Traceability and Technology: An Overview Study

Vertragsnummer: 81230527

Projekt: 16.2190.3-0002.00

Organic Services GmbH
Nina Kuljian, Gerald A. Herrmann, Frank Gerriets
Contact:
Gerald A. Herrmann
E-Mail: g.herrmann@organic-services.com
Phone: +49 8158 92293-06

Commissioned by
Gesellschaft für Internationale Zusammenarbeit (GIZ)
Katja Albrecht
E-Mail: katja.albrecht@giz.de

Content

List of Figures

List of Tables

1. Introduction

The *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* is a service provider in the field of international cooperation with the objective of sustainable development (GIZ.de, 2018). The GIZ programme "Sustainable Supply Chains and Standards" aims to promote sustainable global agricultural supply chains by increasing the share of sustainably produced commodities (i.e. cocoa, coffee, rubber, and palm oil) on the German market and by supporting the development of sustainable growing regions. As a part of this effort, the GIZ partners with companies that want to make their supply chains more sustainable. Traceability of sustainably produced commodities throughout the supply chain is often core to this effort yet requires companies to gain insight into the digital solutions that are available for traceability and remote-sensing (GIZ, 2018). The GIZ has commissioned Organic Services GmbH to conduct a study on digital solutions for traceability and remote-sensing in September and October of 2018 with the objective to better be able to support companies in this effort. This is the report of this study.

2. Drivers of Traceability in the Food Industry and Sustainability Sector

The concept of and need for traceability in the food sector arose about 25 years ago, when information about food products began to be stored and transmitted separately from the product itself, due to technological advancements (Olsen, 2017 S.1). Traceability has now become a buzz-word, and a concept that is often used without a definition or shared understanding. Many companies make claims about traceability in their supply chains without being exact about what that means in the reality of their products and supply chains. Yet, while it may seem that traceability has become an objective in and of itself, this is not the case. Instead, there are certain drivers for traceability in the food industry, different objectives that can be reached through establishing traceable supply chains. Traceability on the other hand is a purely descriptive concept that doesn't have values or attributes – most basically, traceability is simply a record-keeping mechanism that attaches information about food products to them (Olsen, 2017 S.16). Traceability has also become relevant in supply chains other than in the food industry, especially in the case that these supply chains work with sustainability certification, such as timber, cotton, or palm oil.

2.1 Food Safety

Food safety practices describe how food products should be handled, prepared and stored in ways that prevent food-borne illness and protect food from contamination. These practices include standards around hygiene, temperatures, production timelines, etc. Traceability is an important concept in food safety, because when contamination is discovered, it is important to determine exactly where the source of the contamination was, as well as which products have been affected. This can inform a targeted re-call and protect the health and safety of consumers.

2.2 Food Fraud Prevention

Food fraud is the act of purposely altering, misrepresenting, mislabelling, substituting or tampering with a food product, always with the aim to incorrectly sell a less valuable food product as a more valuable food product. When food fraud is committed, the volume of the more valuable food product is artificially increased throughout the supply chain. Traceability is one of the measures that companies take to protect their supply chain from food fraud, as traceability increases the amount of information that is attached to food products as they travel through the supply chain, and such make it more difficult to commit fraud.

2.3 Marketing Claims

2.3.1 Origin

Differentiation from other products on the market is core to any marketing and branding effort. For food commodities, consumers have traditionally made purchasing decisions based on price, how well a certain food fits into their dietary needs, and perceived quality, such as taste and freshness. However, marketing claims of food companies can also be connected to the product's origin. For example, the place the food product was grown can be associated with a certain quality or flavour, as for example in the case of Champagne (sparkly wine produced in the province of 'Champagne' in France), or Parma ham (ham from the 'Parma' region in Italy). In both cases, the brand name of regional origin is protected by the EU authorities. Another example of a product marketing claim that includes product origin is "single origin coffee", where a certain flavour profile relates to the country of region of coffee origin, or even the example of a coffee microlot, where the information about the plot of land that a coffee was grown on is very specific. Of course, it is important for companies who brand their product based on its origin that they can ensure that the product branded in that way does in fact originate from the claimed area. Traceability is a tool that companies can use for this purpose.

2.3.2 Sustainability

Differentiation of a food product can also be done based on sustainability claims, meaning claims regarding the production process of a food product. A growing portion of consumers is concerned about the unintended effect that their purchase may have for the environment, or the animals and humans that were involved in the production of a food product. They may therefore opt to purchase a product with a sustainability label that has been produced and/ or traded following a certain standard or set of requirements (such as organic, Fairtrade, RSPO, FSC, etc.). Traceability can be used as a tool for companies (and is often required by standard owners) to ensure that the product labelled with the sustainability label or claim has in fact been produced according to the sustainability standard. While sustainability certification originated in the food industry, it is now commonly applied in non-food products as well, such as for example timber, gold, or apparel and home goods.

2.4 Traceability and its Drivers

The fact that traceability is always a means to an end, rather than an objective in and of itself is very important: a company, supply chain or sector that considers establishing traceability must always keep in mind what the larger objective is that they aim to reach, as it will inform what type of traceability and/ or transparency system they should put into place.

The overall objective also informs how traceability efforts are combined with and embedded within the larger supply chain management effort: efforts to manage risk, efforts to build supplier relationships, marketing and branding efforts, and efforts to manage pricing all are connected to traceability efforts. Decisions made, and strategies employed in these other areas will inform what is needed in terms of traceability.

Furthermore, the overall objective also informs the part of the company that will lead the traceability effort – often, there is a quality management department that manages food safety as well as any other supply chain and quality requirements of a company. In other cases, there may even be a certification department that manages the third-party certifications that may drive traceability efforts.

At the same time, it is important to distinguish between the larger objectives that one wants to reach through traceability and the traceability mechanism that is employed for that purpose.

3. Supply Chain Models in the Food Industry and Sustainability Sector

There are many different types of supply chains present in the food industry, as well as in sustainability certification in other sectors. For this report, however, we would like to make two basic distinctions as these greatly influence the way that the different traceability mechanisms can work.

3.1 Open Supply Chain vs. Closed Supply Chain

A very basic distinction is that between an open and a closed supply chain:

- In an open supply chain, basically every company can participate, and not all supply chain actors may be known.
- In a closed supply chain, all supply chain actors are known.

An interesting case are supply chains that function within organic and sustainability certification. In this case, regulations (organic) or standard owners (sustainable) require that every company that wants to participate in a certified supply chain by producing or trading (buying and selling) certified products must become certified and is therefore known to one or more certifiers. That means that the companies must adhere to a set of criteria and agree to report certain information as well as facilitate audits at their offices and sites (see for example: Fairtrade International 2015 p.6, RSPO 2018a, Utz Certification Protocol Version 4.1 2016, p.9, MSC 2018a, FSC 2018). However, this does not imply that a company functioning within that system has a closed supply chain – a company may still purchase their product from a supplier without knowing the supplier's sources. A special case in the field of voluntary certification is the organic certification scheme that is also protected by the European legal system (as well as by about 90 other states) and is characterized by collaboration between organic certification bodies and country authorities as well as stricter controls of production and trade. However, it holds true here as well, that organic supply chains may still function as open supply chains, as knowledge of the entire supply chain is not required.

