Evolution of Agritech Business 4.0 – Architecture and Future Research Directions

Eashwar S and Paras Chawla

1Research Scholar, Department of ECE, Chandigarh University, Mohali, Punjab.  
2HOD, Department of ECE & EE, Chandigarh University, Mohali, Punjab.

Email: 1eashwar@bonfilsautomation.com, 2drparaschawla.ece@cumail.in

Abstract. Protection of farmer’s welfare, improving their standard of living and maintaining the connect between urban and rural population are important for sustainable development. Agriculture 4.0 based on Industry 4.0 evolved to produce crops in different manner by applying new technologies, adopt emerging technologies to bring efficiency in food web, incorporate cross industry technologies and applications. Agri Food 4.0 is a survey based on industrial farming using advancements in Blockchain, Artificial Intelligence, IOT, Big Data. The challenge is to make the technologies interoperable and also to integrate agriculture production with food distribution network. In this research work, we propose to present the architecture of Agritech Business 4.0, a transparent model to integrate agriculture production with food distribution network by adopting I4.0 technologies. It is necessary to have a common framework that uses Internet of Things, Smart DLT, Big Data Analytics etc. thereby the communication between the technologies can be harnessed for better agricultural production, food security, transparency and decentralization. We have also presented few open research problems and future research directions in this paper.

Keywords: Sustainability, SDG, Agriculture 4.0, IOT, Blockchain, Artificial Intelligence, Smart Distributed Ledger Technology.

1. Introduction

Industry 4.0 (fourth industrial revolution), developed in Germany in 2011, incorporates IoT (Internet of Things), Cyber Physical Systems (CPS), System Integration, Big Data Collection and Cloud Computing for intelligent manufacturing.

1.1. Agriculture 4.0 [1]

- Produce crops in a different manner using emerging technologies. Some of the promising research areas in this direction are:
  - Hydroponics
  - Algae Feedstock
  - Desert Agriculture
  - Sea Water Farming
- Adopt emerging technologies in the food chain. Some examples are:
Vertical and Urban Farming
- Genetic Modification
- Cultured Meats
- Applying Additive Manufacturing technologies to food

Integrate cross-sector technologies such as:
- Drones
- Internet of Things
- Precision Farming
- Nanotechnologies
- Data Analytics
- Distributed Ledger Technology
- Artificial Intelligence
- Food Sharing and Crowd Farming

1.2. Agri Food 4.0 [2]

In Agri Food 4.0 is a survey focused on Industrial Farming

Challenges in Emerging Technologies as per Agri Food 4.0

| Blockchain                        | Internet of Things                                    | Big Data                                           |
|-----------------------------------|------------------------------------------------------|----------------------------------------------------|
| Large Energy Consumption          | Data Security, privacy and anonymity                  | Trust Privacy and Security                         |
| Blockchain Integration with other technologies (BDA, IOT & CPS) | Decentralization                                     | Decentralization                                   |
| Limited Storage capacity and Scalability | Throughput and Latency Issue                        | Data control when multiple actors are involved     |

Figure 1: Challenges in Emerging Technologies as per Agri Food 4.0

This survey [2] clearly reveals the integration of emerging technologies shall solve agriculture problems such as water, carbon emission, food production and soil conservation.

Poor management of resources negativity impacts safety, quality, quantity, human resources, technology, products and natural resources.

The farming sector has to undergo technological advancements in order to satisfy the demands of consumer on quality food, decrease food supply chain costs, to satisfy the change in consumer needs, to lower environmental footprints and to increase the income of all stakeholders involved in farming and agribusinesses.

Majority of Indian population survive on Agriculture and its allied services, and hence pertinent to harness the power of the fourth industrial revolution in the field of agriculture to increase agricultural produce without damaging environment. To overcome the climate change issues and to practice sustainable farming, technology offers the best way forward. Cloud computing and sensor-based
automation helps optimization, reduces wastage and increases the profit margin. Precision farming, livestock management, monitoring through drones etc. are some of the techniques that can be implemented for sustainable agriculture. Hence Agriculture 4.0 emerged to apply advanced technologies in farming so as to meet the production challenges and to reduce the cost of production. But this is not enough. In the present scenario, farm to food table is still a challenge. Agricultural produce goes waste due to mismanagement in the supply chain sector. Hence it is very important to have an integrated mechanism by which we can track the agricultural produce right from farm to food table to minimise the loss and smooth flow of produce. The consumer is empowered with the information of the produce, so that intelligent choice can be made.

