International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 1 | Issue: 1 | Jul-Aug 2020 Available Online: www.ijscia.com

Big Data in Agriculture

Matthew N. O. Sadiku[1]*, Tolulope J. Ashaolu[2], and Sarhan M. Musa[1]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]College of Food Science, Southwest University, Tiansheng Road Beibei District, Chongqing, 400715, P.R. China
E-mail: sadiku@ieee.org; ashaolut@gmail.com; smmusa@pvamu.edu
*Corresponding author details: Professor Matthew N. O. Sadiku, sadiku@ieee.org

ABSTRACT
Big data and analytics are helping to improve and transform a multitude of industries in the modern world, and agriculture industry is no exception. Today, data is transforming one of the world's oldest industries: agriculture. Agriculture has become increasingly high-tech and data-driven over the years. To counter the global problems of increasing food demand and climate changes, agriculture professionals are now pushing for data-driven agriculture, which offers cost savings and business opportunities. This paper addresses the use of big data in agriculture and the management of farming processes.

Keywords: big data; big data analytics; agriculture; farming

INTRODUCTION
Agriculture is critically important for the future of our modern society. It is regarded as one of the oldest vocations known to mankind. It is the backbone of any nation's economy as well as the global economy. In some places like Africa and India, majority of rural residents depend on agriculture for their livelihood. Agriculture supplies our food, energy, and medicine [1].

Today, the agriculture sector is facing several challenges such climate change, increasing population, increasing labor shortages, land and water constraints, increasing urbanization, environmental degradation, changing dietary habits, coping with the latest technology, achieving more with less, etc. The United Nations has estimated that the global population will reach 9.8 billion by 2050, indicating the urgent need to produce more food production in order to feed the growing population with less land to grow it on. These enormous challenges can be dealt with by adopting advanced technologies such as Internet of things, cloud computing, GPS technology, satellites, drones, robots, and artificial intelligence. These technologies are transforming agriculture and generating massive volumes of data, known as big data. Big data is critical to help agriculture meet the challenges.

Agriculture has gone through several revolutions: industrial revolution, green revolution, biotechnology revolution, and more recently the big data revolution. It is undergoing a digital revolution. Traditional skill-based agriculture is rapidly transforming into digital and data-driven agriculture with big data playing a critical role in enhancing productivity. To extract useful information from the generated data requires a new generation of practices/tools known as "Big Data Analytics." Data analytics is aimed at deriving knowledge and wisdom from data as illustrated in Figure 1 [2]. Digital information on soil, weather, climate, crop, etc., is fundamental to digital agriculture and predictive data analytics.

BIG DATA CHARACTERISTICS
Big data (BD) is a relatively newer technology that can make use of smart city services. The three main sources of big data are machines, people, and companies. As shown in Figure 2 [3], big data can be described with 42 "Vs". The first five "Vs" are volume, velocity, variety, veracity, and value [4].

- *Volume*: This refers to the size of the data being generated both inside and outside organizations and is increasing annually. Some regard big data as data over one petabyte in volume.

- *Velocity*: This depicts the unprecedented speed at which data are generated by Internet users, mobile users, social media, etc. Data are generated and processed in a fast way to extract useful, relevant information. Big data could be analyzed in real time, and it has movement and velocity.

- *Variety*: This refers to the data types since big data may originate from heterogeneous sources and is in different formats (e.g., videos, images, audio, text, logs). BD comprises of structured, semi-structured or unstructured data.

- *Veracity*: By this, we mean the truthfulness of data, i.e. weather the data comes from a reputable, trustworthy, authentic, and accountable source. It suggests the inconsistency in the quality of different sources of big data. The data may not be 100% correct.

- *Value*: This is the most important aspect of the big data. It is the desired outcome of big data processing. It refers to the process of discovering hidden values from large datasets. It denotes the value derived from the analysis of the existing data. If one cannot extract some business value from the data, there is no use managing and storing it.

On this basis, small data can be regarded as having low volume, low velocity, low variety, low veracity, and low value. Additional five "Vs" have been added [5]:

- *Validity:* This refers to the accuracy and correctness of data. It also indicates how up to date it is.

- *Viability:* This identifies the relevancy of data for each use case. Relevancy of data is required to maintain the desired and accurate outcome through analytical and predictive measures.

- *Volatility:* Since data are generated and change at a rapid rate, volatility determines how quickly data change.

- *Vulnerability:* The vulnerability of data is essential because privacy and security are of utmost importance for personal data.

- *Visualization:* Data needs to be presented unambiguously and attractively to the user. Proper visualization of large and complex clinical reports helps in finding valuable insights.

