International Journal of Information Science and Computing
Citation: *IJISC*: **10**(01&02): 01-13, June and December 2023
DOI: 10.30954/2348-7437.1.2023.2

INFORMATION SCIENCE AND TECHNOLOGY FOUNDATION

Review Paper

Smart and Digital Agricultural Systems in the Context of Developing Countries — *The Root for Digital Society*

P.K. Paul[1]*, Nilanjan Das[2], Abhijit Bandyopadhyay[3], Mustafa Kayyali[4] and Ricardo Saavedra[5]

[1]*Executive Director (MCIS Program), Head/ Coordinator & Asst. Professor, Dept. of CIS, Raiganj University, West Bengal, India*
[2]*Assistant Professor, Siliguri Institute of Technology, Siliguri, West Bengal, India*
[3]*Teacher-in-Charge, Raniganj Institute of Computer and Information Science (RICIS), Raniganj, West Bengal, India*
[2]*Manager, HE Higher Education Ranking, Syria*
[5]*Director & Chair (International Programs), Azteca University, Mexico*

*Corresponding author: pkpaul.infotech@gmail.com

Received: 17 Sept., 2023 **Revised:** 30 Nov, 2023 **Accepted:** 05 Dec., 2023

ABSTRACT

Agricultural Systems are changing rapidly for various latest methods of cultivation including agricultural inputs, securing irrigation resources, and obtaining pesticides and fertilizers to increase crop production. And for all the activities Agricultural Informatics play a leading role and also for overcome of the existing techniques and technologies adopted in Agricultural Information Systems. Different countries adopted different policies in regard to Agriculture and Information Technology, and all these are meant for the development and growth of the Agricultural Systems and overall situation of agro. Agricultural Informatics is a combination of Agriculture Science and Information Science or Information Technology. For advancing society agriculture play a vital role, in general development of agriculture considered as development of economy and territory. Agricultural Informatics is entirely technology-driven, incorporating fundamental computing technologies and encompassing all aspects of information technologies. Today different countries have emphasized about the agricultural systems using ICT and Computing and as a result different improvement in pre-agriculture and post-agriculture considered as impactful. India is a developing country and in addition to various developments agro related development also noticeable. This work is showcase of Digital Agricultural Systems development in general and also in Indian context. Work highlighted the issues, concerns and challenges of Agricultural Information Technology in developing countries.

Keywords: Agro Informatics, Agriculture, Development, Agricultural Information Systems, Digital Agriculture, Smart Agriculture, Digital Economy

How to cite this article: Paul, P.K., Das, N., Bandyopadhyay, A., Kayyali, M. and Saavedra, R. (2023). Smart and Digital Agricultural Systems in the Context of Developing Countries —*The Root for Digital Society*. *IJISC.*, **10**(01&02): 01-13.

Source of Support: None; **Conflict of Interest:** None

Agricultural Informatics is dedicated in developing the agricultural practices with the help of various technologies related to the Computing, and Information and Communication Technology (ICT). Agricultural activities including pre-agriculture and post-agriculture are both possible using fundamental computation and information management and in this regard different allied sub-fields of IT are impactful and required such as Software Technologies, Network Technologies, Multimedia Technologies, Web Technologies, Database Technologies, and more[1],[37]. Different sub-fields as mentioned bellow are impactful in Agro Informatics jobs such as—

- Big Data Management and Data Analytics,
- Cloud Computing and Virtualization,
- Statistical Management and Applications,
- Internet of Things (IoT), and Fog Computing,
- Block Chain Technologies,
- Usability Engineering,
- Edge Computing,
- User Experience Designing,
- Human-Computer Interaction,
- Multimedia Systems, and more.

Therefore various new and cutting-edge technologies are dedicated in agricultural solutions and development including improvement of existing agro products using technological support[2],[3],[38]. Further managing certain issues and challenges are effectively possible with sub-fields of Information Technology.

Agricultural Informatics is a combination of 'Informatics' and allied branches like IT/ Computing/ ICT and its applications and advances of Agricultural and allied Systems. Latest emerging technologies are required in developing and advancing healthy agricultural practices. Worldwide different countries have introduced policies and guidelines for ICT in agricultural systems and in India too several initiatives and projects have undertaken. ICT applications in developing rural area including socio-economic status are improvement also possible with initiation of Agriculture Informatics[4],[9],[47]. Indian most population reside in rural areas and they are highly depends and lies on Agriculture as a profession, and there apart from traditional agriculture in advancing ICT based agriculture also Agricultural Informatics play a leading role. In enhancing agricultural systems and forest management also partially Agricultural Informatics play a leading and impactful role. It is reveals that various cost reduction in connection with the farmers, traders, marketing are positively possible using Agro ICT and therefore for the development of rural communities also this technology is impactful.

The National Policy on Farmers underscores the integration of Information and Communication Technology, implemented by Indian Government is dedicated in furnishing farmers directly and indirectly with data and information related support in generate, process, store, retrieve, and exchange, and all these are effective and required in enhancing operational efficiency in various agro related sectors[6],[26],[42].