1.3. Customer Viewpoint for Information Related to Food

![Figure 2: Customer Viewpoint for Information related to food [3]](image)

A survey was conducted by Shaosheng Jin et al. [3] in China and it was found that the consumers are interested in knowing the food data such as fertilizers used, production standard, nutrition, provider, quality certificate, harvest date, place of origin and circulation process.

In Section 2, we present the review of literature,

2. Literature Review

The work carried out by various researchers and organizations on Agriculture 4.0, using Advanced sensors, Artificial Intelligence (AI), Biotechnologies, Cyber Security, Drones, Internet of Things (IoT), AR/VR, Cloud Computing and Robotics have unequivocally proved it to be the future.

Raphael A. Viscarra Rossel and Johan Bouma [4] in their work have stated that increasing food productivity using Fertilizers causes irreversible damage to environment. Employing Soil sensors will improve the efficiency of food production, minimize environmental side effects and also provides information about soil and biochemical attributes.

Revathi Nukala et al. [5] have analysed the research advancements and challenges in food distribution network, with respect to meat, fruits and vegetables. They also present the utilization of IoT technologies in food retail.

Mahammad Shareef Mekala and P. Viswanathan [6] observed the applications of various IoT sensors for monitoring and management of farms. With the assistance of the sensors various information are collected such as temperature, pH, humidity, soil nutrition levels, water levels etc. Cloud Computing is the backbone in implementing smart agriculture model.
Akash Suresh Patil et. al. [7] proposed a framework using blockchain for cybersecurity. A new security framework is developed that combines blockchain and IoT devices providing secure communication for smart agriculture.

Kamlesh Lakhwani et. al. [8] in his paper analysed the application of IoT to agriculture and forestry.

Luis Barreto and Antonio Amaral [9] have analysed the challenges faced in smart farming, highlighting the issues and security threats using empirical methodology to increase the fundamental awareness needed. Some security challenges in smart farming were also identified by the authors.

Jhonattan Miranda et. al. [10] have researched the use of sense, smart and sustain concept in response to the challenges in agriculture industries. The authors developed S3 Technology. The papers present contextual analysis of S3 concept applied to agriculture sector.

UM Rao Mogili et. al. [11] reviewed the implementation of UAV’s for pesticide spraying and crop monitoring. A camera was attached to the UAV, which took pictures that were used to analyze geographical indicator. With GPS co-ordinates the infected areas were sprayed with pesticides, quantum of water to be irrigated and the amount of chemicals needed for growth.

Almaw Ayele Aniley et. al. [12] proposed the monitoring of soil temperature and water content using dual probe heat pulse (DPHP) sensor with the help of IoT. The system includes both hardware and software such as NodeMCU, DPHP Moisture sensor, thermistor, 3D printer box, stainless steel cylindrical tubes, Arduino IDE and measures the parameters at an accuracy of 3 digits.

Janna Huuskonen and Timo Oksanen [13] developed a novel augmented reality system. With the help of AR system, the farmer can supervise two autonomous machines as was demonstrated in the test field.

Ahmed A. El-magrous et. al. [14] a inexpensive Weather Soil Sensor Station (W-SSS) was designed, developed and tested. The sensor was operated using Arduino microcontroller and Wi-Fi connected to the cloud. The information from the sensor can be accessed through a mobile application. It represents the differences in soil and weather conditions respective to nearby station and those in the field.

Samudra Vishal Mukherji et. al. [15] proposed the uses of IoT with Message Queuing Telemetry Tracking (MQTT) concept. It collects data of field atmosphere using MQTT, CC3320 Launchpad and sensors sends it to Remote Monitoring Station (RMS) which will inform the farmer for proper maintenance.

Muhammad Ayaz et. al. [16] work featured the application of IoT and wireless sensors in agriculture. Use of Sensors in agriculture helps farmers to know about crop status, soil preparation, irrigation, insects and pest detection. They also provide information to the farmers from sowing till transportation. They have employed UAV for crop surveillance.

