Transforming Agriculture Supply Chain with Technology Adoption-: A Critical Review of Literature

Chapa Karunanayaka, Kasuni Vidanagamachchi and Ruwan Wickramarachchi
Department of Industrial Management
University of Kelaniya
Kelaniya, Sri Lanka
karunana_im14054@stu.kln.ac.lk, kasuniv@kln.ac.lk, ruwan@kln.ac.lk

Abstract

With the increase in the global population, natural disasters and climatic changes the agricultural supply chain faces lots of challenges due to fluctuations of both supply and demand sides. This is adding pressure on the agriculture supply chain demanding it to be more productive and efficient. Adapting to technology to improve the agriculture supply chain have been identified as one solution. As the rest of the world is moving towards digital transformation, agriculture supply chains should follow the suite in order to meet the current challenges they face. This article reviews the literature on technology and technology applications in the agriculture supply chain. This article has identified the technological applications that have been built with respect to agricultural processes. Among them, it has found that, IoT as the technology which was based on many technology applications developed within the past few years. Further, this highlights IoT, Big Data and Blockchain as true enablers for the transformation of the agriculture supply chain to a digital agriculture supply chain.

Keywords
Agriculture Supply Chain, Technology, Digital Transformation

1. Introduction

The global population is expected to increase by 2.3 billion people from today's levels, reaching 9.8 billion by 2050 and at the global level agricultural production and consumption in 2050 are projected to be 60% higher than today (FAO 2018). With the increasing population in the world, the expected demand for agricultural products will become higher than ever before adding pressure on the agriculture supply chain. Adding to this, climatic changes, natural disasters and food wastages due to mismatch between demand and supply are also challenging the agriculture supply chain.
FAO (2017) describes how the demand will undergo structural changes. It states that population growth, urbanization and percapita increases in income as the factors which owe to the structural changes in demand which will result in the natural resource base upon which agriculture depends become increasingly stressed. Further, it states that climate changes affect food availability and has adverse impacts on crop yields, fish stocks and animal health. Manhindarathne and Min (2018) state that recent food crises and growing concerns about global climate change have placed agriculture on top of the international agenda. Thus, they mention that twenty-first-century agriculture is being challenged like never before.

These problems have become crucial, demanding a proper solution to transform the agriculture supply chain more productive and efficient. FAO (2017) says major transformations of agricultural systems, rural economies and natural resource management will be needed if we are to meet the multiple challenges before us and realize the full potential of food and agriculture to ensure a secure and healthy future for all people and the entire planet.

In a research that has done for Sri Lanka by Ginige et al. (2016) has mentioned that an analysis has revealed that one of the root causes for this problem is not receiving the right information at the right time in the right format for the agriculture supply chain actors; that is lack of information visibility within the agriculture supply chain. Kaloxylos et al. (2013) have also mentioned that lack of information has been recognized as a critical issue for a long time in the agri-food sector.

With the 4th industrial revolution, the world has begun to move towards a digitized world. Digitization has touched almost every aspect of human life all over the world, greatly affecting supply chain processes. Technology adoption has proved significant transformations in other industries providing them numerous benefits. Technologies such as IoT, cloud computing, big data, blockchain have been identified as potential enablers which can provide a solution to the problems prevail in the agriculture supply chain. With the adoption of technologies, it is intended to build an efficient and productive agriculture supply chain.

Realizing the significance of integrating technology with agriculture supply chain, this study has focused on identifying the technological applications that have built, with their usages and advantages. Further, this study also highlights the technologies that have been identified as true enablers for the transformation of the agriculture supply chain to a digital agriculture supply chain.

2. Methodology

This study was conducted related to the fields of agriculture and technology. In bringing the outcome of this study, data was collected from articles, journals, research papers published in reputed journals and conferences and from websites that were published between 2015 and 2019. A recent time period was selected in order to obtain more useful and relatable content. Further to that, during this time period, some of the key technologies were accepted as technologies that can lead to business transformation. Research papers were collected from major research databases such as Scopus, Science Direct, Emerald Insight and Researchgate etc. At the final stage, 50 research papers were critically reviewed to determine to enable technological applications.

3. Findings and Discussion

For the review of articles, a conceptual diagram (Figure1) was developed to provide a clearer understanding of the issues and concepts for the analysis of the technologies and technological applications that were built which drives agriculture supply chain towards its transformation.

