Blockchain in Agriculture: A Systematic Literature Review

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Abstract. Blockchain has been used to solve problems from different sectors. In agriculture, Blockchain is being applied for improving food safety, and transaction times. The increasing interest of Blockchain technology in agriculture calls for a clear, systematic overview. In this sense, we present a systematic literature review (SLR) whose objective is to collect all relevant research on Blockchain technology in agriculture to detect current research topics, main contributions, and benefits of applying Blockchain in agriculture. We have extracted 10 primary studies from scientific databases and web sources published between 2016 and 2018, which means that Blockchain is a recent research area in the agricultural sector. The results show that 60% of papers are focused on food supply chain. Also, 50% of the studies on Blockchain in Agriculture are dominated by Asian community researchers, especially from China. Similarly, the half of the studies addressed challenges related to privacy and security of the Internet of Things with Blockchain technology.

Keywords: Agriculture · Blockchain · Systematic literature review

1 Introduction

Agriculture is one of the most important sectors in the world. The agricultural productivity is important for a country's economy as well as the security, nutrition, and health of its population. In recent years, farmers have adopted different technologies such as IoT and Blockchain aiming to obtain greater yields in the agricultural process.

Blockchain technology has been used for responding to a wide range of challenges from different domains such as financial [1, 2], health [3, 4], and energy [5, 6], to mention but a few. In the agriculture sector, Blockchain is being applied in supply chain management systems to provide transparency, security, neutrality, and reliability of all the operations in a supply chain. Blockchain will also help in solving most of the Internet of things challenges related to security and reliability.

It is important to identify what topics related to the agriculture sector have been already studied and addressed in Blockchain and what are currently the biggest

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challenges and limitations that need further studies. To address these questions, we presented a Systematic Literature Review (SLR) to identify relevant papers related to Blockchain in agriculture. The systematic literature review presented was performed by following the methodology proposed by Brereton et al. [7]. This information could help other researchers in identifying possible research areas for future research as well as farmers to know technologies and approaches that are being used.

Although there are currently several works that present a systematic literature review of the Blockchain [8–12], there is still no proposal that presents a systematic literature review of Blockchain in agriculture.

The rest of this paper is organized as follows: Sect. 2 presents the research methodology which is divided into three parts: systematic review planning, systematic review execution, and results, while Sect. 3 presents a discussion of the obtained results. Finally, our conclusions are presented in Sect. 4.

2 Research Methodology

The main goal of a systematic literature review is to detect relevant literature in the subject area. This systematic literature review presented was performed by following the methodology proposed by Brereton et al. [7]. The process consists of three major phases: planning, execution, and result analysis. The first phase refers to planning the review, identifying its needs and defining its protocol which involves (a) research questions, (b) search strategy and (c) studies selection. The second phase consists of the execution of the established plan extracting relevant information. Finally, the third phase consists of providing results and conclusions.

2.1 Systematic Review Planning

This phase defines the way the systematic review will be performed and the research objectives. Hence, we define research questions to be addressed, and planned how the information sources and studies will be selected. This phase is composed of three steps: question formulation, search strategy, and studies selection.

Research Questions
This section presents the three research questions that guided us throughout the research and helped us meet the goals of the Systematic literature review. Table 1 presents the questions and the main motivations.

Search Strategy
The search strategy is at the core of a systematic review. The first stage of our search strategy was to identify the digital libraries and web sources wherein the search for primary studies would be carried out. We selected four digital libraries:

1. IEEE Xplore Digital Library,
2. ACM Digital Library,
3. ScienceDirect (Elsevier),
4. Springer

Table 1. Research questions

Research question (RQ)	Question	Motivation
RQ1	What research topics have been addressed in current research on Blockchain for agriculture?	To detect the main uses of the Blockchain in the agriculture
RQ2	Are there any use cases applicable to the IoT?	To identify cases where is combining IoT with Blockchain technology
RQ3	What are the main benefits of the Blockchain in the agriculture?	To identify the main benefits of the Blockchain in agricultural sector

Furthermore, we selected two Web sources to broaden or results:

5. Google Scholar,
6. Web of science.

The second stage consists of a keyword-based search. To this end, two tasks were performed: (1) we identified a set of keywords related to our research topic; and (2) we identified synonyms for the keywords and related concepts (see Table 2).

