity and drought, soil quality, tree productivity, farming practices, pest control and pruning impact pod quality and overripe or underripe pods influence the quality of cacao beans and cacao pulp. Harvesting techniques such as proper timing, careful pod opening to prevent contamination and damage to beans also influence cacao. Cacao should be harvested when fully ripe for optimal sugar and acid balance. Cacao beans undergo an additional fermentation step for proper flavour development. Duration of this process, temperature of fermentation and frequent turning to reduce excess moisture as well as overnight pre-drying or the use of dryers after fermentations are all steps to be conducted according to expert judgement with only visual tests, individual tasting and some expensive laboratory tests at certain points in time as aid. Storage and transportation risks add to the process. Unfortunately, rejection rates of produce from farmers are not openly

shared as information. Thus, we can also not evaluate the loss in value and food loss resulting in low quality produce.

While NIRS (Near Infrared Spectroscopy) are commonly used in labs, its potential in the field for standardising quality control is significant and underexplored. The technology could streamline post-harvest processes, reducing the reliance on subjective cut-tests and costly laboratory tests. Results could become available for any quantity; whole batches or small buckets can be scanned, and results become available in real time.

Using Cacao-Techs' newly developed data sets on cacao quality creates new possibilities for quality control. The non-invasive unlimited real time scans monitor quality control values after the prior identification of key quality control measures. In the cacao value chain these have the potential to effectively reduce the amount of under- and over fermented beans, reduce food safety risks, identify freshness of pulp, reduce bitterness in cacao beans and identify a minimum quality of cacao necessary for large buyers to maintain quality standards in the industry. Not all aspects have been fully developed in Cacao-Tech that focuses on two easy to evaluate characteristics, sugar content and Brix in the pilot, but there is a large potential of uses for quality parameters defined by NIR scans. The increased availability of quality data can also improve farming practices and feedback from buyers to farmers can improve cacao quality further in the future. While the initial calibration and the investment in hand scanners are considerable, once these are produced, better produce, less food loss and less under and over fermented beans and pulp have gone off.

5.1.3 Availability of Produce

Having a clear overview of what volumes and what quality of cacao are available, where, and when is essential for all partners in the cacao value chain—from farmers to exporters to chocolate manufacturers. Knowing quality and volumes in advance helps processors to plan production, logistics, and make more accurate inventory. Timely information allows exporters and buyers to respond quickly to market demands and price fluctuations. All of this reduces waste; it prevents overharvesting, spoilage, and storage issues, especially in regions with limited infrastructure. Transparency about what produce becomes available is key to fairer prices. Harvest results per week from last years' harvest can provide a good start for harvest forecasts this year if adjusted with, for example, weather information. More data on production also increases compliance with sustainability standards and food regulations. Comparing volumes from last year and over time also can prevent food adulteration, thus preventing cacao from undefined origin from getting into a certified and deforestation free value chain.

All of these opportunities result from data support and digital tools and platforms that Cacao-Tech provides. Educating farmers in record keeping and using digital tools provides them with quality information for on-farm management. Already existing local information on registered fields and farms and organic certification can be connected to information on availability of produce for stronger partnerships and communication between actors. However, this also requires high quality accuracy in information on available produce. While traceability often involves a lot of record keeping, which is prone to data entry mistakes, taking this information from scans is more reliable and less work. EUDR and other regulations put a high administrative burden on farmers to fill each buyer's traceability system without being ensured of a buy. Using NIR scans as a basis of traceability reduces admin procedures and adds quality information.

5.1.4 Traceability is Key to Food Recalls

Food recalls are a serious challenge for almost every business in terms of organisational costs and reputation. Time is of the essence. Traceability is key to effective management of food recall. While food recalls are rare, they have a high impact and investments in preventing them, and a good information system through cost-effective scans can better reduce risk than incidental laboratory tests. While not part of the project, there is potential to make food recalls effective.

5.1.5 Trusted Value Chain Partners

Trust in the cacao value chain is currently not based on objective quality and management indicators, but replaced by other more subjective values, such as treating one like family. In the absence of objective measures, a subjective cut test replaces quality control, and good business practice is the basis of trust. Adding quality evaluation and traceability to current business practices, might lead to very different results then current business practices have, for example when farmers discover that they do not deliver the quality they think they have, they will not easily accept new technology. At currently 85% accuracy, there are good prospects that quality measures can actually implement more trust in the long run.

5.1.6 Resource Efficiency and better Processes

Introducing traceability and data-driven quality control into the cacao value chain can significantly improve resource efficiency and process optimisation. With traceability, stakeholders can pinpoint where inefficiencies or quality issues occur (e.g., poor fermentation at a specific cooperative). This allows for targeted small interventions that are less costly. Understanding the flow of inputs and outputs can optimise the use of the inputs. A controlled fermentation process in the case of beans minimises spoilage. Key aspects are a digital infrastructure and easy access to stored information, e.g. by using AI bots. Farmers have a low affinity for digital tools, but the introduction of digital tools can make the sector more attractive for young employees. Agreed quality indicators and protocols can be integrated in the data process and can eventually lead to shared standardised metrics. Ethical sharing of data and fair data governance across different actors can enhance clear communication and will be explained in more detail on p.41.

When cacao arrives in Europe, it is a big deal and loss for traders and bean buyers, when a batch is rejected for its purpose. Beans for human consumption is the most delicate value, in particular Cadmium concentrations make beans unfit for human consumption. Often warehouses do not store a load when its quality is doubted. The buyer or trader will be called, and this person will do additional lab testing and find a new buyer for the batch, for example in the cosmetic industry where cadmium is not an issue. Producers are understandably not very open about rejection rates. In case a batch is rejected, the damage is mostly carried by insurance which will investigate. Developing better inhouse quality control, is the best way forward.

The following table provides an indicative calculation for the impact of digital cacao quality monitoring from the pilot. It follows a Theory of Change model (TOC, https://impactmanagementplatform.org/impact/) describing the inputs used for quality control, the activities performed and valued, the output, the outcome and the impact for the 3 most valued impacts. For a more exhaustive way of definition and formulation of the TOC

can be found on the impact management platform. Value chain partners ranked the impact pathways according to their needs: stable cacao quality (Table 5-1), reduction of waste (Table 5-3) and farmer income increase (Table 5-4).

Cacao quality refers to the use of NIR technology (non-invasive) scans in the testing and evaluation of cacao, currently done with a so called cut test and additional laboratory testing.

