LIVERUR

PROJECT H2020

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Living Lab Research Concept in Rural Areas

Blockchain Use in Agriculture

DEVELOPED BY CESIE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773757.

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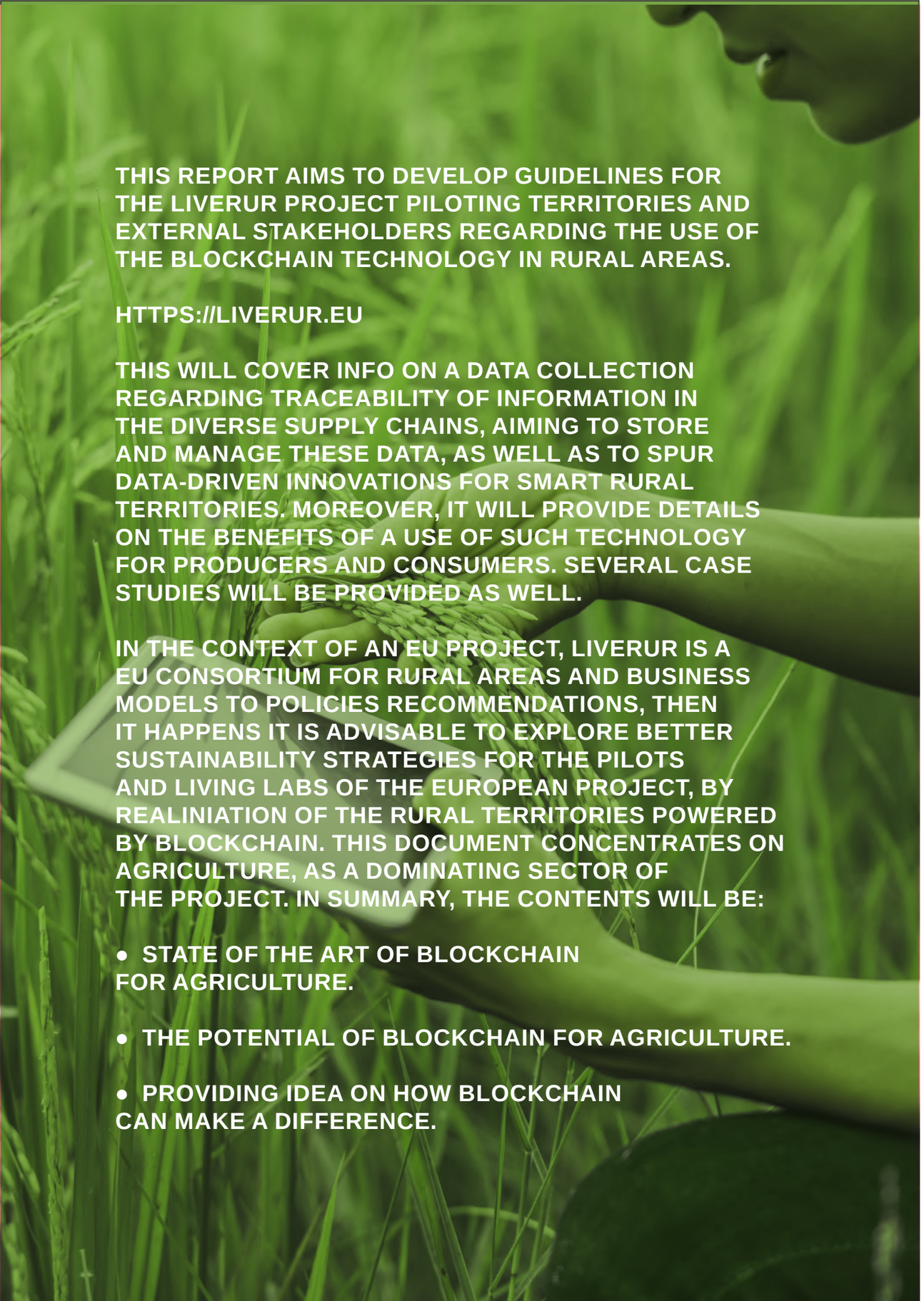

1. INTRODUCTION

Taking into consideration Industry 4.0, it is expected that over the next 10 years there will be dramatic changes in the Agri-food system, driven by advanced digital technologies and innovations (blockchain, Internet of Things (IoT), Artificial Intelligence (AI), Immerse Reality, etc.), changing consumer preferences and demands, the influence of e-commerce on global Agri-food trade, climate changes and other factors. To achieve the UN Sustainable Development Goals (SDGs) and going beyond to a “world with zero hunger” by 2030, FAO is calling for more productive, efficient, sustainable, inclusive, transparent and resilient food systems (FAO, 2017 p. 1401). The digital agricultural transformation is crucial in providing opportunities for these achievements.

Blockchain technology is the concept or protocol behind the running of the blockchain. Blockchain technology makes cryptocurrencies (digital currencies secured by cryptography) like Bitcoin work just like the internet makes email possible.

The blockchain is an immutable (unchangeable, meaning a transaction or file recorded cannot be changed) distributed digital ledger (digital record of transactions or data stored in multiple places on a computer network) with many use cases beyond cryptocurrencies.

Immutable and distributed are two fundamental blockchain properties. The immutability of the ledger means you can always trust it to be accurate. Being distributed protects the blockchain from network attacks. Each transaction or record on the ledger is stored in a “block.” The information contained in a block is dependent on and linked to the information in a previous block and, over time, forms a chain of transactions. Hence the word blockchain.

The blockchain is the brainchild of a person or group of people known by the pseudonym, Satoshi Nakamoto (presumed pseudonym for a person or group of people) who invented and implemented the first blockchain network after deploying the world’s first digital currency, Bitcoin. Blockchain, or distributed ledger technology (DLT), is already finding utility across several business sectors including financial, banking, retail, automotive, and aviation industries. The technology is finding its way in agriculture too, and has the potential to revolutionize the way farming is done.

The most common application of blockchain in any industry sector (and not only agriculture) is creating an immutable record of transactions or events, which is particularly helpful in creating a trusted record of traceability and provenance of products and raw materials. This also allows consumers to be aware of the source of the ingredients used in their food products. At the same time, it can help food companies to isolate the cause of any disease outbreak impacting the food value chain. Cost cuts and higher margins are at stake for the whole food supply, savings in intermediaries that are granted to the farmers and their suppliers.

Blockchain can also act as a platform to connect farmers with vendors, food processing, and packaging companies, providing a secure and trusted environment to both buyers and suppliers to transact without the need of a middleman. This also results in elimination of margins that need to be paid to these intermediaries, and helps improve the margins for buyers.

Another case is that small farmers in Europe have not the best access to agricultural insurance coverage, which leaves them vulnerable to adverse climatic situations such as droughts. Smart contracts based on blockchain can also be used to provide crop-insurance, which can be triggered given certain set conditions are met, enabling farmers to secure their farms and family livelihood in case of extreme climatic events such as floods or droughts. Enhanced access to insurance and to investment by means of crops tokenization that are well worth of exploring for the sake of farmers.

Indeed, blockchain is likely to be an integral part of Agritech/Agri-food offer for an immense opportunity to European agriculture. Blockchain has already started witnessing implementation in systems providing proof of ownership, platforms for farmer cooperation, and agricultural financing tools. Unlike Asian and Latin American countries, Europe markets have shown a relatively positive attitude towards adoption of blockchain, while only Africa is eager to adopt it. This is why the EU opportunity to make a dare step.

In order to exploit the full potential of blockchain with regard to traceability, we must therefore think of this technology as a tile to be integrated with other available solutions.

Finally, increasing sustainability of supply chains and transparency in the Agri-food value chain are key objectives of the European Commission's Green Deal and the Farm to Fork Strategy2 he potential that blockchain technologies offer, has not been fully harvested by stakeholders in the Agri-food sector. This concerns both, the private and the public sector. This report will show how can Blockchain be adopted and the potential benefits.

Section 2 in this report will introduce the background of ICT and other tech investments to help the small farmers, so that section 3 contains the state of the art of blockchain and agriculture and supply chain, to move forward to providing ideas on how Blockchain can make a difference in section 4, and some interesting conclusions and recommendations in section 5.

2. HOW ICT AND OTHER TECH INVESTMENTS ARE HELPING (SMALL) FARMERS

One of the greatest challenges for rural area development in Europe is a high-tech increase. Thereby, the research problem lays upon digital agrarian hub development and financial support. The trends of agrarian hubs development in Europe include digitalization, innovative development, communication and financial support.

Agriculture has been under the pressure of many challenges such as low productivity, lack of knowledge and exposure to new farming techniques, and lack of access to financial support, especially for the small-scale farmers. These challenges are prompting investments in newer technologies to enhance the productivity through smart agriculture techniques, and on data collection regarding traceability of information in the diverse supply chains, aiming to store and manage these data, aiming to spur data-driven innovations for smart rural territories.

The growing importance of Smart Farming in the European Union (EU) will allow EU to boost its agricultural output whilst ensuring the sustainability of the European agriculture sector. Under this perspective, EU is supporting cutting-edge research and innovation with many researchers around Europe working on innovative projects with the technologies mentioned above, aiming to drive agriculture to a new era. We are going through a period where good practices are essential to be promoted, in order to set the pillars for Smart Farming of the future.

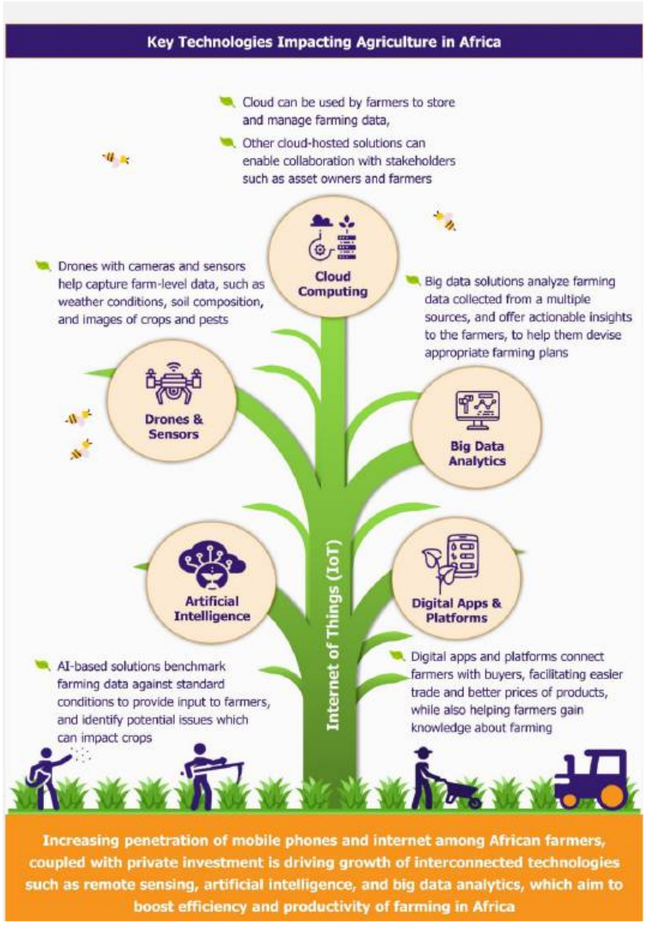

Fig. 1 - Key Technologies Impacting Agriculture (EOS 2020)

So, there have been an increased use of various technologies in agriculture, such as Smart Farming (Moysiadis 2021), which is based on Information and Communications Technologies (ICT). Smart Farming is aiming to increase productivity and improving the quality of the final product while reducing cost production: Internet of Things (IoT), Wireless Sensor Networks (WSNs), Big Data Analytics, Open Source Software, Cloud Computing, Artificial Intelligence, Unmanned Ground Vehicles (UGVs), Drones/Unmanned Aerial Vehicles (UAVs), and many other ICT solutions. Many tech start-ups have developed solutions targeting various aspects of agriculture, including finance, supply chain, retailing, and even delivering information related to crops and weeds. These solutions are accessible to farmers through front-end devices such as smart phones and tablets, or even SMS. Some of the top start-ups for agriculture are included in the Annex 1 of this report. The technologies described in this section aim to change the approach of how farmers and agronomists work in the field by reducing labour efforts, and by operating with accuracy on an everyday basis. UAVs could be the eyes of the farmers and help them to identify precisely diseases or areas with low production while UGVs can operate in the field in various tasks like seeding, weeding, spraying, or harvesting. Above these, a suitable WSN is mandatory to collect data from sensors and support the orchestration of all connected devices.

