Blockchain for agricultural sector: The case of South Africa

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New technologies are playing a fundamental role in the postmodern era of globalization where interpersonal interactions at the international level and the exchange of goods, services, information and capital are the basis of all activities. The agriculture sector is constantly facing numerous challenges including the steady growth of the population, climate change, the increasing number of catastrophes, the loss of biodiversity and the spread of parasites. This paper analyzes the impacts of Blockchain applications in agriculture and the food supply chain, through a survey literature review, providing the various players in the agriculture value chain with new tools and key technologies to improve production and distribution processes. To demonstrate the importance of applying the Blockchain in the agriculture sector, especially for emerging countries, the case of South Africa is examined. This focus is one of the unique aspects of this paper, which is the first to deal with this kind of solution applied to the South African context. Our findings indicate that Blockchain, in the e-agricultural context, has the potential for reshaping the entire sector, contributing also to the resolution of the food crisis. This paper discusses the overall implications, limits, challenges and potentials of these applications, from a critical point of view.

Keywords: blockchain, innovation management, digital transformation, agricultural sector, agri-food, South Africa

Introduction

New technologies are playing a fundamental role in the postmodern era of globalization where interpersonal interactions at the international level and the exchange of goods, services, information and capital are the basis of all the activities. Blockchain technology, in particular, is attracting more and more the attention of the academic world and the corporate sector.

The use of data and information in the agricultural sector has increased its value as a key factor for the development of productivity and sustainability. Information and Communication Technology (ICT) has improved the degree of effectiveness and efficiency in the processes of collecting, saving, analyzing, and using data in the agricultural sector (Xiong et al. 2020).

By allowing immutable and decentralized transactions, Blockchain technology is applied in various sectors, both financial and non-financial.

More specifically, the agriculture sector is constantly facing numerous challenges, including the steady growth of the population, climate change, the increasing number of catastrophes, the loss of biodiversity and the spread of parasites. Therefore, innovation in agricultural processes is necessary to overcome these challenges and make agriculture a profitable activity for small- and large-scale farmers.

New technology applications such as Blockchain, Internet of Things (IoT), drones, Big Data and artificial intelligence can provide the various players in the agriculture value chain with new tools and key technologies to improve production and distribution processes.

Despite the great potential of new technology applications, it is essential to consider their relative costs and implementation risks when assessing the possibility of using them in various sectors of the economy.

To verify whether a process could benefit from a Blockchain-based solution, the first step is to identify use cases, followed by the identification of the fundamental guidelines of the process (including regulatory requirements, stakeholders, legal frameworks, interoperability with the existing system and other key requirements), and the identification of the technology that could help to address the challenges of the particular case analyzed. In many cases, in fact, a much simpler digital solution could be the answer to the problem.

Taking into account the great potential of Blockchain technology, this paper aims to review the main applications of Blockchain in the agricultural sector, with a particular focus on South Africa.

In Section I, after a literature review of Blockchain technology in order to deepen its definition and characteristics, the research questions are presented.

In order to demonstrate the importance of applying Blockchain in the agriculture sector, Section II analyzes the main applications in this sector.

After a brief overview of the South African agriculture sector and the contribution of agriculture to the South African economy (Section III), Section IV presents a use-case: the ‘Blockchain for Agrifood’ Project.

Finally, Section V presents limits, challenges, and policy recommendations and the last section provides the conclusions of this paper.

Literature review and research questions

The birth of the Blockchain is linked to the publication of the white paper entitled “Bitcoin: A Peer-to-Peer Electronic Cash System” in 2008 by Satoshi Nakamoto, whose identity is still unknown.

This paper describes a purely peer-to-peer version of electronic money known as Bitcoin. With this event, Blockchain technology, literally a chain of blocks, made
its public debut. The Blockchain is a type of Distributed Ledger Technology (DLT), a distributed, shared, encrypted database that acts as an irreversible and incorruptible repository of information. It is a digital platform that stores and verifies the entire chronology of transactions between users through the network (Nakamoto 2008).