Furthermore, it is important to note that there are certain laws that authorities have put into place to create at least a minimum level of control as well. Certainly, most countries require that companies that produce food products have a business registration and undergo food safety as well as financial audits. In addition, there are laws regarding the import of food products from other countries.

3.2 Supply Chains that include product streams of certified and non-certified product vs. supply chains that facilitate only certified product streams

As this study focuses on the sustainability sector of food and non-food products, an important distinction is to be made between supply chains that include both certified and non-certified products vs. supply chains that facilitate certified product streams only.

Many sustainability certifications as well as organic certification require that certified products are kept separate from those that are not certified – all throughout each step of production, storage, transportation, and processing (see the supply chain descriptions and standards of several sustainability certification schemes such as Utz (Utz 2018), RSPO (RSPO 2018b), MSC 2018a). This requirement of product separation follows the logic of thinking of commodities in terms of product characteristics that must be protected by not mixing a product with certain characteristics with one that does not share these characteristics. Therefore, in sustainability certification, separation is more important when consumers can see or feel the sustainability properties of a product (Mol & Oosterveer 2015). Organic certification is a good example of this. While in the case of organic products, the difference between organic and conventional is not visible to the consumer, among other attributes of the organic certified product, consumers expect a health benefit of organic consumption due to the lack of chemicals in organic production. This attribute must therefore be protected by not mixing organic product with conventional product.

Supply Chains that only facilitate a certified product stream

There are supply chains that facilitate certified product streams only, because every supply chain actor produces, processes, trades, transports and stores exclusively certified products. This is common in the beginning of the supply chain – for example in the case of a cooperative of smallholders, sustainability certification is usually pursued for all smallholder members and marketed jointly. No additional work must be done at this level to separate certified product from non-certified product. There are supply chains where this same principle holds true for the rest of the supply chain – where processors, exporters, importers and manufacturers all hold the same sustainability certification. The certified product is therefore naturally separated from product that is not certified and therefore holds different characteristics; the certification requirements are automatically fulfilled.

Supply Chains that facilitate both certified and non-certified product streams

More common are supply chains where one or all the supply chain actors who participate in the supply chain handle both certified and non-certified product: supply chain actors process, store, transport, buy and sell both certified as well as non-certified products. In this case, two different scenarios exist:

- There are supply chains who systematically separate the certified product stream from the non-certified product stream. This can be done for example buy building separate storage sites for certified and non-certified product (or separate areas within the same storage area), or by running separate processing runs (for example certified product is processed on one specific day of the week, and staff ensures that the processing facility is empty before and after processing of the certified product). When transported, supply chain actors can separate in certified and non-certified containers, truckloads, bags, etc. that are marked with the certification label.
- There are supply chains that don't separate the certified and non-certified product flow in this way. Instead, all product is channelled through the same product stream: the same storage sites, processing sites, etc. This results in the mixing and mingling of certified and non-certified products, unless the supply chain actors apply certain mechanisms. These will be discussed in more detail later, under point 4.

4. Traceability Mechanisms Applied in the Food Industry and Sustainability Sector

A discussion of traceability in the food and sustainability sector requires a definition of the term traceability. In industry conversations, this is however usually lacking. The term traceability is often used without definition, and to describe a range of mechanisms that are all applied to increase supply chain transparency yet may differ significantly from each other. And the European authorities have defined what is legally required of food companies in terms of their ability to trace food products simply as knowing the supplier they purchased a food product from as well as knowing the buyer they sold a food product to. Traceability requirements in the sustainability sector in contrast to 'organic' are defined only by the private standard-setter, not the legal authorities.

The general definition of traceability is often cited as: "*Traceability is the capability to trace something. In some cases, it is interpreted as the ability to verify the history, location, or application of an item by means of documented recorded identification"* (Wikipedia 2018a). However, in the supply chain management of commodities, the definition of traceability must be broader, as product parameters such as qualities or provenance are relevant. We therefore refer to the definition of Olsen in "Food traceability in theory and in practice", published in 2017 by the Arctic University of Norway (Olsen, 2017). Olsen defines traceability as "*the ability to access any or all information relating to that which is under consideration throughout the entire life cycle, by means of recorded identification*". Basically, anything can be "under consideration"; in supply chains, product batches, trade units, or logistics units are traced, these are defined by Olsen as TRU's (traceable resource units). The life cycle of food products ends when food products are consumed – in a practical sense however an important point is also the point of sale to the consumer. This is also a key point in the case of sustainability certification. Of course, any type of information may be recorded in a traceability system. This depends on the objective of the traceability system.

As the objective of this study is to provide an overview of existing traceability options, we chose however not to simply provide one single definition of traceability in the food industry, but to instead differentiate between four types of traceability mechanisms: supply chain mapping, mass balancing, batch traceability, and Book & Claim systems. In addition, we point to new and innovative approaches to traceability that have been created in recent years through the combination of more mechanisms.

It is important to note that while traceability efforts are usually supported by digital tools, these traceability mechanisms are not firmly linked to the technological tools or systems that companies may use to implement these concepts. Any of these concepts may be implemented using a technological tool or software, or they may be implemented using more "old-fashioned" tools such as paper record-keeping or record-keeping using the MS Office package (such as Excel tables).

Secondly, we want to mention that we purposefully left aside traceability definitions that include the objective of traceability efforts in the definition, such as for example the distinction between "management traceability", "regulatory traceability" and "consumer traceability", as introduced by Mol and Oosterveer (Mol & Oosterveer 2015).

In addition, we want to introduce the terms "identity preserved" and "segregation" here. These terms are often mentioned respectively considered as traceability mechanisms. We have not included them as they are no mechanisms, but rather goals that may be achieved through applying different mechanisms, for example by standard setters RSPO, Utz, and Fair Trade USA, as well as solution provider Chainpoint:

- ✓ The term "identity preserved" describes a supply chain model that routinely traces the final product to the specific original source of the raw product, such as for example the smallholder cooperative, farm, plantation, or collector that first sold the raw product. The mechanism used to create this supply chain model is usually chain batch traceability, which is relatively simple as a commodity is traced and not a multi-ingredient processed product. However, one can also envision short supply chains operating at a low volume that would manage to do so using different traceability mechanisms such as simply separating the products from the different sources from each other (which is in fact a batch traceability as well).

- ✓ The term segregation is used to describe two of the above-mentioned supply chain models: supply chains that only facilitate certified product flow, and supply chains that facilitate both certified and non-certified product flow, but systematically separate these product streams from each other. Product separation can be reached through supply chain management or by using the batch traceability mechanism.

4.1 Supply Chain Mapping

Supply Chain Mapping is a generic term that describes the collection of information about participants in the supply chain without further information about TRU's, product transactions and volumes. Different types of information can be collected – names and locations of suppliers, relationship between suppliers/buyers, information on the products that they sell, or information on their production process and/ or certification status.