Impact pathway	Stable cacao quality and better use of resources
Inputs	NIR scanners are provided by few companies globally and are customised towards the specific uses. Those requiring smaller ranges of waves are usually around 2,000-3,000 euros but can get as expensive as 30,000 euros. The initial investment replaces the use of beans and produces for laboratory testing and replaces the laboratory tests, providing results in real time.
Activities	Scanning of batches at multiple stages in the cacao bean value chain for over and underfermentation, microbiological analysis and residue testing will replace other subjective testing methods. Beans testing at multiple stages (on farm quality check, before transport, on arrival in warehouse) each time requires the opening of a bag, and all beans are wasted, which will be done with a non-invasive scan. No need to extract beans from bags. Over and underfermentation can lead to the rejection of whole batches at multiple stages in the value chain and can be better controlled and the level detected with a scan providing a degree of quality. The discovery of traces from pest and disease or other contaminations (e.g. with heavy metals) makes whole batches unsuitable for human consumption and there is a need to find other destinations to avoid spillage, which can be found out at the source with a scan, shared data, exchange of information and traceability, which leads to transparency.
Output	Quality aspects of a particular cacao batch will be shared through a platform with all value chain partners, most likely for beans, other uses to be investigated. These range from sugar content, fermentation stage, flavour aspects, disease and pest, food safety aspects, fat, fibre.
Outcome	Increased value chain efficiency and reduced waste from non-invasive testing and reduced over and underfermentation. Exact amounts need to be investigated: In a standard industrial cacao supply chain, quality control testing is conducted at several points: at the cooperative or buying station, the exporter's warehouse, third-party certifiers, and upon arrival in Europe. At each stage, small samples are taken— usually 300 to 500 grams per bag—from a selection or composite of bags. Across all steps, approximately 25 to 45 kilograms of beans per lot (usually one full container) are taken out. Due to handling, testing, and disposal (e.g. for microbiological or residue analysis), this results in a total effective loss of almost one full bag (about 65 kg) per 40-foot container (own calculations). Cargill sources an estimated 500,000 metric tons of beans per year according to their website, which translates to roughly 30,800 containers (based on 16.25 metric tons per container). At one 65 kg

Impact pathway	Stable cacao quality and better use of resources
	bag lost per container, this means around 2 million kilograms (2,002,000 kg) of beans are lost annually in quality control processes. With current prices around US$9 per kilogram (https://tradingeconomics.com/commodities), this equates to a total estimated value loss of approximately US$18 million per year—purely from quality control sampling and testing procedures, not even quality losses.
Impact	Impact would be measured as the reduction in food waste by X%, equivalent to a reduction in CO_2 emissions from X%. Additional research is required to determine results in practice and cannot be based on the small pilot included in this study. The production of 100 kilogram of cacao beans generates approximately 1.47 kilograms of CO_2-equivalent emissions. This figure includes emissions from land use change, cultivation, and initial processing stages (Vervuurt et al., 2022) Applying this to the estimated 2,002,000 kilograms of cacao beans lost annually through quality control processes, we can calculate the potential CO_2 impact of reducing that waste. For every 1% reduction in waste—equal to 20,020 kilograms of cacao—the equivalent reduction in emissions would be around 294.29 kilograms of CO_2-equivalent. A 10% reduction would therefore result in a savings of approximately 2.9 metric tons of CO_2-equivalent emissions per year. These estimates indicate how relatively small reductions in post-harvest loss can make a significant measurable difference in the cacao sector's carbon footprint.

Table 5-1 Expected impact of using NIR-based quality control on value chain efficiency.

From the tentative impact and outcome calculations for the cacao bean value chain it shows that the use of NIRs has the potential to lead to considerable cost savings in the cacao value chain. In particular for larger aggregators, that collect from multiple farms through middle men, this alternative is attractive, while it also reduces waste and CO_2.

Different value chain actors value different aspects of operational efficiency in the value chain. The following table shows which actors attach importance to what key values.

Values	Important for beans, pulp or both	Large farm	Smallholders	Association	Transport, storage and warehousing	Processing	Buyers	Consumer
Price	Both	X	X	X				x
Price stability	Beans	X	X	X			X	
High volumes	Both	X		X	X	X	X	
Stable quality/ quality control	Beans	X					X	
Availability of produce	Both			X			X	
No/reduced rejection rates	Beans	X		X	X		X	
Fast reliant recall infrastructure	Beans	X		X	X	X	X	X
Trusted partners	Both	X	X	X				
Resource efficiency	Pulp	X	X	X		X		
Better processes	Beans	X				X	X	
Software functionality and interoperability	Beans	X		X			X	
User-friendliness of app	Beans		X				X	X

Table 5-2 Expected benefits in operations.

5.2 Sustainability Impacts of Cacao Quality Tracing and Pulp Extraction

Sustainability in the cacao value chain is essential for ensuring the long-term viability of the industry.

5.2.1 Waste Reduction and Circularity

Circularity is a value developing rapidly in Ecuador. It is developing more rapidly than certification schemes. UNOCACE has several projects with partners from Europe on circularity. The reason this are that farmers have the opportunity to valorise more products from cacao, and this might increase the profitability of cacao, the sustainability of value chain partners and might reduce pressure of climate change.

Farmers are cautiously optimistic regarding the profitability of in particular cacao pulp, bioplastics and biochar for which emerging markets are shaping by technological innovation and increasing sustainability incentives of cacao buyers and other industries that want to become fossil free. Interviews with stakeholders in the region revealed that many farmers have been experimenting with cacao pulp extraction and are trying to create additional value streams. Cacao pulp is available in supermarkets in Ecuador. While early growth of the market was promising, Covid hampered the development of the industry, which is why at this moment in time it is difficult to say if there is real market growth. However, several indications show that there is: about 40 companies globally currently work with cacao pulp, some larger players start developing cacao pulp as a product and some key challenges, such as expensive technology to develop shelf-stable products from highly perishable pulp are becoming more affordable and new products form pulp emerge. The use of smart technology is levelling the playing field through real time market data, weather forecasts, precision farming that reduces the use of pesticides or organic plantation that makes more parts of the cacao suitable for human and animal consumption as well as increasing biodiversity. New cacao products are easier findable through the internet and online marketplaces (tropicalcacao.com).

While carbon credits in Ecuador will need a change of governance first, it is on the agenda of policy makers (MAATE, 2023; Palma 2024). Cacao farming has a rather low carbon footprint, compared to other industries. The practice of agroforestry and regenerative agriculture can sequester carbon by planting cacao alongside trees that absorb carbon, although at this moment in time only 20% of farms are agroforestry farms, while 80% are monocrop farms. In particular timber can sequester carbon and deliver additional investment opportunities. While this is not everywhere the case in Ecuador, farmers are very interested in biodiversity and restoration of ecosystems.

Impact pathway	Avoided food waste/ increased use of resources
Inputs	Depulper, hygienic products, extra buckets and extra means of transportation if whole pods are transported (not necessary in current situation).
Activities	80% of the cacao pod is wasted. Project produces cacao ingredients from cacao pulp, reducing cacao waste by up to 30%; 91% of pulp is disposed on farm in Ecuador (Franco, Unpublished data).
Output	Pilot: 4,000 kg/day from 1 farm, x 200 days. Also, other farms are producing pulp or have the capacity to produce pulp. Limitations to pulp extractions are on the demand side. The new market needs to develop.
Outcome	Estimations of waste that can be avoided in Ecuador are derived from the amount of beans traded in 2022. Ecuador produced 0,375 MT of beans in 2022, which is 20% of the cacao pod. Pulp is 30% of the cacao fruit, thus the potential is to remove 0,6 MT pulp/y in Ecuador (2022) and globally 7.5 MT pulp/y. This provides a large potential to reduce GHG emissions from cacao waste. GHG emissions need to be investigated in an LCA. As an example: avoided GHG emissions from spray dried pulp (produced in Ecuador and traded in Switzerland) has positive effects in 11 out of 18 GHG categories based on LCA (ReCiPe method, Franco, 2025), impact

Impact pathway	Avoided food waste/ increased use of resources
	on global warming – 19.6 kg CO_2-equivalent per 1,000 kg of unmanaged pulp (FAO, 2021).
Impact	Globally an estimated 7.5 million metric tons (= 7.5 MT) of pulp/year is available. This potential can be accessed through adoption and replication of the current and a needed 50-90 new companies exploring the market, assuming an average capacity of between 1,000 to 6,000 metric tons.Pulp producers expect the market to grow and prepare to meet future demand. The production capacity is expected to grow at least threefold, with investments in processing, logistics, and partnerships.

