Plant Archives Vol. 24, Special Issue (GABELS), 2024 pp.45-49 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2024.v24.SP-GABELS.007

REVOLUTIONIZING AGRICULTURE: A COMPREHENSIVE OVERVIEW OF DIGITAL AGRICULTURE TECHNOLOGIES

Babita Bharti[1*], Vishal Bharti[2], Bharti Gautam[1], Neha Negi[1] and Jag Mohan[1]
[1]Department of Agriculture, Maharishi Markandeshwar (Deemed to be) University, Mullana, Ambala. Haryana, India
[2]Department of Computer Science & Engineering, MMEC, Maharishi Markandeshwar (Deemed to be) University, Mullana, Ambala. Haryana, India
*Corresponding author E-mail: mebabitabharti@yahoo.com

ABSTRACT

Digital agriculture technologies have emerged as transformative tools for revolutionizing conventional farming practices, optimizing resource utilization, and bolstering productivity while mitigating environmental impact. In this rapidly growing field, agricultural productivity and resource management are enhanced through the use of data analytics, advanced technologies, and applications under precision agriculture. This paper provides an overview of digital agriculture technologies, focusing on their core components, advantages, challenges, and future outlook. At the heart of digital agriculture lies precision farming, leveraging advanced sensors, drones, and GPS technology to monitor and manage crops with unparalleled accuracy. Remote sensing techniques, including satellite imagery and drones, provide valuable insights into crop health and environmental conditions, facilitating timely interventions. The integration of Internet of Things (IoT) devices enables real-time monitoring and control of agricultural operations, from automated irrigation systems to smart livestock management. Artificial intelligence (AI) and big data analytics empower farmers to analyze vast datasets, predict crop yields, and optimize farming strategies. However, widespread adoption of digital agriculture technologies faces challenges such as high initial costs, limited rural infrastructure, and data privacy concerns. Farmers and other stakeholders may contribute to the widespread adoption of precision agriculture and enhance crop yield, resource management, and environmental sustainability by recognizing and resolving these issues. In a nutshell, this paper analyzes and highlights digital agriculture technologies which offer unrivalled opportunities to enhance productivity, sustainability, and resilience in Agriculture.
Keywords: Digital Agriculture, technologies, Sustainability, Precision agriculture, Remote sensing, Data Analytics.

Introduction

Digital agriculture, sometimes referred to as precision agriculture or smart farming, is an evolving field that optimizes agricultural methods through the use of digital technologies. To enhance agricultural productivity, coordinate-related data can be captured, processed, and applied using a variety of technological tools, hardware and application systems, navigation, geological information, and telecommunication technologies (Z. Lv 2020; Dutta *et al*., 2021). Precision farming is based on specific navigational coordinates and considers it as an accounting unit, which is a key difference from the traditional conception of agriculture (Mogili *et al*., 2018; Tsoraeva *et al*., 2020). Agriculture is currently going through its "fourth revolution," as digitalization quickly transforms entire societies, including the agricultural-food sector (Walter *et al*., 2017). This advancement may help attain the Sustainable Development Goals by tackling the three main issues facing the agriculture industry: increasing production, minimizing environmental impact, and conserving natural resources (Basso and Antle, 2020; FAO, 2022; Khanna *et al*., 2022; Lajoie-O'Malley *et al*., 2020). Today's productive farms use data from sensors, drones, satellites, weather stations, and other field monitoring devices to inform their decisions in the modern age of digital agriculture technology (Pedersen *et al*., 2019; Cullu *et al*., 2019, Sarker *et al*., 2019). By maximizing resource use and enhancing crop output and quality, artificial intelligence has tackled issues with climate change, increase in population, employment, and food security (Talaviya *et al*., 2020).