Supply Chain Mapping can be done throughout the entire supply chain, or only "one-up/ one-down", meaning only for direct suppliers and/ or buyers. Supply Chain Mapping certainly comes into consideration only in case somebody wants to map supply chains across company borders.

Often, supply chain mapping efforts follow the logic of thinking of commodities as originating from certain suppliers or being sold to certain buyers: a lot of the time, the names of companies participating in the supply chain are a focal point. While Supply Chain Mapping is therefore quite different from product traceability, it is a prerequisite of product traceability as Supply Chain Mapping creates transparency about those involved in a specific supply chain. So, it is often the starting point for any transparency and traceability approach.

4.2 Mass Balancing

Mass balancing describes a calculation that compares the product volumes that are "input volumes" and the product volumes that are "output volumes", while also considering conversion factors (output = input * conversion factor[1]). The mass balancing mechanism can be applied at various points and/ or with various purposes: at a processing site, comparing input volumes with output volumes, at the country-level when comparing registered surface areas with national production and so on (please see ISCC 2016 as an example of mass balancing). Of course, the purpose of the mass balance check or the type of information gained from the mass balance check depends on the definition of the input and output volumes. Often, a differentiation between product volumes with certain marketing and/ or sustainability claims is done both at the input and the output level. This is the case when mass balancing is applied in sustainability certification and in non-segregated supply chains to ensure that the volume sold as certified product corresponds to the volumes purchased as certified (see: Utz 2018, RSPO 2018).

In other applications, specifically in the organic sector, mass balancing is applied to supply chains that separate the certified product from the non-certified product and to ensure that no artificial increase of certified volumes has been done in the supply chain. In this case, a connection between the traded volumes and the certified surface area is made to prevent food fraud (Check Organic, 2018).

---

[1] Conversion means the processing of a commodity, e.g. olives to olive oil, cocoa beans to raw cocoa products

Mass balancing follows the logic of thinking of commodities in terms of volumes – volumes produced, processed, transported, and stored – and focuses on the monitoring of these volumes within a given timeframe (a day, year, or harvest cycle for example).

4.3 Batch Traceability

Batch traceability describes a record-keeping system that groups product into traceable resource units (TRU's - batches and trade units), has a mechanism for identifying these TRU's, a mechanism for documenting connections between TRU's (transformations), and records the attributes of the TRU's, which is what is being traced (Olsen 2018, S.4). Other mechanisms, such as mass balancing also use mechanisms to identify product volumes, yet don't record the connections between the transformations.

There are different types of transformations. It is important to differentiate, even at a conceptual level, between internal batch traceability and chain batch traceability.

Internal batch traceability relates to the traceability of processes and transformations within a company: all information on each internal step is recorded, including transport, storage and processing steps. That includes transformations that are done, and relevant characteristics of internally created batches or TRU's. The relationship between incoming trade items and raw material (or ingredient) batches needs to be recorded, as well as the relationship between production batches and outgoing trade items. Any batch traceability effort depends on the existence of a good internal batch traceability system (Olsen 2017, p.4). Internal batch traceability is the most common system applied as it is important for food safety within companies (including "one up, one down") as a prerequisite for recalls.

Chain batch traceability relates to the traceability across the supply chain including several companies. This requires that more than one company in the supply chain cooperate with each other, which makes it more complex than internal batch traceability. Data confidentiality and levels of access are a big issue (Olsen 2017). Batch traceability along supply chains requires all parties to participate: to integrate each suppliers' numbering into their internal batch numbering and to communicate theirs to the next level. Thus, such a system requires high proficiency and willingness to cooperate, as chain batch traceability breaks off with one non-cooperating link.

Batch traceability follows the logic of thinking of commodities as being grouped in batches of raw material or boxes of products traveling through the supply chain in this way, and potentially undergoing various transformations and transactions.

4.4 Book & Claim Systems

Book & Claim systems are a supply chain and traceability model that exists in the sustainability sector, is however an outlier as it is almost opposite to most other traceability efforts: in a Book & Claim system the production attributes that are considered as important and valuable – the fact that the product was produced following a certain standard or set of criteria – is separated from the product itself, rather than attached to it (Mol & Oosterveer 2015). The products as well as the sustainability points are traded separate from each other, must however correspond in volume/ value. Manufacturers and retailers can buy credits in the form of certificates, either directly from certified growers, while buying the actual product elsewhere, or from an independent body or via a trading platform (RSPO 2018).

In Book & Claim systems product quality differences are not visible to the consumer. There are some sustainability products, where Book & Claim systems are even the only logistically available option, as for example in the case of electricity that is transported through the same grid (Mol & Oosterveer 2017).

4.5 Inclusion of Various Mechanisms to New and Innovative Traceability Efforts

Traceability efforts are always a part of the larger supply chain management work and often core to how a company does business or how a certification scheme interacts with clients and consumers. In recent years, by including several of the above traceability mechanisms, new and innovative approaches have been combined with new technology to create secure supply chain systems. Examples of such new and innovative management systems are for example the combination of Batch Traceability with Blockchain Technology or the enhancement of the organic certification system in Italy by an integrity management system that combines supply chain mapping with mass balancing and real-time certification data in a closed supply chain. Other example is the use of remote-sensing technology to determine the origin of a product or the sustainability status of agricultural land in the very beginning of the supply chain and connecting this to traceability information throughout the supply chain, or the use of Internet of Things applications to enhance traceability efforts by collecting data in this way and incorporating it into a traceability system.

5. Technological Tools Applied for Traceability Efforts

There are many technological tools available on the market that companies in the food industry or sustainability sector as well as certifiers and standard-setters of sustainability standards can use to reach their supply chain management objectives by implementing one or more traceability mechanisms. In most (if not all) cases, the use of a technological tool is desirable as it will ensure effectiveness and efficiency of traceability efforts.

An important characteristic of a traceability tool is the *traceability mechanism(s) that it offers, and at what scope exactly,* as this most basically determines the *what*, *where* and *when* of the traceability effort.

For example, if a tool offers supply chain mapping, there is a big variation in what part of the supply chain is mapped, with some tools focusing in on smallholder mapping only, and stopping mapping efforts there, while other tools don't provide the level of detail in the beginning of the supply chain but include the many supply chain actors in the chain, such as traders, processors and manufacturers.

Similarly, the scope of the type of information that is included in the mapping varies. Some tools aim to provide companies with a very basic mapping of company names and locations. Other tools focus on certification data, whether external information such as certification status and validity of certificate or internal certification information such as non-compliances and corrective measures. And there are tools that focus on sustainability information such as poverty scorecards or land use information, as well as tools that offer high customization in terms of the type of information that is mapped.

A tool that offers batch traceability on the other hand may offer internal batch traceability only, including all product transformations and transactions from the purchase order creation to the dispatch of the product – transport, storage, processing, manufacture. Other tools offer chain batch traceability. This requires a rights & roles system that allows for both sharing and protection of confidential business information. Without this type of system, often available at "platform/portal" tools, a joint effort of several companies along the supply chain is not possible. Core to success to chain batch traceability is also the use of a standardized language to be used by all participating companies, in order to successfully communicate and share information. GS1 Germany has developed a standard for this purpose. The EPCIS standard was developed with the objective to enable trading partners along the supply chain to exchange information about the status of products while the product moves through the supply chain (Wikipedia 2018 d) based on a unique identifier.