Table 5-3 Impact of valorisation of cacao pulp in terms of waste reduction, GHG emission reduction

5.2.2 Living income of smallholder farmers

Rikolto (2024) estimates that there are more than 85% of cacao and coffee producers in Ecuador that live on an income that's under the living income benchmark. They are also vulnerable to the effects of climate change, meaning that harvests are decreasing as a result of climate change and an increasing number of plant pests and diseases. While there are different benchmarks, the living income in Ecuador is approximately US$8,201 per year (figures for 2021, last calculated benchmark). The living income benchmark is up to 1.6 times the minimum wage, even though Ecuador has one of the highest minimum wages in Latin America. While the real income of these farmers is estimated to be US$1,400 to US$4,000 per year (Solidaridad, 2023). It needs to be noted here that after 2021 the cacao price increased tenfold and new calculations should be made soon.

There are about 189,000 cacao farmers with an average of 3.32 hectares per household with a median of 1.1 tons of cacao per hectare and cacao being about 60% or more of the annual income. The estimated additional income comes from other crops or work outside the farm. (Solidaridad, 2023).[2] With small farms the average productivity is lower, about 0.53 tons per hectare.

Activities to increase the income gap according to Solidaridad are firstly, to increase productivity. A productivity increase of 33% could lead to an extra US$618, - per year. These numbers however do not consider the price reductions resulting from a higher supply of cacao. Providing farmers with feedback on the quality of their cacao is important to achieve this 33% of extra productivity. This information comes from channelling quality information from cacao NIR scans back to farmers that can base productivity and harvest calculations on these figures. If prices would be linked to certification schemes (organic, carbon farming, etc.) another US$233,- impact on net income could be realised. Traceability is an enabler for premium prices, as premium prices are only paid if organic or low carbon farming practices can be guaranteed.

[2] Solidaridad bases its data on collected data from Nestle's Agri-services from Cacao Plan

Observations and information from missions to Ecuador show however, that prices are at this moment on plafond and buyers cannot pay more for certified cacao. With additional sources from other on-farm income, the living income gap could be reduced by 16%. This reduces the interest of farmers to be certified (Interview UNOCACE 04-12-2024). The remaining income gap needs to come from other farm production.

Cacao pulp is one of the options that could raise the living income.

Impact pathway	Increase in living income smallholder farmers <4ha
Inputs	Pulp is naturally harvested by farmers together with the beans. There are no extra inputs needed on farm level. It might be however, that processes need to be redesigned on farm to adjust the very small window before pulp perishes (extraction within 8 hours), some hygienic/food safety measures are needed to be taken into consideration which could require farmers to buy gloves or extra buckets. For pulp no extra means of transportation are needed, but for whole pod harvesting about 30% of smallholder farmers said they would need to rent a car/truck to deal with the larger volumes. Training of farmers might be required.
Activities	Collect pulp next to beans, extraction and collection of pulp becomes an extra step in the postharvest process. Whether farmers can realise an extra income from pulp as a food depends mainly on whether they can manage the 8-hour window to extract and cool pulp professionally.
Output	Pulp collected from farmers enters the value chain and will be sold as ingredient for drinks and other foods. The difference in weight (and price) between wet and dry cacao pulp is about 35%. Estimations assume that between 50-80% of pulp can be extracted from wet beans, meaning that the extra income is also in this range (Interview UNOCACE 07-03-2025). The estimated average farm gate value for cacao is US$250 per hectare, thus a US$1,000 for 4 ha. About 35% is pulp and 65% is beans. The pulp surrounds the beans and some of it is needed for their fermentation. Therefore, only about 70% of all pulp can be extracted and valorised. This corresponds to an extra income of US$61,25 per hectare (250*0,35*0,7), or about US$245 for 4 ha.
Outcome	The cacao pulp decreases the gap with the living income. How much contribution to the living income can be achieved on a given farm depends on trade-offs in needed labour, purchase of materials for hygienic/food safety measures and transporting capacity. This requires further investigation. While the potential is large, not all farms might be accessible for whole pod processing.
Impact	Cacao pulp decreases the income gap to the living income (living income is approximately US$8,201 per year in Ecuador, figures for 2021, last calculated benchmark). While the income of smallholder farmers (1-4 ha) is estimated to be US$1,000 to US$4,000 per year (Solidaridad, 2023), an extra US$245 could be earned from material currently wasted, the pulp alone.

Table 5-4 Expected impact of pulp valorisation on the living income of smallholder farmers.

5.2.3 Fair Trade/Distribution of Wealth and Risks and Inclusivity

Fair trade ensures that cacao farmers receive a fair and stable price for their beans, which is crucial in the cacao market that is dominated by buyers and characterised by volatile price developments. While cacao buyers can ensure the risk of price volatility at the commodity futures market, farmers and in particular smallholder farmers rely on the sale of cacao for their income. Fair trade guarantees avoid exploitation of farmers. The fairtrade organisation invests in communities to build housing and schools and helps farmers to gain access to markets. Traceability or block chain models can interconnect value chain partners and buyers can help farmers by passing on the risk protection achieved through insurance. Most smallholder farmers are part of cooperatives, and these are organised in UNOCACE to increase bargaining power and inclusivity.

5.2.4 Increased Employment and Attractive Jobs for Youth

With an average farmer age of 54 and many small plots of land that get divided over and over again, cacao production is not an attractive profession anymore. Adding technical components to farming interests young people and provides new opportunities in monitoring harvests with drones, precision farming and new business models based on traceability. The NGO Yocotoco reported from their studies that young farmers got interested in conservation efforts through tracing wild animals and identifying biodiversity with new technological means. This opens the way to new attractive jobs in rural communities.

5.2.5 The Valuation of Certification Schemes and Premium Prices

Traceability is an enabler for premium prices guaranteed through certification schemes guaranteeing organic production, low carbon practices, biodiversity efforts and acknowledging indigenous communities' and women's agency in cacao farming. However, identifying the exact quality of cacao provides more security, transparency, and trust as we concluded based on our interviews.
The following table gives an overview on the distribution of values in the value chain. All values identified are depicted on the left side. The horizontal axis shows at what stage in the value chain the values are perceived and can be realised.

Values	Important for beans, pulp or both	Farm level	Association	Transport, storage and warehousing	Processing	Buyers	Consumer
Reducing waste	Both	X	x	X	x	X	X
Farmer income	Both	X	x			x	x
Fair trade/ distribution of wealth and risks	Beans	X	x			x	X
Inclusivity	Beans	X	x				X
Increased employment	Both	X	X				
Attractive jobs for youth	Both	X	X				
Circularity	Both	X	x	X	x	x	X
Low Carbon	Both	X	x	X	x	x	X
Organic	Both	X	x			x	X
Biodiversity	Both	X					X
Indigenous communities	Both	X				x	x

Table 5-5 Sustainability impacts expressed important by participants in the cacao value chain.

5.3 Other Values in the Cacao Value Chain

5.3.1 Country of Origin

Most value chain partners name the country of origin as information they want to know. The country of origin corresponds with Ecuador's' findings that the origin of cacao was probably in Ecuador, and it also underscores the importance of Ecuador as one of the countries with the best cacao. The National Arriba variety is internationally seen as one of the best cacao flavours, even though most cacao farms planted CCN-51 during the last years mainly cacao monoculture. The price of Arriba cacao is also slightly higher than the price of CCN-51 cacao, even though under current prices this difference is getting smaller. In particular small chocolate makers market the origin of cacao as a value of quality or want to address those consumers that have a personal bond with Latin America. For large farmers, the current growth of Ecuadorian cacao is a remarkable achievement, and they are therefore proud to market country of origin labelling. Also, many human rights problems are less pronounced in Ecuador than in African cacao exporting countries, which is something that makes farmers distinct from other export nations. Some buyers have expressed to particularly not wanting to buy from West African sources because of the issues in West Africa.