Figure 1. Conceptual Diagram

The world has introduced various kinds of technologies by today making the industries highly competitive while delivering an excellent service to the customers. Big data, IoT, cloud computing, blockchain and other technological advancements have taken over the world with their potential to transform existing processes for better. These emerging new technologies affect every industry (Büyüközkan, and Göçer 2018). The industries across the world try to incorporate these technologies into their processes to gain the useful advantages behind them, aiming to provide better services to the customers while strengthening their profits. Just like all the other industries, the agriculture industry has also attracted by most of these technologies which are described below.

Along the agri-value chain, each touchpoint holds critical information that can help businesses make the most of their resources, provide greater transparency in their processes and protect consumers. Big Data has been identified as a technology that can add value across each touchpoints starting from the selection of right agri-inputs, monitoring the soil moisture, tracking prices of markets, controlling irrigations, indicating the right selling point and getting the right price. Therefore, BGA (Big Data Analytics) is expected to play a significant role in shaping up the modern agriculture, meeting the expectations of the stakeholders on three main dimensions viz., accuracy, accessibility, and accountability (Sharma and Patil, 2018). Further Sharma and Patil (2018) states opportunities for Big Data applications in agriculture. It includes benchmarking, sensor deployment and analytics, predictive modelling, and using better models to manage crop failure risk and to boost feed efficiency in livestock production.

With the arrival of the Internet of Things (IoT) in the technological landscape, all devices are now connected and interact with each other (smart devices) via wireless network infrastructure. IoT facilitates the provision of information and communication. These new emerging technologies like IoT and drones have been identified to use to improve the accuracy of the collected data (Sharma, et al. 2018).

With regards to satellite imaging, Sharma and Patil (2018) mention that this has the potential to capture images of farmer fields to 1 m x 1m resolution (20 – 25 pixels), which is improving further with invent of technology. These images can capture various data points such as Leaf Area Index, plant height, canopy etc. which is indicative of crop vigour and hence can be used to accurately estimate farm yield. According to them, recent progress in Big Data and advanced analytics capabilities and agri-robotics such as aerial imagery, sensors, and sophisticated local weather forecasts can truly transform the agri-scape and thus holds promise for increasing global agricultural productivity over the next few decades. Further, they mention that, financing to farmers as another challenge that data can solve. As banks are facing the challenge of determining the creditworthiness of farmers, they mention the fact that lending to farmers becoming efficient, logical and data-driven, if the bankers have access to data on likely crop output from farmer's field. Deichmann et al. (2016) state that digital tools enable market agents to better coordinate product supply and demand, strengthen existing trade networks, facilitate the assembly of products to reach a critical mass, and enable products to be delivered cost-effectively to new markets. Sharma et al. (2018) have also mentioned the importance and value of the use of new technologies to the agriculture supply chain. They say the smart farming techniques have been found to be enhancing the crop yield and productivity.

In agriculture, blockchain-based data management has been identified as one that can be beneficial especially around data that relates to land and resource use records, purchase and use of pesticides and other harmful agents, traceability and even flows of finance across the whole value chain (Kamble et. al. 2019).

Through the adoption of technologies to agriculture supply chain, it is expected to improve its performance. Deichmann et al. (2016) have identified the impact towards the agriculture supply chain in the form of improved market efficiency, farm productivity enhancement and enabling efficient logistics.

Identifying the fact that technology can provide solutions to the problems prevail in the agriculture supply chain, researches have come up with many technological applications during the past few years. The following table summarizes the literature that consists of technology applications related to the agriculture supply chain.

Table 1. Technology applications

Process	Subprocesses	Technology				
		Mobile	Website	IoT	Big Data	Blockchain
Crop Selection	Market demand and sale potential, Budget required for cultivation, Feasibility of the crop considering climate and	[9]			[15] [16] [18]	

	quality of land, Crop productivity compared with others					
Land Preparation	Identifying any effects from previous cultivations, Identifying fertilizers needed, Layout design for efficient irrigation, Leveling	[9]				
Seed Selection	Identifying price and quantity need and average yield, Identifying suitability to particular area and climate, Identifying water requirement and resistance to diseases, Identifying the location of distribution offices for the seed	[9]				
Seed Sowing	Identifying appropriate time to sow the seed and optimal water conditions at sowing time, Applying the best method for the sowing of seeds, Identifying seed sowing depth			[11]		
Irrigation	Providing the right amount of water to the plants after identifying the frequency of irrigation			[11]		
Crop Growth	Monitoring the moisture content in the soil proper fertilization, Weeding, Monitoring for pest attacks and taking immediate actions where necessary, Comparison of crop growth rate, leaf size, crop colour	[9] [1] [6] [8]	[6] [7]	[11] [12] [13] [5] [7]	[18]	
Harvesting		[9]			[18]	
Storage			[3]			
Transportation	Identifying transportation modes and people, Transport		[10]			
Selling	Identifying buyers and crop prices, Selling	[1] [4]	[10] [3]		[17]	[14]
Providing advisory services on the researches that have done		[2]			[16]	