Aneta Łukowska et. al. [17] developed a mobile platform using devices for soil sampling. After examining the soil sample, they found the constituents. The data of soil properties were recovered using the onboard system installed in the robot, so farmers can react to unexpected changes.

Kirtan Jha et. al. [18] reviews the use of automation techniques to reduce the loopholes in agriculture. Due to various difficulties based in traditional farming, there is a necessity to implement smart farming using sensors, IoT and machine learning.

Sukumar Katamreddy et. al. [19] examined various technologies employed in precision agriculture related to Industry 4.0. They found the gap by surveying various technologies and standards which will provide a way for a better and improved Agriculture 5.0.
Angelo Corallo et. al. [20] proposes a model for food information with supply chain to modern consumers. The work consists of two components of Industry 4.0: IoT and big data. The contextual analysis was obtained by implementing it in Olive production.

Sayan Kumar Roya and Debashis De [21] predicted the weather using genetic algorithm. The moisture sensor enables the system to forecast precisely by detecting dampness level of soil. With the utilization of soil moisture sensor, it will provide information whether water is required or not. If the moisture level crosses the preset value, quadrotor UAV will water the plants.

Maanak Gupta et. al. [22] presents the study on various internet connected devices will make way to cybersecurity issues in smart agricultural farm. The use of IoT and smart communication technologies makes it vulnerable to a smart farm. Based on the proposed multi-layer smart farming architecture explains possible cyber-attack scenarios.

Yu Gu and Tiaobin Jing [23] proposed three major use of IOT in food distribution network. The three vital applications are monitoring of fresh farm goods, without compromising the quality of food security sources, building an agricultural product management system with the help of IOT to increase the integration level of supply chain and reducing the expenses on distribution network and enhance the distribution network efficiency.

Lucia Ramundo et. al. [24] in their paper presents a state of the art of intelligent and new innovations set a platform for entire food supply chain. In addition, the advances towards implementation of Internet of Things (IOT) are also discussed.

Neha S. Naik et. al. [25] designed an autonomous agricultural robot prototype for seed sowing for four different crops such as cotton, maize, soybean and wheat. The four-wheeler vehicle is powered by LPC2148 Microcontroller which enables effective seed sowing at optimum depth and optimum distance between crops. The coverage area of Agribot is limited due to its dependence on DC Battery.

Fangfang Dai et. al. [26] conducted an extensive analysis of the current use of blockchain in cybersecurity. In order to resolve security concerns, this paper analyses the benefits that blockchain has brought to cybersecurity and highlights recent findings and implementation of blockchain in cybersecurity relevant fields.

Andreas Kamilaris et. al. [27] in his work explores the effect of blockchain technologies on agriculture and food supply chain. However, there are still problems and concerns that need to be tackled, beyond the technological stage. Additionally, governments should take initiatives in blockchain technology to make it secure, efficient and transparent in food safety and integrity.

Sunil Luthra et. al. [28] reviewed IOT based technologies in the context of agriculture supply chain management and found the significant gap in employing these technologies in developing countries. They also mentioned the challenges such as low R&D facilities and industry standards in India. IOT Based technology has significant scope in agriculture supply chain management which has to be investigated.

Janna Huuskonen and Timo Oksanen [29] studied the application of augmented reality and drone imaging for identifying the location for soil sampling.

A systematic review on blockchain agriculture was conducted Oscar Bermeo-Almeida et. al. [30] found that most of the studies are from Asia especially from China. Further, they also found that majority of the studies addressed privacy and security related challenges.

Miguel Pincheira Caro et. al. [31] presented Agriblock IOT, a traceability system for Agrifood supply chain management. The preliminary research work presented here identified that Hyperledger Sawtooth has better performance with respect to Ethereum counterpart.
Malaya Dutta Borah et al. [32] developed a web-based application in food distribution network by applying blockchain technology.

M. Dakshayini and B. V. Balaji Prabhu [33] proposed a decision support model called Big Data – Blockchain (BD-BC) to avoid middlemen in agricultural supply chain.

