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REVIEW ARTICLE

EMPLOYMENT OF BLOCKCHAIN TECHNOLOGY IN AGRICULTURE AND FOOD SECTOR – A REVIEW

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Abstract

Agriculture sector is the backbone of a given economy. Globally, this sector does not only provide food and basic materials, but also employs an immense percentage of population. Nonetheless, it is afflicted with many predicaments such as inappropriate means of communication, food adulteration and lack of openness in the supply chain. Thus, utilisation of digital technologies can be one of the prospective solutions to these many problems. These technologies are various however; blockchain technology has captivated the most attentiveness. This state of the art technology is a distributed record of transactions permitting associates to document transactions in a devolved data log in processor network. In agriculture and food sector, blockchain can be used to promote food safety, stop food fraud and affirm legitimacy of agricultural commodities. Furthermore, can also be used to achieve superior prices and payment options, land title enrolment and for transparent payment of subsidies to farmers. The victory of blockchain technology mainly depends on its security, decentralisation, lucidity and constancy. Even though this technology has enormous potential benefits in agriculture and food sector, it still has diverse obstacles that hamper its wider recognition among farmers and food supply chain.

Introduction:-

Agriculture plays a pivotal role in the life of a particular economy. It is the fundamental economic component and a solution to a healthful planet (Mulvany, 2003). Apart from supplying food and basic materials, it provides job possibilities for the majority of the population and also export. However, the sector suffers from a number of problems such as inappropriate means of communication, price hijacking, food adulteration and lack of honesty in the supply chain (Balakrishna and Ratna, 2020). For example, clients often grumble about the lack of openness about their purchases and the products they use. One attainable solution is the utilisation of digital technology in agriculture and food sector. One of the many benefits of digitised agriculture is enhancing productiveness and competence. IBRD, WB (2017) revealed that digitised agriculture creates a more productive and viable system that leads to food security and substantial profit. According to Jeremic and Brankov (2020), digitisation is based on application of technology to transfer vast quantity of information. These technologies are numerous and include

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artificial intelligence, Internet of Things (IoT) and blockchain. The latter has received more attention and may be a better solution as it records each stage of food production in relation to food supply and can establish the section of the chain that causes the problem quickly (CHAIRE AgroTIC, 2017).

Blockchain:
In the food supply chain, agricultural producers and other stakeholders are obeying the firm guidelines set before them. Nevertheless, a variety of eating disorders can emerge and sometimes it takes a long time to establish the origin of the problem (Tripoli and Schmidhuer, 2018). Consumer reliance in agribusiness sector has been undermined by food scandals and the rise of numerous health problems due to food such as obesity (Jeremic and Brankov, 2020). According to Ge et al. (2017) consumers are more worried about food safety and require more information about food sources. They are complaining about the lack of openness in food and the way they are prepared. In the midst of this situation, innovation in agricultural production is one way to conquer these problems and to make agriculture a charismatic business. Therefore, the use of Information and Communication Technology (ICT) in agriculture is one way to address the challenges facing the sector (FAO and ITU, 2019). Blockchain technology, as a revolutionary tool, is a state-of-the-art technology to help change many markets and many economies (Jeremic and Brankov, 2020). For this reason, it is considered to be the best solution to the problems facing the agricultural sector.

What is blockchain?
One of the new agricultural techniques in modern farming is blockchain. The first blockchain was initiated by Satoshi Nakamoto, who suggested Bitcoin cryptocurrency in 2008. According to Mirabelli and solina (2020) blockchain technology was first executed in the financial sector back then. In finance, this technology permitted digital money to be exchanged through an unreliable network of unknown without any third party mediation such as the central bank (Nakamoto, 2008). Nevertheless, blockchain technology has been utilised in several other areas like healthcare (Mettler, 2016; Angraal et al., 2017; Azaria et al., 2016), smart cities (Biswas and Muthukkumarasamy, 2016), smart contracts (Christidis and Devetsikiotis, 2016; Kosba et al., 2016), energy markets (Goranovic et al., 2017; Andoni et al., 2019; Mengelkamp et al., 2018), government sector (Carter and Ubacht, 2018; Olnes et al., 2017) and business models (Momo et al., 2018). Immutability, openness and reliability are the traits that make blockchain technology a victory. Hence, blockchain can be described as the unchanged ledger to record transactions, which are managed in a network of distributed network of nodes (Mirabelli and Solina, 2020). This is an ordered block list, where each block contains a list of transactions of varying size (Arena et al., 2019). According to Yadav and Singh (2019), the three predominant definitions of blockchain are: Technically,it is a back-end database that keeps a distributed ledger and has the ability to be openly inspected. Commercially,it is a switching network to move values, assets and transactions between peers without the need for intermediary while legally speaking; it authenticates transaction history, and replaces earlier trusted entities.