The above table will be useful for the stakeholders to get an idea on processes and what technologies have been adopted and, processes where technology adoption is lacking. Following points provide example applications that highlight the use of technology extracted from selected articles.

[1]: Farmer's club in Turkey: Receive SMS alerts to the farmers who registered regarding weather forecasts, crop prices, crop diseases, Government subsidies (FAO 2018).

[2]: sharing news, electronic publications, advisory and educational materials and resources, research data and other information on the web (FAO 2018).

[3]: Export Moldova – Market assistance website.
This provides a portfolio of important information to traders and producers to facilitate their access to export markets. The information covers 13 products and drills down to detailed information on information on export markets, varieties, packaging, and postharvest handling and processes, as well as EU quality standards (FAO 2018).

[4]: AgMarket in Hungary. This is a mobile application which has developed to allow the user to easily find producers and healthy agricultural products. The program intends to improve direct market access for small farms, increase sales opportunities and enable customers to evaluate producers and products, providing feedback to the farmers and other customers. The contact data, as well as the description and location of the local markets and products, are searchable and can be displayed in detail. Producers may also use a traditional web-page to register themselves and administrate their offerings. The mobile application can be downloaded from iOS and Android smartphone app stores (FAO 2018).

[5]: This mentions the use of drones for agriculture. They use an Unmanned Aerial Vehicle-based low-cost remote sensing system in precision agriculture. The application focuses on weed control, nutrient management, soil and damage mapping (FAO 2018).

[6]: Pest warning system - This was introduced to raise awareness of the dangers of pesticides and to help local farmers adopt more environmentally sustainable agricultural practices. These efforts have already led to a 30 per cent reduction in the number of pesticides used by local farmers each season. The main function of the system is to monitor pests and diseases, with the installation of six solar-powered agro-meteorological monitoring stations and a number of insect pheromone traps. The problem with such a system is getting the data directly to farmers, and the previous system of posting paper flyers in the squares was far from adequate to ensure all farmers were adequately and promptly informed. To overcome this, an SMS system was developed (FAO 2018).

[7]: Remote plant disease monitoring system and comprehensive decision support with on-site an intuitive, web-based user interface. (SmartVineYard) (FAO 2018).

[8]: The project gathers information about pest control and frost prevention from weather stations throughout the country and sends this information to farmers via cell phones, for example, to alert farmers ahead of peak pest seasons to help them choose the best time for pesticide application. (FAO 2018).

[9]: Govi Nena in Sri Lanka. This is comprised of two components as a real-time mobile-based information system and a management dashboard. The mobile application is the front-end for farmers to monitor the aggregate production level in near real-time. The management dashboard is a graphical terminal customizable according to other value chain participants (i.e. banks, government agencies, agrochemical companies, etc.). The Govi Nena platform is intended to offer a great opportunity to consolidate linkages in the value chain by eliminating coordination failure and uncertainty. (Sugathadasa et al. 2016)

[10]: e-NAM - National Agriculture Market (NAM) is a pan-India electronic trading portal which networks the existing APMC (Agricultural Produce Market Committee) *mandis* to create a unified national market for agricultural commodities. The NAM Portal provides a single-window service for all APMC related information and services. This includes commodity arrivals & prices, buy & sell trade offers, provision to respond to trade offers, among other services. While material flow (agriculture produce) continues to happen through *mandis*, an online market reduces transaction costs and information asymmetry. NAM addresses the challenges by creating a unified market through online trading platform, both, at State and National level and promotes uniformity, streamlining of procedures across

the integrated markets, removes information asymmetry between buyers and sellers and promotes real-time price discovery, based on actual demand and supply, promotes transparency in auction process, and access to a nationwide market for the farmer, with prices commensurate with quality of his produce and online payment and availability of better quality produce and at more reasonable prices to the consumer. (Sharma and Patil 2018).