P2418.3 [34] is a standard that provides a common framework for DLT in agriculture.

Satoshi Nakamoto [35] presents the concept of bitcoin and proof of work (PoW).

After a thorough literature review it is found that the application of modern technologies to agriculture and supply chain management are not integrated. It is necessary to have common framework that integrates smart agriculture and food supply chain management, thereby the communication between the technologies can be harnessed for better agricultural production and food security.

3. Research Gaps

Based on the literature review:

- Agriculture and food supply chains are complex due to heterogeneous stakeholders and lacks transparency, decentralization and traceability.
- Literature review clearly reveals the integration across emerging technologies allows smart agriculture to solve problems such as water, carbon emission, food production and soil conservation.
- It is also found that there is no integrated system for connecting smart agriculture and food supply chain management.

Based on the above observations, it is important to design and develop a system to integrate agriculture with food supply chain management through Smart Distributed Ledger Technology (SDLT). It is necessary to have common framework that uses Internet of Things, SDLT, Big Data Analytics thereby the communication between the technologies can be harnessed for better agricultural production, food security, transparency and decentralization.

Figure 3: Solution – Agritech Business 4.0
4. Agritech Business 4.0

4.1 Definition

An architecture to Combine I4.0 technologies to integrate agricultural production with food distribution network to manage resources effectively and efficiently.

4.2 Architecture of Agritech Business 4.0

Agritech Business 4.0 consists of seven layers

4.2.1. Food Production and Distribution is depicted in the figure given below:
In Food Production and Distribution Network otherwise termed Farm to Fork, there are five elements. Land, Water, Seeds, Fertilizers, Pesticides are the inputs. The Farm process consists of crop selection, irrigation, preparation of soil, seed selection, sowing, crop protection, fertilizing and Harvesting. Cleaning, weighing, grading, blending, processing and packaging are the food processing stages followed by transportation and distribution. There are middlemen – Distributors, Dealers, Wholesalers and retailers who take them to consumers both in urban and rural areas.

4.2.2. **Data Layer**

![Figure 6: Data Layer for Agritech Business 4.0](image)

In this digital era, data can be easily collected at every stage. For example, from the farm process stage we can get temperature data, moisture content data, fertilizer data, pesticide data, water supply data, harvest and yield data. From the food processing stage, we can obtain food production data, processed data and food identification number for traceability. We can also get quality control data, tracking of food, food safety, pricing and billing information. All these data collected are processed and sent to the network layer through data layer. Data layer includes the underlying data blocks as described earlier, chain structure, time stamp, hash function, encryption etc. which is described in the figure above.

4.2.3. **Network Layer**

The network layer generally adopts peer to peer network and handles Propagation and validation. Following are the requirements identified – performance, DoS resistance, anonymity, low cost of participation and topology hiding. Design considerations are important as it involves various aspects such as precise vs randomised in band peer discovery, high vs low number of connections, scalefree vs random topology generation, stable vs changing connections, push vs announce and request, flooding vs gossip, short relay delay vs long relay delay. They are not just two possible choices as mentioned above, there are much more combinations, tradeoffs and design decisions. We leave it to the creativity of the researcher to consider the various aspects and requirements in the design decision of network layer.

4.2.4. **Consensus Layer**

Next comes the consensus layer where in Proof of work or Proof of stake or Proof of trust or a hybrid mechanism could be implemented. Performance evaluation metrics such as Algorithms throughput, Profitability of mining, Scalability, Degree of decentralization, optimized for IOT, use of Artificial intelligence and Security vulnerabilities.
4.2.5. **Incentive Layer**

Incentivisation has been proved to be an effective mechanism such that participating nodes are self-motivated for maximising their own profit.

4.2.6. **Contract Layer**

Algorithms and scripts for smart contract are encapsulated in the contract layer. Solidity Contract from open zeppelin could be integrated. Definition of abstract token contract and abstract store contract is done, followed by test driven development approach such that the focus is on one function at a time. The contract code is implemented after the test cases are successful. Finally, custom development chain is created. Following the above steps, it is easy for the blockchain developer to create algorithms and scripts.