Importance of digitalization in Agriculture Sector

Technologies hold great possibilities for extensive use in all aspects of agricultural production, including greenhouses, horticulture, livestock production, and arable systems (Wolfert *et al*., 2017). The use of digital technologies is expanding rapidly in quantity and scope, influencing the digital transformation of agricultural production and the agri-food sector worldwide. Farmers can now manage agricultural operations more successfully and remotely (MacPherson *et al*., 2022; Walter *et al*., 2017; Wolfert *et al*., 2017). Automation and self-governing machinery, farming systems, and processes are also made possible by digital technologies (FAO, 2022). By using precision farming, data gathered from several sources, such as sensors recording vegetation health and yield monitors recording yield potentials can be used to guide the distribution of fertilizer or pesticide use within a field as well as the timing of its application (Spati, Huber and Finger, 2021). As an example, milking robots enables animal-specific performance records to be recorded in livestock production systems (Martin *et al*., 2022). As more and more sensors and data sources are linked to actual decision-making, artificial intelligence is becoming an essential component (Galaz *et al*., 2021).We can realize data-intensive applications more and more efficiently thanks to big data technologies, cloud computing, and high-performance computing (Lokers *et al*., 2016). Autonomous technologies are becoming more and more important in cattle production, replacing human decision-making and manual labour entirely or at least partially. This is turning farms into "cyber-physical management systems" (Van Hilten and Wolfert, 2022; Jakku *et al*., 2019). Beyond Efficiency, Substitution, and Redesign, digitalization can help agricultural systems perform better economically and socially, leave less of an environmental impact, and enhance animal welfare (FAO, 2022; Walter *et al*., 2017). More efficient monitoring and enforcement of sustainability criteria may also be made possible by higher levels of transparency in digitalized agri-food systems.

Key Technologies in Digital Agriculture:

a.) Sensor Technologies

Precision agriculture relies heavily on sensor technologies, which make data collecting and analysis easier and enable well-informed decision-making in a variety of crop management contexts (Lee *et al*., 2010; Mladen *et al*., 2021). Agriculture's historical evolution is poised for another significant transformation thanks to the combination of state-of-the-art sensor technologies and data-driven innovations (Shukla *et al*., 2023). Sensing technologies cover a wide range of technologies, including ground-based sensors like weather stations, soil moisture sensors, and nutrient sensors, as well as remote sensing methods like satellite images, aerial photography, and drones (Sishodia *et al*., 2020). Digital agriculture technologies like GPS, GIS, remote sensing, and active canopy crop sensors as well as sensor-based N optimization algorithms can optimize crop yields while requiring the least amount of input, which makes them useful instruments for maximizing sustainability and profitability in developing nations (Farid *et al*., 2023). Remote sensing has made it possible to quantify yields more effectively and efficiently in real time and at high resolution, even in systems where this has historically been challenging, like grassland systems that are regularly mowed or grazed (Vroege Vrieling, and Finger, 2021b). In addition, the use of Geographic Information System (GIS) and Global Positioning System (GPS) applications in precision agriculture improves data collection and analysis for precise location tracking, mapping, and informed crop management decision-making, as well as resource utilization optimization (Tagung *et al*., 2022).

b.) **Robotics And Automation**

Automation and robots have become an essential component of digital agriculture; they have been thoroughly studied and used in a range of agricultural processes, including planting, inspecting, spraying, and harvesting (Mahmud *et al*., 2020). Numerous advantages are provided by these technologies, such as enhanced productivity, heightened efficiency, and optimal use of available resources. Farmers can also make well-informed decisions using data-driven decision-making by using up-to-date information on crop status, weather patterns, and soil health (Balaska *et al*., 2023). To satisfy the practical needs of labor-saving and effective agricultural production, agricultural robots have increased in categories and diversified in application scenarios, such as field robots, fruit and vegetable robots, and animal husbandry robots (Cheng *et al*., 2022). A low-cost, two-wheeled robot with wireless control and a spray mechanism for applying fertilizer and pesticides has been designed for use in harvesting fields (Ghafar *et al*., 2023).