On the one hand, in the next decades, we will be spectators of the new era of Smart Farming, but until then, many obstacles should be overwhelmed. More specifically, although UGVs can operate continuously on an everyday basis, their operational speed is still very slow compared to manual work. In addition, their accuracy in some tasks like harvesting and weeding is still an open issue. UAVs also have still some disadvantages, like energy consumption, which restrict them to operate more time in the field. Moreover, in order to be more autonomous, more research efforts should be spent on their usage without human intervention, and new regulation rules should be adopted on this basis.

On the other hand, Wireless Sensor Networks WSNs will be the backbone of the whole infrastructure, so their characteristics will play a vital role in many factors. For example, reducing the energy consumption of the sensor nodes is mandatory since they operate with batteries. In addition, low latency is essential in tasks like control of UAVs or UGVs, especially in tasks where human protection is crucial.

Finally, big data, machine learning, and further data processing by means of AI, for the elaboration and storage of the tremendous amount of data produced from the huge amount of sensors and the involved UAVs and UGVs in Smart Farming, an innovative infrastructure based on Cloud Computing is indispensable. In more detail, Cloud Computing can offer a plethora of storage and computational resources, and these resources are reliably available from any place at any time. In addition, an elastic model of resources can lessen the overall cost, as we can use the available resources only when we need them.

Nevertheless, Cloud Computing is not only useful when Big Data is present but is also suitable for many other occasions. For example, its centralized control is proper to aggregate data from the deployed sensors in the field and provide the derived information in a visualized form, easy to understand from the farmers or agronomists, on their phones or tablets from anywhere and at any time. In essence, Cloud Computing offers an abstraction layer able to provide multiple user-friendly services to final users. Applications like soil monitoring (Zhou 2016), smart irrigation (López-Riquelme 2017), disease or insect detection (Rupanagudi 2015), and Farm Management Systems (FMS) (Kaloxylos 2014) are some examples of the services that can be provided from a Cloud Infrastructure at the edge devices.

From our point of view, **all these ICT technologies are just tools for incremental innovation** that face strong adoption barriers as their benefits or their ROI return on investment for small farmers are unclear, differently for big farmers. For the small farmers in particular, but for the whole agriculture sector, there is a need for a disruption at the technological, organisational, economical, and social levels. This is exactly the role of Blockchain that will take advantage of the before mentioned ICT technologies being adopted in Agriculture, to introduce many innovations that will provide farmers with extraordinary competitive advantages. Blockchain is a transformative ICT that have the potential to revolutionized how data is used for agriculture

3. STATE OF THE ART OF BLOCKCHAIN FOR AGRICULTURE AND SUPPLY CHAIN

Blockchain is a specific type of database. It differs from a typical database in the way it stores information; blockchains store data in blocks that are then chained together. As new data comes in it is entered into a fresh block. Once the block is filled with data it is chained onto the previous block, which makes the data chained together in chronological order. Different types of information can be stored on a blockchain but the most common use so far has been as a ledger for transactions.

In Bitcoin's case, blockchain is used in a decentralized way so that no single person or group has control—rather, all users collectively retain control.

Decentralized blockchains are immutable, which means that the data entered is irreversible. For Bitcoin, this means that transactions are permanently recorded and viewable to anyone.

This bunch of advantages shape not only a powerful technology but a new paradigm where many actors work together differently from the status quo, in a sincerely open, transparent, and so effective way that new wealth is created and distributed properly across all the actors working on any area. And agriculture is a sector with very many actors that need of enhanced transparency and effective ways of working.

Let us introduce further concepts around the blockchain technology by using one of its examples in the supply chain.

3.1. BLOCKCHAIN AND THE SUPPLY CHAIN

Supply chains are intrinsically complex flows of goods, money and services. Their traceability refers to the collection, documentation, and application of information related to all processes in the supply chain in a manner that provides guarantee to the end-user and other stakeholders along the supply chain on the provenance, location and life history of a product. It represents the ability to conduct a full backward and forward tracking to determine characteristics of the good by means of records. In line with the UN's sustainable development goals, the sustainable management and traceability of these supply chains can positively affect lives to receive a higher income around the globe – which is especially true in low income countries, where 63% of the employed population still work in the agricultural sector (Mehrländer 2020)

Often, the **opaqueness of supply chains hinders customers from understanding the provenance of a product,** as well as **its social and environmental impact for smallholder farmers** and other participants of the supply chain. While increasing numbers of customers seek out organically produced goods, industry fails with the demand to provide such goods at a satisfactory standard. Currently, the only way for customers to be promised higher standards is through certification schemes. These schemes tend to be **too costly for single smallholder farmers** and even corporates may shy away from the investment. Hence, farmers and workers may carry on receiving low prices for goods that could be distinguished as sustainably sourced.

Customers experience a lack of comprehension of existing sustainability labels and a lack of clarity on the detailed origin of goods. They lack comprehensive information on, for example, the emission occurring along the chain and the human rights situation in production locations. This uncertainty is understood to be a barrier to increasing purchasing behaviour for sustainably sourced goods for customers with a high purchasing power. The lack of transparency along complex supply chains, thus makes it difficult to unveil the **low wages for smallholder farmers, the poor working conditions for farm and factory workers, the environmental impact and the lack of sustainable farming and processing practices**. (Mehrländer 2020)

The lack of transparency in supply chains stems, among other things, from their complex nature that commonly involves a wide range of stakeholders: farmers, processors, marketers, handlers, consumers, governments, and the general public. Along the chain, participants have their own interests and are reluctant to share economically sensitive information that can generally cause barriers on the exchange. Smallholder farmers are the weakest actors and have the least bargaining power in the supply chain to actively influence prices and payouts.

The advantages of sustainable supply chains based on Blockchain is that it **stores information with the consensus of all participating parties**. Once the information is stored and verified by all parties, it creates an **indelible record, resistant to tampering** by any individual party. Unlike a centralised database held by a single entity, a Blockchain continues to run even if individual participants pull out or go bankrupt. This technology allows immediate transactions and enables networks to associate transactions with conditions: If transaction A has happened, then transaction B will be automatically executed. An example of such, a **smart contract** is an immediate pay out of an invoice when the product has been delivered to the next stage in the supply chain and both parties agree that all standards are fulfilled. Isn't it great for a little farmer?

Smart contracts – structured as *if… then…* clauses – define the rules and penalties around a digitally represented agreement and also automatically enforce the obligations arising out of that agreement. Usually, these actions are connected with the execution of transactions on the Blockchain. The conditions can be triggered by certain events on the Blockchain, requests from users, transactions, or other smart contracts. The advantage lies in particular in the fact that it is not dependent on a central instance and can therefore also execute anonymous processes securely.

A **token** is a digital asset that is stored on the Blockchain and can be connected to a real-world value. Tokenisation in this context allows **association of unique information to goods and services** to a certain time period, and can be used as **collateral to unlock financing**. The advantage here is that every payment along the chain will be recorded and the traceability of transactions enable transparency. For developing and emerging markets, Blockchain has the ability to offer transparency on how goods are being sourced, processed and transported as each step along the chain of custody can be immutably recorded in real-time onto the Blockchain. This capacity to shed light on the origins of consumer goods is one of the more promising attributes of Blockchain technology for local producers, logistical partners, and custody. It could reward those using sustainable practices thanks to a layer of trust that has been created by a decentralised ledger and the increased price consumers may be willing to pay. All logistical information can be on-chain and all parties will trust a single source of truth that will lead to a faster facilitation of trade.

Oracles are an extension of the smart-contract concept. They enable smart contracts to interact with systems outside the Blockchain. In this way, they can react to external data or events and process them on the chain. This external data can be of any nature: Inputs from digital platforms (e.g. CRM or marketplaces) or website input (via a Web API) are conceivable, as are values from all possible areas recorded by sensors. They will be at the heart of the Agri-food traceability process. In this context, IoT (sensors, RFID, NFC, etc) and mobile solutions are particularly relevant, since they help to reinforce the bond between the physical and the digital world. The failure of even just one oracle can invalidate the quality of the whole traceability process and — especially in case of smart contracts — it may automatically trigger negative repercussions along the entire supply chain. Moreover, inbound oracles pass external data to smart contracts and outbound oracles communicate smart contract-based data to the outside world.

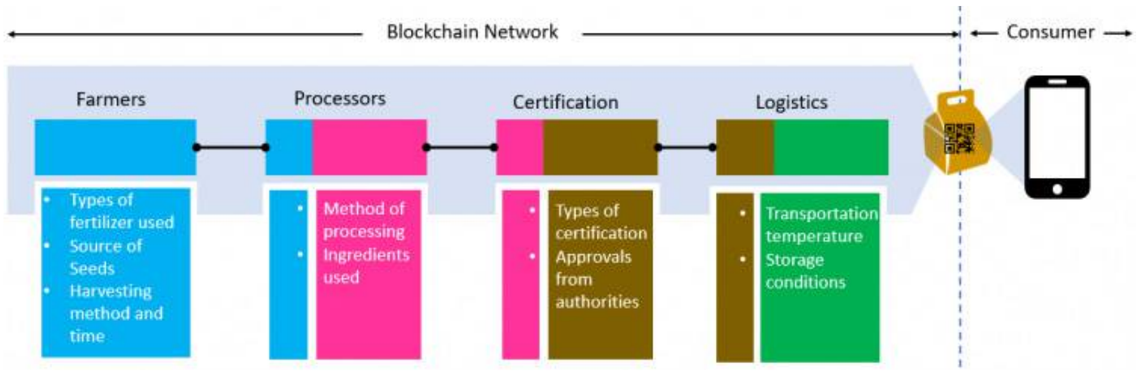

Fig. 2 - A simplified application of blockchain to the supply chain in Agri-food (Sharma 2020)

3.2. BLOCKCHAIN TO PROMOTE TRANSPARENCY ACROSS AGRICULTURE SECTOR

If transparent supply chains are indeed beneficial to local producers, the added-value in terms of decentralisation has to be highlighted with the benefits for the first-mile actors. Blockchain-powered decentralised platforms are more easily utilised by larger actors of the value chains that are trading together without trusting each other, but provide little benefits to first-mile actors. Currently, there are more supply chain business cases in the private sector that focus on centralised and permissioned ledger solutions to help larger enterprises and put less of a focus on decentralisation and sustainability. Decentralised supply chain leads to transparency, availability and the resulting verification of all parties' data and more sustainable farming practices. The decentralisation of data can enable access to finance and immediate payment which supports the first-mile actor financially. The assumption is that transparency of production processes; customers are willing to pay more for a sustainably sourced product. This could incentivise the first-mile actor to produce more sustainably to receive a higher income.

Traditionally, sustainable supply chains have to be verified by a third party to prove their environmental, social, and ethical production practices. As this third party needs to be trusted, the validation process is often centralised in human hands – be it non-governmental organisations, certification issuers or auditors. While this does not mean that trusted third parties need to be systematically replaced, this merely indicates a current unlikeliness of leveraging full decentralisation. While trying to achieve a high level of decentralisation, information exchange between all stakeholders on the supply chain has to be standardised. Furthermore, a data model that everyone can access is crucial in this context to fully leverage the value chain cooperation. By opting for a decentralised model, the governance is equally distributed, however, the data quality and credibility has to be ensured. Individual data of single actors that is not crucial for other actors along the chain should not be accessible. A good balance between data transparency and privacy is required.