4.2.7. **Application Layer**

The application layer, apart from execution of transactions also supports Decentralized Applications (dApps). End users communicate with the blockchain network through applications in the application layer. Scripts, APIs, user interfaces, and frameworks are all part of it. The blockchain network serves as the back-end mechanism for these applications, and they often communicate with it through APIs.

5. **How Agritech Business 4.0 will change the life of a common man?**

Agritech Business 4.0, when implemented, is anticipated to bring several advantages. Following are the key points:

- Streamline Food Distribution Network reducing the cost.
- Verification of regulatory compliance is easy.
- There will be saving of approximately $ 31 billion in food fraud [36].
- Subsidy disbursement is easy for the government.
- Food traceability and authenticity of Agri Inputs.

6. **Research Problems and Future Directions**

1. Holistic Cyber Physical System for Agritech Business 4.0
2. Data collection, integration, mining and fusion for Agritech Business 4.0
3. Scalable IOT cloud platforms for small and large farms
4. New sensors development for Agritech Business 4.0
5. Design of algorithms for smart contract to be encapsulated in contract layer
6. Development of Algorithms for Issuing and allocation policies for incentivisation
7. Decision making on the selection of consensus mechanism based on the performance metrics.
8. Development of new hybrid consensus algorithms
9. Network Design decisions to optimize the aspects and requirements as described in network layer
10. Light weight AI based IOT and Distributed Ledger Technology applications
11. Robust and low-cost user-friendly devices for Supporting Agritech Business 4.0
12. Interoperability of devices and communication technologies for Agritech Business 4.0

7. **Conclusion**

The architecture of Agritech Business 4.0, is proposed. While detailing the architecture, we have proposed certain research problems which we will consider solving them in future. When SDLT is used in integrated agricultural production and food distribution network, you can ensure transparency, security, streamlined operations, analytics, customer engagement and satisfaction. Availability of data, analytics and streamlined operations benefits all stakeholders thereby increasing the performance of farmers and people involved in agribusiness. Security of the system helps in the increased trust and
reliability. Customer engagement and satisfaction shall bring motivation to farmers. The optimized system shall reduce food wastage thereby increasing the profit margin of the farmers.

8. References

[1] www.oliverwyman.com/our-expertise/insights/2018/feb/agriculture-4-0--the-future-of-farming-technology.html#:~:text=Agriculture%204.0%20will%20no%20longer,pesticides%20uniformly%20across%20entire%20fields.&text=These%20advanced%20devices%20and%20precision,high%2C%20safe%2C%20and%20environmentally%20friendly

[2] M. Lezoche, H. Panetto, J. Kacprzyk, J. E. Hernandez, and M. M. E. Alemany Diaz, “Agri-food 4.0: A survey of the Supply Chains and Technologies for the Future Agriculture,” Comput. Ind., vol. 117, 2020, doi: 10.1016/j.compind.2020.103187.

[3] S. Jin, Y. Zhang, and Y. Xu, “Amount of information and the willingness of consumers to pay for food traceability in China,” Food Control, vol. 77, pp. 163–170, 2017, doi: https://doi.org/10.1016/j.foodcont.2017.02.012.

[4] R. A. V. Rossel and J. Bouma, "Soil sensing: A new paradigm for agriculture", Agricult. Syst., vol. 148, pp. 71-74, Oct. 2016, doi: https://doi.org/10.1016/j.agsy.2016.07.001.

[5] R. Nukala, K. Panduru, A. Shields, D. Riordan, P. Doody and J. Walsh, "Internet of Things: A review from 'Farm to Fork'," 2016 27th Irish Signals and Systems Conference (ISSC), Londonderry, 2016, pp. 1-6, doi: 10.1109/ISSC.2016.7528456.

[6] M. S. Mekala and P. Viswanathan, "A Survey: Smart agriculture IoT with cloud computing," 2017 International conference on Microelectronic Devices, Circuits and Systems (ICMDCS), Vellore, 2017, pp. 1-7, doi: 10.1109/ICMDCS.2017.8211551.

[7] A. S. Patil, B. A. Tama, Y. Park and K.-H. Rhee, "A framework for blockchain based secure smart green house farming", Proc. Adv. Comput. Sci. Ubiquitous Comput., pp. 1162-1167, 2018. doi: https://doi.org/10.1007/978-981-10-7605-3_185.