Instead of the 5 "Vs" above, some suggest the following 5 "Vs": Venue, Variability, Vocabulary, Vagueness, and Validity [6].

Industries that benefit from big data include the healthcare, financial, airline, travel, restaurants, automobile, sports, agriculture, and hospitality industries. Big data technologies are playing an essential role in farming: machines are equipped with sensors that measure data in their environment.

BIG DATA ANALYTICS

Every day, data is growing bigger and bigger, and big data analysis (BDA) has become a requirement for gaining invaluable insights into data such that companies could gain significant profits in the global market. Big data analytics and the Internet of things (IoT) form the foundation of the smart city model. Smart city initiatives need big data analytics to function. Once the big data is ready for analysis, we use advanced software programs such as Hadoop, MapReduce, MongoDB, and NoSQL databases [7]. Big data analytics refers to how we can extract, validate, translate, and utilize big data as a new currency of information transactions. It is an emerging field that is aimed at creating empirical predictions. Data-driven organizations use analytics to guide decisions at all levels [8].

Data scientists know how to use tools that identify patterns and relationships that may otherwise remain hidden. They are part of virtually every major industry, and agriculture is no exception. Agricultural big data analytics is expected to ensure better farming practices, decision-making, and a sustainable future for humankind. This will involve artificial intelligence and machine-learning technologies to determine better farming practices and decision-making [9].

WHY BIG DATA IN AGRICULTURE?

Data were always regarded as an important source of knowledge for farmers, agricultural professionals, and policy-makers. Farming has been empirically driven for over a century but the data collected was not digital. The agriculture community deals with a massive amount of structured and unstructured data. In order to make economically and environmentally sound decisions a management of information is needed. The raw information from crops is turned into profitable decisions only when efficiently managed.

Big data is sometimes regarded as a combination of technology and analytics that can collect and process data in a more useful and timely way to assist decision-making. It is the focus of in-depth, advanced, game-changing business analytics. It is poised to reproduce long-standing relationships between food system players and thus it deserves scholarly attention from food scientists [10].The adoption of analytics in agriculture has been growing, with the objective of presenting the analytics to farmers in an approachable format. Figure 3 illustrates big data in agriculture [11].

Big data is moving into agriculture in a big way and forming agricultural "big data," which creates the necessity for large investments in infrastructures for data storage and processing. Agricultural big data means a lot of data is created naturally from different stages from sowing seed to harvesting. Important arrangements for the management of big data include agreements on data availability, data quality, access to data, security, responsibility, liability, data ownership, privacy, and distribution of costs. An important aspect of big data is that it requires using analytical tools to extract value from it, improving the productivity of farmers and agriculture professionals. Without such analysis, big data can be expensive, time consuming, and useless.

APPLICATIONS OF BIG DATA IN AGRICULTURE

Big data and Internet of things are poised to revolutionize farming practices and operations of agro-food sector. Application of big data is a key tool to digitalize the agriculture sector. Modern agricultural practices adopt digital technology for the transformation of traditional agriculture to modern agriculture. It covers virtual agriculture, precision agriculture, smart agriculture, automated agriculture, digital agriculture, data-driven agriculture, sustainable agriculture, lean agriculture, and so on [12]. Thus, big data applications in agriculture include smart farming, data-driven agriculture, precision farming, sensor deployment and analytics, and predictive modelling [13, 14].

- *Smart Agriculture/ Farming:*

The integration of big data in the agricultural sector leads to the concept of smart farming or smart agriculture. The ultimate goal of agriculture is to achieve smart farming. The concept of smart farming refers to farm managing using data analytics, communications systems, IoT, ICT, sensors, GPS, satellite, robots, drones, etc. With all of these technologies, farmers can collect data, monitor the field conditions without physically going to the field, and make strategic decisions [15]. Smart farming is important for tackling the challenges of agricultural production in terms of productivity, environmental impact, food security, and sustainability. Smart agriculture is a major tool to handle and manage the threats, challenges, risks, diseases, and pest attack and ensure sustainability. Figure 4 depicts smart farming [16].

- *Data-driven Agriculture*:

Modern farming practices will become increasingly data-driven and data-enabled. Data-driven agriculture offers cost savings and business opportunities. It sets the grounds for the sustainable agriculture of the future. Data-driven agriculture has proven useful for all parties throughout all stages. Big data analytics is an essential tool for big data-driven agriculture. Farmers can now leverage big data and use data-driven risk assessments to evaluate the chances of disruptive events.