Achieving good data quality is not part of the Blockchain technology solution. There are different ways achieving this goal, one is the Internet of Things (IoT) technology, where sensors monitor and record certain situations and environments, in an accurate and unbiased manner. A second solution is to diminish the human error by educating and capacitation of those handling the data, e.g. through training courses, guidelines, and handbooks.

An 'oracle' at the heart of the Agri-food traceability process: As such, another issue is raised by the identity and integrity of these solutions that must record, inside the blockchain, the information coming from the 'real' world. These solutions are commonly called oracles1 (Corbo and Renga 2021)

Blockchain oracles are third-party services that provide smart contracts with external information. They serve as bridges between blockchains and the outside world.

Blockchains and smart contracts cannot access off-chain data (data that is outside of the network). However, for many contractual agreements, it is vital to have relevant information from the outside world to execute the agreement.

This is where blockchain oracles come into play, as they provide a link between off-chain and on-chain data. Oracles are vital within the blockchain ecosystem because they broaden the scope in which smart contracts can operate. Without blockchain oracles, smart contracts would have very limited use as they would only have access to data from within their networks.

It's important to note that a blockchain oracle is not the data source itself, but rather the layer that queries, verifies, and authenticates external data sources and then relays that information. The data transmitted by oracles comes in many forms – price information, the successful completion of a payment, or the temperature measured by a sensor.

Within each project, it is therefore necessary to identify the weakest oracle and to implement the necessary technological remedies. In this context, IoT (sensors, RFID, NFC, etc) and mobile solutions are particularly relevant, since they help to reinforce the bond between the physical and the digital world. The failure of even just one oracle can invalidate the quality of the whole traceability process and — especially in case of smart contracts — it may automatically trigger negative repercussions along the entire supply chain.

3.3. TRACEABILITY, PROVENANCE, AND MORE IN THE AGRICULTURES SECTOR

Demand for organic, local products is constantly rising. Blockchain enables consumers to verify the journey of their product, tracing it from farm to table.

Some promising contexts are those that allow strong consumer engagement, as observed for coffee, cocoa or cotton: consumers in developed countries value sustainably sourced and traceable coffee, chocolate and clothes and are thus more likely to withstand higher prices for demonstrated sustainability.

The focus should be kept at one challenge at a time and not trying to solve all problems at once. Therefore, the effort of the project e.g. tracking the origin, improving the financial flow of payments, decentralised verification of products has to be planned in detail and be openly communicated. For a project to be successful, the identification of benefits of all actors in the supply chain is an imperative precondition. Understanding – and potentially optimising – current processes along the chain is the first step before digitising the assets that will be displayed on chain.

The verification that the digital product is appropriately identifiable in the real world is still an unresolved problem. Attempts to solve it continue, using Internet-of-Things devices such as sensors or QR codes in order to reduce opportunity for human error or fraud. These more technologically advanced methods, however, always require accurate cost-benefit calculations to ensure that projects are economically viable and market-ready. Often, regular checks through certification or uploading of pictures are still required to ensure the digital chain displays the correct information at a low cost. In order to access this information, all parties should have the same viewing permissions to access the due- diligence information.

Digital readiness is a crucial point in deciding whether DLT can be applied in the agricultural supply chain and if first-mile actors have access to the needed infrastructure (including reception in the chosen location). Additionally, affordable internet access is crucial.

3.4. BLOCKCHAIN-BASED PLATFORMS TO IMPROVE FARMER AND BUYER COLLABORATION

One trend is to empower buyers to make further informed purchase decisions. For example, Nestlé collaborated with OpenSc1, a blockchain platform, to trace milk from farms and producers in New Zealand to Nestlé factories and warehouses in the Middle East. This is the pilot project, but a big step that demonstrates the company's commitment towards transparency. Nestlé wants its consumers to make informed decisions, so they want to utilise blockchain technology to share reliable information with consumers. OpenSc platform is founded by WWF-Australia and The Boston Consulting Group Digital Ventures. Interestingly, in 2017, Nestlé introduced blockchain technology in the IBM Food Trust platform and gave access to its consumers the data related to Mousline purée in France.

The most usual exploitation is marketing, as detected in (Corbo and Renga, 2021), 60% of the 82 worldwide projects they analysed, blockchain is mainly chosen to exploit commercial and marketing opportunities. It is a fact, since this technology has been the subject of media hype, many companies use it to try to demonstrate their transparency towards the consumer – therefore offering the possibility to access traceability information about their product. Moreover, most of the time, some digital instruments able to increase the user experience (in particular, QR codes, and NFC tags) are used with communicative purposes.

Transparency, immutability, and sharing of data throughout the whole supply chain are the main benefits of this technology, together with the speed in finding information about each product. On the one hand, all this is allowed by the specific consent mechanisms of each platform, which make it impossible — or at least very difficult — to modify the entered data. On the other hand, it's enabled by the distributed ledger that makes data accessible on a continuous, real-time basis. These characteristics have a further effect of increasing consumer confidence or, more generally, the confidence of whoever can access the data; however, it still has to be clarified how much this can translate into an effective commercial benefit.

And the second clear usage in not just marketing but enhanced selling, as blockchain in agriculture is uniquely positioned to help not only simplify transaction processes but also to level the playing ground for small-scale farmers and crop growers, especially from poor regions.

It is estimated that $940 billion worth of food (Startus 2020) goes to waste every year worldwide. In part, this happens because farmers and growers from less developed countries do not always have access to wide markets, which leaves them incapable of selling all the food they produce.

There are blockchain solutions by giving small players access to their proprietary blockchain-based platform for trading agricultural products and building trust between market participants. Their product allows individual market participants to form small co-operatives and work together.

Another benefit blockchain brings to the table is the ability for agricultural producers to set prices more efficiently and effectively. This allows managing their output to match the demand for their products.

3.5. TOKENS, TOKENIZATION, AND TOKENOMICS

Following and Expanding the scope of blockchain-based platforms to improve farmer and buyer direct transactions of section 3.4 and linked to the transparency and traceability of sections 3.1, 3.2 and 3.3, there is the innovation of **tokenization**.

Tokens, in a general sense, are units of value issued by an organization, but in the context of tokenomics, it is more specifically built on top of an existing blockchain. Tokens have been rebranded with the advent of blockchain, but tokens have always been around. Concert tickets, gym membership cards, and drivers' licenses are all examples of tokens representing value with a more specific use case than currency (Sahu 2020)

This value may be in the form of access to a service, rights over an asset, ownership of an organization, etc. Tokens can thus fulfill different roles in any given native ecosystem by codifying all kinds of values.

There are several types of tokens, namely **utility and security tokens**, **fungible and non-fungible** tokens (NFT), and **natural** tokens. There are more types for enhancing the Layer 1 and Layer 2 utility DLT platforms, and **synthetic** tokens that **tokenize** other cryptocurrencies, tokens or cryptoassets. They are all very interesting as a flourishing new category of digital assets that migrate to the ledger. Out of them, we will here focus on the **natural tokens** as they represent a basket of one several physical goods, that will be the Agri-food tokens that we will see in the examples of OpenVino and Argan Oil.

Tokenomics (token economics or crypto-economics) study the economic institutions and policies of the distribution, production, and distribution of goods and services that have been tokenized. Blockchain technology has become the driving force of innovation on the internet.

Such developments have mobilized economic transactions that rely on tokens and do not require centralized intermediaries like banks or big enterprises. The nature of these commercial systems differs from the traditional industrial economies as its characteristics are decentralized, requiring very little capital to scale, and offering significant security of transactions.

Tokenomics is evolving with innovations in tokens, and thus there is a growing number of tokens with more refined properties. These tokens, apart from the classifications mentioned above, can be based on the following perspectives:

- **Rights:** tokens may give the holder property rights or give the holder access rights.
- **Durability**: tokens can remain stable in the face of censorship and attacks.
- **Regulatory**: tokens are easy to classify and regulate (if required)
- **Purpose:** tokens are created to serve as proof of behaviour (value creation) or represent existing assets/ access rights.
- **Supply:** there may be a fixed supply of token or unlimited.
- **Token-flow:** tokens can be generated linearly (destroyed after use) or remain in circulation temporal: tokens may or may not have an expiration date

What makes Tokenomics Different?

They are fundamentally different from the economics we operate in. In the modern economy, economic forces that govern our lives have, over time, become increasingly channelled in a few centralized bureaucratic institutions. With access to the internet and distributed ledgers, resources of various kinds (including financial capital, supply chain information, etc.) are now flowing through these information networks. Developments in blockchain provide secure and reliable ways to model token economies to reflect better markets' underlying logic in the face of new technologies.

3.6. SMART CONTRACTS TO TRANSFORM AGRICULTURE FINANCE AND INSURANCE

Thanks to the application of smart contracts via blockchain, migrating data onchain, and tokenization, it is possible to program, automate, and simplify transactions which regulate relations within the supply chain without the need for further checks.

In agriculture, smart contracts have unique implementations in the form of helping farmers insure their crops and claim damages with insurance companies. Normally, it is a painfully slow and burdensome process, both on the side of the grower and the company that insures them.

Unpredictable weather anomalies make it difficult to correctly estimate and quickly report the exact losses they cause. This leaves room for fraud and makes the process an operational nightmare.

Through setting up tailored smart blockchain contracts, the damage claim can be triggered via changes to weather conditions that meet certain criteria, easing the process for farmers and insurers.

Another benefit resulting from the use of smart contracts is the possibility to regulate and guarantee the maintenance of product quality throughout the whole supply chain. For example, a product that exceeded the maximum temperature set during its transportation phases could be automatically prevented from being accepted and paid for by the end purchaser (Corbo and Renga, 2021).

One quick example (Ellis 2020) is to provide1 loans to growers and food companies based on its traceability data, or extending a line of credit using enhanced supply chain data collected by tracking fruit through the blockchain, or ground-breaking blockchain projects in the Agri-food industries at the height of the Covid-19 crisis in April 2020, local commodities firms completed a $12 million wheat transaction in a matter of hours — as opposed to the usual weeks — using the Hyperledger Fabric blockchain (Ellis 2020).

3.7. IMPROVING ICT TECH AND MOBILE INTERNET ACCESS TO BOOST BLOCKCHAIN IMPLEMENTATION

Increasing penetration of mobile phones and internet among farmers coupled with private investment is driving growth of interconnected technologies such as remote sensing, artificial intelligence, and big data analytics, which aim to boost efficiency and productivity of farming EOS 2020)

The GSM Association predicts mobile internet penetration to improve significantly over the next five years, to ~39% by 2025. Improved access to internet services is expected to boost the farmers' ability to interact with the blockchain solutions, thereby increasing development and deployment of more blockchain-based solutions for farmers.