A tool that offers mass balancing must define how this mass balancing is done. For example, standardized production yields and/ or conversion rates are required to determine input and output at the production and/ or processing level. In addition, the timeframe of the mass balance calculation must be defined, i.e. is the mass balancing done for the input and output of one harvest, one processing run, or a day or year.

So, besides the traceability mechanism that the tool offers, *the type of data the tool requires and/ or is capable of absorbing as well as the way in which data collection is organised* is very important to the traceability effort. These shape the *who* and *how* of the traceability effort – which project partners are needed and how will they provide information.

There are traceability tools that include a survey function for collecting information. Other tools use mobile technology and apps to collect information, this is especially common when mapping information about smallholder farmers in the very beginning of the supply chain. There are tools that collect data from existing systems, whether the Enterprise Resource Planning (ERP) systems present at companies, databases available in certain sectors or at authorities (for example in the case of organic certification data). And of course, there are "platform/portal" tools that collect data through manual entry or data upload by participating companies. Additionally, of course there are tools that are based on distributed ledger or blockchain technology and collect information in the blockchain. Other tools use third parties such as publicly available data through authorities or third-party certifiers as data providers. For example, land use data is often available publicly, and certification bodies have databases available that provide the certification status of the sustainability certification that they offer for all suppliers that a company aims to map.

When determining a company's traceability effort, it is *important to consider the power balances and imbalances between the supply chain actors that participate in the supply chain*, and to map out which supply chain actors would need to participate as well as the likelihood of their collaboration. In some chain traceability efforts, a push is done by a company towards the end of the supply chain, and the participation travels through the supply chain to its beginning, with each company asking its suppliers to join. In other cases, a company in the end of the supply chain directly targets the very beginning of its supply chain, as it requires additional business intelligence on where its products originate and – in the case of many commodities – has identified the very beginning as the riskiest part of the supply chain. Less common are traceability efforts that originate in the beginning of the supply chain, as is for example the case with protected origin certifications, where traceability is organized from the product origin forward through the rest of the supply chain. It is also important to mention traceability approaches that are mandated by an authority. Sustainability standard setters can require a certain kind of traceability as a part of their certification, such organizing the entire certified sector in that way. Government authorities can also require traceability, with their current requirement of simply knowing the supplier a product was purchased from and sold to posing a limitation to traceability efforts. There are other examples of sector efforts, such as the Italian organic wheat sector that established a sector-wide mass balancing system to prevent fraud (Check Organic, 2018).

Of course, the *technological features* of the tool are also important. Most traceability tools are cloud-based tools offered in the SaaS (Software as a Service) model and accessed via internet connection. Much fewer traceability tools are installed on a computer. It is important that the technological features of the tool match the conditions under which the required project partners work. It is no coincidence that many tools that focus on smallholder farmer mapping use mobile technology and apps, as well as offer the ability to work in an offline mode and then upload information when internet connectivity is again available. Most tools do not require specific skills of users other than the ability to use an internet browser. Additionally, while some tools offer an off-the-shelf solution, other tools are customized to each new client and application. This characteristic likely informs both the *implementation timeline* of a tool as well as its *cost structure of initial and ongoing/ annual costs*.

In the case of establishing traceable supply chains, the technological piece must always be embedded in inclusive and thorough project-management, as any traceability effort must be understood as *a larger organizational or sectoral change process* that requires changes in internal procedures, yet also how a company relates to its suppliers, sub-suppliers, and the larger community. Service providers must go far beyond offering purely technological expertise. It is therefore important to understand where a service provider and tool are "at home". For example, it is important to understand with what types of objectives a tool has been applied (i.e. food safety/ fraud prevention/ marketing and sustainability claims/ etc.). It is also core to understand in which commodities or industries a service provider has worked before, as each industry has its own characteristics that require a specific adaptation of the traceability approach. It is an important success factor that a service provider and a tool can speak the language of the project partners, literally as well as culturally, and in terms of industry-related terminology.

In addition to "traditional" technology tools that offer the effective and efficient organization of the three supply chain mechanisms of supply chain mapping, mass balancing, and batch traceability, there are other tools and technologies that can be used to increase transparency and improve the traceability in a supply chain. We would like to include some of these tools here as well, based on their relevance to implementing traceability in the food industry and sustainability sector. We have grouped the large variety of tools that exist into three broader categories, Blockchain and distributed ledger-technology, Internet of Things (IoT) applications, and Remote-Sensing Technology.

5.1 Distributed Ledger/ Blockchain Technology

Blockchain or distributed ledger technology was first conceptualized in 2008, when "Bitcoin: A Peer-to-Peer Electronic Cash System" was published under the alias "Satoshi Nakamoto". This led to the beginnings of the Bitcoin Blockchain in 2014, and a quickly growing public interest in the technology starting 2016. Blockchain technology is now discussed so extensively, that it is difficult to believe that only 1% of companies is estimated to currently use Blockchain, and only 8% of companies is estimated to be in the short-term planning or active experimentation with Blockchain (Artificial Lawyer 2018).

The two basic categories of Blockchain are permissionless Blockchains such as Bitcoin, where everyone can join the network without any restrictions to read, write or take part in the general agreement and permissioned Blockchains, which is what companies typically use (IBM 2018a). This is key, as the core function of Blockchain technology is to store information, with the information being spread out across the globe on volunteer computers, rather than in one central database. Members of a Blockchain therefore share a common view with the truth, it's possible to see all details of a transaction end-to-end, which reduces vulnerabilities like error, fraud and inefficiency. Blockchain reduces the complexity of transactions: while an ordinary transaction requires each participant to have its own, separate ledger and relies on intermediaries for the validation of the transaction, Blockchain transactions share a single tamper-evident ledger where transactions can't be altered once they have been recorded, and all parties must give consensus before a new transaction is added to the network. This eliminates or reduces paper processes and increases efficiency (IBM 2018a). The Blockchain is built by putting each transaction into a block and then connecting each block with the one before and after it, creating an irreversible chain (IBM 2018a). The important data points of a Blockchain are the transaction timestamp, the transaction details, and a hash that combines the hash and the details of the previous transaction (IFT 2018). Data is stored across the user network (decentralized) rather than in traditional databases (centralized).

A Blockchain needs three things: for the nodes to work together, for miners to verify transactions, and incentives for the volunteers in this network (Hirsch 2018). The decentralized nature of Blockchain technology affects how security is handled. In centralized systems, attacks are done directly to the hardware itself, with the aim to compromise the system by targeting the weakest human component with the most elevated access rights. In the case of Blockchain, all information provided to the Blockchain is accepted only if it is authenticated, which means that elevated privilege levels are removed and security risks in form of operator and IT administrators are drastically reduced (Hirsch 2018). This decentralized nature also makes a Blockchain very auditable: each individual operation or interaction is recorded and archived, and the authenticity is guaranteed (Hirsch 2018).