Attributes of blockchain:
The major aspects of blockchain technology are logging, inalterability of recorded data, disintermediation and decentralisation databases, security and openness (CHAIRE AgroTIC, 2017). These attributes contribute to secure blockchain application system. Additionally, they sustain the constancy of the data and assure transparency to consumers (Malik et al., 2018).

Logging:
Transactions are added sequentially. They are time stamped and attached to each other.

Inalterability of recorded data:
The data is reproduced numerous times and the minor mitigation changes the whole chain.

Disintermediation and decentralisation databases:
Central server is not obligatory owing to the peer-to-peer (P2P) nature of the network.

Security:
Attacks are made more difficult due to the duplicated agreement nature of the blockchain system. A digitised signature assures the authenticity of the transactions.

Transparency:
Nodes accommodate the complete chain and can access transactions.

How does it work?
Figure 1 below illustrates how the blockchain based system work. This could be explained in easy six steps.

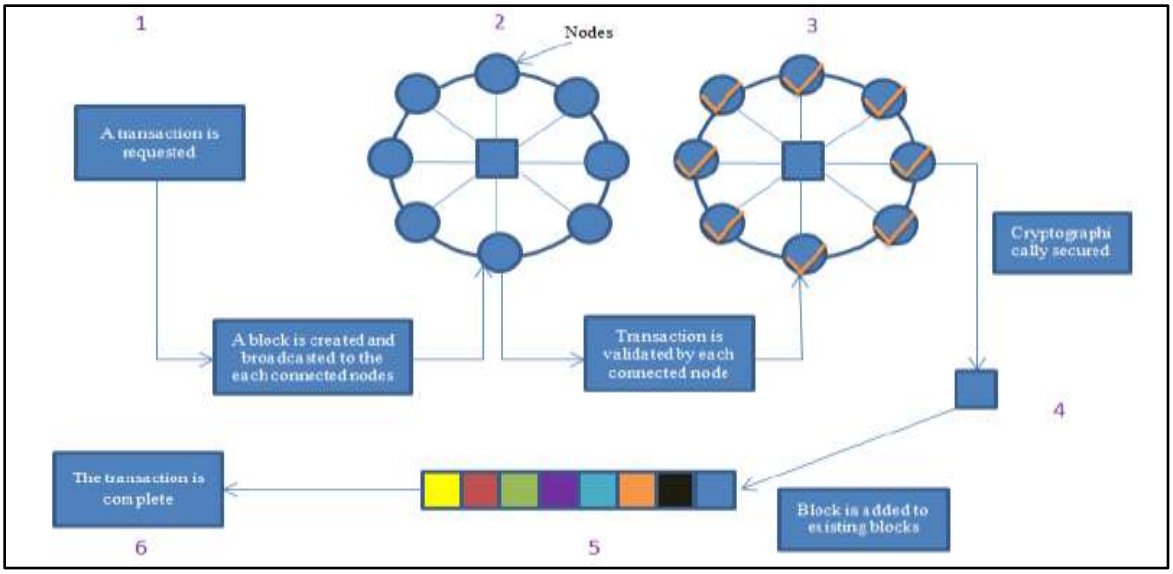

Figure 1:- Working of blockchain.
Source: Yadav and Singh 2019

Step 1: Transaction is implored.
Step 2: This transaction is sent to the nodes in the network.
Step 3: Transaction gets substantiated once an agreement about this implored transaction is reached.
Step 4: A cryptographically secured new block is generated.
Step 5: This new block is added to the existing blocks.
Step 6: Completion of transaction

Types of blockchain:
Blockchain networks have three paramount types' viz. consortium blockchain, private blockchain and public blockchain. Each type has different traits and roles (Addison et al., 2019; FAO and ITU, 2019; CHAIRE AgroTIC, 2017).