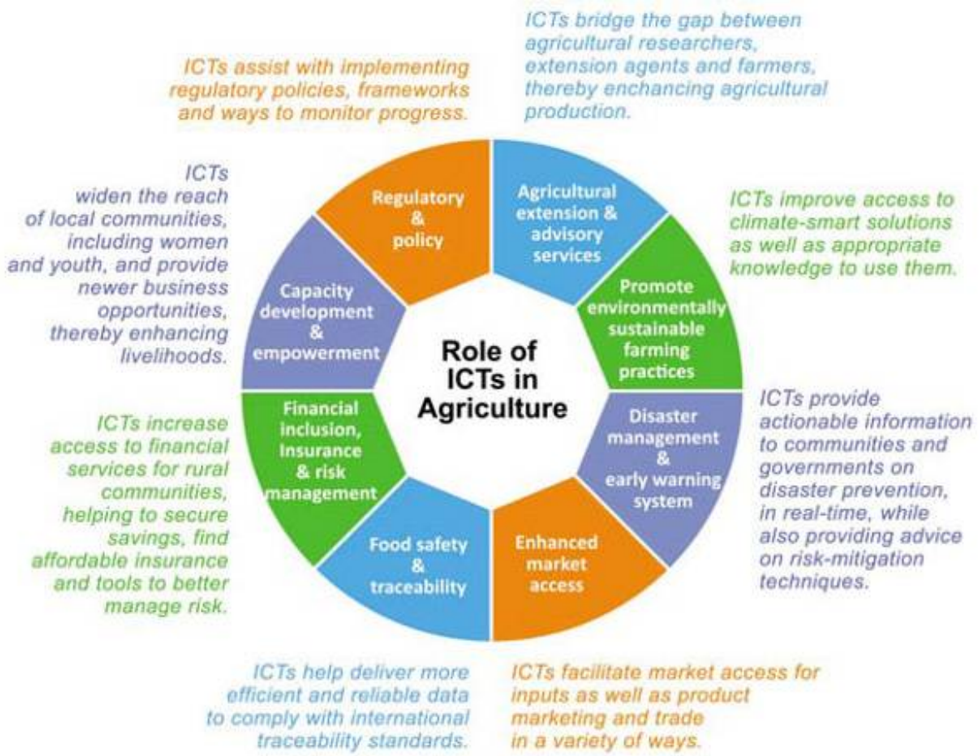

Fig 3 - ICT for blockchain (Sylvester 2020)

3.8. BIRD EYES MAP FOR THE MAIN APPLICATIONS OF BLOCKCHAIN IN AGRICULTURE

In a sort of summary as shown in Fig. 4, blockchain improves the following areas within the agricultural sector (Startus 2020):

- **Optimization of the Food Supply Chain —** Reducing the time of food origin tracing to a matter of seconds — ensuring safety and improving efficiency.
- **Crop Insurance —** Communicates loads, geo way-points and basic compliance information with carriers and registers the quality of the product, its price, location, and parties involved.
- **Transactions —** Helps farmers to sell commodities at fair prices, pre payments and down payments made faster and easier, and lowering transaction fees thereby supporting smaller farmers to enter the market.
- **Traceability —** Smart contracts insure a farmer's crops and claim damages thus replacing old and burdensome insurance processes, which could take up to months.

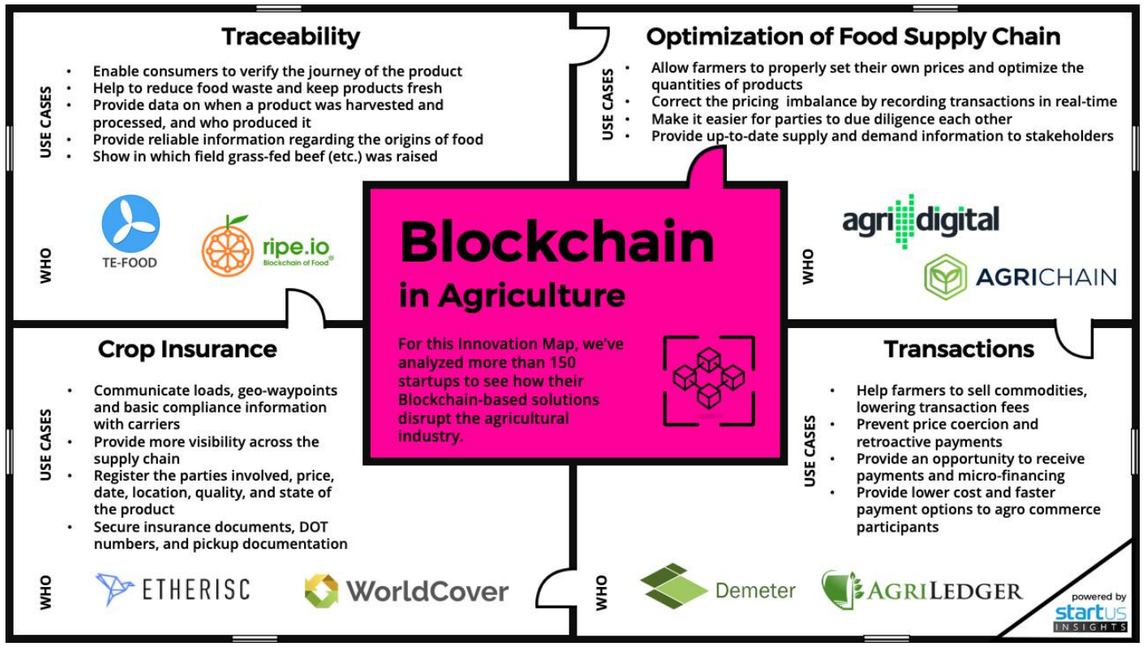

Fig. 4 - Summary chart of the applications of blockchain in agriculture 1

In the following sections, we will see the impact of all these examples, and further examples with the extensive usage of tokenization.

4. THE POTENTIAL OF BLOCKCHAIN FOR AGRICULTURE — HOW BLOCKCHAIN CAN MAKE A DIFFERENCE

Within the food supply chain there are different participants involved in each step, from farmers, to processors, manufacturers, certifying agencies, government agencies, logistics, distributors, retailers and so on. Each of these participants shares critical information about the product that sits in their own local server. This information is not accessible to other participants and thus, there is an increased chance of food fraud in the system.

If a consumer wants to buy organic tomato ketchup, they rely on the label claim. The manufacturer of ketchup relies on the supplier of tomato puree or concentrate processor. The tomato processor relies on the claim/ organic certification furnished by the farmer or farmer association. If any of the participants provide a false claim, both the consumers and other participants are cheated.

Blockchain provides a secure environment where each of the participants in the blockchain network has access to each data and these data, once entered and verified, cannot be modified. For example, a farmer that provides an organic food certificate, which is verified by an authorised agency, cannot have that certificate tampered with a later date.

In order to exploit the full potential of blockchain with regard to traceability, we must therefore think of this technology as a tile to be integrated with other available solutions: Mapping of traceability-focused technological solutions carried out by the Smart Agri-food Observatory1 in 2019 shows that 43% of 44 mapped solutions offered in Italy were enabled by blockchain, marking a yearly increase of 111% . Furthermore, it is important to point out the growth of IoT (30% of solutions, +63% yearly increased adoption), in many cases used in combination with blockchain. No updated reports are on Agri-food but, in the 2021 context of general blossom of the blockchain technology, it is projected a similar pattern of exponential development and adoption for the next years.

In conclusion, blockchain is becoming a very important technology for traceability, in the food industry and elsewhere, despite of being in its very early days as a tool for the sector. It is therefore important that Agri-food companies already do not to rush into implementing blockchain solutions without nurturing the right skills in their teams, in order to avoid the trend effect with a consequent dispersion of resources that in many cases is inefficient.

4.1. HOW BLOCKCHAIN DEAL WITH OBJECTIVES LINKED TO PROVENANCE AND SUSTAINABILITY

In the area of major companies and large companies, it is possible to highlight some of the following examples:

1) The **IBM Food Trust** initiative started with their collaboration with Walmart China and Tsinghua University. This collaboration has grown into a global consortium that includes companies such as Dole, Driscoll's, Kroger, Nestle, Tyson and Unilever. This data traceability provided by the IBM platform reduced the time it took to trace a mango from the store back to its source from 7 days to 2.2 seconds. Such traceability can allow identification of contaminated products and allow for recall before they are consumed.

2) **Carrefour** is a pioneer in this regard and in March 2018 became the first retailer to use blockchain technology for food products, applying it to its Carrefour Quality Line Auvergne chicken. Currently, the technology is rolled out to nine animal and vegetable product lines such as free-range chicken, eggs, cheese, milk, oranges, tomatoes, salmon and ground beef steak. The technology has enabled consumers to have traceability capabilities, with simple smartphone QR scanning consumers are able to download and access a full suite of information about their scanned product; where and how the animal was reared, the name of the farmer, feeds and treatments used, quality standards met, and where the animal was slaughtered. Carrefour would like to have applied this technology to all of its Quality Line food products by 2022.

3) **Chinese e-commerce Alibaba and JD.com** are using blockchain-backed traceability to improve consumer confidence in the authenticity of food products. Beijing-based JD.com started by tracking beef from Kerchin, a company in Inner Mongolia (a province in northern China), to customers in Beijing, Shanghai and Guangzhou. They have also worked with Australian exporter InterAgri and processor HW Greenham & Sons to track Black Angus beef from where it is bred and raised through to processing and transporting.

4) **The BeefChain** was founded by Wyoming cattle ranchers who wanted to know where their beef was being sold. This company received certification from the United States Department of Agriculture (USDA) as a Process Verified Program, and it is the first blockchain company to receive such USDA certification.

5) With more than 70 independent farms participating in Honeysuckle's traceable turkey program, **Cargill,** the Minnesota-based agricultural giant owner of Honeysuckle, hopes to establish a stronger connection with consumers. While incorporating a blockchain element to the supply-and-distribution chain means development of a data-rich environment, Cargill's current emphasis in using the technology centres is seen as data warehouses to analyse and support the blockchain technology.

In the case of **small farmers**, a group of applications have been reported, like these:

a) **AgriDigital** kicked off a pilot in the Australian grains industry to prove the potential of DLT, partnering with CBH Group, a grain growers' cooperative that handles, markets and processes grain from the Wheatbelt region of Western Australia to prove the technology had a place in the supply chain. From then, AgriDigital's commodity management solution to handle contracts, deliveries, invoices, cash prices, and payments throughout the grains harvest. It is used as a customer-facing platform to manage business communications with farmers, including SMS notifications to alert farmers of deliveries (Sylvester 2019) "[which] remove a lot of pain for us – our farmers don't need to ring up anymore, because they just know what's going on";

b) **FARMS** (Sylvester 2019) offered an easy entry to formal financial risk management while increasing farmers' financial literacy. Research has shown that it takes farmers without agricultural insurance four years longer to recover from a bad season compared to farmers with insurance. At the same time insurance uptake remains low as mentioned previously. The FARMS scheme lets farmers grow into an insured state in three stages: exploring, gained trust and fully covered; and

c) **AgUnity**, is a solution promoted by FAO, the Gates Foundation and the International Finance Corporation (IFC) is the creation of farming co-operatives run for and by local farmers. Co-operatives harness the power of collective bargaining (for example, better prices at the market and cheaper supply purchase costs), create a network between farmers within which they can agree to share equipment and resources at an agreed price/ trade, and provide farmers with access to market information that can help farmers select more profitable crops to plant. It has developed a solution that is providing a pathway to financial inclusion for the world's poorest farmers. The AgUnity App is a simple mobile service that helps small farmers plan, trade and track everyday transactions. This is a way for farmers to cooperate, store value, save money and easily buy products and services. The application ensures that everyone gets paid by creating a secure record when smallholder farmers hand over their crops to a co-operative, or hire another farmer's equipment. Issues and disputes currently arise when a farming co-operative and a farmer disagree over a previously agreed price for a crop or even the total volume of the crop provided, either because of graft or simply because of a lack of proper documentation.

And last, briefing few more examples from (Kamilaris, Prenafeta Boldú, and Fonts, 20181):

A) **AgriLedger** uses distributed crypto-ledger to increase trust among small cooperatives in Africa;

B) **OlivaCoin** is a B2B platform for trade of olive oil, supporting the olive oil market, to reduce overall financial costs, increase transparency and gain easier access to global markets;

C) the **Soil Association Certification** has launched a pilot technology that tracks the journey of organic food;

E) in 2018, the World Wildlife Foundation announced a **blockchain supply chain traceability** project to crack down on illegal tuna fishing;

Overall, blockchain in agriculture and the food supply chain market is projected to grow exponentially stronger at a compound annual growth rate (CAGR) of 47.8 percent **to reach US$429.7 million by 2023** from an estimated value of US$60.8 million in 2018. Blockchain has enormous potential to significantly impact the way agricultural business is done, increasing trust between parties, facilitating information sharing throughout the supply chain and significantly reducing agricultural transaction costs (Treat and Brodersen, 20172).

The size of blockchain innovations in the agriculture market is expected to grow from an estimated $41.2 million in 2017 to nearly $430 million by 2023, representing an impressive **47.8% compound annual growth rate** (CAGR).