c.) Internet of Things (IoT) based systems

A worldwide connected network of individually addressable "things" that use standard internet communication protocols is known as the Internet of Things (IoT). It is the most efficient and important strategy for creating answers to problems (Verdouw *et al*., 2016; Tzounis *et al*., 2017). Additionally, farmers may estimate production levels, evaluate weather conditions, and remotely monitor plants and animals by using IoT technology's sensors and equipments (Dhanaraju *et al*., 2022). Farmers are unable to manually monitor and examine every plant to address nutritional deficiencies, pests, and diseases; nonetheless, IoT technology is still advantageous and has helped farmers reach a new milestone in modern agriculture (Mittal and Singh, 2007). By 2050, it is anticipated that the Internet of Things will have increased agricultural production by 70% (based on estimated demand) since technology makes it simple to implement new ideas (Sarni *et al*., 2016).

d) Cloud Computing in Agriculture

Concept of "Cloud computing," as used in the information technology (IT) industry today, is a computing paradigm that provides on-demand access to application data or storage space to a large number of privately, publically, or hybrid networked devices (Kishor *et al*., 2023). Cloud computing allows for the rapid recording of meteorological and other climate data through linked devices, which is useful for agricultural activities and may be directly applied to decision-making. Cloud-based farm management systems aim to provide decision support systems and integrate data from several sources. According to Basso and Antle (2020), growers now have access to information for dynamic management planning that were previously exclusive to corporate mega farms.

Challenges and future outlook

Digital or precision agriculture's future is a very complicated matter. On one hand, it is anticipated that their regular application will help to actually raise farm income levels; these solutions will guarantee that higher yields are obtained with lower input levels. However, implementations have to be done so as not to harm the environment. There are some important issues which need consideration. These include a lack of digital infrastructure, insufficient knowledge and training, shortages of resources, concerns about data security and privacy, and resistance by farmers (David and Emmanuel, 2023). One of the biggest obstacles to the shift to digital agriculture is the lack of infrastructure and technical know-how, as well as the availability of financial and economic resources. If digital techniques and innovations are implemented on a greater scale, both locally and internationally, agricultural economists might assist to evaluate the implications for sustainability and resilience (Woodard *et al*., 2018). Better information about the advantages and disadvantages of digital technologies for the public and private sectors must be made available in order to prioritize and drive policymaking.

Conclusion

Digital farming holds great promise for raising agricultural yields and enhancing resource management. It maximizes farming methods by utilizing cutting-edge technologies such as automation, variable rate applications, and sensors. It also increases sustainability, minimizes resource waste, and facilitates well-informed decision-making. There are still issues with cost, accessibility, data management, and education, though. Digital agriculture has the ability to transform farming and satisfy the world's food demand while reducing its negative effects on the environment with more study and cooperation. The process of conducting agricultural economic research will undergo a transformation due to the digitalization of the agri-food industry. Data from the levels of plants, animals, fields, farms, and the full food value chain will be accessible, gathered by billions of digital devices and platforms.

References

Balaska, V., Adamidou, Z., Vryzas, Z., Gasteratos, A. (2023). Sustainable Crop Protection via Robotics and Artificial Intelligence Solutions, Machines, 11, 774.

Basso, B. and Antle, J. (2020). Digital agriculture to design sustainable agricultural systems. *Nature Sustainability*, 3, 254–256.

Cheng, C., Fu, J., Su, H. and Ren, L. (2022). Recent Advancements in Agriculture Robots: Benefits and Challenges. *Machines*, 11(1), 48.

Cullu, M.A., Teke, M., Mutlu, N., Bilgili, A.V. and Bozgeyik F. (2019). Integration and Importance of Soil Mapping Results in the Precision Agriculture; Institute of Electrical and Electronics Engineers Inc.: Piscataway, NJ, USA, 2019.