Table 2. Keywords used during the systematic review.

Area	Keywords	Related concepts
Agriculture	Agriculture, agricultural	e-Agriculture
		Agribusiness
		Farming
Blockchain	Blockchain	Blockchain

The search strings were built by combining the keywords presented in Table 2 with the connectors "AND" and "OR". Thus, the search chain that we use is the following:

(Agriculture OR e-agriculture OR Agribusiness OR Farming OR Agricultural) AND Blockchain.

Studies Selection

Regarding the studies selection, it began with the selection of only the studies that included at least one keyword referring to the Agricultural sector (e.g. Agriculture, farming, agricultural, e-agriculture), and the other one concerning to the Blockchain technology (Blockchain).

Secondly, we discarded those papers that were not directly related to the Blockchain technology and the agricultural sector.

Thirdly, the set of results obtained was reduced by applying the following exclusion criteria:

1. Papers written in other languages than English.
2. Master and doctoral dissertations.
3. Duplicated articles obtained from Google Scholar and Web of Science.

The objective of this step was to determine which piece of literature found by the search string provides important contributions to the agricultural sector. In cases where we were uncertain about the relevance of the paper, the full-paper was downloaded and sections such as introduction and conclusions were reading.

2.2 Systematic Review Execution

This phase consisted in executing the search in the digital libraries and web sources selected to evaluate the obtained studies considering the inclusion and exclusion criteria. The result of this process was a set of about 44 studies which were filtered by using the inclusion criteria established to give a set of about 18 relevant studies. This set of works was again filtered according to the exclusion criteria.

We obtained 10 primary studies in total (see Table 3). The inclusion and exclusion criteria help us to ensure that the studies were relevant for the research questions established at the planning phase.

Table 3. Total of primary studies.

Data source	Results
IEEE Xplore Digital Library	3
Springer	1
ScienceDirect (Elsevier)	1
Google Scholar	4
Web of Science	1

Information Extraction

Therefore, aiming to answer the research questions, we extracted from studies (1) basic information (publication title and authors), (2) information related to the study (main contribution, objective), and (3) results (topics that have been addressed, their benefits on agricultural sector, and cases applicable to the IoT).

Table 4 provides a general perspective of all studies selected.

Basic Information of the Studies

Figure 1 shows the publication year distribution of the selected primary studies. Most studies were published after the year 2016. This shows that Blockchain is a very recent research area in the agricultural sector. As can be seen, one paper (1%) was published in 2016, five papers (50%) were published in 2017 and four (40%) papers were published in 2018. This shows an increasing number of publications in recent years, which shows also a growing interest in Blockchain technology in the agricultural sector.

Table 4. General perspective of primary studies.

Work	Data source	Objective
Feng [13]	IEEE Xplore Digital Library	Provide an agri-food supply chain traceability system based on Radio-Frequency Identification and Blockchain to enhance food safety and quality of Chinese agri-food markets
Xie et al. [14]		Provide a secured data storage scheme based on Blockchain for agricultural products tracking
Tse et al. [15]		Improve the problem of agricultural food supply chain traceability
Patil et al. [16]	Springer	Provide security and privacy to smart greenhouse farms through a lightweight Blockchain based architecture
Leng et al. [17]	ScienceDirect (Elsevier)	Validate the hypothesis that the chain of agricultural supply chain based on double chain structure can obtain three advantages: (1) consider the openness and security of transaction information and the privacy of enterprise information, (2) self- adaptively complete rent-seeking and matching of resources, and (3) improve the credibility of the public service platform and the overall efficiency of the system
Lin et al. [18]	Google Scholar	Demonstrate that an Information and Communications Technology e-agriculture with a Blockchain infrastructure is the next step in the evolution of ICT e-agriculture
Lucena et al. [19]		Describe and highlight the gains obtained with the implementation of a Blockchain Business Network for Brazilian Agriculture exports
Carbone et al. [20]		Define a food-on-demand business model based on new Quality of Experience (QoE) food metrics to provide better performing value chains
Vinod Kumar [21]		Resolve the major issues in traditional rice supply chain management, logistics industry through of Blockchain technology
Papa [22]	Web of Science	Validate the hypothesis that agricultural sector has a great need for information that supports traceability