While most current applications of Blockchain technology are in the financial market, Blockchain technology has the potential to be applied in many different industries; please see here an overview of potential use cases (Hirsch 2018).

While not prominently featured in this overview, the potential of Blockchain for supply chain integrity has been extensively discussed in the food industry and sustainability sector, with first applications having been implemented. Different types of use of the Blockchain technology can be envisioned in this field:

- Blockchain technology could be used for traceability, to trace products throughout the supply chain (IFT 2018), or to create more transparency (Hirsch 2018).
- Blockchain technology could be used in the field of supply chain certification, to assign and verify certifications of certain properties of physical products (Hirsch 2018).
- Blockchain technology could be used to create automation and trust through smart contracts (Ewan & Miles 2018).

In Annex 3, we will describe some of early examples of Blockchain technology being applied for supply chain management.

5.2 IoT, Remote-Sensing and GIS Tools

Internet of Things, Remote Sensing Technologies and Geographic Information Systems are combined in this chapter as the application of these technologies is often in one or other way integrated when services are offered that are of interest for traceability and for proof of collecting or producing products in agricultural, forest and agroforest systems.

5.2.1 Internet of Things

The Internet of Things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect, collect and exchange data, creating opportunities for more direct integration of the physical world into computer-based systems, resulting in efficiency improvements, economic benefits, and reduced human exertions.

There are numerous IoT applications in farming such as collecting data on temperature, rainfall, humidity, wind speed, pest infestation, yield determination during combine harvesting, application of mineral fertilizers/ pesticides, and soil content (Meola 2016). This data can be used to automate farming techniques, take informed decisions to improve quality and quantity, minimize risk and waste, reduce effort required to manage crops (Wikipedia 2018b), and to assess data for surveillance and certification purposes.

5.2.2 Remote-Sensing Technology

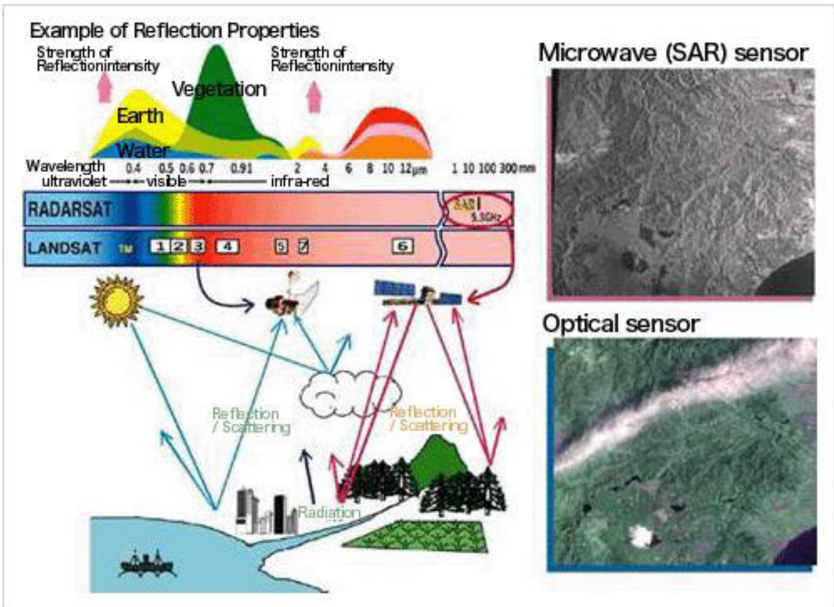
Remote Sensing is the technology of probing without touching the target.

Remote Sensing has various methods. Investigation using proper sensors equipped on satellites is called Satellite Remote Sensing. Sensors equipped on satellites observe electromagnetic waves emitted from the sun or from the satellite itself reflected by the sea, forests, cities, and clouds through optical sensors, active and passive microwave sensors.

Passive remote sensing relies on naturally reflected or emitted energy of the imaged surface. Most remote sensing instruments fall into this category, obtaining pictures of visible, near-infrared and thermal infrared energy. Active remote sensing means that the sensor provides its own illumination and measures what comes back. Remote sensing technologies that use active remote sensing include LIDAR (Light Detection And Ranging, in analogy to radar) and radar.

The following can be inferred from the obtained data:

- ✓ Vegetative conditions: Deforestation, desertification, agricultural status
- ✓ Land surface temperatures: Heat island phenomena
- ✓ Sea surface temperatures: The meandering of the Gulf Stream, El Nino events, estimation of fisheries
- ✓ Surface altitudes: Mapping
- ✓ Clouds: Weather forecasts, precipitation predictions, inner conditions of typhoons
- ✓ Water: Reservoir volumes, flood damages



Text and graph see the website of the Remote Sensing Technology Center of Japan (Remote Sensing Technology Center of Japan 2018).

5.2.3 Geographic Information System (GIS)

A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations. Public databases, e.g. cadaster information is part of the data.

Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium using a CAD program, and geo-referencing capabilities. With the wide availability of ortho-rectified imagery (from satellites, aircraft, Helikites and UAVs), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of by the traditional method of tracing the geographic form on a separate digitizing tablet (heads-down digitizing) (Wikipedia 2018 c).

GIS uses spatio-temporal (space-time) location as the key index variable for all other information. Just as a relational database containing text or numbers can relate many different tables using common key index variables, GIS can relate otherwise unrelated information by using location as the key index variable. The key is the location and/or extent in space-time. Related by accurate spatial information, an incredible variety of real-world and projected past or future data can be analyzed, interpreted and represented.

6. Traceability Tools and Providers

There are many different service providers on the market for each of these different tools. In addition, there are several providers that offer products that range across all types of categories. In some cases, the different products can be combined to ensure that traceability objectives are reached. Combination of several mechanisms as well as embedding the traceability mechanisms in a larger supply chain management approach that includes other types of controls and risk management measures can (greatly) increase the effectiveness of traceability tools.

To provide an overview of the key tools that are available to companies who aim to improve their traceability, we first conducted internet research. In the following, we selected a smaller subset of the many providers of traceability tools that we encountered. Our selection was made based on relevance of the tools to the GIZ, with the main criterion being that the tool should enable chain traceability rather than internal traceability. In addition, we followed the objective to include a variety of different tools in the overview, as the GIZ strives to be able to support different supply chain actors with different needs and objectives in their traceability efforts and therefore needs an understanding of the breadth of tools available on the market.

We then developed a survey with several open and closed questions that aimed to gain a basic understanding of each participating tool, establish the tools track record in the industry, and define the pre-conditions required for use of the tool. We also asked some more in-depth questions about the tool such as the type of data used, the technology applied, the costs of the tool, the implementation projects, and the inclusion of smallholder farmers. We finally aimed to understand the unique strengths of each tool that differentiate the tool in the market form other solutions and providers.

Please find the entire questionnaire in Annex 1, and the summarized answers in the Excel File that is sent separately as an Appendix to this report.