[8] K. Lakhwani, H. Giane, N. Agarwal and S. Gupta, "Development of iot for smart agriculture a review" in Emerging Trends in Expert Applications and Security, Springer, pp. 425-432, 2019. doi: https://doi.org/10.1007/978-981-13-2285-3_50.

[9] L. Barreto and A. Amaral, “Smart Farming: Cyber Security Challenges,” in 9th International Conference on Intelligent Systems 2018: Theory, Research and Innovation in Applications, IS 2018 - Proceedings, 2018, pp. 870–876, doi: 10.1109/IS.2018.8710531.

[10] U. R. Mogili and B. B. V. L. Deepak, “Review on Application of Drone Systems in Precision Agriculture," in Procedia Computer Science, 2018, vol. 133, pp. 502-509, doi: 10.1016/j.procs.2018.07.063.

[11] J. Miranda, P. Ponce, A. Molina and P. Wright, "Sensing smart and sustainable technologies for Agri-Food 4.0", Comput. Industry, vol. 108, pp. 21-36, 2019. doi: https://doi.org/10.1016/j.compind.2019.02.002.

[12] Almaw Ayele Aniley et. al. (2019). Advanced Sensor Materials Based Real-Time Soil Moisture Content and Temperature Monitoring Using IoT Technology in Smart Agriculture. International Journal of Environmental Protection, 39(7), 639-644.
[13] J. Huuskonen and T. Oksanen, “Soil sampling with drones and augmented reality in precision agriculture,” Comput. Electron. Agric., vol. 154, pp. 25–35, 2018, doi: 10.1016/j.compag.2018.08.039.

[14] A. A. El-magrous, J. D. Sternhagen, G. Hatfield and Q. Qiao, "Internet of Things Based Weather-Soil Sensor Station for Precision Agriculture," 2019 IEEE International Conference on Electro Information Technology (EIT), Brookings, SD, USA, 2019, pp. 092-097, doi: 10.1109/EIT.2019.8833811.

[15] S. V. Mukherji, R. Sinha, S. Basak and S. P. Kar, "Smart Agriculture using Internet of Things and MQTT Protocol," 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon), Faridabad, India, 2019, pp. 14-16, doi: 10.1109/COMITCon.2019.8862233.

[16] M. Ayaz, M. Ammad-Uddin, Z. Sharif, A. Mansour and E. M. Aggoune, "Internet-of-Things (IoT)-Based Smart Agriculture: Toward Making the Fields Talk," in IEEE Access, vol. 7, pp. 129551-129583, 2019, doi: 10.1109/ACCESS.2019.2932609.

[17] A. Łukowska, P. Tomaszuk, K. Dzierżek and Ł. Magnuszewski, "Soil sampling mobile platform for Agriculture 4.0," 2019 20th International Carpathian Control Conference (ICCC), Krakow-Wieliczka, Poland, 2019, pp. 1-4, doi: 10.1109/CarpathianCC.2019.8765937.

[18] K. Jha, A. Doshi, P. Patel, and M. Shah, “A comprehensive review on automation in agriculture using artificial intelligence,” Artif. Intell. Agric., vol. 2, pp. 1–12, 2019, doi: https://doi.org/10.1016/j.aiia.2019.05.004.

[19] S. Katamreddy, J. Walsh, S. Ward, and D. Riordan, “Closed loop process control for precision farming: An Agriculture 4.0 perspective,” 2019, doi: 10.1109/ISSC.2019.8904938.

[20] A. Corallo, M. E. Latino and M. Menegoli, "Agriculture 4.0: How Use Traceability Data to Tell Food Product to the Consumers," 2020 9th International Conference on Industrial Technology and Management (ICITM), Oxford, United Kingdom, 2020, pp. 197-201, doi: 10.1109/ICITM48982.2020.9080349.

[21] S. K. Roy and D. De, “Genetic Algorithm based Internet of Precision Agricultural Things (IopaT) for Agriculture 4.0,” Internet of Things, p. 100201, 2020, doi: https://doi.org/10.1016/j.iot.2020.100201.