5.3.2 Innovativeness of Ecuadorian Cacao Industry

Ecuadorian farmers like to mention their innovativeness to attract new markets, but also to show that they are addressing sustainability issues such as climate change and circularity. Being innovative is also seen as a way of showing the quality of cacao. The uniqueness that front runners can have in the cacao market can lead to higher prices and it shifts the perception from merely being a bean supplier towards a promising innovator that invests in the quality of its produce. It shows their engagement in business relations and moves them from supplier to co-creator of trends and creator of values in the market. Many associations see their added value in bringing innovation to in particular smallholder farmers and many international buyers also invest in innovativeness and new on farm machinery. Consumers are in general also fascinated by storytelling of craftmanship, ingenuity and inventiveness, while also wanting to see developments towards more sustainability and environmentally friendly sourcing in particular in an industry that sells luxury products. Farmers often use digital tools, tracing and tracking for the mere purpose of marketing their farms credentials with videos attached and stories told.

5.3.3 Regional Development

Like innovativeness, contributing to a dynamic regional industry is seen as a way for farmers to distinguish themselves from being mere bean suppliers, positioning instead as co-creation partners and important players in the region. It often also shows farmers involvement with the community and local values as well as their contribution to prosperity. This is important for attracting donor money and subsidies for the region.

5.3.4 Investment Climate

In particular for pulp production, it is important to show the profitability of pulp extraction and create a sense of innovativeness and technology development in the industry that enhances newly developed products from cacao, while also contributing to sustainability. For attracting investment, it is imperative to show that there is a growing pulp industry developing high quality products that sell on the market. Investors need to believe in a growth story, showing that new developments are the future and not merely a hype.

Values	Important for beans, pulp or both	Large farms	Smallholders	Association	Transport, storage and warehousing	Processing	Retail	Consumer
Country of origin	Beans	X	x	x				X
Innovativeness	Both	X		x		x		
Regional development	Both	X	x	X		x		
Investment climate	Pulp	X		X		x	x	

Table 5-6 Other values.

5.4 Conclusions

Developing Cacao-Tech might bring a variety of value to the Ecuadorian industry and enhances the position of European traceability-based business models enhancing ethical and sustainable cacao production. The direct cost benefits of addressing quality control at key points in the value chain alone might save millions in costs in the industry and enhance trust and traceability through less cumbersome data collection and higher data quality, resulting from scanned information compared to manual data entry in other solutions. Introducing new products from the cacao fruit can enhance the industries' sustainability and provides additional income sources for farmers, in particular smallholder farmers. It is a solution for systemic and the more complex problems that the industry has to overcome, such as increasing trust and transparency.

6 Data Infrastructure and Digital Support Tools for Traceability and Quality Assessment

This chapter summarises the results from the digital tools analysis required to support the cacao value chain. The analysis focuses on traceability and quality management. Initially, it defines the key concepts, including the enabling technologies. Next, it outlines the specific requirements these systems must meet within the cacao value chain. Existing solutions for cacao traceability are then mapped and analysed. The chapter concludes with identifying key gaps to be addressed for the development of traceability systems tailored to the needs of Cacao-Tech.

6.1 Key Digital Technologies for Traceability and Value Chain Information Management

Cacao traceability systems consist of three digital technology layers (based on Atzori et al., 2010; Ma, 2011; Verdouw et al., 2016): the device layer, the integration layer and the application layer.

The device layer contains a mix of autoID generators, such as barcode scanners, RFID transponders or personal appearance or DNA identification devises; sensors that measure biochemical and photonic components and remote sensing technology collecting information from a distance, such as satellites or drones. In the cacao value chain, these are rarely used due to its fragmented character. Cacao-Tech uses a proximal sensing reflectometer (handheld NIRs, https://www.viavisolutions.com/en-us/osp/products/micronir-spectrometers) because of its unique technical features—such as thermal stability of signal, signal range—which are essential for capturing a high-quality and stable NIR reflectance curve suitable for predicting the composition of biological material. Once the prediction model is built, multiple features of biological material (e.g. moisture, fat, brix) can be predicted from a simple scan of cacao beans and cacao pulp (other aspects are possible). The cacao quality estimation from the scan is equipped with a time-stamp, can be done without laboratory testing and without manual entry of data. Consumers could reach the information through QR codes associated with the product.

The second layer, **the integration layer**, then defines the way data is processed, managed and shared. Options include linear data sharing, centralised data platforms, distributed data sharing and federated data sharing. Linear data sharing moves data point by point from one partner to the other, the most common way of data sharing at the moment. Other forms include centralised data platforms that collect, store and control data from various sources into one shared data base. Both do not meet the high standards of the DRG4FOOD project. The cacao industry is highly decentralised which needs to be mirrored in the Cacao-Tech structure, which collects, manages and shares decentralised data through exchange consent across the value chain. ***Data Spaces*** are important enablers of this approach, allowing participants to retain direct control over their data, but agree to share it through standardised interfaces and governance frameworks. Managing decentralised data-spaces is, however, a challenge particularly due to different data structures and cybersecurity measures which are different and are not compatible at all stages in the value-chain. Another important federated concept which should be seriously considered in the future,

are ***Data Trains***, that enable data processing across multiple, decentralised data sources—without sharing the data itself. Instead of transferring raw data between organisations, a data train moves to the data, executes the algorithms locally and only shares the (non-confidential) results. While data trains would be the preferred option, there is not enough open-source information available yet and the concept is not sufficiently crystallised at this moment in time. **Interoperability enablers** (i.e. FAIR=findable, accessible, interoperable and reusable data principles) are used to support the data integration and allow the different types of data to 'speak the same language' by proving common agreements on the format, content and meaning of the information to be shared (i.e. messages, codes) as well as on the method by which they are to be communicated technically. The currently developing trend in the food industry is to standardise metadata structures, which is soon going to be reflected in legal requirements such as the digital product passport (https://data.europa.eu/en/news-events/news/eus-digital-product-passport-advancing-transparency-and-sustainability). Cacao-Tech is future proof as it applies the standard FAIR metadata structures that are currently being established in plant/crop research (BrAPI, MIAPPE, the appropriate phenotyping standards) and applied/tested in other on-going food-related projects (e.g. METROFOOD). In the future, these FAIR data systems are to significantly transform the food industry. The DPP (Digital product passport) is designed to close the gap between consumer demands for transparency and the current lack of reliable product data. Particularly, DPP is bound to enhance transparency across product value chains by providing comprehensive information about each product's origin, materials, environmental impact which aligns well with Cacao-Tech aims.

Finally, artificial intelligence adds another layer to the technology package, **the application layer**. Cacao-Tech uses analytical AI methods (e.g. CNN=convolutional neural networks, random forest, MPL = multiprogramming language) in its NIR data processing analytical chain that enables the determination of quality of cacao from its spectral NIR signature. In Cacao-Tech, these algorithms identify multiple biomaterial characteristics of cacao from a single non-invasive scan and can replace subjective cacao quality tests. Current accuracy levels reach ~90% e.g. for the estimated cut-test categories. Additionally, data is directly created from the scan and automated to avoid manual entry, often prone to data tempering, common typing mistakes and human errors.