The following service providers were contacted (31 in total):

- 15 questionnaires were received from: Foodcoin/ Global Traceability/ GRAS/ Hispatec/ Koltiva/ Optel/ Verify Technologies/ ChainPoint/ fTrace - GS1 Germany/ Group Integrity/ Ecert Basic/ Check Organic/ EECC/ Abaco Group/ Global Forest Watch.
- 16 questionnaires were sent, but no answer received: Unique Trace/ Sourcemap/ Edible Software/ iTrade/ SupplyShift/ Utz/ IBM Food Trust/ Bureau Veritas/ Arc-net/ Te-food/ Provenance/ 365 farmnet/ European Space Imaging/ VanderSat/ DLR/ Auracle Mote Sensing.

The fact that only half of questionnaires were received and the fact that Organic Services could not ask additional questions adds to some basic thoughts on the usability of the results of this survey:

1. Presentation of tools on websites is often more promotional than technical. Thus, information from websites is based on keywords without being able to understand functionalities offered in detail.
2. The definition of traceability, the traceability mechanisms and technological tools follow a systematic that was developed for this study and might not be shared by service providers and be interpreted in a different way. This might lead to a misplaced categorization which might in some cases be wrong to if being consulted directly with the service provider.
3. Traceability and technological tools are subject to a very fast development, so that
    a. service providers offer (promotion!) functionalities that are not yet fully developed, but feasible once the request by a client is contracted;
    b. services offered are changing rapidly in functionality and additional services are included;
    c. combinations of traceability and other technological tools are integrated depending on the nature of the project in question, even if such combination is not core to the tool offered.
4. Ideas/ Projects of clients seeking technological solutions are complex, and each project has a characteristic approach and goal. It cannot be assumed (at least not at this point in time) that projects are standardized enough to apply the grid for a decisive selection of the tool fitting best.
5. New service providers are coming up fast as investors are focusing on start-ups and existing companies in this sector. In addition to compliance management, fast growth is expected in this sector of digitalizing commodity chains.
6. The best information to understand the special focus of each of the service providers' tools might be to look at their clients and or the description of implemented applications as these point towards the special solutions offered.

Conclusion: Each project will have to be analysed and technical specifications to be developed. After pre-selection of possible solution providers, these should send their assessment and offer.

The recommendation thus is to use the below Table on Service Providers as an educational tool and as a basis for better understanding of the current situation rather than as a tool that should be given to interested parties (GIZ project partners) as a grid for selection. It is recommended to assess project needs individually in contact with respective service providers.

In the following table all Service Providers (also those that have not replied) are characterized based on answers respectively on information found and conclusions drawn from their websites.

Table 1: Service Providers of Traceability and Remote-Sensing Tools

Traceability Tools and Providers	
Service Provider	Product
ChainPoint offers the tool ChainPoint *(Information based on answers to survey and conclusions drawn on that basis)*	ChainPoint is a traceability tool that offers the traceability mechanisms of supply chain mapping, mass balancing, batch traceability, Book & Claim and any desired combination of these mechanisms.
Edible Software offers Food Traceability Software (Information based on Edible Software website)	Food Traceability Software is a batch traceability tool focused on traceability in the fruit & vegetable sector.
EECC offers the tool EPCAT *(Information based on answers to survey and conclusions drawn on that basis)*	EPCAT is an electronic product code tool that follows the GS1 standard EPCIS. It enables trading partners to share information about the physical movement and status of products as they travel throughout the supply chain and a chain batch traceability tool that also offers the traceability mechanism supply chain mapping.
A daughter of GS1 Germany, fTrace offers the tool fTrace. *(Information based on answers to survey and conclusions drawn on that basis)*	fTrace is a batch traceability tool based on GS1 standards, fTrace focuses on chain batch traceability and uses EPCIS for dynamic data transactions.
Global Traceability offers the traceability solution Radix Tree. *(Information based on answers to survey and conclusions drawn on that basis)*	Radix tree is a platform tool that offers the traceability mechanisms of batch traceability, supply chain mapping and mass balancing. It allows companies to connect with suppliers, track products, verify data, and simplify administration.
Hispatec offers the ERPagro product suite. *(Information based on answers to survey and conclusions drawn on that basis)*	ERPagro is a batch traceability tool that also offers mass balancing and supply chain mapping functionalities. Integration with data from IoT devices and public data sources is offered.
iTrade offers the tool iTracefresh (Information based on iTrade website)	iTracefresh is a batch traceability tool that can be used for both internal and chain batch traceability and has a focus on the fruits&vegetable industry.
Koltiva offers CocoaTrace as well as other commodity platform solutions (PalmOilTrace, RubberTrace, SeaweedTrace, TimberTrace, PatchouliTrace, and SupplyChainTrace). *(Information based on answers to survey and conclusions drawn on that basis)*	CocoaTrace is a commodity platform solution that includes the traceability mechanisms of smallholder mapping, mass balancing of production, as well as offers internal- and chain batch traceability. In addition, an internal audit tool is also available.
Optel Geotraceability offers the tool GeoT. *(Information based on answers to survey and conclusions drawn on that basis)*	GeoT is a batch traceability tool that also includes smallholder mapping and mass balancing functionalities and integrates with Optels own GIS tool.

Organic Services offers the tool Check X	Check X/ Check Organic is a generic tool that combines certification data and product transaction data in a Supply Chain Mapping and Mass Balancing tool that offers the integration with batch traceability tools and remote-sensing tools.
Organic Services offers the tool Group Integrity/ Ecert Basic *(Information based on answers to survey and conclusions drawn on that basis)*	Group Integrity/ Ecert Basic is a compliance management tool that offers batch traceability functionalities.
SourceMap offers the tool Open Sourcemap *(Information based on SourceMap website)*	Open Sourcemap offers the traceability mechanism of supply chain mapping and is a large database that is available to anyone to use, whether consumer or brand.
SourceMap offers the tool Sourcemap Discover *(Information based on SourceMap website)*	Sourcemap Discover offers the traceability mechanism of supply chain mapping.
SourceMap offers the tool Sourcemap Track and Trace *(Information based on SourceMap website)*	Sourcemap Track & Trace is a batch traceability tool with a focus on supply chain traceability from smallholder farmers.
Supply Shift offers a product portfolio of a few different tools and solutions (Information based on Supply Shift Website)	Supply Shift offers several supply chain mapping tools.
UniqueTrace offers a traceability platform. *(Information based on UniqueTrace website)*	The Traceability Platform is a batch traceability tool focused on chain traceability.
Utz (Information based on Utz Website)	Utz developed a traceability system for their own certification, and now also offers this as a service to others, offering the traceability mechanisms of batch traceability, mass balancing and Book & Claim.
Verify Technologies offers the tool Verify Portals. *(Information based on answers to survey and conclusions drawn on that basis)*	Verify Portals is a batch traceability tool that also includes supply chain mapping and mass balancing functionalities.
Blockchain-based Traceability Tools	
Bureau Veritas offers the tool Origin. (Information based on Bureau Veritas website)	Origin is a Blockchain-based traceability tool that offers the traceability mechanisms of batch traceability and supply chain mapping.
Foodcoin Ecosystem offers the tools WALLOK, PRORID, DIGID, FOODSCAN, DiPay, and Smaco *(Information based on answers to survey and conclusions drawn in that basis)*	The foodcoin tools support the traceability mechanisms supply chain mapping and mass balancing.
IBM offers the tool IBM Food Trust (Information based on IBM Website)	IBM Food Trust is a Blockchain based traceability tool that offers the traceability mechanisms of batch traceability and supply chain mapping.