Figure 2 shows the geographical distribution of the selected papers. Most of them (30%) were published by universities or companies in China. Another common publication country was Singapore with 2 papers (20%). The rest of countries (USA, Australia, Malaysia, and Taiwan) had one paper published. The geographical distribution of the selected primary papers shows that Blockchain technology of agriculture sector has gathered research interest around the world.

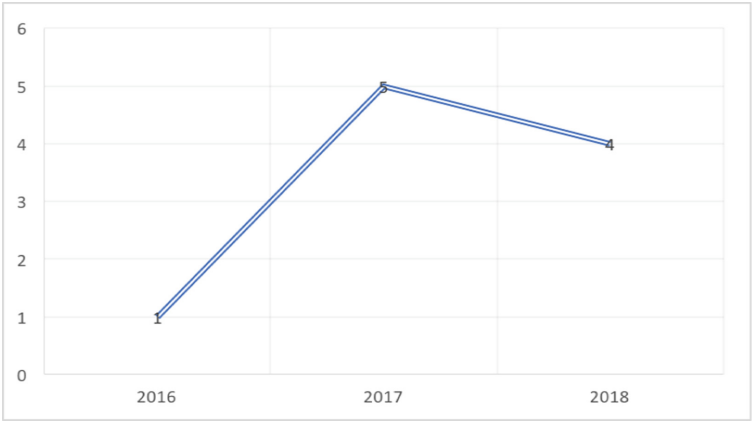

Fig. 1. Publication year of the selected primary studies.

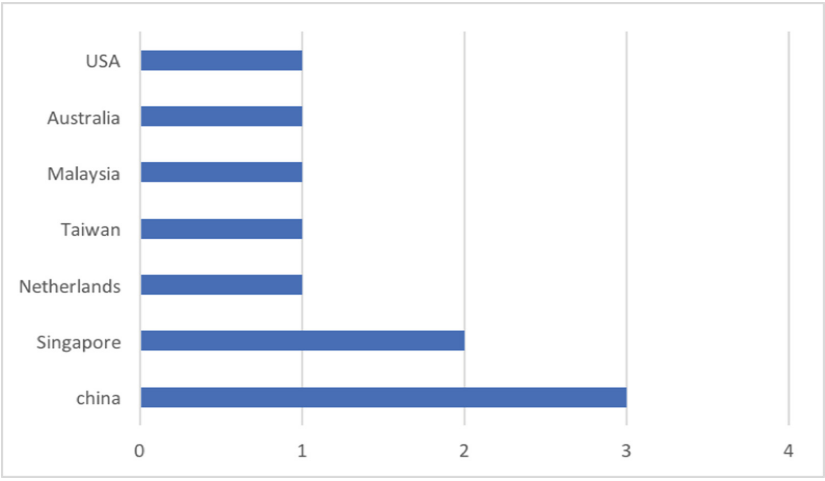

Fig. 2. Geographic distribution of the selected primary papers.

Figure 3 shows the publication type of the selected papers. Publication type means the channel where the paper was published. The publication types included in this study were conference, journal, and symposium. Most of the papers were published in conferences (6) (60%). The rest of the papers were published in journals (3) (30%), as a symposium (1) (10%). In addition, Table 2 shows the publication channel of each selected paper. As can be seen, each paper was published in different publication channels (Table 5).