6.2 Requirements Cacao Value Chain

The Ecuadorian cacao value chain is becoming increasingly complex due to growing regulatory, consumer and market demands. Ensuring traceability, quality of produce and managing chain information in cacao value chain would provide a number of benefits to all stakeholders. First, with stricter organic regulations and the EU Due Diligence Regulation (CSRD) at the door, the need for enhanced traceability in the cacao value chain is more pressing than ever. Also, the EU Deforestation Regulation (EUDR) requires proof of deforestation-free and traceable cacao. Second, programmes such as Fairtrade, Rainforest Alliance, and organic labels are pushing for traceable practices to verify social and environmental claims. Third, there is increasing retailer and buyer pressure demanding traceable cacao to meet their own sustainability goals and reporting obligations including an increasing number of speciality brands that use traceable cacao to market "bean-to-bar," single-origin, or sustainably sourced products, which often command higher prices and consumer loyalty. Also, investors and lenders increasingly require traceability and sustainability data to support ESG (Environmental Social and governance)-compliant

financing. Smallholders with traceable, verified practices may also gain better credit access. Finally, civil society organisations and NGOs (non-governmental organisations) increasingly promoting ethical practices, often by demanding end-to-end traceability to hold supply chain actors accountable.

However, it is not easy to address this increasing need for traceability. Key challenges to overcome include the fragmentation of the cacao value chain, a current lack of trust and lack of infrastructure to use data between cacao value chain partners in Ecuador. The VC heavily relies on outdated processes and limited collaboration in the cacao sector on capitalising on available technology and market opportunities. The large presence of smallholder farmers (>70% of farms) and small intermediaries and aggregators create a complex, disconnected network of on-the-spot sales without any verification of cacao quality. The fragmentation also means that the use of technology needs to be at low costs, affordable for everyone and available everywhere, anytime and for flexible purposes in the field. This poses high demands on technology usually used in scientific laboratories.

The lack of trust and differences in cultural values means that data sharing is largely underdeveloped and replaced by personal connections with no transparency and limited formalisation of agreements in the sector. With much room for atomisation and digitalisation of time consuming and produce consuming tasks, operational costs could be substantially lowered and subjectivity in quality control could be eliminated. Technologies such as NIRS (Near Infrared Spectroscopy) could significantly improve the efficiency and transparency of quality control processes. These tools have the potential to streamline operations and create more trust among value chain partners, especially in an industry where standardisation is still in its infancy. The existing distrust also means that value chain partners need to have the agency to decide when and with whom to share data until objective quality standards have crystallised and can be met by farmers.

The requirements of the value chain stakeholders were investigated in in-depth semi-structured open interviews (n=9). The respondents were carefully selected with respect to the relative importance (key stakeholder for the Cacao-Tech project) and having a balanced group of respondents. The respondents included a farming cooperative in Ecuador, 3 manufacturers, 3 trading companies and 2 NGOs. We asked open questions about needs and wishes, as well as barriers and opportunities. In the analysis we related the responses the DRG4Food key themes (Figure 6-1). The results show that digital literacy, transparency, data fairness and privacy are the most frequently addressed digital responsibility goals.

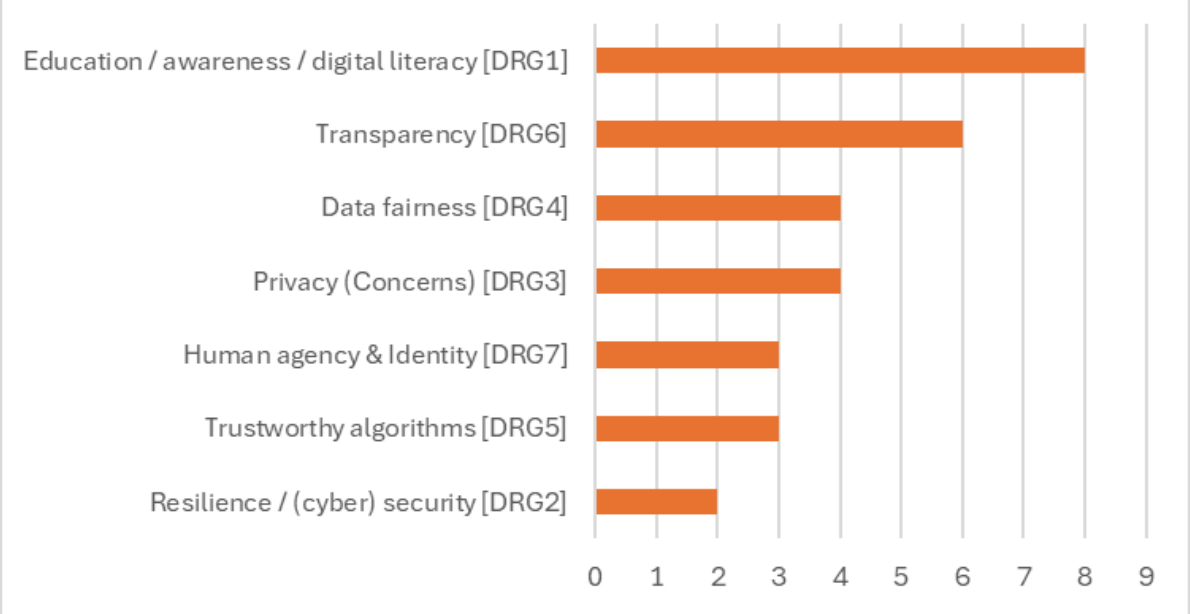

Figure 6-1 Main Digital Responsibility Goals (DRGs) addressed by the interviewed value chain stakeholders (excluding consumers).

Furthermore, the interviews showed that stakeholders generally call for practical, low-cost systems with a high level of interoperability. The EUDR is a highly important topic in this regard, and tools that support compliance are in high demand. The main challenges mentioned include data verification, data ownership, and cooperation among partners. However, there are nuances in information needs between farmers, cooperatives, manufacturers, traders and NGO's promoting fair trade. These are summarised in Table 6-1.

Farmer cooperative	Manufacturer	Trading company	NGO
• Concerns about **Data ownership** • Wants system with **data integrity** & **verifiability** • Ensuring product **transparency & credibility in** VC • Recognising/ rewarding **good practices** • Knowing how to address **issues with data deviations and malpractice** is key moving forward	• Would like to see **transparent info on payments** in the value chain • Values **integrity** • Trust is good but **proof is better** • Often knows the farmers personally – **more motivated to convey info accurately**	• Customers just want the **cheapest product** • Worried about **being too transparent** with the data and l**osing business** • Concerning with **reliability and accuracy of data** • Finds it hard to get **specific info from value chain** – further away from source • Needs **improved communication** between stakeholders	• Would like to see **more transparency both ways** – not only for the consumer • Opportunity for **farmers to connect with other markets** and consumers • Worried about **data ownership** • Would like to see more **open-source tools** • Still rely on people entering data

Table 6-1 Summary of the findings per interviewed stakeholder of the cacao value chain.

Finally, country of origin data as equivalent for cacao quality and farm origin geographic data (e.g., GPS coordinates) were mentioned most frequently across stakeholders as being most valuable (Table 6-2). This is most likely because of the EUDR regulation, mandating that commodities such as cacao originate from deforestation free plots (coordinates), but also shows the desire of value chain partners to have trust-based relationships with all partners in the value chain. Also, many chocolate manufacturers base their marketing story on the country of origin or personal details of farmers in order to spark a connection with the consumers, which highlights a need for authenticity in the cacao industry. Farm-level data such as the plot size and product specifications were seen as the second and third (respectively) most valuable information.