David, M. and Emmanuel, N. (2023). Digital Technology Adoption in the Agriculture Sector: Challenges and Complexities in Africa. Hindawi Human Behavior and Emerging Technologies, Volume 2023, Article ID 6951879, 10 pages

Dhanaraju, M., Chenniappan, P., Ramalingam, K., Pazhanivelan, S. and Kaliaperumal, R. (2022). Smart Farming: Internet of Things (IOT)- Based Sustainable Agriculture. Agriculture, Pp. 12(10).

Dutta, A., Roy, S., Kreidl, O. and Boloni, L. (2021). Multi-Robot Information Gathering for Precision Agriculture: Current State, Scope, and Challenges. IEEE Access, 161416-161430.

FAO. (2022). The State of Food and Agriculture 2022: leveraging agricultural automation for transforming agrifood systems. Rome, Italy: Food and Agriculture Organization (FAO).

Farid, H.U., Mustafa, B., Khan, Z.M., Anjum, N.M., Ahmad, I., Mubeen, M. and Shahzad, H. (2023). An Overview of Precision Agricultural Technologies for Crop Yield Enhancement and Environmental Sustainability. *In Climate Change Impacts on Agriculture, Springer, Cham.*, 239-257.

Galaz, V., Centeno, M.A., Callahan, P.W., Causevic, A., Patterson, T., Brass, I., Baum, S., Farber, D., Fischer, J., Garcia, D. and McPhearson, T. (2021). Artificial intelligence, systemic risks, and sustainability. *Technology in Society*, 67: 101741

Ghafar, A.A., Hajjaj, S.S., Gsangaya, K.R., Sultan, M.T., Mail, M.F., Hua, S.L. (2023). Design and development of a robot for spraying fertilizers and pesticides for agriculture. Materialstoday Proceedings, 81, 242-248.

Jakku, E., Taylor, B., Fleming, A., Mason, C., Fielke, S., Sounness, C. and Thorburn, P. (2019). 'If they don't tell us what they do with it, why would we trust them?' Trust, transparency and benefit-sharing in smart farming. *NJAS-Wageningen Journal of Life Sciences,* 90–91, 100285.

Khanna, M., Atallah, S. S., Kar, S., Sharma, B., Wu, L., Yu, C., Chowdhary, G., Soman, C. and Guan, K. (2022). Digital transformation for a sustainable agriculture in the United States: opportunities and challenges. *Agricultural Economics*, 53, 924–937.

Kishor, K., Saxena, N. and Pandey, D. (2023). Book edited "Cloud-basedIntelligent Informative Engineering for Society 5.0" pp. 1-234.

Lajoie-O'Malley, A., Bronson, K., van der Burg, S. and Klerkx, L. (2020). The future(s) of digital agriculture and sustainable food systems: an analysis of high-level policy documents. *Ecosystem Services,* 45, 101183.

Lokers, R., Knapen, R., Janssen, S., van Randen, Y. and Jansen, J. (2016). Analysis of Big Data technologies for use in agro-environmental science. *Environmental Modelling & Software,* 84, 494–504.

Lv, Z. (2020). Construction of soil environment information management platform based on ArcGIS. *IOP Conf. Ser. Earth Env. Sci*., 546, 032039.

MacPherson, J., Voglhuber-Slavinsky, A., Olbrisch, M., Schöbel, P., Dönitz, E., Mourati adou, I. and Helming, K. (2022). Future agricultural systems and the role of digitaliza tion for achieving sustainability goals. A review. *Agronomy for Sustainable Development,* 42, 70.

Mahmud, M.A., Abidin, M.S., Emmanuel, A.A. and Hasan, H.S. (2020). Robotics and Automation in Agriculture: Prestne and Future Applications. Application of Modelling and Simulation, 4, 130-140.

Martin, T., Gasselin, P., Hostiou, N., Feron, G., Laurens, L., Purseigle, F. and Ollivier, G. (2022). Robots and transformations of work in farm: a systematic review of the literature and a research agenda. *Agronomy for Sustainable Development*, 42, 66.

Misaki, E., Apiola, M., Gaiani, S. (2016). Technology for small scale farmers in Tanzania: A design science research approach. *Electron. J. Inf. Syst. Dev. Ctries*. 74, 1–15.