Provenance offers the tool Provenance. (Information based on Provenance Website)	Provenance offers a Blockchain-based traceability tool that uses the traceability mechanisms supply chain mapping and batch traceability.
Te-food offers the tool Te-food. (Information based on Te-food website)	Te-food is a Blockchain-based traceability tool that offers the traceability mechanisms of supply chain mapping and batch traceability.
Internet of Things/ Remote-sensing Tools	
365 Farmnet (Information based on 365 Farmnet Website)	365 Farmnet offers various Internet-of-Things-services to agricultural producers.
ABACO offers Siti4Farmer (incl. Siti4Land, Sensing4Farming) *(Information based on answers to survey and conclusions drawn on that basis)*	Siti4Farmer offers various IoT, satellite, and GIS solutions to agricultural producers and innovative tools to monitor production in the food supply chain.
Auracle Geospatial (Information based on Auracle Website)	Auracle Geospatial offers various remote sensing services, such as data acquisition, satellite image processing, spatial analysis and interpretation, and Geographic Information Systems (GIS).
European Space Imaging (Information based on European Space Imaging Website)	European Space imaging offers remote sensing services such as satellite tasking, online solutions, and 3D products.
Webtool for Sustainability Analysis/ Remote-Sensing	
Global Forest Watch offers the tool Global Forest Watch Pro (GFW Pro) *(Information based on answers to survey and conclusions drawn in that basis)*	Global Forest Watch Pro is an application that translates geospatial data into actionable insights.
Global Risk Assessment Services offers the GRAS tool *(Information based on answers to survey and conclusions drawn in that basis)*	The GRAS Tool is a free-of-charge webtool that provides comprehensive datasets and analysis functions to assess the sustainability risk of an agricultural production area. Datasets reflect the four main pillars of sustainability, biodiversity, land use change, carbon stock and social indices. Detailed analysis results can be exported in an automated individual report for each analysis case.

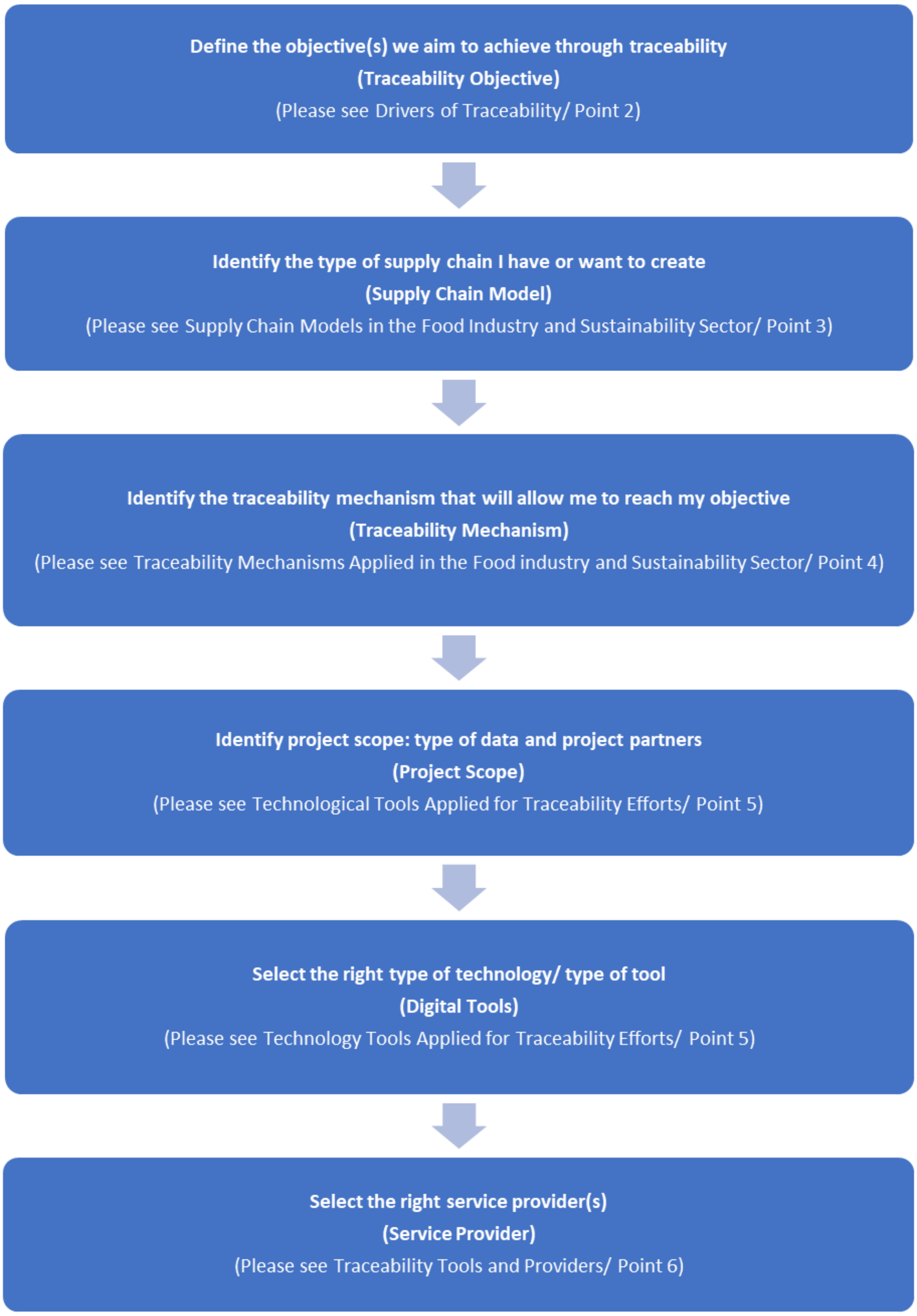
The above table is a summary of the internet research as well as the analysis of the completed surveys received from service providers. Much additional information was given by the service providers about their tools. Please find this information in the Excel File that is provided as an Appendix to this report and contains a summary of the answers to the survey questions.

7. Steps or Questions to Determine Traceability-Approach and Select Technology Tools and Providers

In the previous report, we have discussed the drivers of traceability, and we have categorized different supply chain models that exist in the food industry and the sustainability sector. We have also categorized traceability efforts as using three traceability mechanisms, supply chain mapping, mass balancing and batch traceability as well as described Book & Claim systems. We have also introduced technologies applied for traceability efforts and described the most important characteristics of a digital traceability tool. Finally, we have provided an overview over key tools and providers present on the market based on an internet research as well as survey-based research. A lot of information has been collected, processed, structured, and presented.

As a final remark, we would now like to describe how we think this information could be used by structuring the decision-making process that we believe a company should walk through when deciding on their own traceability effort. Before choosing a tool or services provider, it is important to clarify the most important information that will determine what a company needs in a traceability tool and in a services provider. We therefore propose a six-step decision-making process.