There is no unanimously accepted definition of Blockchain. Nevertheless, it is possible to outline three complementary conceptualizations of this technology (Mavilia and Pisani 2018).

From a technical point of view, the Blockchain is a database consisting of a ledger divided between users and can be openly inspected; it is not, therefore, physically present in a single server, but is placed on several computers at the same time, all synchronized in real-time.

From the business point of view, it is a network where transactions, exchanges of values and exchanges of goods between users can be carried out without the existence of central mediators.

On the other hand, from a legal point of view, the Blockchain validates transactions, replacing the old centralized bodies.

Each block in the Blockchain contains at least the following fields (Demestichas et al. 2020):

- the block number;
- the data or transactions stored;
- the hash value of each previous block;
- the hash value of the current block.

In each block there is always another field called ‘nonce’. The existing link between the values of hashes (of the current block and the previous block) explains the meaning of this cryptographically linked chain (Demestichas et al. 2020).

A commonly used algorithm for cryptography implementation is the SHA256 hash generated by the National Security Agency.

Thanks to this hashing algorithm, it is not possible to practice reverse engineering techniques. Once the data has been entered into the Blockchain, it cannot be modified in any way. In fact, if someone tries to tamper or corrupt the data stored in a block, changing its hash, this will lead to an interruption of the cryptographic link, and all the subsequent blocks will no longer be valid and connected to the Blockchain (Demestichas et al. 2020).

Currently, the most promising Blockchain applications can be found in the financial sector. Further fields of application can be seen in the insurance sector (Dai and Vasarhelyi 2017), data protection, intellectual property protection, electronic voting systems, and identity verification as well as in government services, the health sector, and medical research (Nichol and Brandt 2016), for social purposes and for the catching-up of developing countries (Mavilia and Pisani 2020).

The applications of this technology can be divided into two macro areas: financial and non-financial applications.

Taking into account the great potential of this technology, the non-financial field included, the research questions that this paper poses and wants to answer are:

- What are the main Blockchain applications that can be implemented in the agricultural sector? (RQ1)
- What are the main characteristics of the agricultural sector in South Africa in socio-economic terms and which pilot projects can support it? (RQ2)

After answering these research questions, this paper analyzes the possible limitations and challenges that can be identified (from the user-farmer and the government perspective), and then provides several policy recommendations.

Blockchain applications for agricultural sector

In order to respond to RQ1, in this section a critical review of the literature is carried out to analyze the main applications and some of the most emblematic practical cases.

Different studies and numerous pilot projects have been launched to evaluate the Blockchain applications in the agricultural sector (Tripoli and Schmidhuber 2018). Niknejad et al. (2020) indicated that the research into the concept of Blockchain in the food and agriculture industry started in 2016 and continued to receive increasing attention, particularly in 2019. Moreover, their results demonstrate that India, China, and the USA are the leading countries in publishing papers focused on Blockchain technology in the food and agriculture industry (Niknejad et al. 2020).

This growing trend is driven by several concerns. The main ones are linked to: food contamination and fraud problems, data security and security in intelligent agriculture and IoT-based solutions, trust and efficiency in financial transactions in the agricultural supply chain, and transparency and integrity of agriculture data (Li, Wang, and Li 2020).

Agricultural supply chains

The agricultural supply chains present substantial inefficiencies which affect all the players in the chain, from producers to consumers. It is estimated that the cost of operational supply chains constitutes two-thirds of the final cost of goods (Niforos 2017).

Blockchain technology due to its technical and governance characteristics seems a suitable system in order to communicate information to all stakeholders in the Agri-food supply chain (Motta, Tekinerdogan, and Athanasiadis 2020).

The application of Blockchain technology in this supply chain management has been implemented since 2016 (Rijanto 2020). From the literature, it has been observed that traceability was the most promoted application of Blockchain in the agricultural field (Yadav and Singh 2019).