Mittal, A. and Singh, A. (2007). Microcontroller based pest management system. In Proceedings of the Second International Conference on Systems (ICONS'07), Martinique, France, 22–28 April 2007; IEEE: Martinique, France, 2007; p. 43.

Mladen, J., Ivan, P., Željko, B., Dorijan, R. and Domagoj, Z. (2021). Sensors and Their Application in Precision Agriculture. *Tehnički Glasnik* 15(4), 529-533.

Mogili, U.M.R. and Deepak, B. (2018). Review on application of drone systems in precision agriculture. *Pro. Comp. Sci.*, 133, 502–509.

Pedersen, S.M., Medici, M., Anken, T., Tsiropoulos, Z., Fountas, S. (2019). Financial and Environmental Performance of Integrated Precision Farming Systems; Wageningen Academic Publishers: Wageningen, The Netherlands.

Sarker, N.I., Islam, S., Ali, A., Islam, S., Salam, A., Hasan Mahmud, S.M. (2019). Promoting digital agriculture through big data for sustainable farm management. *Int. J. Innov. Appl. Stud*., 25, 1235–1240.

Sarni, W., Mariani, J. and Kaji, J. (2016). From dirt to data: The second green revolution and the Internet of Things, Deloitte Insights, Deloitte Review.

Shukla, B.K., Maurya, N., Sharma, M. (2023). Advancements in Sensor-Based Technologies for Precision Agriculture: An Exploration of Interoperability, Analytics and Deployment Strategies. *Engineering Proceedings*., 58, 22.

Sishodia, R.P., Ray, R.L. and Singh, S.K. (2020). Applications of Remote Sensing in Precision Agriculture: *A Review. Remote Sensing*, 12(19).

Spati, K., Huber, R. and Finger, R. (2021). Benefits of increasing information accuracy in variable rate technologies. *Ecological Economics*, 185, 107047.

Tagung, T., Singh, S. K., Singh, P., Kashiwar, S. R., Singh, S.K. (2022). GPS and GIS based Soil Fertility Assessment and Mapping in Blocks of Muzaffarpur District of Bihar. Biological Forum- *An International Journal*, 14(3), 1663-1671.

Talaviya, T., Shah, D., Patel, N., Yagnik, H., Shah, M. (2020). Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides. *Artificial Inlelligence in Agriculture*, 4, 58-73.

Tsoraeva, E., Mezhyan, S., Kataeva, M., Hugaeva, L., Rogova, T. (2020). GIS technologies used in zoning agricultural land for optimizing regional land use. E3S Web Conf. 224, 03001.

Tzounis, A., Katsoulas, N., Bartzanas, T. and Kittas, C. (2017). Internet of Things in agriculture, recent advances and future challenges, *Biosyst Eng*, 164, 31–48

van Hilten, M. and Wolfert, S. (2022). 5G in agri-food a review on current status, opportunities and challenges. Computers and Electronics in Agriculture 201: 107291.

Verdouw, C., Wolfert, S. and Tekinerdogan, B. (2016). Internet of things in agriculture, CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 11.

Vroege, W., Vrieling, A. and Finger, R. (2021b). Satellite support to insure farmers against extreme droughts. *Nature Food*, 2, 215–217.

Walter, A., Finger, R., Huber, R. and Buchmann, N. (2017). Smart farming is key to devel oping sustainable agriculture. *Proceedings of the National Academy of Sciences*, 114, 6148–6150.

Wolfert, S., Ge, L., Verdouw, C. and Bogaardt, M.-J. (2017). Big data in smart farming - a review. *Agricultural Systems*, 153, 69–80.

Woodard, J.D., Sherrick, B.J., Atwood, D.M., Blair, R., Fogel, G., Goeser, N., Gold, B., Lewis, J., Mattson, C., Moseley, J. and O'Mara, C. (2018). The power of agricultural data. *Science*, 362, 410–411.