- *Precision Agriculture*:

As the name suggests, precision agriculture makes a precise plant and cattle treatment possible. It is about providing more accurate farming techniques for planting and growing crops. Its main objective is to ensure profitability, efficiency, and sustainability using the big data to guide both immediate and future decision making. It can be implemented in various situations where there is a shortage of rainfall, soil is not fertile, or temperature is worse. Precision agriculture and data analytics are pushing for a new agriculture input industry structure, causing a new set of capabilities to be required. With precision farming, farmers can monitor crop health and other natural events. They can foresee the yields with absolute accuracy even before sowing. Farmers who implement precision agriculture are gaining unprecedented visibility into their operations [17].

- *Boosting Productivity and Innovation:*

Due to increasing global food demand, farmers need to harness data and innovation to improve productivity and feed a growing global population. Implementing precision agriculture enables farmers better manage key resources including seed, fertilizer, and pesticides, while increasing productivity.

- *Managing Environmental Challenges:*

Data-driven farming can help make it easier for farmers to navigate shifts in environmental conditions.

- *Cost savings and Business Opportunities:*

The agriculture sector stands to gain a lot from data-driven farming. The resulting savings can help farmers better manage risk against the vagaries of domestic and global markets.

- *Better Supply Chain Management:*

The growing availability of rich data and actionable insights will help farmers to trace their products throughout the supply chain. Retailers, distributors, and other key stakeholders will be able to tailor their products and services to the needs of the market.

- *Risk Assessment:*

Farming always involved some risks, such as unexpected crop disease, natural disasters, or extreme weather conditions, which may be out of the control of farmers. With big data, nearly every system, decision or event can be considered in the risk analysis plan. Every mistake can be accounted for, along with the appropriate solution. Farmers can use real-time data to ensure damage remains minimal. Big data for risk assessment is applied in benchmarking, sensor deployment, analytics, and predictive modeling. Applying these approaches to make predictions using big data can help farmers model and manage risks related to raising livestock and growing crops.

Other areas in which agriculture uses big data include crop management, livestock care, supply chain management, crop forecasting, climate predictions, benchmarking, visualization, and food security.

BENEFITS

Big data is expected to cause major shifts in roles among traditional and non-traditional players. It will change the way farms are operated and managed, real-time forecasting, and tracking of physical items. Big data has the potential to implement the interventions needed to reverse worrying trends of food insecurity, increase food production, and implement sustainable solutions. Agriculture industry may see the biggest efficiency gains and improvements from big data and analytics. It may be the best way to revolutionize the agricultural sector [18, 19].

Other benefits of big data in agriculture include [20]:

- Provide predictive insights to future outcomes of farming and drive real-time operational decisions.
- Increase farming productivity.
- Improve farming operations and consumption of resources like water and electricity.
- Create a sustainable agriculture that is attractive to youths and future generations.
- Stop migration of the labour force.
- Reduce food waste.
- Optimize fleet management to increase delivery reliability.
- Attract greater investments in agriculture industry.

CHALLEGES

Agriculture is facing many challenges, particularly in developing nations. Although promising many benefits in agriculture, big data's main challenge relies in its adoption and how to make the data collected relevant and useful for farmers. Understanding the best way to utilize massive amounts of data remains a major important challenge. The increasing implementation of big data analytics may lead critics to ask whether this technology will eventually replace humans in several capacities. Data bias and variance are important challenges to address when developing predictive algorithms, which heavily rely on data [21]. Farmers are the most novice players in the big data application to farming, particularly those in developing nations.

Other challenges facing big data in agriculture include the following:

- What will farmers do after agriculture is digitalized and automated?
- The promise of big data remains largely unfulfilled.
- Data access, privacy, security, ownership, and use of farm data.
- The culture of modern agriculture creates some significant ethical and legal questions.
- Power asymmetry between farmers and large agribusinesses exists.
- Unequal access to and use of information could widen social inequity.
- Limited ICT infrastructure and skills in poorer nations may cause the "digital divide."

Although the benefits of big data in agriculture have clearly outweighed the uncertainty, the challenges must be addressed for increased uptake of big data applications in farming or agriculture.

CONCLUSION

Big data and smart farming are relatively new concepts. Big data is inevitable in agriculture. Its potential to "revolutionize" agricultural industry is of interest to the industry and researchers across the world. The new capabilities underpinning big data include cloud computing, social media, artificial intelligence, sensor technology, the Internet of things, robotics, and mobile technologies [22]. Currently, discussion on big data applications takes place mainly in Europe and North America. However, applications are expected to grow rapidly in other countries like China and India. Countries that facilitate usage of data-driven agriculture find it easier to fulfil the needs of their citizens.