The blockchain is already **reshaping the industry's way of doing business** by decreasing the risk of fraudulent activities, boosting transaction speeds, helping farmers control and analyse crops, and much more.

4.2. CASE STUDIES

This section reproduces few case studies from (Motta 2020) highlighting those of the EU when available.

Case study (Company)	Framework		Token		Implementation	
	Ethereum	Hyperledger	Utility	Asset	Software	Hardware
Tuna tracking and certification (Provenance)	X	X			X	X
Olive oil tracking (Ambrosus)	X			X	X	X
Celeia dairy (OriginTrail)	X				X	
Pork meat traceability (TE-FOOD)			X	X	X	X
FoodCoin	X			X		
Wine provenance (EzLab)	X				X	X
Total	5	1	1	3	5	4

Table 1. Summary of the case studies from (Motta 2020)

4.2.1 TUNA TRACKING AND CERTIFICATION (PROVENANCE)

Provenance system aims to enhance the transparency of information among the supply chain peers, by guaranteeing that certification and standards are met by all the actors of the supply chain. The system is composed of six modular programs: registering, standards, production, manufacturing, tagging, and user-facing. These six modular programs are independently compiled but registered on the same blockchain, creating a co-existence environment within the same system. Blockchain is used to record the transactions by storing the data in a public and shared ledger allowing the chain to be auditable. Moreover, it allows the activation of smart contracts that facilitate the operation of the user within the chain also for monetary or information exchange (Provenance, 2015, 2016).

Provenance, in collaboration with the NGO Humanity United and International Pole and Line Foundation (IPNLF), conducted a 6 months' project in Indonesia, to track-and-trace yellowtail tuna. The project aimed to use a mobile application together with blockchain technology and smart tagging to track-and-trace the origin and the authenticity of the social sustainability certification. The goal was to create a solid proof of compliance via a solution applicable throughout the supply chain. This would allow to prevent certification double-spending, and test the technology also from the consumer point of view. The whole system implemented data interoperability to track-and-trace items and certification in a secure, continuous, accessible system (Provenance, 2016). For tracking smart tags across the supply chain a point of sale (POS) was introduced. To register the fish, the fishermen needed to send an SMS, with this SMS a new asset is created in the chain with a permanent and unique ID. The unique ID is physically attached to the fish caught using a QR Code, RFID tag, or other technologies. Afterward, the digital asset moves to the supplier along with the catch, and a digital transaction is registered on the blockchain. The identity of the fishermen is saved as well. Tracking and tracing can be verified by exploring the blockchain with public software libraries.

In this case, blockchain was used for sharing information across all stakeholders of the chain, including fishermen, factories, certifier, and consumers. Blockchain was used both for the identification of both physical goods and validating certification. System integration with existing large-scale enterprise resource planning (ERP) was one of the challenges, as most of them do not follow the product throughout the whole supply chain. The unique ID in the form of an address on the blockchain was registered at the beginning of the chain, and propagated across the chain, allowing for matching data across data silos. Having data stored on the blockchain, also enabled it to operate as backend layer on the top of the existing ERP systems, and was used as an audit tool. The backend functionality of the blockchain allowed data to be shared and collected from the first mile with an end-to-end record system. Also using smart sticker and smart packing, the end consumer can use their smartphones to track the provenance of their tuna.

4.2.2 OLIVE OIL TRACKING (AMBROSUS)

This case study considers the application of Ambrosus in the olive oil industry in France. The stakeholders of this supply chain are the olive farmer, the first processor at the olive mill, the packaging at the factory, the supplier, and the retailer. The first step of the process is when the farmer transports the olives to the olive mill, and this is also when counterfeiting may occur. Adulteration can be more difficult to detect, and there is no unique method to spot all the types of contamination. A traceability management system, called GestOlive, aims to address such problems by collecting information, entered manually by the producer. The system does not follow the product after it lefts the mill.

An alpha version used a 'hardware-in-place' approach to analyze methods of phenolic compounds,α-tocopherol and oleic acid already exist (Ambrosus, 2017b). Also, RFID tags were used to uniquely identify the product items. The unique identifier is associated with process and transportation information, stored in a blockchain. Consumers can access information stored in the blockchain via QR codes.

The architecture was based on Amber, a token that follows food products alongside supply chains, recording and handling sensor data through the combination of an Ethereum smart contract and blockchain solutions. The system enables quality assurance across the supply chain, by allowing a complete and rapid digital transformation of the chosen quality parameter into digital content on the Ethereum blockchain. The system is integrated with a detection system sensor that generates the certificates. The sensor is implemented via smart packaging or assembled with an RFID tag, or bio-tracers inside the packaging (Ambrosus, 2017a). These certificates are then stored on the blockchain (Ambrosus, 2017a, c; Versetti and Meyer, 2017).

4.2.3 CELEIA DAIRY (ORIGINTRAIL)

The company OriginTrail introduced the concept of traceability in the supply chain using blockchain for storing supply chain data. This system runs on a token economy, the trace token system. It tokenizes data exchange and the supply chain processing functionalities. The project uses Ethereum to ensure the proof of concept and the initial set-up. The company system works around two principles:

A) Seamless and automatic data connection and interoperability between IT systems of different stakeholders in multi-organization supply chains, with consensus mechanisms for ensuring the integrity of data;

B) A decentralized public solution for performance, cost and scalability issues by providing a tailored decentralized system for supply chain data based on the blockchain (Rakic et al., 2017).

The regulatory environment of the dairy industry already pushes the company to have a state of the art of the traceability system. The dairy sector mainly focuses on the origin of the milk, and the IT and ERP system is configured for tracing static data. OriginTrail transformed the current IT system to provide the origin of the products and its ingredient to the final user. They have separated the production and data keeping processes, in order to create a complete tracking system. Moreover, they used the packing to gather data, via the EAN code on the packaging. Also, to gather data, they look for the correct proxies to obtain the same type of information that is shared all over the supply chain. They look into the IT/ERP systems for the truck routes, they manually insert data regarding milk farmers, and the rest of information was accessed by the marketing department. Afterward, OriginTrail started to optimize the system for dynamic data. The dynamic data were about the routes and farm included in the dairy production in a specific time frame. The data were input in an XML form. Static data, like name, description, photo, nutritional values of products etc., were also included in the OrginTrail system.

Data are collected via a web interface data. For every incoming sourcing file, a hash was created and stored on the Ethereum. Data are still stored centrally, as for this use case a decentralized solution for data storage was inefficient and non-cost effective.

4.2.4 PORK MEAT TRACEABILITY (TE-FOOD)

TE-FOOD aims to enhance food traceability in emerging markets. The TE-FOOD system has three layers: a blockchain layer, an off-chain data layer, and a client application layer. The blockchain layer is divided into three subsystems: a market area for exchange called TFOOD market, a management system for the unique ID, and traceability and food quality ledger. The off-chain data layer is composed by the alerts and reporting by actors in the supply chain. The client application layer supports both TE-FOOD and third-party apps. The system includes both hardware and software components. For the hardware, it provides identification tools such as plastic security seals (1D/2D barcodes), label stickers (2D barcodes), RFID tags, printed paper bags (2D barcodes), and TE-FOOD scale labels (2D barcodes). For the software part, TE-FOOD provides a web solution for all the actors in the supply chain.

Regarding the blockchain technology, TE-FOOD provides immutable and public shared data system for the supply chain actors via a token system. The utility of the token is multiple. First, it is used as payment for transactions. Secondly, it is used as a value system for exchanging information between companies. Thirdly, the consumer will be rewarded to use the app to read QR, and she can spend tokens to order food analysis. Also, token holders can rate suppliers in the blockchain, to create a reputation/scoring system. All the data gathered via the token system will be stored in a public ledger (TE-FOOD, 2017).

The first TE-FOOD implementation was done in Ho Chi Minh City to track-and-trace pork meat. The implementation was carried out via a mobile app taking into account all the actors of the supply chain (farms, agents, slaughterhouses, wholesalers, food producers, markets and retailers, veterinaries, and authority). The animal was identified by a unique ID and QR-code that was stored on the blockchain via the mobile app. Another unique ID and QR-Code was given to the truck transporting the pig after been bought by the agents, and checked by the veterinary. At the slaughterhouse, the QR-code and ID are checked via the app for the authenticity of its provenance. After the meat have been slaughtered, a unique ID and QR-code is given by the veterinary who assessed the quality of the pig. The truck that transports processed pork meat also has a unique ID and QR code. The wholesaler may scan the ID via QR-code to access the meat provenance and verify this quality. At the market, retailers attach a new QR-code with a colour style barcode to the packaging. Finally, the consumer can scan it to know the provenance and the name, address and all the others relevant information of all the actors of the supply chain that have had any interaction with her meat. Thanks to the unique IDs the authority could any moment check the provenance and quality of the pig or the processed meat (TE-Food and LAUREL, 2017).

The system was rolled out in the beginning of 2017, and more than 6000 companies have been trained to use it in South Vietnam. From September 2017 the system has been expended to tracking eggs and chicken, and TE-FOOD reported that 250,000 chicken and 2 million eggs are tracked every day (TE-Food and LAUREL, 2017).

4.2.5 FOODCOIN

FoodCoin system is an Ethereum-based blockchain system designed to create a global market of food and agricultural products on the platform 1000 EcoFarm. This market is open to all actors of the agri-food supply chain from the producers to the consumers. The system works with a token system, called FoodCoin, to buy and sell goods on the 1000 EcoFarm platform. The system employs blockchain to ensure the validity of the reported transactions has seven technical elements (Foodcoin, 2017): a database implemented as a distributed ledger; its own cryptocurrency, called FoodCoin; a multi-functional crypto-wallet, called the Wallok; its own payment system, called DiPay; a remote user verification; a system for smart contracts, and a product authentication system, called the Product Origin ID.

A producer or farmer can sell their products, and the corresponding transactions are implemented via smart contracts, which are checked at every stage of the supply chain by its actors (farmer, logistic company, customer broker, consumer, bank, and insurance company). A bank can be used as a third party to verify the transactions and convert the coin into fiat currency.

The 1000 Ecofarm is a business to business and B2C online food market for natural food that accepts payments with cryptocurrency, the Food coin. FoodCoin is the main source of exchange between the users of the platform. The number of coins is mathematically limited, and its exchange with fiat currencies is a deflationary model due to its limited market cap.

4.2.6 WINE BLOCKCHAIN (EZLAB)

Wine Blockchain is a project of EzLab that uses blockchain technology to enhance the traceability and the authenticity of wine. The project aims to fight adulteration and forgery of Italian wines via a QR code on the bottle. The QR code allows the final user to verify the authenticity of the products and their certifications, using an app. The data collected at the first mile comes from hardware and software, and they are stored both on a blockchain and the AgriOpenData platform to certify product and automate the supply chain. All the data stored on the blockchain and the AgriOpenData platform are published using a tool that allows producers to format and control access level to their data. The final consumer can access this information via the QR code. Finally, all data flow into a blockchain to ensure immutability, certified by a single AgriOpenData node.

Wine Blockchain wants to build transparency and trust among the producer and the final consumer by showing the provenance of the wine thanks to the scanning of a QR code via a mobile app. Two wineries have implemented this special QR code for their wine bottles. The QR code on the bottle allows the final consumer to learn about the production process of the wine. Every process is registered on the blockchain by a sequential ID. At the first mile a unique ID is given, such as 23456a, then during the process and production the unique ID is extended, for example, during the production the code become 23456a-1, and after it has been bottled, it is 23456a-1/b. The information stored about the product concern its geographical context, the cultivation process, the winemaking process, and distribution and sale (Chase, 2017; EZ Lab, 2017 ; Smart Agri-food , 2018).

4.3. A SINGULAR EXAMPLE: OPENVINO

This is another example in the wine production and sales, that is hugely interesting as a case that contains the fourfold benefits of blockchain: transparency in production for an organic wine of great quality, a direct sales method at a fast cash-in crowd sale, a self-pricing and light logistic process, and a powerful engagement and loyalty programme with strong influencers advocating for global sales.