Type of traceability information	Count	Typical wording in the quotes
Origin / geographic data (farm, country, coordinates, polygons, GPS (global positioning system, region)	10	"Origin information… producer, the farm, geographical location…", "origin of the farm", "Origin country", "coordinates … GPS", "polygons… very important"
Farm-level data (family info, plot/lot size, farm info, deliveries)	8	"family information, plots, plot size…", "farm level data", "farm sizes, locations", "farm info"
Product specifications & quality metrics (batch/lot numbers, sugar, micro/macro, Brix, pH, pulp quality)	5	"batch information, sugar, micro, macro…", "quality of the pulp… Brix and pH", "lot numbers", "batch numbers"
Process / harvest & logistics records (dates, transport, storage, pesticides, weather)	4	"Process records: details on harvest… transportation and storage…", "date of collection… date of departure…", "purchase of pesticides… weather information"
Segregation status & mass-balance / deforestation compliance	4	"materials… really segregated…", "very clear mass-balance account", "non-deforestation-free vs deforestation-free", "polygons… very important"
Time & timestamp data	4	"Time. Day.", "timestamp", "dates", "coordinates, time…"
Financial transparency (price, payment, distribution of money)	3	"Farm gate price", "payment", "distribution of money along value chain"
Visual evidence (images / photos)	3	"maybe an image…", "Sending photos…", "image… low quality on maps"
Historical records (history of product or farm)	2	"History of the product, history of the farm"
Compliance / certification evidence	1	"Compliance with standards: verifiable evidence of… organic, fair trade…"
Social-impact indicators (child labour, fair salaries, diversification)	1	"Child labour etc, Fair salaries etc, Diversification"

Table 6-2 Types of traceability information mentioned in the interviews.

6.3 Consumer Needs for Traceability

The consumer needs for traceability of cacao products were investigated in a first limited exploratory consumer survey and a focus group discussion. The consumer survey (n=55) aimed to gain a deeper understanding of consumer preferences gained from 55 (n=55) valid

responses. The majority of the responses were gathered at the conference "Chocoa" (4-9 February Amsterdam). In the survey consumers were asked about their preference for mock-ups (displayed in Figure 6-3) of a chocolate bar that displayed low, medium and high levels of traceability, with an increasing price (see Figure 6-1). The survey results show that when given a low vs medium choice, consumers clearly chose for medium levels of traceability information (86%). When given the choice between a medium and high level of traceability information, the consumer preference was not as clear (57% medium and 43% high). This suggests that consumers want more than the bare minimum, but after a certain (medium) level of traceability information, other factors, such as price, could be playing a larger role. In the product with a low level of traceability, consumers experience a lack of information on packaging.

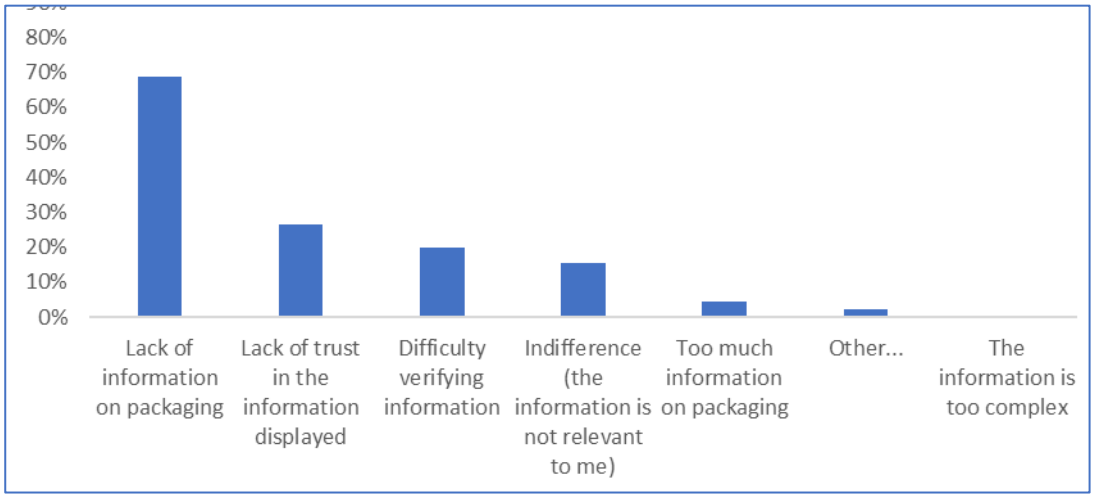

Figure 6-2 Consumers' response to the product with a low level of traceability information.

Figure 6-3 Mock-up designs of chocolate bars with a low, medium and high level of traceability information.

In addition to the survey, a focus group session (n=7) was performed to gain a deeper insight to consumers' preferences regarding traceability information, and consumer perspectives regarding the importance and relevance of various types of traceability information. The

focus groups revealed that while most participants did not scan a QR (Quick response) code for additional information they valued the existence of the QR code and the opportunity to verify information when needed. Most admitted that the limited time spend in the supermarket does not allow time for verification of information. The most trusted brands, were trusted due to their transparency, consistency in addressing societal and environmental issues and critical attitude towards measuring impact. Social and environmental impacts were valued higher than information on production processes or price composition.

6.4 Landscape of Existing Traceability Tools

The landscape of existing traceability systems is investigated based on a combination of desk research, insights from the stakeholder interviews and the cacao fair visits. This resulted in the longlist of 42 tools (in ANNEX2: Long list traceability tools) which we categorised in 7 types of traceability tools:

- **Traceability/Company-specific**: company-driven platforms for end-to-end traceability and sustainability in supply chains. Includes systems for cacao traceability, sustainability data portals, and tools supporting EUDR compliance. The tools included in this category are: AtSource (Olam), Bean Tracker (Tony's Chocolonely), Cacao-Trace (Puratos), CacaoWise (Cargill), ICE Commodity Traceability (ICE CoT) Service, and Katchilè (Barry Callebaut).
- **Traceability/Supply Chain**: dedicated solutions for supply chain visibility—from farm to consumer, often based on Blockchain or SaaS platforms. The tools included in this category are: BanQu, Bext360, Farmer Connect, INATrace, Open Food Chain, seedtrace, SourceTrace, TraceX and Trusty.
- **Traceability/Farmer**: tools for traceability at the farmer or cooperative level. Includes farm-to-factory platforms, deforestation risk monitoring, and digital mapping to verify origin and sustainability at the source. The tools included in this category are: Beyco, Farmstrong CC1, KoltiTrace (Koltiva), Meridia (Verify), MJTec and Tracer (Plant-for-the-Planet).
- **Traceability/NGO:** NGO-backed platforms that use blockchain or other tech to promote transparency and sustainability in agri-food supply chains. Often open-access and aligned with social or environmental missions. The tools included in this category are: FairFood and KOBO/GIZ.
- **ESG/Sourcing**: platforms that support sustainable sourcing, supplier risk assessments, and ESG compliance. Includes ethical trade networks and tools for monitoring, mapping, and reporting across global supply chains. The tools included in this category are: 3rd Risk, Impact Buying, Integrity Next, Kodiak Hub, Osapiens, Sedex, Source, Intelligence and Sourcemap.
- **Farm Management**: digital farm management systems offering tools for data collection, compliance (e.g. EUDR), mapping, and operations optimisation. The tools included in this category are: Cropin, Farmforce, Mergdata (Farmerline), Orijin, Smallholdr and Taroworks (FarmerLink).
- **Satellite Monitoring/Deforestation**: satellite imagery platforms used to detect deforestation, assess land use, and reward sustainable farming practices. Supports compliance with EUDR and zero-deforestation commitments. The tools

included in this category are: Carble, Geocledian, Nadar, Satelligence and Trade in Space.