Consortium blockchain:
This type of blockchain is managed by a consortium instituted by a cluster of members. Affirmation and inclusion of records to the blockchain is predicated on a consensus mechanism by a pre-screened group of nodes (Addison et al., 2019). It is regarded to be partially decentralised.

Private blockchain:
This blockchain is also called "permissioned ledger". It is administered by a centralized system. At most, people with distinct authentication and authorisation can be members of this network and thus can confirm and add data to the blockchain. Nevertheless, the blockchain may be openly accessible. Partakers in this blockchain appreciate and believe in one another (FAO and ITU, 2019).

Public blockchain:
It is also called "permissionless blockchain." In this blockchain, anybody can authorise transactions and participate within the agreement process, anybody can forward transactions for sanction and inclusion within the blockchain if the transactions are sound and anybody can view transactions. Hence this kind of blockchain is actually decentralised (CHAIRE AgroTIC, 2017).

Why blockchain?
Blockchain is the record of accounts and transactions recorded and saved by all members (Xiong et al., 2020). Each participant save a copy of all preceding transaction performed throughout the system. Nonetheless, no single party or node owns the system that indicates it is a decentralized system. Every action within the system is easily seen and verifiable by all stakeholders. Therefore, this sort of decentralized system promotes the base of confidence (Yadav and Singh, 2019). Additionally, transactional costs are reduced because blockchain technology doesn't need a middleman for the transaction. The blockchain-based system is also more systematic since these transactions are irreversible and wishes of any public and personal institution intercessor is prevented.

Obstacles for the use of blockchain in agriculture:
Advancement of technology is not often neutral. Blockchain technology is no exception. This technology has substantial potential benefits in the agricultural and food sectors. These advantages incorporate the capability to discover information in the food supply chain, consequently helps ameliorate food safety. Furthermore, it renders a secure way to store and control data and it can lessen costs of transaction (Xiong et al., 2020). Nevertheless, multiple obstacles still prevail, that impede its widespread recognition among farmers and food supply systems. These obstacles involve technical aspects, education, policies and regulatory frameworks (Kamilaris et al., 2018). In a case study in the Netherlands, Ge et al. (2017) revealed that small to mid-size enterprise (SME) cannot embrace blockchain technology owing to lack of dexterity. In respect to education, there is finite education (lack of general awareness of blockchain) and training plans (ICT4Ag, 2017). Farmers need to conclusively appreciate blockchain prior to embracing it. In case of regulatory frameworks, there are no rules regarding the framework. According to Deshpande et al. (2017), there is not yet an established system to regulate blockchain transactions across the globe. Lack of understanding between policy makers and technical experts is another obstacle. There is no ordinary appreciation on how blockchain technology and transactions regarding some currency should be utilised (ICT4Ag, 2017). Lastly, there is digital divide among developed and developing world. This is in respect to digital accomplishment and approach to the blockchain technology.

Potential use of blockchain in agriculture:
Blockchain technology was first utilised in cryptocurrencies. Notwithstanding, its employment to other transactions has considerable potential. Agriculture is one field where this technology can be implemented. In this sector, blockchain technology can be utilised to avert food fraud, foster food safety, and substantiate the origin and legitimacy of agricultural commodities and materials. It can also be used to attain superior prices and payment options, land title enrolment and for transparent payment of subsidies to farmers. These are all achievable since blockchain technology ameliorates traceability and openness (Aldag and Eker, 2018).

Avert food fraud:
Food scam costs the worldwide food industry around $ 30 – 40 billion per annum (Sanghera, 2018). The need for antibiotic-free, GMO-free and organic food has increased, and subsequently dishonest labelling has become ordinary. Employing the traceability and transparency that blockchain technology offers, food scam that occurs mainly through false labelling can be averted. Blockchain technology effectively controls the whole supply chain.