Organic Costaflores S.A. is a boutique wine producer in Perdriel, Luján de Cuyo, Mendoza, Argentina, where organic grapes are grown for Costaflores red wine (blend) called **MTB* – Mike Tango Bravo.**

Let us see how the project is then we will disectionate the several benefits of this extraordinary use case.

Fig. 5 – La botella que se tokenizar a razon 1 Botella OpenVino = 1 Token MTB

OpenVino® was an experimental collection of open-source software packages, business processes and designs, by a global team of idealists. While the first implementation of Openvino was developed as a proof-of-concept for the Costaflores boutique winery in Mendoza, Argentina as early as 2018, subsequent versions available in 2021 were freely available for other wineries in the world. Here is an in-depth project overview.

What were the requirements of OpenVino?
They consisted in 6 points where blockchain has a deep impact in:

1) Growing the Grapes – all things about organic viticulture (collecting that data)
2) Making and Delivery the Wine – from the crush and bottling, to storing, shipping and exporting (collecting data again)
3) Managing the Business – general accounting, inventory, financial, personnel, taxes (and data, again)
4) Selling Wine-backed Cryptocurrency – using the blockchain to build customer-defined pricing (this is tokenomics)
5) You Drink It, You Own it – how customers respond to their drinking experience (this is about engagement)
6) Telling their Story – Getting the word out (and more and more engagement with global influencers).

The goal of the The OpenVino Project was to create the **world's first open-source, transparent winery, and wine-backed cryptocurrency by exposing Costaflores' technical and business practices to the world**. The primary objectives of this project were to answer the following four questions:

- What is the truth, importance and meaning of "organic / eco / bio" in wine and agriculture in general?
- What would happen if we were to share ALL the accounting and operational details of our business with the world?
- When the cost of a bottle of wine can vary by orders of magnitude ($1, $10, $100, $1000), how can we assess a wine's REAL VALUE?
- How can we objectively evaluate the QUALITY of a wine, based on a consumer's experience, and the wine's effect on their consciousness?
- Ancillary objectives of The OpenVino Project included:
- Develop a **new business model** that other companies can reference, adopt and adapt; an altruistic experiment to create a new ethical and sustainable business model.
- Build a "self-running" company using many of the concepts related to Distributed Automated Organizations[1]
- Share knowledge – by **exposing Costaflores viticulture and business practices to the world**, they wanted to both share their experiences with other viticulturists and winemakers, and thus become a known reference site in the world, and learn from others who observe their practices and offer suggestions and constructive criticism.
- Spawn a **new crypto asset** – create the world's first "wine-backed" currency and trading platform.
- Reduce costs by monetizing the promotion platform, fomenting competition amongst Costaflores providers, and **utilizing Costaflores own cryptocurrency** to buy and sell services and products.
- **Redefine the way wine was valued.** Wine is both a commodity and an art form. A consumable foodstuff, and the elixir of muses. With this project they tried to redefine the way this commodity/art form was valued, by giving the valuation tools to the marketplace, to the consumer.
- Incorporate the ultimate traceability tools (Vine → Wine → Dine → Mind) that allow them to follow their product from vineyard to mouth - and beyond.
- Integrate open-source technologies and cloud services development techniques. The project's development was documented as a case-study for future cloud services developments.

1 https://en.wikipedia.org/wiki/Decentralized_autonomous_organization

4.3.1 ON TRANSPARENCY

As said in the introduction of this rapport, transparency is a key value for building sustainable, ethical, profitable businesses, and is an important tool for small companies.

Despite being under greater public scrutiny, large enterprises can often benefit by keeping secrets: proprietary trade information, opaque competitive practices, and "insider" market information. For example, large wineries can negotiate advantageous purchasing deals for packaging materials and logistics, whereas smaller brands are relegated to higher prices or inferior services and products. Higher up the food chain, beverage conglomerates can manage and manipulate the marketplace by obliging merchants to purchase smaller or newer associate brands in exchange for access to "must-have" brands. So for medium and large corporations, "keeping their cards close to the chest" can be advantageous and instrumental.

But **small companies, small farmers, lack this kind of leverage**, having nothing to hide, or more to the point, nothing worth hiding. However, small companies can benefit from transparency. Costaflores **was too small of a company** to have the leverage to negotiate advantageous purchasing deals, but by publishing openly its packaging materials and logistics requirements and purchases, Costaflores openly invited providers to compete for its business. By participating in these transparent transactions, these providers received Costaflores business, albeit small, but they could benefit from positive publicity and branding associated with the ethical and sustainable business practices of this project.

4.3.2 PROMOTE ETHICAL BUSINESS PRACTICES

Consumers value honesty, integrity, and "fair-trade" practices in a marketplace muddied with confusing nomenclatures and certifications.

Today there is much confusion amongst wine consumers regarding the meaning of *Organic / Eco / Natural / Fair Trade / Biodynamic* labels. With The OpenVino Project, Costaflores strived to become a touchstone or reference point to help consumers and industry reporters undo this confusion.

With The OpenVino Project, they defined, implemented, automated, and monitored their ethical business practices, with hopes of positively answering the following questions:

- Are Costaflores employees compensated fairly for their efforts, and do they become owners of the growing success story?
- Do their sales and marketing claims reflect truth and authenticity?
- Do Costaflores production and logistics processes minimize their impact on the environment?
- Does The OpenVino Project contribute ideas and intellectual property that are beneficial to society?
- Does this project promote Costaflores fulfilment of legal and fiscal obligations, both in the spirit and letter of existing laws?

4.3.3 WHAT ABOUT SUSTAINABILITY

Within The OpenVino Project, they exposed the underlying costs, both financial and ecological, in the production, sales, and distribution of wine, and implemented self-correcting formulae for evolving a sustainable (and autonomous) company.

This included defining how profits and participations were distributed, both to Organic Costaflores S.A. employees and to shareholders, with the aim of plotting predictable growth and incentives, both for employees, and committed stakeholders.

4.3.4 AND HOW DID CONSUMER DEFINED PRICING WORK?

With The OpenVino Project they challenged the wine industry and the world to demystify wine pricing. How can it be that the price of 750ml of fermented grape juice can vary so much? A bottle of wine can cost $1, $10, $100, $1000, or $10,000: five orders of magnitude. What is the “real value” of a bottle of wine? How can quality be quantified? How can one create the world first wine-backed cryptocurrency or cryptoasset? And how can a trading platform for this new currency be used to generate “consumer defined pricing”?

4.3.5 COLLECTING DIRECT CONSUMER FEEDBACK

Still today, wine industry experts define and dictate quality evaluations of wines. This most often takes the form of points ratings by expert critics, or by medallion awards at international wine contests. These evaluations, though valuable, are flawed to the extent that they only represent the qualitative values of a few people and their tastes at specific points in time (tastings) where specific conditions and predispositions of the quality judges may be circumspect. In other words, these expert opinions are valuable, but they remain anecdotal. The proof in the pudding lies in what actual wine drinkers think about the wines they are drinking.

But, documenting end-drinker opinions and circumstances require time and effort on behalf of the consumer. With The OpenVino Project they broke ground by compensating customers for their feedback. In exchange for the information they provided about their product, they provided them with actual shares in the company, Organic Costaflores S.A. The concept is: ***“You drink it, you own it.”.***

By collecting authentic consumer experiences, they created a feedback loop, allowing them to qualify and quantify experiences associated with wine, and justify consumer defined pricing. And by making consumers part-owners in the enterprise, they leveraged the positive “owner’s bias”.

4.3.6 WHY DON’T EDUCATE AND LEARN CONSUMERS

As the first open-source winery, Costaflores shared with the world, through didactic and accessible tools, how grapes are grown, and how wine is made, distributed and sold. They exposed the business practices and technical procedures to an unprecedented degree. By teaching their “secret recipe” to the world, they invited constructive criticism from others with deeper experience and knowledge, and they invited innovative approaches.

4.3.7 AND FINALLY, WHY DON’T DEFINE NEW STANDARDS

The OpenVino Project is intended to be a touchstone for building transparent, ethical, sustainable wine businesses. All software tools and components, wherever possible were intended to be built upon existing open-source applications and would be downloadable. All documents, videos, and other didactic components were made available under Creative Commons licensing.

For further information of the OpenVino project consult: https://ico.costaflores.com and https://wiki.costaflores.com/display/OP

Summing up: this is a great case of **deep transformation of a traditional business of grape growing, wine producing and selling**, that under the blessing of blockchain a new engagement with consumers that access freely to the production data onchain, **directly purchase and resale the wine they love**, so that intermediaries are no longer who name the price but the pure market instead, globally. This implementation of OpenVino was a first step, because it still is highly improved by means of novel developments like the Automated Market Makers after the full tokenization of the wine production as natural tokens (See next section about the Argania Oil) and a reshape of logistics under the new reality of direct sales over the world onchain, with the blockchain. The company Miraflores moved forward from a market that they could barely sell their bottle of wine with a price of less than 1 USD at the delivery time (three years after the wine production, stored and curated in barrels) towards a decentralised market where they sold at a departing prices of more than 4 dollars per wine bottle and peaked their sales at 12-15 USD, receiving cash from the very moment of barrelling and delivering the bottled wine 3 and more years later.

This is a huge advantage. Many other little farmers might follow this example, by delivering their competitive advantage onchain.

4.4. MORE IDEAS ON TOKENIZATION; NATURE TOKENS — EXAMPLE OF THE ARGAN OIL PROOF OF CONCEPT

In the context of concern about the origin, quality and safety of food products, there is need of a more powerful and fruitful digital food traceability system and a fair trading mechanism with local cooperatives and compliance with relevant certifications.

According to Reports & Data[2] the Argan Oil Capital Market was $ 220.87 Million in 2019 and grows at a rate of 10.7% to reach $ 499.90 Million in 2027. Very little of this value goes to the small farmers.

This is an exercise by taking the advice of OpenVino for working out further a tokenization process to enhance the competitive of small farmers: A **Natural Token** to expedite sales transactions and a traceability mechanism for the **provenance**, the origin of the Argania fruits (southeastern Morocco), and **compliance** with ecological certifications of such a product that has surprising multiple usages.

This is the case of natural products of origin such as **Argan Oil** that can only be produced with the fruits collected from trees endemic to the south-western region of Morocco, the Argania. The risks associated with the production and marketing of Argan Oil are:

- Fraud and use of fruit that does not come from the south-western region of Morocco
- Exploitation of local farmers and cooperatives
- Fraud in the production process and crimes against Public Health
- Manipulation of purchase and sale prices
- Improper transport of the final product

Current exploitation, sales, and distribution systems are lacking in transparency and trust. The absence of an immutable digital record describing the different stages of the value chain, so the pricing mechanism represents an obstacle to the efficient and safe marketing of this natural product, as well as the small farmers get very little out of this excellent product and have little defense from the mixing with other oils outer their region.

In this sense, Blockchain technology offers a technological foundation to ensure detailed and transparent traceability from source to destination, a high digitization of the supply chain and finally a mechanism to digitally label the quality of a product having taken into account the entire history of the product from the beginning to the end.

In addition, we expect that the tokenization of Argan Oil, its conversion into a digital asset on a Blockchain platform, would speed up trading operations and establish a fair, dynamic pricing mechanism based on the merit of producers and product quality.

4.4.1 BRIEFING THE SOLUTION

The tokenization would be deployed on the Ethereum platform that offers two interdependent services related to the production of Argan Oil and its sales by means of a Natural Token.

Traceability has two objectives: to describe the production processes and to control the parameters that guarantee the origin, the quality of the processing and the fulfilment of the official certifications as a Natural Product.

— **Origin:** The trees of Argania fruit are endemic to Morocco. The most important data at the level of traceability is related to the physical location of the trees and the cooperatives or companies that collect the fruit.