[11]: A model to capture the soil moisture, temperature and humidity data.
This was intended to help farmers in managing the irrigation time of their agriculture correctly. The resulting of the system that is an application can be of great benefit to its users. The user can directly divide own land into as many regions as desired in this application. Therefore, the users will provide saving in their time and water. Also, this application is reliable because it provides weather information instantaneously from the central stations. (Kiani, and Seyyedabbasi 2018).

[12]: Integration of the IoT technologies with image processing software for identification of factors hindering the growth of crops.
Using the loT network, the exact variations the plant undergoes with time have assessed allowing to pin-point the specific deficiencies that the plant faces in terms of mineral requirement or environmental adjustments. The images have been obtained from the SD Card that has been installed on the loT Sensing network and fed into the system. By corroborating the histograms for all the sets, it was analyzed to conclude the deficiency that is currently affecting the plant. Therefore, using the loT Sensing network that contains the exact temperature, soil moisture, humidity data, the information has been collaborated to validate the findings by the image processing results obtained. (Kapoor et al. 2016).

[13]: Use of drone for monitoring and observing crop quality, crop yield and protecting the land from damages and theft (Sharma et al. 2018).

[14]: AgriDigital's initial blockchain pilot in 2016 executed the world's first settlement of a physical commodity on a blockchain. The pilot captured real-time data of a grain sale between a grain grower and a buyer and then executed that transaction on a blockchain (FAO and ITU 2019).

[15]: Development of a geospatial crop modelling approach for assessing the impact of different varieties. Results show that new DT varieties could give a yield advantage of 5–40% across drought (Kamilaris et al. 2017).

[16]: Development of a farm management platform that provides personalized agricultural advice on how to optimize costs, increase productivity and access markets. Results showed a 64% increase in productivity in the first year, 112% in the second year (Kamilaris et al. 2017).

[17]: Development of a platform that enhances farmers' ability to meet export market standards/ certifications while at the same time ensuring a more stable and predictable supply of good quality for exporters (Kamilaris et al. 2017).

[18]: The Agroclimate Impact Reporter (AIR) is an application built by the government, specifically Agriculture and Agri-Food Canada'sNational Agricultural Information Services (NAIS). Climate data from volunteers, farmers and media reporting is gathered using this tool and then the data is anonymized and mapped by NAIS, which maps can then be used by anyone interested in information about current/historical weather conditions municipally, regionally or nationally. The tool is explicitly intended to help producers mitigate weather-related risks (Bronson and Knezevic 2016).

4. Conclusion

As the agricultural supply chain is facing problems with the increasing population, natural disasters and climatic changes, there is a need of transforming the agriculture supply chain to a whole new one which is high in productivity and efficiency. Adopting technology to the agriculture supply chain has been identified as a potential solution and there are more and more applications that develop day by day. According to the review, it was found IoT as the main technological category that has built more applications compared to others during the past few years. Most of these applications were made using sensors and was mostly used in the crop growth stage. As the base technology, mobile technology has played a significant role in IoT devices. Mobile technology has been used to provide advisory services to farmers as well. Big data and blockchain have been identified as the technologies that will make a huge impact on the agriculture supply chain with other prevailing technologies in future. With this, the article has presented a summary of all those published technology applications and technologies to provide benefits to the reader in several aspects. The reader will be able to identify the technologies that will transform the agriculture supply chain, about the technology applications, identify the areas that have technology applications and identify the areas that do not have or lack.

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Biographies

Chapa Karunanayaka is an undergraduate of the Department of Industrial Management, University of Kelaniya, Sri Lanka. She is a final year undergraduate who is reading for the BSc (Hons) Degree in Management and Information Technology. Ms Chapa is following Operations and Supply Chain Management as her specialization area.

Kasuni Vidanagamachchi is a lecturer at the Department of Industrial Management, University of Kelaniya, Sri Lanka. She holds BSc (Hons) in Transport and Logistics Management from University of Moratuwa, Sri Lanka and a Master's Degree in Business Administration (MBA) from Postgraduate Institute of Management, Sri Lanka.

Ruwan Wickramarachchi is a senior lecturer at the Department of Industrial Management, University of Kelaniya, Sri Lanka. He holds BSc. in Industrial Management from University of Kelaniya, Sri Lanka and MPhil in Management Studies from the University of Cambridge, United Kingdom. He received his PhD in Distribution Simulation from Sheffield Hallam University, United Kingdom.