Foster food safety:
Food safety is a state in which food is processed, managed, and stored in healthy way to hamper ailments to happen to human populace (Kamilaris et al., 2018). Consumers are starting to doubt the food they eat and the question is always "What is the source of my food?" (Sanghera, 2018). These days food sensitivities and food related ailment are increasingly common and consumers are starting to call for the information related to the foods they eat. Blockchain technology can be applied to guarantee food safety in the agricultural supply chain, consequently answer the question raised by consumers. This technology enhances traceability and openness permitting stakeholders in the agricultural value chain to ascertain the bad processes along with bad actors (Tian, 2017). This confirms that perfect conditions are sustained from the farm to the market (Underwood, 2016). Companies like IBM and Walmart are working in the field of food safety by employing blockchain technology.

Affirmation of legitimacy of agricultural inputs:
Farmers are uncertain whether the inputs they purchase are genuine. Similarly, local retailers are selling counterfeit commodities to farmers to extend their profit margins at farmer's loss. Furthermore, occasionally retailers are also unaware of the authenticity of the commodities sold to them by suppliers (Aldag and Eker, 2018; Sanghera, 2018). The principal question here is "are the inputs real?" The solution to this problem is to use blockchain technology

since it will increase the traceability of each input sold, from the producer to the final purchaser. Cosby et al. (2016) emphasized that blockchain will make it attainable for retailers and farmers to grasp about the genuineness and source of the inputs they purchase by utilising their smartphones to scan blockchain barcode on each product.

Superior pricing and payment options:
Globally, farmers present their commodities to several national agricultural boards. Notwithstanding, they encounter a massive hindrance in the deliverance of funds for their commodities. Moreover, they encounter expensive remittance options such as bank transfers. Blockchain technology can solve some of these problems (Chinaka, 2016). It will help issue rapid remittance options at a lower cost.

Land title enrolment:
The procedure of lodging the selling or buying of land is often unmanageable and highly vulnerable to fraud worldwide. Seller, buyer or lessee always asks whether the land they buy, sell or lease is free from lawsuit. Blockchain technology makes all types of land records more effective since the system is more open because recorded data is reachable and publicly available. The government of India in Andhra Pradesh state, in collaboration with Swedish start up ChromaWay, developed the blockchain solution for land enrolment and recording, the first pacemaker in this space (Sanghera, 2018).

Payment of subsidies:
Globally, agriculture is excessively dependent on government subsidies (Aldag and Eke, 2018). The government distributes a segment of its budget to farmers as agricultural subsidies. Nevertheless, it is always questionable how much money really reaches the farmers. The implementation of blockchain technology will enhance transparency in the administration and conveyance of subsidies. Swan (2015) revealed that the blockchain would ensure that targeted subsidy payments reach local farmers and help prevent theft of the existing system.

Trimming transaction costs and fair pricing:
Lowering of transaction costs can be attained with blockchain technology, which leads to reasonable prices. Through this technology, commodity buyers are able to deal directly with their suppliers and make payments through mobile transfer. This will make it easier for buyers and suppliers to negotiate reasonable prices for their agricultural commodities. Farmers, on the other hand, receive a fair remittance for their agricultural products; the retailer pays a satisfactory price for the distributed agricultural products. Furthermore, blockchain technology eliminates agents or middlemen; retailers can also save money (Ge et al., 2017).

Discovery of the genesis of agricultural commodities:
Blockchain technology can be employed to trace the origin of agricultural commodities. Traceability ameliorates the trust of sellers and consumers in the product (Aldag and Eker, 2018). Blockchain technology enables retailers to confirm that the commodity they get is precisely what they paid for, as each step in the transaction process is documented on the blockchain from the time of enrolment, remittance, and transportation of the products. Worries of misrepresenting information are mollified, as any statement by the supplier about the origin of his/her products can be affirmed by tracing how the product moves from the farmer to the point where it entered the shop. From a consumer perspective, the blockchain will make them believe in the origin of their food and the effectiveness of their production (Lemieux, 2016).