[22] M. Gupta, M. Abdelsalam, S. Khorsandroo and S. Mittal, “Security and Privacy in Smart Farming: Challenges and Opportunities,” in IEEE Access, vol. 8, pp. 34564-34584, 2020, doi: 10.1109/ACCESS.2020.2975142.

[23] Y. Gu and T. Jing, “The IOT research in supply chain management of fresh agricultural products,” in 2011 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce, AIMSEC 2011 - Proceedings, 2011, pp. 7382–7385, doi: 10.1109/AIMSEC.2011.6011477.

[24] L. Ramundo, M. Taisch and S. Terzi, "State of the art of technology in the food sector value chain towards the IoT," 2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), Bologna, 2016, pp. 1-6, doi: 10.1109/RTSI.2016.7740612.

[25] N. S. Naik, V. V. Shete and S. R. Danve, "Precision agriculture robot for seeding function," 2016 International Conference on Inventive Computation Technologies (ICICT), Coimbatore, 2016, pp. 1-3, doi: 10.1109/INVENTIVE.2016.7824880.
[26] F. Dai, Y. Shi, N. Meng, L. Wei and Z. Ye, "From Bitcoin to cybersecurity: A comparative study of blockchain application and security issues," 2017 4th International Conference on Systems and Informatics (ICSAI), Hangzhou, 2017, pp. 975-979, doi: 10.1109/ICSAI.2017.8248427.

[27] A. Kamilaris, A. Fonts, and F. X. Prenafeta-Boldó, “The rise of blockchain technology in agriculture and food supply chains,” Trends Food Sci. Technol., vol. 91, pp. 640–652, 2019, doi: 10.1016/j.tifs.2019.07.034.

[28] S. Luthra, S. K. Mangla, D. Garg and A. Kumar, "Internet of Things (IoT) in agriculture supply chain management: A developing country perspective" in Emerging Markets from a Multidisciplinary Perspective, Berlin, Germany:Springer-Verlag, 2018, doi: https://doi.org/10.1007/978-3-319-75013-2_16.

[29] J. Huuskonen and T. Oksanen, “Augmented Reality for Supervising Multirobot System in Agricultural Field Operation,” in IFAC-PapersOnLine, 2019, vol. 52, no. 30, pp. 367–372, doi: 10.1016/j.ifacol.2019.12.568.

[30] O. Bermeo-Almeida, M. Cardenas-Rodriguez, T. Samaniego-Cobo, E. Ferruzola-Gómez, R. Cabezas-Cabezas, and W. Bazán-Vera, “Blockchain in agriculture: A systematic literature review,” Commun. Comput. Inf. Sci., vol. 883, pp. 44–56, 2018, doi: 10.1007/978-3-030-00940-3_4.

[31] M. P. Caro, M. S. Ali, M. Vecchio and R. Giaffreda, "Blockchain-based traceability in Agri-Food supply chain management: A practical implementation," 2018 IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany), Tuscany, 2018, pp. 1-4, doi: 10.1109/IOT-TUSCANY.2018.8373021.

[32] Borah M.D., Naik V.B., Patgiri R., Bhargav A., Phukan B., Basani S.G.M. (2020) Supply Chain Management in Agriculture Using Blockchain and IoT. In: Kim S., Deka G. (eds) Advanced Applications of Blockchain Technology. Studies in Big Data, vol 60. Springer, Singapore. https://doi.org/10.1007/978-981-13-8775-3_11

[33] Dakshayini M., Balaji Prabhu B.V. (2020) An Effective Big Data and Blockchain (BD-BC) Based Decision Support Model for Sustainable Agriculture System. In: Haldorai A., Ramu A., Mohanram S., Onn C. (eds) EAI International Conference on Big Data Innovation for Sustainable Cognitive Computing. EAI/Springer Innovations in Communication and Computing. Springer, Cham. https://doi.org/10.1007/978-3-030-19562-5_8

[34] www.standards.ieee.org/project/2418_3.html

[35] S. Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System, 2008, [online] Available: www.bitcoin.org/bitcoin.pdf.

[36] www.juniperresearch.com/press/press-releases/blockchain-to-save-the-food-industry-$31-billion-b