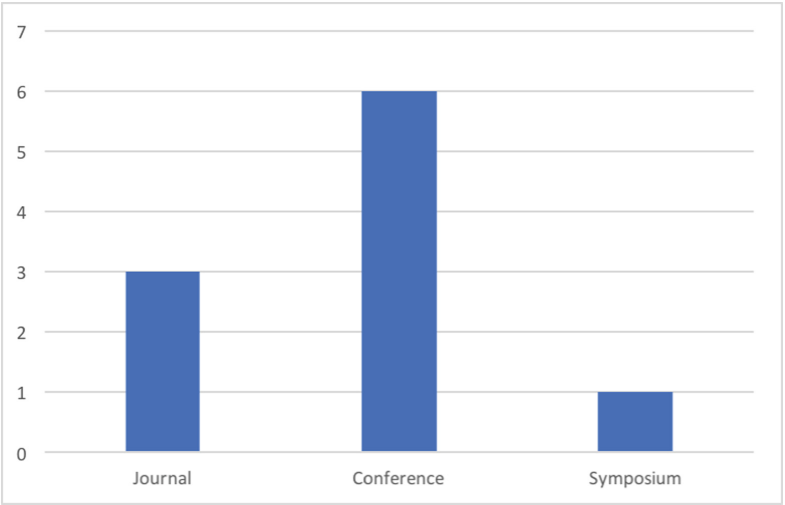

Fig. 3. Publication type.

Table 5. Chanel of publication of the primary studies.

Chanel	Paper
2016 13th International Conference on Service Systems and Service Management (ICSSSM)	[13]
2017 3rd International Conference on Big Data Computing and Communications	[14]
2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)	[15]
Advances in Computer Science and Ubiquitous Computing. CUTE 2017, CSA 2017	[16]
Future Generation Computer Systems	[17]
Environments	[18]
4th International Conference on Management Science and Management Innovation (MSMI 2017)	[22]
Symposium on Foundations and Applications of Blockchain (FAB '18)	[19]
Eighth International Conference on Advances in Computing, Electronics and Electrical Technology - CEET 2018	[20]
Advanced Science and Technology Letters	[21]

2.3 Results

Table 6 shows the studies selected in this systematic literature review, as well as a comparison of them regarding the relevant information established in the previous section. The order of the studies does not determine its importance regarding the goals of this study.

Table 6. Relevant information of the primary studies.

	Topics	Main contribution	IoT	Benefits in agricultural sector
Tian [13]	Agri-food supply chain traceability	An agri-food supply chain traceability system based on Radio-Frequency IDentification and Blockchain technology	No	All the information of the agri-food in the supply chain is transparent and open. In this sense, (1) logistics enterprise can implement real-time tracking for the agri-food products, (2) supervision regulator can execute traceability management and responsibility investigation for a defective product, and (3) the consumer can obtain the full information of the products in the entire agri-food supply chain. These points are important to establish a healthy market environment
Xie et al. [14]	Secured Data Storage	(1) An overall scheme of agricultural tracking data storage based on Blockchain. (2) A double-chain storage structure	Yes	The tracking data is written into the block unchangeably. Thus, the safety of the data and the safety of the food is also guaranteed
Tse et al. [15]	Food supply chain's processing	A supply chain system platform for production processors, brokers, and consumers	No	(1) A complete and smooth information chain which allows all the transaction information transparent among the distributors, suppliers or other relevant parts in the supply chain. The mistakes or errors coming from any part of the supply chain can be found easily. The participants can find out

(*continued*)

Table 6. (*continued*)

	Topics	Main contribution	IoT	Benefits in agricultural sector
				the solution in a short time and improve the efficiency of the supply chain. (2) Once fake or perishable food flow into the market causing the food safety incidents, it can be much easier to find the original source of the food or material for accountability
Patil et al. [16]	Remote monitoring and automation	A framework for Smart Greenhouse farming based on Blockchain, which provides lightweight and decentralized security and privacy	Yes	(1) Addressed challenges on the Internet of Things such as decentralization, anonymity, and security. (2) Improved reliability, faster and efficient operations and scalability
Leng et al. [17]	Agricultural supply chain	An agricultural supply chain system based on double chain architecture, considering dual chain structure and its storage mode, resource rent-seeking and matching mechanism and consensus algorithm	No	(1) Transparency and security of transaction information and privacy of enterprise information. (2) Improve the credibility of the public service platform and the overall efficiency of the system
Lin et al. [18]	Storage of agricultural and environmental monitoring data	An information and communications technology e-agricultural system based on a Blockchain which includes water quality monitoring data	Yes	Increase the probability of export to international markets since compliance with international standards becomes a transparent and undisputed matter
Lucena et al. [19]	Grain supply chain	A case study for grain quality assurance tracking based on a Blockchain Business Network	Yes	All the members of the Grain Exporters Business Network can share the same business rules and transaction data in their nodes reducing disputes among