Present state of acceptance of blockchain technology in agriculture:
Numerous companies are devoted to exploring the employment of blockchain technology in the agriculture and food sectors. Within these sectors, retail giant Walmart is one of the earliest industrial uses of this technology, piloting with mango and pork products (Kamath, 2018). Currently Walmart require the utilisation of IBMs Food Trust blockchain service alongside Walmart's leafy green suppliers owing to extensive food safety events (Redman, 2018). Furthermore, Walmart, Alibaba, and JD.com are vigorously executing blockchain projects on food traceability employing blockchain technology to track the whole process of food production, processing, and sale (Xiong et al., 2020). Another company that is applying a blockchain-based solution is IBM, Walmart's key technology associate. IBM has evolved its blockchain-based service for the food industry called IBM Food Trust. According to Redman (2018), IBM Food Trust enables companies of varying sizes who cannot develop and maintain their own blockchain solutions, to utilize IBM solutions within a variety of Software as a Service (SaaS). A more proactive example of blockchain technology adoption in the food and agriculture sector is demonstrated by the Grassroots Farmers Collective (2019), which could be a much smaller organization than Walmart. Grassroots

Farmers Collective is a food producer and uses blockchain to compose well founded information about the form of farm and origin of food to end consumers. However, Sengupta et al. (2019) revealed that blockchain technology will be more popular in the food and agriculture sector when benefits are maximized.

Prospects for future research:

These days blockchain is one of the most fascinating and discussed research topics (Mirabelli and Solina, 2020). It has a bright future in agriculture and food industry. However, significant restrictions remain in the utilisation of blockchain technology in agriculture and the food industry, which are becoming areas for further research. Blockchain does not evenly integrate directly with prevailing systems. Therefore, one of the areas of further study may be to provide an appropriate solution for integrating blockchain with prevailing databases and legacy systems. In addition, it is important to further study the motives of the transaction parties to provide reliable and accurate information to the ledger of the blockchain. Another area that needs to be investigated is the consistency of the blockchain-based system with regulatory issues. Last but not least, further research is required on how easily the blockchain-based solutions can be provided to different stakeholders since some members in the agricultural supply chain, such as farmers are generally not very advanced in technology (Xiong et al., 2020; Yadav and Singh, 2019).

Conclusion:-

Blockchain technology will undoubtedly make advances in all areas. Agriculture and food sector are no exception. In the agriculture and food sector, blockchain technology can foster food safety, avert food fraud and substantiate the origin and legitimacy of agricultural commodities and materials. Other applications include accomplishing superior prices and payment options, land title enrolment and transparent payment of subsidies to farmers. It is clear that the use of blockchain technology in the agriculture and food sector has great potential for success. However, there are still numerous obstacles that hamper its development in these areas.

References:-

1. Addison, C., Boto, I., Heinen, T. and Lohento, K. (2019):Opportunities of blockchain for agriculture. 55th Brussels Briefing. Brussels, May 15th. Available at: http://brusselbriefings.net. (Accessed: 9th May 2020).
2. Aldag, M.C. and Eker, B. (2018):How to use blockchain technology in agriculture. Conference paper. Available at: https://www.researchgate.net/publication/329442777. (Accessed: 10th May 2020).
3. Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., McCallum, P. and Peacock A. (2019):Blockchain technology in the energy sector: A systematic review of challenges and opportunities.Renewable and Sustainable Energy Reviews.,100: 143 – 174.
4. Angraal, S., Krumholz, H.M. and Schulz, W.L.(2017): Blockchain technology: applications in health care.Circulation Cardiovascular Qualilty and Outcomes.,10(9): e003800.
5. Arena, A.,Bianchini, A., Perazzo, P., Vallati, C. and Dini, G.(2019):BRUSCHETTA: An IoT Blockchain-Based Framework for Certifying Extra Virgin Olive Oil Supply Chain. In: Proceedings of the 5th IEEE International Conference on Smart Computing. Washington, United States, pp. 173 – 179.
6. Azaria, A., Ekblaw, A., Vieira, T. and Lippman, A. (2016):MedRec: Using blockchain for medical data access and permission management. In: Proceedings of the 2nd International Conference on Open and Big Data. Vienna, Austria, pp. 25 – 30.
7. Balakrishna, R.G. and Ratna, K.K. (2020):Quality Improvement in Organic Food Supply Chain Using Blockchain Technology. In: Deepak B, Parhi D, Jena P (eds) Innovative Product Design and Intelligent Manufacturing Systems. Lecture Notes in Mechanical Engineering. Springer, Singapore
8. Biswas, K. and Muthukkumarasamy, V. (2016):Securing smart cities using blockchain technology. In: Proceedings of the 18th IEEE International Conference on High Performance Computing and Communications, 14th IEEE International Conference on Smart City and 2nd IEEE International Conference on Data Science and Systems.Sidney, Australia, pp. 1392 – 1393
9. Carter, L. and Ubacht, J. (2018):Blockchain applications in government. In: Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age, pp. 126.
10. CHAIRE AgroTIC. (2017):Blockchain and agriculture. CHAIRE AgroTIC, Montpellier, France, pp.40. Available at: www.agrotic.org/wp-content. (Accessed: 9th May 2020).
11. Chinaka, M. (2016):Blockchain Technology -- Applications in Improving Financial Inclusion in Developing Economies: Case Study for Small Scale Agriculture in Africa. Available at: https://dspace.mit.edu/handle/1721.1/104542. (Accessed: 17th May 2020).