The Blockchain stores immutable records that are transparent and, potentially, accessible to any user. This technology has the potential to create huge efficiencies for each actor in the supply chain and can help to create more efficient business models at the agricultural and farm level (Bogomolov et al. 2019).

In addition, through Blockchain technology, users are able to build digital identities. Blockchain technology generates a large amount of data from transactions in
agricultural supply chains and agricultural financial services. The Blockchain technology stores each recorded transaction, and it is able to provide the actors in the supply chain with detailed records of their operations, financial service activities and more accurate and better quality market information.

Blockchain technology could potentially act as a core technology that integrates other emerging digital technologies, such as artificial intelligence, IoT, big data, and 3D printing into its platform, to continuously improve the management of the agricultural supply chain.

Logistics, traceability and quality standards
In order to ensure food safety it is critical to monitor the development of agricultural products and to manage an efficient logistic system in the food market, as well as in its production chain.

The dynamic nature of information in the food or agricultural production chain makes it difficult to trace. Tracking is a necessary tool to ensure food safety and quality, and to avoid the risks of contamination. In this scenario, the Blockchain increases trust among stakeholders by ensuring transparency and immutability in transactions (Salah et al. 2019).

The Blockchain provides a platform for traceability in agricultural supply chains. It is thus able to keep track of the origin, and guarantee the authenticity of agricultural products. In fact, food is the most direct way to get in touch with a place (Baralla et al. 2018). Demestichas et al. (2020) showed that Blockchain can advantageously help to obtain traceability by storing data in an irreversible and immutable way.

This solution will make regulatory control easier as the product can be traced along the entire supply chain, and possible fraudulent behaviour that is discouraged in this way can be identified. It is therefore possible to prevent fraud (the so-called false labels) in the food market (Aldag and Eker 2018).

The greater traceability of the production and processing of agricultural products will improve the ability to ensure compliance with food standards (national and international) and sustainability.

However, considering elements such as hierarchy, Blockchain experiences and the industrial sector have a significant impact on logistics professionals in this field (Hackius and Petersen 2017).

Financial services for agricultural sector
The agricultural sector will benefit from the Blockchain by reducing costs, and risks for sellers and banks, and bringing greater efficiency gains to supply chains for commercial financing operations.

Other types of financial services, such as payment, insurance and credit services, can be carried out using Blockchain, thus helping the actors in the agricultural supply chain to reduce costs and risks, and to manage liquidity and maximize returns.

Smart contract and commercial finance
The Blockchain uses smart contracts to automatically execute payment settlement in real time, evaluating delivery first, then verifying that the buyer has sufficient funds, and finally securing the funds on behalf of the buyer awaiting delivery. These smart contracts can facilitate entrepreneurial collaboration of inter-organizational business processes in the context of smart rural supply chains (Prause and Boevsky 2019).

The Blockchain can also increase access to commercial finance. Commercial finance has not been able to meet demand, particularly from SMEs and emerging economies.

Digital payment services
As with payments, for many players in the agricultural value chain, financial transactions are mainly based on cash. This process is slow and expensive, and is subject to risks such as theft and loss.

Digital payment services make it possible to reduce costs and risks deriving from cash-based transactions, while also generating data on the cash flows of the actors in the value chain that can be used to assess credit risk. For example, the AgriLedger platform allows farmers to carry out transactions via the Blockchain using smartphones (Kim and Laskowski 2018).

Another example is represented by the FarmShare platform through which users can exchange agricultural products, paying with cryptocurrency (Kim and Laskowski 2018).

Agricultural insurance
As for insurance applications, agricultural insurance is a risk management tool that helps to stabilize agricultural income and investments in the event of losses. With the Blockchain, insurance payments would become fully digitized and automated with the use of smart contracts and better insurance coverage would be possible.

For example, the Etherisc platform uses the Blockchain to provide insurance for growers in developing countries (Kim and Laskowski 2018).