The majority of the tools investigated are based on a centralised platform approach (n=27). The other tools apply a distributed approach by using Blockchain (n=10) or we could not find information about the data sharing approach (n=5). None of the tools use a federated data sharing approach. **This lack of data sharing systems that respect privacy and data sovereignty is a major gap of traceability in cacao value chains**. Current traceability systems lack federated data architectures that allow secure, decentralised data sharing while preserving farmer privacy and control. There is a growing demand for detailed farm-level data—particularly geolocation information to comply with regulations such as the EUDR—which often conflicts with principles of data sovereignty, consent, and ethical use. Ownership of farmer data is frequently ambiguous, raising serious legal and ethical concerns, especially in light of GDPR and similar privacy laws. For instance, most solutions investigated store precise geographic data on cacao origins within centralised systems. This exposes farmers to unforeseen risks, including criminal misuse, such as extortion since cacao prices are very high. As a result, farmer trust is eroding, and many are increasingly reluctant to share sensitive data. While emerging technologies in federated learning and privacy-preserving data sharing could offer safer alternatives, none of the platforms reviewed currently implement such approaches.

Several important gaps have been identified in current tools used in the cacao value chain. One major issue is their focus on a linear supply chain. Most tools are designed to handle only the processing and marketing of cacao beans, while by-products such as pulp and husk are ignored. These tools also don't support traceability in a circular value chain, where all outputs, including side streams, are tracked and given value. Another gap is the lack of integrated quality management features. While existing solutions provide information about identification, location, and sustainability, they don't include tools for monitoring and controlling product quality throughout the value chain. Manual data entry is another challenge. Many tools rely heavily on it, which increases administrative work, leads to errors, and discourages use. Automated data collection using sensors or smart devices is not widely implemented. Smallholder farmers also face barriers. Although some tools are designed for them, many require internet access, or digital skills beyond sending text messages, that not all farmers have. As a result, it's difficult to get farmers to contribute data. Data quality and verification are also weak points. There are few reliable ways to check the accuracy of input data. Information such as membership records, plot verification, and lot identification is often incomplete or unverified. Even though data could be shared, its trustworthiness is often in doubt. Finally, farmers are burdened by fragmented systems. They frequently have to enter the same data into multiple platforms for different buyers. This lack of coordination among traceability systems creates unnecessary complexity and makes life harder for farmers causing information fatigue.

7 Conclusions and Recommendations

Ecuador's cacao value chain is complex and global, dominated by smallholder farmers (70–90%). It includes informal relationships, limited trust, and a focus on cacao beans, with side streams such as pulp, butter, and powder underutilised. Trust is low across the value chain due to informal agreements, one the spot sales and inconsistent quality control. Cacao-Tech aims to build trust through digital traceability, data of good quality, and stronger partnerships between farmers, cooperatives, processors, and buyers. The study identified major trust and information gaps showing a need for improved transparency, quality measurement, traceability, circularity and sustainability. through the Cacao-Tech initiative, which uses NIR technology and whole pod processing.

This report documents the findings and estimations from the pilot in Ecuador performed in 2024/25. The project lasted for a year. Further research in the demonstration phase will show if the results will manifest at scale.

Cacao pulp, a by-product of bean production, is gaining attention for its potential in drinks, sugars, and syrups. Valorising this waste stream can increase farmer income, reduce environmental impact, and support circular economy goals. Whole pod processing and traceability can improve quality control and reduce waste, increase operational efficiency, enhance sustainability through circularity and reduced GHG (Greenhouse Gas) emissions and improve new income streams for smallholders. Technology and data sharing enables these processes and supports many values that are appreciated in the cacao value chain. Consumers value transparency, sustainability, and origin information. Retailers and manufacturers are responding by integrating traceability and sustainability into their sourcing strategies. However, awareness of circularity remains low.

Current traceability systems are fragmented, centralised, and often exclude by-products such as pulp. There is a need for more decentralised or federated traceability systems that support circular value chains, preserve data privacy and reduce the administrative burden on farmers.

Cacao-Tech showed potential to scale up the developed technologies. Technological development should focus on user-friendliness, interoperability and the promotion of fair data governance. It should align its traceability components with sustainability certifications and market demands. Cacao-Tech can increase its impact by supporting farmer training and logistical infrastructure development for cacao pulp.

8 Literature

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ANNEX 1: Questionnaire (Example)

UNOCACE

15 Jan 2025
Cacao pulp and husk
Time of interview: 1 hour

1. Do you currently deliver cacao juice, pulp or other cacao products? Why/ not?
2. What is your experience in pulp extraction?
3. What market insights do you have on the cacao pulp industry in general?
   a. Prospects for smallholder producer regarding cacao pulp?
   b. What is the perception of small producers regarding cacao pulp production, are they interested in diversifying their production into pulp?
   c. How feasible do they see this option in the long term?
   d.
   d. What about other companies who are extracting and selling pulp, who are they?
   e. What challenges or successes have they encountered in terms of demand, extraction technology, or partnerships?
4. What are the prospects for pulp production, and do you plan to increase your production or explore new markets?
5. What infrastructure do you have in place for pulp production? Can it be used for the pilot? What would still be needed (for example infrastructure, machinery, technical support)?
6. What is the expected volume of pulp (in Kg) that you expect could be delivered per month / year in a good year? And in a bad year?
7. How would the seasons impact the available output?
8. What would be the frequence (per year) and the ideal set-up? Why?
9. What would be UNOCACE's interest to work with the cacao pulp? And what do you see as the main challenges?

Cacao Beans – Factors and Importance:

1. Do you use any type of fertiliser? or is everything organic? As I understand it, if it is handled in an organic way, the whole process is more expensive. How do the organic prices relate to the conventional prices one year ago, and now?
2. What about the organic market? Is it growing or not with current prices?
3. What do you see as an opportunity to change any part of the process to make it more efficient/low cost/etc.~~?~~
4. Place these factors in order of importance for your customers: Why are they important/ less important? Did we miss import\ant factors that determine quality and value?

- Bean size
- Removing sick pods
- Organic certification
- Origin traceability
- EUDR compliancy

- Regenerative
- Carbon footprint
- Insights about the producer (young / female)
- Cadmium.
- Exact location of the farm (geo location)
- Genetics
- Flavor.
- Post harvesting.
- Fat Content.
- Other

5. How do you measure and control consistency in the quality of the beans?

What do your clients value about UNOCACE?

- Margins/ fair prices
- Collective organisation of sales
- Services to producers?
- Trust in fair process
- High quality beans
- Variety bean
- Communications
- Quality of post harvesting
- Sustainability factors
- Buying from smallholder producer
- Buying organic
- Social factors: average income on cacao per member, number of women / indigenous people, number of producers trained etc indigenous cacao production
- Buying from a certain region
- Producers trained on Good agricultural practices
- …

1. What information do you store from producers?

How much information do you share and why?

- Land size
- Type of cacao
- Personal characteristics?
- Years with UNOCACE
- Different membership types?
- Annual production?