12. Christidis, K. and Devetsikiotis, M. (2016):Blockchains and Smart Contracts for the Internet of Things.IEEE Access.,4: 2292 – 2303.
13. Crosby, M., Nachiappan, Pattanayak P., Verma, S. and Kalyanaraman, V. (2016):Blockchain Technology: Beyond Bitcoin.Applied Innovation Review (2). Availabe at: https://j2-capital.com/wp-content/uploads/2017/11/AIR-2016-Blockchain.pdf. (Accessed: 17th May 2020).
14. Deshpande, A., Stewart K., Lepetit, L. and Gunashekar, S. (2017):Distributed Ledger Technologies/Blockchain: Challenges, opportunities and the prospects for standards. Overview report. Available at: https://www.bsigroup.com/LocalFiles/zh-tw/InfoSec-newsletter/No201706/download/BSI_Blockchain_DLT_Web.pdf. (Accessed: 13th May 2020).
15. FAO and ITU.(2019):E-Agriculture in action: Blockchain for agriculture: Opportunities and Challenges. FAO, Rome, Italy and the International TelecommunicationUnion, Bangkok.
16. Ge, L., Brewster, C., Spek, J., Smeenk, A. and Top, J.(2017):Blockchain for agriculture and food: Findings from the pilot study. Wageningen EconomicResearch report, the Hague, the Netherlands 112: 34.
17. Goranović, A., Meisel, M., Fotiadis, L., Wilker, S., Treytl, A. and Sauter, T.(2017):Blockchain applications in micro grids an overview of current projects and concepts. In: Industrial Electronics Society, IECON 2017-43rd Annual Conference of the IEEE, pp. 6153 – 6158.
18. Grassroots Farmers Collective. (2019):How We Use Blockchain Technology To Give You Total Transparency. Available at: https://grassrootscoop.com/blog/how-we-use-blockchain technology-to-give-you-total-transparency/. (Accessed: 20th May 2020).
19. IBRD, WB. (2017):Future of food: Shaping the Food System to Deliver Jobs.International Bank for Reconstruction and Development (IBRD)and World Bank (WB), Washington, USA. Available at: https://openknowledge.(Accessed: 9th May 2020).
20. ICT4Ag. (2017):Perspectives for ICT and Agribusiness in ACP countries: Start-up financing, 3D printing and blockchain. Available at:file:///C:/Users/hp/Downloads/91e974bc-eebe-4558-ba02-fe0006606bbf%20(1).pdf. (Accessed: 14th May 2020).
21. Jeremic, M. and Brankov, T. (2020):The Blockchain Technology in Agriculture. In: Subic J, Jelocnik M, Andrei JV (eds)Sustainable agriculture and rural development in terms of the republic of Serbia strategic goals realization within the Danube region – Science and practice in the service of agriculture. Thematic proceedings. Institute of agricultural economics. Belgrade, Serbia.
22. Kamath, R. (2018):Food traceability on blockchain: Walmart's pork and mango pilots with IBM.The Journal of The British Blockchain Association., 1(1): 3712.
23. Kamilaris, A., Fonts, A. and Prenafeta-Boldú, F.X. (2018):The Rise of the Blockchain Technology in Agriculture and Food Supply Chain. Technical report. Available at: https://www.researchgate.net/publication/327534824. (Accessed: 13th May 2020).
24. Kosba, A., Miller, A., Shi, E., Wen, Z. and Papamanthou, C. (2016):Hawk: The Blockchain Model of Cryptography and Privacy – Preserving Smart Contracts. In: Proceedings of the IEEE Symposium on Security and Privacy. San Jose, United States, pp. 839 – 858.
25. Lemieux, V.L. (2016):Trusting Records: Is Blockchain Technology the Answer?Records Management Journal.,26(2): 110 – 139.
26. Malik, S., Singh, A., Kumari, R., Pathak, S., Rohila, S, Choki, S. and Pandey, B. (2018). Leveraging the potential of agriculture sector and food supply with blockchain technology – A review.Journal of Pharmacognosy and Phytochemistry SP5: 116 – 119.
27. Mengelkamp, E., Garttner, J., Rock, K., Kessler, S., Orsini, L. and Weinhardt, C. (2018):Designing micro grid energy markets: A case study: The Brooklyn Micro grid.Applied Energy., 210: 870 – 880.
28. Mettler,M. (2016):Blockchain technology in healthcare: The revolution starts here. In: Proceedindgs of the 18th IEEE International Conference on e-Health Networking, Applications and Services. Munich, Germany.
29. Mirabelli, G. and Solina, V. (2020):Blockchain and agricultural supply chains traceability: research trends and future challenges.Procedia Manufacturing.,42: 414 – 421.
30. Momo,F., Schiavi G.S. and Behr, A. (2018):Business Models and Blockchain: What Can Change?Twenty-fourth Americas Conference on Information Systems. New Orleans. Available at: https://aisel.aisnet.org. (Accessed: 20th May 2020).
31. Mulvary,P. (2003):The role of Agricultural Science and Technology in reducing hunger, improving livelihoods, and increasing economic growth. Linnean Society, 25 March 2003.
32. Nakamoto,S. (2008):Bitcoin: A Peer-to-Peer Electronic Cash System. Available at: https://bitcoin.org/bitcoin.pdf. (Accessed: 10th May 2020).