Credit services
With regard to the credit sector, the main impediments for financial institutions to supply credit products to the sector are the costs of maintaining remote areas, the lack of data to assess the creditworthiness of the applicants or the guarantees.

The Blockchain could provide financial institutions with data on the operations of farmers and other players in the value chain, necessary to provide numerous financial services.

Everex, for instance, is a start-up that offers small loans in developing countries through smart contracts enabling more transparent transactions, and allowing creditors to lower costs and therefore providing borrowers with better conditions (Kim and Laskowski 2018).

Agricultural markets are inherently volatile, and agricultural and price incomes are vulnerable to exogenous shocks. Derivatives are used as a risk management tool to cover price risk and set a future price for the harvest. The Blockchain could also be applied in agricultural derivatives markets.
Land registry

Furthermore, the Blockchain is able to address many of the shortcomings of traditional land registries.

In emerging countries, the process of registering the sale or purchase of land is often complicated and highly susceptible to fraud. Land cartels corrupt the land registration process, making it difficult for buyers to know if the land is litigation free (Aldag 2019).

Blockchain technology can provide a secure, fast, and immutable method for registering land titles, which will promote trust in the reliability of the system. A virtuous example is land management in Ghana (Eder 2019). In addition, even if the land is owned by farmers, when their ownership is not registered, as often happens, they cannot obtain funding for all the inputs they desire (Jain 2019).

BenBen Ghana has devised and developed a useful platform for capturing transactions and verifying land ownership data, enabling smart contracts through Blockchain technology to ensure that land records are found or remain unchanged (Janssen and Bolt 2018).

Agricultural sector in South Africa

To respond to RQ2, this section analyzes the South African agricultural sector in order to better understand its characteristics.

South Africa is by far the most developed country on the African continent. South Africa represents an operational base that has advantages over the rest of the African landscape. The development prospects of this country are significant not only as a market in itself, but also as a hub for the wider sub-Saharan area, both in the commercial field and for production partnerships.

After the end of apartheid, the South African economy has undergone a process of great transformation, going from a structure based on the primary sector to a model in which services and manufacturing have gradually increased their importance: according to the data of 2017, these sectors respectively contribute 29.7% and 67.5% to the formation of the country’s GDP, while agriculture contributes the remaining 2.8%.

The agrarian question in South Africa is long-standing and closely related to its colonial history and the apartheid regime.

The agricultural sector employs a total of 870,000 people and production is around 15 billion euros. Although it represents only 2.2% of GDP, the government attributes a fundamental role to the sector in the economic and social development of the country. This is testified by the central role of the agrarian reform issue in the country’s political debate. The Agri-food industry, which represents 25% of the manufacturing sector, is capable of producing very competitive high quality goods in international markets.

With the opening of the country to international markets, South African farms have seen foreign sales increase, and have concluded numerous collaboration agreements with foreign companies.

This, in addition to promoting the penetration of local companies by foreign companies, has allowed South Africa to access the latest technologies and sector expertise, and to improve the competitiveness of local companies on international markets.

In addition, South Africa is the gateway to most of the products and consumer goods destined for other African countries, which use the country’s logistics and distribution structures and its technological equipment (packaging, transport, etc.) to supply the own markets.

The main productions are:

- Fruit growing: The variety of climatic conditions in the country allows the growth of species in temperate and tropical areas. The production of citrus fruits (especially oranges) is by far the most important and represents, in terms of value, the first export item in the agricultural sector.
- Wine production: South Africa is the eighth largest wine producer globally, with a percentage equal to 3.8% of the world production. The vineyards, as a whole, occupy an area of over 100 thousand hectares and are located mainly in the Western Cape, and in some areas of the Northern Cape along the Orange River. The production counts many qualities of fine wines and exports exceed 400 million litres.
- Corn: The country is one of the world’s largest producers of corn, coming mainly from the so-called ‘Corn triangle’, where peanuts, sunflowers, cotton, and cork are also grown.