Figure 1: Six Step-Decision-Making Process



We have described a few hypothetical examples of supply chain actors walking through the above described process. We hope that these illustrate a range of different objectives that companies may aim to reach through implementing the different traceability mechanisms and show how which traceability mechanism and therefore which digital tool will be successful depends largely on the objectives of the traceability effort and the supply chain model. Additionally, these examples should illustrate how the above described decision-making process may be helpful to companies who want to create more sustainable supply chains and create better traceability as a part of this effort. We attempted to create hypothetical examples that bear some similarity to the reality in different commodities and types of companies and supply chains. Please find an overview of the different examples as well as the examples themselves in the Annexes to this report.

8. References

- Artificial Lawyer (2018): *Hype Killer – Only 1% of Companies Are Using Blockchain, Gartner Reports*, [online] Available at: https://www.artificiallawyer.com/2018/05/04/hype-killer-only-1-of-companies-are-using-Blockchain-gartner-reports/
- Astor (2017): *Your Roomba May be Mapping Your Home, Collecting Data That Could Be Shared*, The New York Times, [online] Available at: https://www.nytimes.com/2017/07/25/technology/roomba-irobot-data-privacy.html
- Check Organic (2018): *Organic Integrity Platform*, [online] Available at: https://www.check-organic.com/solutions-and-projects/solutions/organic-integrity-platform.html
- DNV (2018): *Certificates in the blockchain*, [online] Available at: https://www.dnvgl.com/assurance/certificates-in-the-blockchain.html
- Drum (2018): *Blockchain's Latest Triumph: Mango Tracking*, [online] Available at: https://www.motherjones.com/kevin-drum/2018/05/blockchains-latest-triumph-mango-tracking/
- Ewan & Miles (2018): *Coffee with Blockchain: Filtering out the hype*, [online] Available at: https://developer.ibm.com/articles/cl-coffee-with-blockchain-introduction-to-how-blockchain-works/
- Fair Trade USA(2017): *Fair Trade USA Compliance Criteria for the Trade Standard 1.1.0*, [online] Available at: https://www.fairtradecertified.org/sites/default/files/filemanager/documents/APS/FTUSA_STD_TradeCC_EN_1.1.0.pdf
- Fairtrade International (2015): *Fairtrade Trader Standard*, [online] Available at: https://www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/generic-standards/TS_EN.pdf
- FAO (2018): *Illegal, Unreported and Unregulated (IUU) Fishing*, [online] Available at: http://www.fao.org/iuu-fishing/en/
- FSC (2018): *Chain of Custody Certification*, [online] Available at: https://us.fsc.org/en-us/certification/chain-of-custody-certification
- GIZ.de, (2018): *About GIZ*, [online] Available at: https://www.giz.de/en/html/index.html
- GIZ (2018): *TOR Untersuchung von digitalen Rückverfolgungs- und Fernerkundungsinstrumenten*, Available as Annex to this report
- Hirsch (2018): *Blockchain – More than a Buzzword?* [online] Available at: https://blog.intact-systems.com/blockchain-more-than-a-buzzword/
- IBM (2018) a: *IBM Blockchain 101: Quick-startguide for developers*, [online] Available at: *https://developer.ibm.com/tutorials/cl-ibm-blockchain-101-quick-start-guide-for-developers-bluemix-trs/*
- IBM (2018) b: *The Blockchain Bean*, [online] Available at: https://www.ibm.com/thought-leadership/blockchainbean/
- IDFA (2018): *Walmart Exec to Demonstrate Benefits of Blockchain for Dairy*, [online] Available at: https://www.idfa.org/news-views/headline-news/article/2018/07/11/walmart-exec-to-demonstrate-benefits-of-blockchain-for-dairy
- IFT (2018): *The Potential of Blockchain Technology Application in the Food System*, [online] Available at: http://www.ift.org/Knowledge-Center/Learn-About-Food-Science/Food-Facts/The-Potential-of-Blockchain-Technology-Application.aspx
- ISGC (2016): *Mass Balance Requirements*, [online] Available at: https://www.iscc-system.org/wp-content/uploads/2017/02/ISCC_DE_204_Mass-balance-calculation-methodology.pdf

- Meola (2016): *Why IoT, big data & smart farming are the future of agriculture*, [online] Available at: https://www.businessinsider.de/internet-of-things-smart-agriculture-2016-10?r=US&IR=T%20
- Mol, A. & Oosterveer, P. (2015): *Certification of Markets, Market of Certificates: Tracing Sustainability in Global Agro-Food Value Chains*, [online] Available at: https://pdfs.semanticscholar.org/f51e/d5cad7101aed8357d378dae1a55051f6d7e8.pdf
- MSC (2018) a: *The MSC Chain of Custody Standard*, [online] Available at: https://www.msc.org/standards-and-certification/chain-of-custody-standard
- Olsen (2018): *The components of a food traceability system* in Trends in Food Science & Technology 77, May 2018, Available at: https://www.researchgate.net/publication/324927313_The_components_of_a_food_traceability_system
- Olsen, P. (2017): *Food traceability in theory and in practice*, [online] Available at: https://www.researchgate.net/publication/324438650_Food_traceability_in_theory_and_in_practice_-_Doctor_philos_thesis
- Provenance (2018): *Increasing financial transparency with proof of fair payment*, [online] Available at: https://www.provenance.org/case-studies/fairfood
- Remote Sensing Technology Center of Japan (2018): What is Remote Sensing, [online] Available at: https://www.restec.or.jp/en/knowledge/sensing/sensing-1
- Roberts (2017): *Walmart and Blockchain: It Takes Two to Mango*, [online] Available at: https://rctom.hbs.org/submission/walmart-and-block-chain-it-takes-two-to-mango/
- RSPO (2018) a: *How RSPO Certification works*, [online] Available at: https://rspo.org/certification/how-rspo-certification-works
- RSPO (2018) b: *RSPO supply chains*, [online] Available at: https://rspo.org/certification/supply-chains
- Utz (2016): Utz Certification Protocol Version 4.1, [online] Available at: https://utz.org/?attachment_id=3625
- Utz (2018): *Traceability levels*, [online] Available at: https://utz.org/what-we-offer/the-utz-logos/traceability-levels/
- Wikipedia (2018) a: *Traceability*, [online] Available at: https://en.wikipedia.org/wiki/Traceability
- Wikipedia (2018) b: *Internet of Things*, [online] Available at: https://en.wikipedia.org/wiki/Internet_of_things#Agriculture
- Wikipedia (2018) c: *Geographic information system*, [online] Available at: https://en.wikipedia.org/wiki/Geographic_information_system
- Wikipedia (2018) d: *EPCIS*, *Electronic Product Code Information Services*, [online] Available at: https://en.wikipedia.org/wiki/EPCIS
- WWF (2018): *New Blockchain Project has potential to revolutionise seafood industry*, [online] Available at: https://www.wwf.org.nz/what_we_do/marine/Blockchain_tuna_project/