What are potential trust challenges that can exist between producers and cooperatives when it comes to purchasing pulp or beans? How can this be mitigated?

ANNEX 2: Long list traceability tools

Name	Category	Data Sharing Approach	Description	EUDR Compliance	Proven in Cacao / adaptable to cacao	Website Link
3rd Risk	ESG/sourcing	Centralised	Third-party risk management platform	Yes	Unspecified	https://www.3rdrisk.com
AtSource (Olam)	Traceability / Company-specific	Centralised	Sustainability insights platform for supply chains	Yes	Yes	https://www.atsource.io/
BanQu	Traceability / Supply Chain	Distributed (Blockchain)	Blockchain-powered traceability connecting smallholders.	Yes	Unspecified	https://www.banqu.co
Bean Tracker (Tony's Chocolonely)	Traceability / Company-specific	Centralised	Bean-to-bar cacao traceability system	Yes	Yes	https://nl.tonyschocolonely.com/en/pages/bean-tracker
Bext360	Traceability / Supply Chain	Distributed (Blockchain)	AI, IoT, blockchain SaaS for commodity tracking.	Yes	Yes	https://www.bext360.com
Beyco	Traceability / Farmer	Distributed (Blockchain)	Blockchain trading and traceability for coffee/cacao cooperatives.	Yes	Yes	https://beyco.nl
Cacao-Trace (Puratos)	Traceability / Company-specific	Centralised	Sustainable cacao program with quality focus	Yes	Yes	https://www.cacaotrace.com/
Carble	Satellite Monitoring / Deforestation	Not Specified	Satellite-based platform rewarding deforestation-free farming.	Yes	Unspecified	https://carble.co
CacaoWise (Cargill)	Traceability / Company-specific	Centralised	Digital portal for cacao sustainability data	Yes	Yes	https://www.cargill.com/sustainability/cacao/cacaowise-portal

Name	Category	Data Sharing Approach	Description	EUDR Compliance	Proven in Cacao / adaptable to cacao	Website Link
Cropin	Farm Management	Centralised	EUDR compliance add-on of a farm management information system	Yes	Yes	https://www.cropin.com/
FairFood	Traceability / NGO	Distributed (Blockchain)	Blockchain platform for agri-food transparency	Yes	Yes	https://fairfood.org/en/
Farmer Connect	Traceability / Supply Chain	Distributed (Blockchain)	Blockchain-based traceability from farm to retail.	Yes	Unspecified	https://www.farmerconnect.com
Farmforce	Farm Management	Centralised	First-mile traceability and farm management.	Yes	Yes	https://farmforce.com
Farmstrong CC1	Traceability / Farmer	Centralised	Traceable cacao supply, land mapping, satellite monitoring, and farmer support	Yes	Yes	https://farmstrong-foundation.org/technology/
Geocledian	Satellite Monitoring / Deforestation	Centralised	Satellite imagery for deforestation assessment (EUDR Check)	Yes	Unspecified	https://www.geocledian.com
KOBO/ GIZ	Traceability / NGO	Centralised	data collection, management, and visualisation platform used globally for research and social good	Unspecified	Yes	https://www.kobotoolbox.org/
ICE Commodity Traceability (ICE CoT) Service,	Traceability / Company-specific	Centralised	Commodity traceability for EUDR compliance	Yes	Yes	https://www.ice.com/iba/commodity-traceability-service

Name	Category	Data Sharing Approach	Description	EUDR Compliance	Proven in Cacao / adaptable to cacao	Website Link
Impact Buying	ESG/sourcing	Centralised	Sustainable sourcing and procurement	Yes	Unspecified	https://www.impactbuying.com
INATrace	Traceability / Supply Chain	Distributed (Blockchain)	Open-source traceability solution with QR-code consumer interface.	Yes	Unspecified	https://inatrace.org
Integrity Next	ESG/sourcing	Centralised	ESG compliance monitoring platform	Yes	Unspecified	https://www.integritynext.com
Katchilè (Barry Callebaut)	Traceability / Company-specific	Centralised	Cacao traceability and sustainability platform	Yes	Yes	https://www.barry-callebaut.com/
Kodiak Hub	ESG/sourcing	Centralised	Supplier intelligence and risk insights	Yes	Unspecified	https://www.kodiakhub.com
KoltiTrace (Koltiva)	Traceability / Farmer	Centralised	Farm-to-factory supply chain management platform.	Yes	Unspecified	https://www.koltiva.com
Mergdata (Farmerline)	Farm Management	Centralised	Digitising farmer data, mapping, and transactions.	Yes	Yes	https://mergdata.com
Meridia (Verify)	Traceability / Farmer	Centralised	Farm data verification and deforestation risk.	Yes	Yes	https://www.meridia.land
MJTec	Traceability / Farmer	Not Specified	Traceability software for cacao cooperatives.	Yes	Yes	https://www.mjtec.ec
Nadar	Satellite Monitoring / Deforestation	Not Specified	Automated satellite forest monitoring.	Yes	Unspecified	https://www.nadar.earth
Open Food Chain	Traceability / Supply Chain	Distributed (Blockchain)	Blockchain traceability for agriculture supply chains.	Yes	Yes	https://www.openfoodchain.com/

Name	Category	Data Sharing Approach	Description	EUDR Compliance	Proven in Cacao / adaptable to cacao	Website Link
Orijin	Farm Management	Not Specified	Digital operations and sustainability for processors.	Yes	Yes	https://orijin.io
Osapiens	ESG/sourcing	Centralised	ESG compliance and reporting platform	Yes	Unspecified	https://osapiens.com
Satelligence	Satellite Monitoring / Deforestation	Centralised	Satellite data insights for deforestation-free compliance.	Yes	Unspecified	https://satelligence.com
Sedex	ESG/sourcing	Centralised	Ethical trade membership organisation	Yes	Yes	https://www.sedex.com
seedtrace	Traceability / Supply Chain	Distributed (Blockchain)	Blockchain platform for sustainability storytelling.	Yes	Unspecified	https://seedtrace.org
Smallholdr	Farm Management	Centralised	Farm data management for smallholder value chains.	Yes	Yes	https://smallholdr.com
Source Intelligence	ESG/sourcing	Centralised	Supply chain compliance solutions	Yes	Yes	https://www.sourceintelligence.com
Sourcemap	ESG/sourcing	Centralised	Supply chain transparency and mapping	Yes	Unspecified	https://www.sourcemap.com
SourceTrace	Traceability / Supply Chain	Centralised	Farm-to-market traceability SaaS.	Yes	Yes	https://www.sourcetrace.com
Taroworks (FarmerLink)	Farm Management	Centralised	Mobile data collection for last-mile traceability.	Yes	Unspecified	https://taroworks.org
Tracer (Plant-for-the-Planet)	Traceability / Farmer	Not Specified	Mobile app simplifying EUDR compliance.	Yes	Yes	https://www.plant-for-the-planet.org/tracer/
TraceX	Traceability / Supply Chain	Distributed (Blockchain)	Blockchain traceability for	Yes	Unspecified	https://tracextech.com

Name	Category	Data Sharing Approach	Description	EUDR Compliance	Proven in Cacao / adaptable to cacao	Website Link
			agriculture supply chains.			
Trade in Space	Satellite Monitoring / Deforestation	Centralised	Satellite-blockchain integration for EUDR.	Yes	Yes	https://tradeinspace.com
Trusty	Traceability / Supply Chain	Distributed (Blockchain)	Blockchain platform for agri-food transparency.	Yes	Yes	https://www.trusty.id