Big data will significantly affect many aspects of the agricultural industry, although the full extent remains uncertain. More information about the use of big data in agriculture can be found in the books in [23, 24] and related journals: *Agriculture* and *Big Data & Society.*

REFERENCES

[1] M. H. Meisner, "Enhancing data-driven decision making in agriculture: A big data approach," *Doctoral Dissertation,* University of California, Davis, 2015.

[2] S. Himesh et al., "Digital revolution and big data: A new revolution in agriculture," *CAB Reviews,* 2018 13, no. 021.

[3] "The 42 V's of big data and data science," https://www.kdnuggets.com/2017/04/42-vs-big-data-data-science.html

[4] M. N.O. Sadiku, M. Tembely, and S.M. Musa, "Big data: An introduction for engineers," *Journal of Scientific and Engineering Research*, vol. 3, no. 2, 2016, pp. 106-108.

[5] P. K. D. Pramanik, S. Pal, and M. Mukhopadhyay, "Healthcare big data: A comprehensive overview," in N. Bouchemal (ed.), *Intelligent Systems for Healthcare Management and Delivery.* IGI Global, chapter 4, 2019, pp. 72-100.

[6] J. Moorthy et al., "Big data: Prospects and challenges," *The Journal for Decision Makers*, vol. 40, no. 1, 2015, pp. 74–96. https://www.grandviewresearch.com/industry-analysis/industrial-wireless-sensor-networks-iwsn-market

[7] M. N. O. Sadiku, J. Foreman, and S. M. Musa, "Big data analytics: A primer," *International Journal of Technologies and Management Research,* vol. 5, no. 9, September 2018, pp. 44-49.

[8] C. M. M. Kotteti, M. N. O. Sadiku, S. M. Musa, "Big data analytics," *Invention Journal of Research Technology in Engineering & Management*, vol. 2, no. 10, Oct. 2018, pp. 2455-3689.

[9] M. Ryan, "Agricultural big data analytics and the ethics of power," *Journal of Agricultural and Environmental Ethics*, vol. 33, 2020, pp. 49–69.

[10] K. Bronson and I. Knezevic, "Big data in food and agriculture," *Big Data & Society,* January-June 2016, pp. 1–5.

[11] "Big data sets the tone for agriculture transformation! Check how?" June 2019, https://data-flair.training/blogs/big-data-in-agriculture/

[12] M. N. I. Sarker et al., "Promoting digital agriculture through big data for sustainable farm management," *International Journal of Innovation and Applied Studies*, vol. 25, no. 4, March 2019, pp. 1235-1240.

[13] S. Wolfert et al., "Big data in smart farming – A review," *Agricultural Systems,* vol. 153, May 2017, pp. 69-80.

[14] O. Schlam, "4 Ways big data analytics are transforming agriculture," July 2019, https://www.futurefarming.com/Tools-data/Articles/2019/7/4-ways-big-data-analytics-are-transforming-agriculture-450440E/

[15] "Big data in agriculture-smart farming made easy," May 2019, https://www.datahen.com/blog/big-data-in-agriculture/#:~:text=Smart%20Farming%20and%20the%20Role%20of%20Big%20Data&text=The%20concept%20of%20smart%20farming,while%20optimizing%20the%20required%20labor.

[16] R. Sharma, "Big data applications in agriculture: Role, importance & challenges," April 2020, https://www.upgrad.com/blog/big-data-applications-in-agriculture/

[17] M. N. O. Sadiku, Y. Wang, S. Cui, S. M. Musa, "Precision agriculture: An introduction," *International Journal of Advanced Engineering and Technology*, vol. 2, no. 2, May 2018, pp. 31-32.

[18] J. Agboola, "Big data is the future. but where are the farmers?, May *2018,* https://bigdata.cgiar.org/big-data-is-the-future-but-where-are-the-farmers/

[19] M. R. Nichols, "5 Ways big data is revolutionizing the agricultural sector," August 2018, https://www.rtinsights.com/5-ways-big-data-is-revolutionizing-the-agriculture-industry/

[20] "How to encourage farmers to use big data analytics in agriculture," March 2020, https://www.intellias.com/how-to-encourage-farmers-to-use-big-data-analytics-in-agriculture/

[21] 'Power in Prediction – Part 2: A need for data and analytics in the future," https://respiratorycarev2.com/power-in-prediction-part-2-a-need-for-data-and-analytics-in-the-future/

[22] A, Fleming et al., "Is big data for big farming or for everyone? Perceptions in the Australian grains industry," *Agronomy for Sustainable Development*, vol. 38: 2018.