Blockchain use case for food tracking grapes in South Africa

Given the important role that wine production plays in the South African agricultural sector, it is relevant to analyze the pilot project ‘Blockchain for Agrifood’ for tracking grapes through the Blockchain.

The project ‘Blockchain for Agrifood’ was launched in March 2017. This pilot project was carried out by Wageningen Economic Research and TNO in collaboration with RVO, AgroConnect, VAA ICT Consultancy, NVWA, AgriPlace, OTC Holland, Florigcode, BC3, GS1, Control Union, SKAL, and PPM Oost.

This pilot project was commissioned and financed by the Dutch Ministry of Agriculture, Nature and Food Quality within the programme ‘Voedselagenda’, the Dutch Food Agenda.

The ‘Blockchain for Agrifood’ pilot project aims to provide a better understanding of the applications of Blockchain technology in Agri-food, in particular for Agri-food chains.

In order to achieve this result, this pilot project analyzed some issues concerning the relevance of Blockchain applications, the applicability in real contexts and the potential impacts of the Blockchain in Agri-food through the review of the literature.

Another purpose of ‘Blockchain for Agrifood’ is to create and implement a proof of concept, starting from the case study linked to table grapes in South Africa.

This project has built a system capable of tracing the certificates in the supply chain of table grapes in South Africa.

In order to demonstrate the main objective of this proof-of-concept application, i.e., the added value of the use of Blockchain for Agri-food, this project has
implemented a case study relating to the certification and provenance of South African table grapes.

This project analyzes these following aspects in the grape supply chain:

- **Origin**: Through Blockchain it is possible to trace the origin of the grapes from the buyer to producer;
- **Issue of certificate and validation**: Certification authority issues certificate to products. All certificates can be stored on Blockchain and, as a matter of fact, all Blockchain participants can verify the validity of a certificate and the issuer;
- **The certification authority may authorize other companies to issue certificates.** However, certification authorities can also revoke the issue of certificates;
- **Audit of these certificates**: Audit organizations should be able to revoke certificates. These organizations may also block individuals who issue certificates in the event of fraud or other unethical behaviour. The results of the audit processes should also be visible on the Blockchain.

In order to achieve these objectives using the applications of Blockchain technology, the project must implement all aforementioned objectives.

This application focuses on the grape supply chain, produced on a South African farm. This company produces organic grapes. This gives rise to the interest that a certification authority can confirm that this South African farm produces organic grapes.

The certification authorities can issue certificates to this farm, allowing it to certify its production. The grape cases have a unique identification number, such as a barcode. All parties in this chain can verify the validity of this certificate.

After certification, these cases are shipped to a retailer and are sold to supermarkets, and then to the end customers.

Furthermore, when the grapes change ownership, this is registered in the Blockchain. This process allows control of the chain of origin of the grapes.

In the event that auditors find that the farm has used unauthorized pesticides, the auditor can revoke the certificates issued by this farm. This revocation must be registered on the Blockchain.

The case study analyzed shows how it is possible, through the new technological tools, to mitigate the counterparty risk in agricultural transactions up to eliminating them, making secure payments and allowing the traceability and transparency that agricultural value chains need.

**Limits, challenges and policy recommendations**

As can be seen from this paper, digitalization of the agricultural sector through new technologies, in primis Blockchain, presents immense potential benefits for consumers, society and the environment.

In order to unlock the potential benefits, stakeholders need to understand the real value that digital transformation of the agricultural sector in South Africa will bring (Accenture 2018).

Blockchain appears very promising and rich of great potential, showing a good flexibility for applications in several sectors. But it is still immature and hard to apply due to its complexity (Antonucci et al. 2019).

The application of Blockchain in modern agriculture is still in the early stage of development and it is relatively complex because of its interdisciplinarity (Li, Wang, and Li 2020).

The managerial implications for those who work in the agricultural sector with the use of the Blockchain are different.