— Processes: the traceability mechanism collects and store immutable data in the Blockchain that describe each stage of the production process:

- Fruit harvest
- Fruit processing
- Oil Processing
- Oil Shipping

2 https://www-reportsanddata-com.translate.goog/report-detail/argan-oil-market?_x_tr_sl=ca&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=nui

— Certificates: Based on the traced data, there must be a mechanism that crosses the data with the most well-known **Natural Product** certification criteria worldwide.

- EC 834/2007 : EC Regulation on the Production and Labelling of Organic Products[3]
- COSMOS : Certification of Ecological and Natural Products [4]
- NOP Standard : National Organic Program (United States) [5]

Tokenization: The representation of the value of Argan Oil on the Blockchain platform is done using a Token called ARG following the ERC20 standard (fungible token):

> 1 ARG corresponds to 1 litre of Argan Oil physically stored in a duly declared warehouse and reported onchain.

Smart Contract	Code / Name	Description
ArganToken	Code: ARG Name: ERC20 Argan Oil Token	The value of 1 littre of Argan Oil. 1 ARG = 250 euros (departing price)
ArganOperation	Smart Contract to Buy, Sell or Introduce Argan Oil onchain	Operations can be at the level of Token Exchange, or introduction of Argan Oil physically stored by certified producers.

The main processes are:

- Argan Oil Production: Leak Harvest, Fruit Processing, and Oil Processing.
- Certification of the Oil produced based on the information collected during the production process
- Persistence of traceability data in Blockchain
- ARG Token Operations:
    - Supply of ARG Tokens
    - Conversion of litters of Argan Oil to ARG digital tokens (for sale)
    - Direct acquisition of ARG from the farmer and other participants.
    - Buying and selling Argan Oil (transactions with ARG)
    - Transaction bonus through the whole supply cycle

4.4.2 BRIEF DESCRIPTION OF THE COMPONENTS OF THE POC (PROOF OF CONCEPT)

Let us start with the tokenomics, the fees structure and bonus of the natural crypto token – from its qualities to its distribution and production, and much more explanation of the emission strategy of the ARG Token as well as the mechanisms for increasing its value.

Remember that Argan Oil Capital Market was $ 220.87 Million in 2019 and grows at a rate of 10.7% to reach $ 499.90 Million in 2027.

Therefore, by only following the trend, the ARG Token might grow in value of yearly 10.7%, even more along the advantages offered by the Blockchain Platform that would push the volume of transactions up, and could grow exponentially, causing much higher growth of the value.

3 https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF
4 https://www-cosmos--standard-org.translate.goog/cosmos-certification?_x_tr_sl=ca&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=nui
5 https://www-ecocert-com.translate.goog/en/certification-detail/organic-farming-usa-usda-nop?_x_tr_sl=ca&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=nui

A) Tokens Supply

After every farmer rapport with the (checked) reported amount of Argan Oil littres, the platform mints as many million ARG as many 1 litre bottles with Argan Oil are stored for sales, and will put it up for sale in a (decentralised) market. Fees and bonus (examples):

- 1% to tokenize certified Oil into ARG (on sale on the platform)
- 2% on transactions, sales and purchases with the ARG Token.
- 5% “royalties” for the small farmers on the higher benefit on the ARG tokens along the supply chain, resales, and more. This way, they capture not only a fair initial sales price but part of the added value in the likely event of the token valorisation.

The buyers and resellers now work in an open and transparent market, open to new actors that might see the ARG as a good **medium to long-term investment:** As the volume of transactions grows, the value of ARGs will increase according to its market exploitation and everybody including the little farmers will be able to capitalize and make profits with available ARGs.

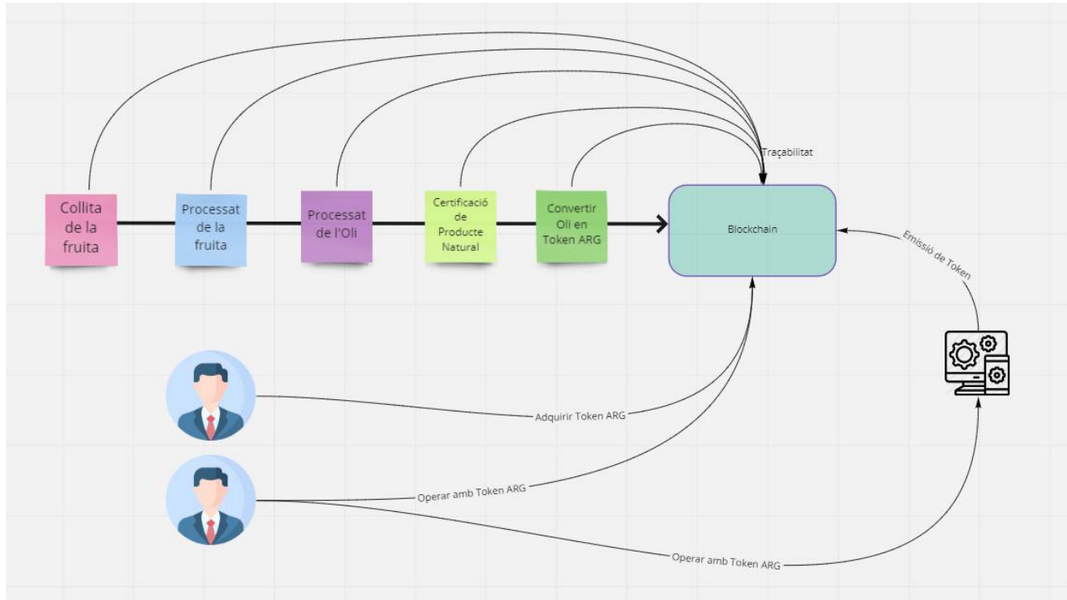

Fig. 6 - Schema of the ARG token

The Blockchain technology ensures that recorded information is unalterable without the consent of participants. This enables an environment of trust where business logic can be automated and the bureaucracy and complexity of processes can be considerably reduced, for the sake of the small farmers and better price and fair transparency for the final users.

The central idea of this work is based on a platform where a buyer only specifies the amount of Oil and ecological certification desired. The Smarts Contracts deployed and the TOKEN used to complete financial transactions do all the work to determine the best price, the best supplier, the duly certified products and the best shipping option. All contractual and environmental details and verifications are done in a transparent, secure, and efficient manner

And this is a Proof of Concept that use the several concepts introduced in this report. This development requires of developers that master the blockchain technology but as well the open mind for enhancing the competitive advantage of small farmers that might reorganized locally around natural tokens for better crops.

4.5 BLOCKCHAIN START-UPS DISRUPTING THE AGRICULTURAL INDUSTRY

Apart from the already explained use cased of TE-FOOD (tefoodint.com) that applies **identification tools** to livestock, transports, and fresh food packages to follow the items throughout the whole supply chain, and AgriLedger.io that is a UK social enterprise project supporting farmers in tracing food origins, getting easier access to financing, and storing transactions data, and **AgriDigital.io** that is a blockchain-based and integrated commodity management solution for the global grains industry, a platform that helps to process complex agricultural transactions through smart contracts, there are further examples from (Startus 2020) with Blockchain Start-ups Transforming the Agricultural Industry are the following:

- **AgriChain.com** – A blockchain company focusing on **enabling peer-to-peer agricultural transactions** and processing while cutting out the middlemen. AgriChain brings together all stakeholders in the agricultural supply chain, allowing them make better-informed decisions, eliminate unnecessary paperwork and dockets, reduce supply chain inefficiency and risk, open markets and increase their bottom line, all on one easy-to-use platform.

- **Demeter.life** – A central hub to **rent and farm micro fields anywhere in the world** – with no middlemen, complexity or the overhead of a big organization. They promote the worldwide movement of biodynamic agriculture, a holistic, ecological and ethical approach. Demeter is the brand for certified products from biodynamic farming.

- **Etherisc.com** – A blockchain startup offering crop insurance to farmers via its **decentralized insurance applications** to collectively build insurance products. Make Insurance Fair and Accessible, help make the purchase and sale of insurance more efficient, enable lower operational costs, provide greater transparency into the industry and democratize access to reinsurance.

- **Ripe.io** – By designing a **transparent digital food supply chain**, the startup harnesses quality food data to create the Blockchain of Food – mapping the food journey. They are building long-lasting trust and confidence in our food supply chain through a platform where everyone can access transparent and reliable information on the origin, journey and quality of their food.

- **Worldcovr.com** (online page unavailable on the October 27,2021 access) – Provide crop insurance to protect against loss of yield using satellites to monitor the rainfall and **trigger payouts automatically**. WorldCover's mission is affordable risk management for the developing world.

5. CONCLUSIONS

There is no one-size-fits-all solution. Every supply chain has to be checked if it has the potential to effectively leverage DLT. The capacity to run Blockchain- powered supply chains will largely rely on the ability to tokenise a traded good. The more unique and identifiable the good is, the more its digital twin will faithfully reflect its identity. Bridging this representational gap between the actual good and its digital token implies that at any given point along the supply chain, the person holding the digital and the physical item can make sure that it corresponds and has not been subject to any tampering. Unprocessed coconuts or pineapples for example are easier use cases for traceability as they can be easily marked and traced – off-chain and on the Blockchain. In comparison, fungible goods such as coffee, are harder to track. Reducing the risk of such fraudulent activity along the supply chain remains a key challenge for Blockchain use cases in agricultural supply chains – the so-called oracle problem.

5.1. THE EXPECTED CONTRIBUTION OF BLOCKCHAIN TO THE AGRI-FOOD SECTOR

According to the observations from research conducted over the last four years by the Smart Agri-food Observatory and summarized in the report (Corbo and Renga, 2021), they identified four main objectives that encourage agricultural and agri-food companies to adopt blockchain technology, listed in order of relevance:

A) Blockchain is linked to commercial and marketing opportunities: In 60% of the 82 worldwide projects that report analysed, blockchain is mainly chosen to exploit commercial and marketing opportunities. As a matter of fact, since this technology has been the subject of media hype, many companies use it to try to demonstrate their transparency towards the consumer – therefore offering the possibility to access traceability information about their product. Moreover, most of the time, some digital instruments able to increase the user experience (in particular, QR codes and NFC tags) are used with a communicative purpose.

B) Blockchain's characteristics of immutability and transparency are used to improve coordination among supply chain players by increasing the visibility of information and, as a consequence, the effectiveness of the whole supply chain linked to the effectiveness of the supply chain (40% of projects analysed in that report).

C) Blockchain is linked to sustainability Environmental and social sustainability are becoming more relevant, according to 21% of the projects analysed in that report. In most of these cases, companies try to keep track and to give visibility to their sustainability practices.

D) Another use of blockchain concerns food safety, making the procedures of product recall more efficient and effective, especially in the large-scale distribution sector. There are also uses related to anti-counterfeiting; blockchain allows stakeholders to keep track of data and its modification over time, making overwrites particularly difficult.

The use cases presented in this report revealed that blockchain technologies can help to overcome challenges and inefficiencies the agri-food sector is facing, and the potential benefits of blockchain implementation in the agri-food sector are various (Papousoglou 2021): Blockchain is a tool that can generate trust if appropriately handled. Data are stored in the blockchain. Blockchain technologies allow tracking the course of food throughout every stage of the supply chain. Data privacy can be preserved as these technologies allow for revealing only action-relevant information. In other words, blockchain could help to manage information along supply chains, support traceability and increase transparency. For instance, consumers could track the origins of the products, while producers could develop plans optimising their production and marketing processes. Moreover, economic benefits could be harnessed as blockchain could create marketplaces without the numerous intermediaries. Providing one concrete example, products' brands could be protected from the existence of counterfeit products by using a unique QR code that redirects to the authentication certification stored in the blockchain. Finally, blockchain-based solutions can also facilitate to bridge the wide range of stakeholders (inspectors, shippers, insurers, payment institutions) to a single place that would result e.g. in reducing the time of performing audits, for the direct benefit of small farmers.