[23] G. Sylvester (ed.), *E-Agriculture in Action: Big Data for Agriculture*. Bangkok: Food and Agriculture Organization of the United Nations, 2019.

[24] United States House of Representatives, United States Congress, Committee On Agriculture, *Data and Agriculture: Innovations and Implications.* CreateSpace Independent Publishing Platform, 2017.

AUTHORS

Matthew N.O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interests include computational electromagnetics and computer networks. He is a fellow of IEEE.

Tolulope J. Ashaolu is a postdoctoral fellow at Southwest University, Chongqing, China. He is the author of several papers and books. His research interests include functional foods and food microbiology.

Sarhan M. Musa is a professor in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He has been the director of Prairie View Networking Academy, Texas, since 2004. He is an LTD Sprint and Boeing Welliver Fellow. His areas of research interests include computational electromagnetics and computer networks.

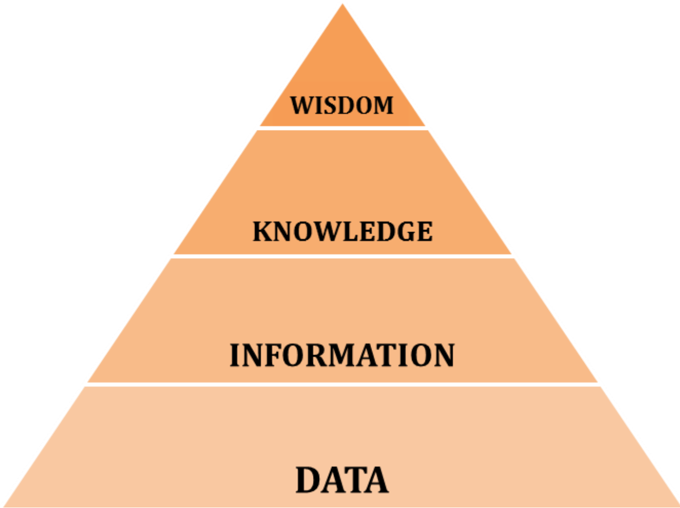

FIGURE 1: FROM DATA TO WISDOW [1].

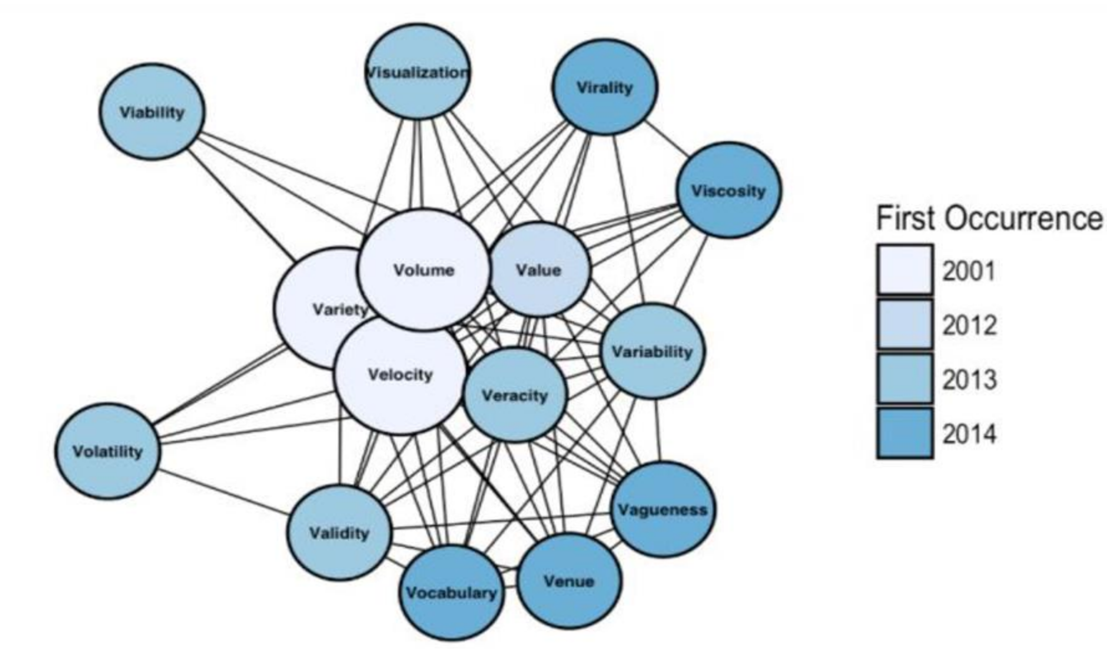

FIGURE 2: THE 42 V's OF BIG DATA [3].

FIGURE 3: BIG DATA IN AGRICULTURE [11].