33. Olnes, S., Ubacht, J. and Janssen, M.(2017):Blockchain in government: Benefits and implications of distributed ledger technology for information sharing.Government Information Quarterly., 34(3): 355 – 364.
34. Redman, R. (2018):More retailers join IBM food trust network. Supermarket News. Available at: https://www.supermarketnews.com/food-safety/more-retailers-join-ibm-food-trust-network. (Accessed: 20th May 2020).
35. Sanghera, A. (2018):Application of blockchain technology in agriculture. Available at: https://yourstory.com/mystory/e3909bc0fe-application-of-blockch.(Accessed: 16th May 2020).
36. Sengupta,U., Singh S. and Kim, H.M. (2019):Meeting Changing Customer Requirements in Food and Agriculture through application of Blockchain Technology.SSRN Electronic Journal. doi: 10.2139/ssrn.3429200
37. Swan, M. (2015):Blockchain: Blueprint for a New Economy.O'Reilly Media, Inc. Available at: https://dl.acm.org/doi/book/10.5555/3006358. (Accessed: 17th May 2020).
38. Tian,F. (2016):An Agri-Food Supply Chain Traceability System for China Based on RFID & Blockchain Technology". In:Proceedings of the 13th International Conference on Service Systems and Service Management (ICSSSM). Kunming, China, 24 – 26 June.
39. Tripoli, M. and Schmidhuber, J. (2018):Emerging Opportunities for the Application of Blockchain in the Agri-food Industry.Food and AgricultureOrganization of the United Nations, Italy, Rome and International Centrefor Trade and Sustainable Development, Geneva, Switzerland.
40. Underwood, S. (2016):Blockchain beyond Bitcoin.Communications of the ACM.,59(11): 15 – 17.
41. Xiong, H., Dalhaus, T., Wang, P. and Huang, J. (2020):Blockchain Technology for Agriculture: Application and Rationale. Frontiers in Blockchain., 3(7). Available at: https://www.frontiersin.org/articles/10.3389/fbloc.2020.00007/full. (Accessed: 12th May 2020).
42. Yadav, V.S. and Singh, A.R.(2019):A systematic Literature Review of Blockchain Technology in Agriculture. In: Proceedings of the International Conference on Industrial Engineering and Operations Management. Pilsen, Czech Republic, July 23 – 26.