First of all, for a user-perspective it is necessary to acquire the necessary skills to be able to implement these applications and to make the best use of this technology.

In fact, when a new technology is introduced, it is not easy for the average employee to use it in a short time.

As a matter of fact, many farmers are unfamiliar with smart agriculture, and they lack the skills required to fully apply Blockchain technology to modern agriculture.

It can be seen that Blockchain technology has a high threshold for the development of modern agriculture (Li, Wang, and Li 2020).

In addition, partnerships with Blockchain technology related service providers are required. In fact, to achieve the result of product traceability, a technology platform with secure, shareable data, based on smart and decentralized contracts is required.

In order to connect and align the interests of each actor in the Agri-food value chain, infrastructure must be redesigned for the modern economy (Mimm 2018).

The explosion in new digital technologies, especially the Blockchain, raises many questions for economic and social actors who need to adapt (Toulon 2018).

From the above, it emerges that the implications for policymakers are numerous and mainly rely on the concept of product traceability and transparency of processes related to the agricultural world, and on access to credit for farmers (Kamble, Gunasekaran, and Sharma 2020).

The Agri-food sector is in a relevant position to deepen the potential application of Blockchain technology in this field. There is a rapid increase in the level of digitization and a greater demand for information about the integrity of the product.

However, it should be noted that Blockchain applications in the Agri-food sector are still in their first steps, but more and more initiatives have been launched by various organizations.

From a policy perspective, several actions can be taken, such as: encouraging the growth of Blockchain ecosystems in Agri-food chains; supporting this technology as part of the general purpose to optimize the competitiveness and ensure the sustainability of the Agri-food supply chain, as well as designing a regulatory framework for Blockchain applications (Kamilaris, Fonts, and Prenfeta-Boldó 2019).

Given the above, in order to avoid wasting of resources and losing future opportunities in the business sector and for governments, it would be advisable to improve coordination for the implementation of these applications (Ge et al. 2017).
In order to implement successful applications, it is necessary not only to work on Blockchain technology. Above all, it is necessary to focus on governance and organizational issues for collaboration, digitization, and standardization of data, including with additional technologies such as big data analysis. The Blockchain needs to reach the stage of maturity. This can be achieved by collaborating with the right main players, and by implementing and testing different Blockchain solutions. This technology offers high development potential in combination with a strategy for digitization, targeted enhancement of its users’ capabilities and an impact-based approach (Janssen and Bolt 2018).

From a political point of view, in order to be able to implement these applications in the most effective and efficient way, it is necessary (Ge et al. 2017) to:

- promote the implementation of Blockchain solutions as a relevant part of the digital strategy of the Agri-food sector, in order to increase transparency, efficiency, competitiveness, and sustainability;
- encourage the development of the Blockchain ecosystem in Agri-food chains;
- create a specific regulatory framework for Blockchain applications in the Agri-food sector;
- provide public investment in R&D in order to highlight the added value of Blockchain applications.

Conclusions

Through the analysis carried out, this paper investigated how new technologies and, in particular, Blockchain technology can be implemented in various projects and initiatives in the agricultural sector, aiming to create trust within value chains and make them transparent and sustainable, integrating all the main stakeholders.

Blockchain, in the context of e-agriculture, has the potential for reshaping the entire sector as well as contributing to the resolution of the food crisis.

Despite this, there are still many aspects that need to be improved and problems to be solved, both technically and beyond. For instance, there are at least three key lessons from COVID-19 related global food supply chain (Lin et al. 2020):

1) the need of real-time accurate information for parties involved;
2) more efficient coordination between the parties globally;
3) more efficient process in order to reduce the time spent in bureaucratic procedures.

These key lessons can represent the starting point for improving existing Blockchain solutions in this sector. Further research will aim to investigate if and how the challenges that still characterize these applications can be definitively overcome, and to find the right way for the implementation of this technology in the agricultural sector in order to exploit its great potential.

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