5.2. BLOCKCHAIN AND AGRI-FOOD IN EU

LIVERUR aims to support businesses, projects and initiatives in designing innovative business models in rural areas, moving towards a Circular Economy and including all important stakeholders by following the Living Lab approach. It involves more than 20 European partners from peripheral areas in which the development of the rural economy is vital for their survival. LIVERUR1 conducts socio-economic analyses to identify, describe and compare the differences between the new approach of Living Lab and more entrepreneurial traditional approaches (mass production, development of prices, optimizing cost structures with companies, rationalization).

On the other hand, Agritech/Agri-food offers an immense opportunity, and blockchain is likely to be an integral part of this opportunity. Blockchain has already started witnessing implementation in systems providing proof of ownership, platforms for farmer cooperation, and agricultural financing tools.

Unlike Asian and Latin American countries, Europe markets have shown a relatively positive attitude towards adoption of blockchain, while only Africa is eager to adopt it. This is why the EU opportunity to make a dare step. As for Europe, Increasing sustainability of supply chains and transparency in the Agri-food value chain are key objectives of the European Commission's Green Deal and the Farm to Fork Strategy.

The potential that blockchain technologies offer, has not been fully harvested by stakeholders in the Agri-food sector. This concerns both, the private and the public sector in the fields of e.g. voluntary and official labelling schemes, proof of origin and ways of production as well as of smart contracts. To boost the use of blockchain applications in the Agri-food sector in a tailored way and to achieve economic, environmental and social gains, it is essential to take stock off:

- the state of play of application of blockchain technologies in the Agri-food sector;
- the experiences gained with blockchain applications in the Agri-food sector, including opportunities as well as challenges faced by the various actors and possible barriers to further roll-out the use of blockchain technologies;
- and of lessons, which can be learnt from other supply chains for the Agri-food sector.

Several instruments at EU level are and will become available to (further) develop blockchain technologies for the Agri-food sector, including the Research and Innovation Programme Horizon Europe, the Digital Europe Programme as well as Pilot projects within the framework of the European Blockchain Partnership (EBP).

5.3. FINAL REMARKS AND ASSESSMENT

In order to exploit the full potential of blockchain with regard to traceability, we must therefore think of this technology as a tile to be integrated with other available solutions.

Mapping of traceability-focused technological solutions carried out by the Smart Agri-food Observatory in 2019 shows that 43% of 44 mapped solutions offered in Italy are enabled by blockchain, marking an increase of 111% in a year. Furthermore, it is important to point out the growth of IoT (30% of solutions, +63% in a year), in many cases used in combination with blockchain.

Numerous stakeholders are taking part in every phase of the agricultural supply chain. The range of stakeholders reaches from farmers to customers with each stage adding different participants in the supply chain. International trade and the participation of stakeholders from various countries around the globe make supply chains additionally complex.

Agricultural businesses are heterogeneous as it regards the extent of adopting technologies, depending – among others – on the available digital infrastructure, and farmers' beliefs in technologies. Some farmers would regard digital technologies as a means to improve the working routine, while other farmers would be afraid of turning into office workers and lose their social connections and in relation to the environment.

Some farmers would be concerned about blockchain adoption. These concerns include the fear of becoming obsolete, a lack of trust in automated documentation, the unauthorised access to their business data. Data ownership turned out to be a general issue that makes farmers hesitant to adopt blockchain.

On the other hand, farmers would also recognise the benefits of adopting blockchain. Bureaucracy could be decreased with a central ledger to be used by the reporting tools. A central ledger could act as a single point of truth and diminish the numbers of audits. Furthermore, administrative costs could be reduced as audits could be performed more efficiently. There might be the opportunity to access international markets more easily and at lower costs as border controls could be facilitated through blockchain technologies. Blockchain could facilitate the creation of digital marketplaces allowing for more flexible and transparent trading at various stages along the supply chain. Moreover, blockchain applications would offer the opportunity of incorporating loyalty programs that are available to farmers to reward their customers. Data on the farmers'

The data prior to the blockchain adoption were retrievable but scattered in participants' systems, reliable but could not be accessed on-demand. They were decentralized, fragmented, and various formats were used to store the data. The adoption of blockchain has shifted the characteristics of data. In blockchain, the data are shared via logical events; are stored in an immutable ledger; are rich, organised despite being distributed; and are secured and immediately available.

The paradigmatic case of OpenVino displayed an application that acts as one-tool-for-all showing that blockchain is like as Swiss knife: the direct engagement with highly informed consumers by the data automatically dumped onchain and the direct sales through a self-organized global online market that works as intermediary between participants of the supply chain.

However, standards are underdeveloped and not mature yet: Being at a stage of rapid technological development, there are no mature standards addressing DLT yet. At this point, there are various competing proprietary and community-managed DLT platforms and frameworks. The absence of international standards carries risks related to customer lock-in, lack of interoperability, privacy and security.

As a conclusion, blockchain is gradually becoming a very important technology for traceability, in the food industry and elsewhere. But it is still in its early days as a tool for the sector. It is therefore important that small farmers do not to rush into implementing blockchain solutions without nurturing the right skills in their providers, in order to avoid the 'trend effect' with a consequent dispersion of resources that in many cases is inefficient.

But certainly, as long as small farmers are digitized, definitely they will benefit from the adoption of Blockchain for business, for marketing, and for operations, saving costs, safer sales, and selling more at a fairer price to get higher share of the added value made out of their crops.

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ANNEX 1. TOP 20 AGRITECH START-UPS IN 2021

1. Connectera

Founded in 2015, Connectera is an Amsterdam-based technology company that "helps to run the most efficient dairy farm by working with farmers to identify issues, recommend solutions and streamline operations." Their mission is to train Artificial Intelligence to learn how to farm, so they can empower farmers of all sizes to increase productivity of their farms, while reducing the impact of farming on the planet. They have developed IDA, an AI-enabled dairy assistant that connects farmers and the value chain to identify issues on farm, recommend solutions and support farmers to make the transition to sustainable farming and agriculture.

2. Kiwi Technologies

Founded in 2017, Kiwi Technologies is the "developer of an unmanned aerial vehicle paired with a custom-designed ground support platform designed to deliver the standard volumes of chemicals and seeds that are needed by commercial farms." Furthermore, this vehicle features an "easy-to-use flight planner that uses GPS technology to ensure even and comprehensive coverage of the farm and offers a safe and precise application that avoids over-spray while limiting runoff, enabling farmers to use the autonomous, GPS and radar guided system to get exactly the coverage that they want and where they require it."

3. Provivi

Provivi is a technology company founded in 2013 by Nobel Laureate Dr. Frances Arnold and co-founders Pedro Coelho and Peter Meinhold with the mission of "applying state of the art technologies to improve life and aspirations of farmers across the globe." The company is known for developing natural and affordable pheromone products as a way to control pests and protect the quality of food crop yields.

4. Terramera

Founded in 2010, Terramera is a "global agtech leader fusing science, nature and artificial intelligence to create game-changing technologies that can solve some of the world's biggest problems." Their revolutionary technology, touted the "Actigate™ technology platform," is known to "reduce synthetic chemical loads and make organic alternatives more effective." This makes farming healthier, more sustainable and productive. As a testament to the ag tech leader's status in the industry, their technology is recognized as a World Changing Idea by Fast Company and is even projected to reduce the global synthetic pesticide load by 80% by 2030.

5. Livestock Water Recycling

Livestock Water Recycling is a patented nutrient recovery platform that is considered the world's leading provider of manure treatment technology. The company reduces the volume of livestock manure by using their own LWR System. This system and technology works by concentrating nutrients into food crop fertilizers and transforming them into a clean source of water. Their technology allows farmers and different agricultural companies to achieve a cleaner and greener manure management system and provides about 20-30% return on investment.

6. Intelliconn

Intelliconn is an agritech start up that seeks to create new technologies and systems to solve the problems facing agriculture today such as grain spoilage, grain quality consistency, and sampling difficulties. Through its VeriGrain automated sampling and data management system, the company is able to automate sampling for a more accurate and representative grain sampling.

7. EarthSense

EarthSense is an agritech company that develops ultracompact and autonomous robots for food crop breeders, scientists and farm growers. Their technology led them to develop and create their own autonomous robot, TerraSentia. This smart agritech robot features an entire lineup of sensors that collect data from plants and crops, allowing farmers and scientists to determine data-driven decisions that will directly affect their crops' health, physiology and stress response.

8. Biome Makers

Biome Makers is a global agritech company that offers the leading soil tech platform BeCrop. It measures the biological quality of different farm soils and delivers agronomic insights to farmers to better optimize farm operations. Through this platform and technology, both customers and farmers are given data-driven and scientific insights that enable them to make the best decision for their farms and crops.

9. Verdical

Verdical is an automated indoor gardening system and platform that allows restaurants and other food-related businesses to grow their greens and other produce with a single swipe. Restaurants and other businesses can greatly eliminate and improve their supply chain by letting consumers interact with their ingredients through the platform.

10. Kakaxi

Built on the idea and importance of farm-to-table transparency, Kakaxi is an AI solar-powered farm monitoring device that allows conscious users to properly monitor and grow their food crops. By using the latest smart technologies in agritech, the platform allows users to monitor food growth and weather data to make for smarter farming decisions. The platform also fills farmers in on important details derived through a time-lapse video of the food's growth.

11. Kray Technologies

As the creator of the world's first digital and fully unmanned drone crop sprayer, Kray Technologies is known in the industry as the most efficient form of crop protection application to date. These drones — meant to replace AG planes — can precisely deliver on-demand fertilizers and pesticides right into farmers' crops and products. This new technology allows farmers to cut down costs significantly and invest in other growth areas and techniques in farming.

12. Motorleaf

Motorleaf is an AI technology company that offers artificial intelligence and machine learning to provide accurate predictions and insights for greenhouse operations. Users are equipped with software tools and the technology to better understand growing conditions and yield forecasts and make data-driven marketing, labour and operational decisions.

13. Trapview

Trapview is an automated pest monitoring and forecasting platform that provides farmers with near real-time indications of pest occurrences. The pest monitoring data allows users to make smarter and more practical decisions in managing pest control and management.

14. AgriWebb

AgriWebb is a farm management software that keeps track of records and assists in audit and accreditations to help farmers improve operational efficiency and make better decisions. The software produces easy reports on livestock performance, paddock efficiency, cost of production and more. Additionally, it also does the full range of management tasks related to farming such as planning, inventory, tasks, biosecurity and more.

15. BioFiltro

BioFiltro is an international wastewater filtration company that offers a patented worm powered wastewater treatment technology that utilizes the digestive power of worms and microbes to remove up to 99% of impurities from wastewater.

The company has a proven track record of over four decades, and operates in over 180 plants worldwide, and filters billions of gallons per year of industrial and municipal wastewater.

16. Smallhold

Smallhold is the first organic mushroom farm in NYC that allows restaurants, grocery stores and other food-related businesses to grow their own mushrooms and greens on-site. The company has so far been featured in several mainstream publications such as The New York Times, The Wall Street Journal and Bon Appetit.

17. Vibe Imaging Analytics

Vibe Imaging Analytics is an agritech company that offers an accurate and reliable grain analyzer called Vibe QM. The analyzer is being used to inspect measure, count and classify grain size, shape, and color through machine vision technology.

18. Vence Corp

Vence Corp is an agritech company that develops software for virtual fencing and autonomous animal control. They also offer wearable devices for livestock which helps in reducing fencing and labor expenses on livestock farms. As of today, Vence only serves farmers and the livestock industry in the state of California in the US.

19. Back to the Roots

Back to the Roots is a leading organic gardening company in the US that aims to reconnect people with food by giving them the opportunity to grow it at home and on-site themselves. So far the company has developed multiple indoor gardening kits such as growing mushrooms, hemps and many more.

20. AgDraft

AgDraft is an online Australian marketplace that allows farmers to find job opportunities in the agriculture industry. Billed as the “LinkedIn for agriculture,” the online platform connects thousands of farmers to different skilled workers and uses a thorough reviewing system to build and establish ties between the two parties.

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Blockchain Use in Agriculture

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