(*continued*)

Table 6. (*continued*)

	Topics	Main contribution	IoT	Benefits in agricultural sector
				business partners, information asymmetries and consequently improving governance
Carbone et al. [20]	IoT Supply Chain Management	A distributed (decentralized) hyperledger platform based on Blockchain technology	Yes	Provide transparent and secure supply chain system as well as trust in the origin and entire process of production, transport, and distribution of the food on the market
Vinod Kumar [21]	Rice Supply Chain Management	A supply chain system based on Blockchain technology that assures the safety of rice during supply chain management processes	No	Integral traceability, fight fraud and minimize the system errors because all the events that occur in the supply chain are registering
Papa [22]	Transparency and Monitoring in Agricultural Trade	Apply Blockchain Technology in Agribusiness	No	(1) Manage the agricultural trade while providing guarantees in the certification procedures. (2) Manage trade while providing guarantees in procedures for certification of their quality or origin. (3) Simplify the work of all actors in the "Agri-chain" and make transactions more transparent

3 Result Analysis: Discussion

Taking into account the results obtained from the systematic literature review presented in this work, nowadays, several researchers are focusing their efforts in the supply chain for the agricultural sector. For instance, Tian [13] studied Agri-food supply chains including production (planting/feeding), picking/slaughter, processing, warehousing, distribution and sales. In [15], authors proposed a system to improve the efficiency of food supply chain. Lin et al. [18] presented an agricultural supply chain system based on double chain architecture that considers the security of the data and

the privacy of enterprise data. Lucena et al. [19] presented a case of study to measure the quality throughout the transportation of grains along its supply chain. In [20], authors proposed a supply chain platform which is used in the fresh food area where agriculture sustainability is an important issue to address. Finally, Vinod Kumar [21] proposed a supply chain system which allows monitor security and quality of warehouse and transportation of rice from farmers to companies. Meanwhile, secured data storage, remote monitoring, and automation are the least studied.

The Internet of Things technology has been widely applied in agriculture, however, there are some challenges related to privacy and security that need to be addressed. To overcome these challenges, several authors use Blockchain which allows the creation of a distributed digital ledger of transactions that is shared among the nodes on IoT network.

With regards to the effects of Blockchain in agriculture, Blockchain technology has been applied with positive results. To name a few, some of its benefits are: (1) all the information in the supply chain is transparent and open, (2) it addresses challenges on the Internet of Things such as decentralization, anonymity, and security, (3) it improve reliability, faster and efficient operations and scalability.

4 Conclusions

The goal of this study was to identify research topics, main contributions, and benefits of the Blockchain technology in agriculture. We obtained and analyzed 10 primary studies from scientific databases and web sources.

The review papers on Blockchain in agriculture is very dominated by Asian research community, especially from China. Only 3 of the 10 reviewed papers are from non-Asian countries. We attribute this to the fact that agriculture is an important sector in China. In other continents, the concept of Blockchain was up to recently adopted. The most frequently addresses research topic is food supply chains. The dominance of studies dealing with food supply chains can be attributed to the importance management for food safety and food quality. Furthermore, 5 of 10 studies present the combination the IoT and Blockchain in order to addressed challenges related to privacy and security of the IoT.

As future work, we plan to extend this work by including a wider set of digital libraries such as the Wiley Online Library. Furthermore, we expect this systematic literature review to include more issues and proposed solutions to overcome challenges and limitations of Blockchain technology. Finally, we plan to evaluate the effectiveness of the proposed solutions in an objective way.

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