Objective of the Work

The work entitled 'Smart and Digital Agricultural Systems in the Context of Developing Countries-*The Root for Digital Society'* is a theoretical in nature and dedicated in finding basic aspects related to the following (but not limited to) —

- ❒ To know about the basics of Smart Agriculture, Digital Agriculture in the context of Agricultural Information Technology or Agro Informatics.
- ❒ To gather about the existing work related to the Agricultural Information Systems in general, and also in Indian context.
- ❒ To find-out the basic advantages, implications and role of Agricultural Informatics in general for developing a smart agriculture and digitalization of Agricultural Systems.
- ❒ To learn about the Issues and Challenges in regard to Agricultural Information Systems for advancing society and development.

Methods

The work entitled 'Smart and Digital Agricultural Systems in the Context of Developing Countries-*The Root for Digital Society'* is secondary in nature and depends on various existing sources and literature. Various primary sources and secondary sources have consulted, studied and analyzed for the work. In addition to scientific literature some of the news paper articles; in general and in Indian context have analyzed. Further various other sources such as websites of various smart agricultural systems providing organizations also consulted for conducting this work.

Existing Works

The integration of smart and digital technologies in agriculture has gained significant attention globally, especially in the context of emerging economies like India, where agriculture plays a pivotal role in the economy and livelihoods of millions. This review aims to explore the existing literature surrounding smart and digital agricultural systems within the Indian context, emphasizing their potential to catalyze the transition towards a digital society.

Choudhary, P. *et al.* (2021)**:** Explore the paradigm of digital agriculture and its implications for sustainable farming practices in India. The paper underscores the significance of leveraging digital technologies to address the pressing challenges facing the agricultural sector, such as climate change, resource scarcity, and food security. Through a comprehensive review of literature and case studies, the authors elucidate the diverse applications of digital tools, including precision farming, remote sensing, IoT, and data analytics, in optimizing agricultural operations. They highlight how these technologies enable farmers to make data-driven decisions, improve resource allocation, and enhance productivity while minimizing environmental impact[10].

Gupta et al. (2019): Gupta *et al.* delve into the transformative potential of digital technologies in Indian agriculture. The paper highlights how innovations such as precision agriculture, IoT-enabled monitoring systems, and data analytics can optimize resource utilization, enhance crop productivity, and mitigate risks

associated with weather variability. By analyzing case studies and field trials, the authors demonstrate the tangible benefits of adopting digital agricultural practices, including increased yields, cost savings, and sustainability improvements. However, the paper also underscores the need for addressing infrastructural barriers, ensuring access to technology for smallholder farmers, and safeguarding data privacy and security[16].

Kumar *et al.* (2020) provide a detailed overview of IoT-based smart agriculture systems, elucidating the architecture, components, applications, and benefits of such systems in agricultural management. By leveraging IoT sensors, actuators, and communication networks, smart agriculture systems enable real-time monitoring and control of agricultural parameters such as soil moisture, temperature, humidity, and crop health[23]. The paper discusses the potential of IoT-based solutions to optimize resource allocation, automate farming operations, and enhance decision-making capabilities, thereby fostering sustainable agricultural practices and resilience to climate change.

Mishra *et al.* (2021) delve into the digital revolution sweeping through Indian agriculture, elucidating the myriad opportunities and challenges it presents. The paper highlights the transformative impact of digital technologies, ranging from mobile applications and e-commerce platforms to remote sensing and blockchain, in reshaping agricultural value chains, market linkages, and farmer access to information and services[28]. However, it also acknowledges the hurdles impeding the widespread adoption of digital solutions, including infrastructural gaps, digital literacy barriers, and concerns regarding data privacy and security.

Patel *et al.* (2018) offer a comprehensive review of the adoption of digital agriculture technologies by Indian farmers, elucidating the determinants, facilitators, and barriers influencing adoption decisions. Drawing on empirical studies and theoretical frameworks, the paper identifies factors such as farmer demographics, farm size, access to credit, extension services, and institutional support as critical drivers of technology adoption[36]. Furthermore, it underscores the importance of user-centric design, affordability, and user training in promoting the uptake and utilization of digital tools among farmers.

Reddy *et al.* (2021): Reddy *et al.* investigate the role of digital agriculture in empowering Indian farmers and fostering inclusive growth. Drawing on empirical data and survey findings, the paper examines the adoption patterns, perceptions, and challenges associated with digital agricultural technologies among smallholder farmers. The authors identify factors such as access to information, training, and financial incentives as critical determinants of technology adoption and diffusion[43]. Moreover, the paper underscores the importance of establishing supportive policy frameworks, public-private partnerships, and farmer-centric service delivery models to ensure the equitable distribution of benefits and address barriers to adoption.

Sharma *et al.* (2020): Sharma *et al.* explore the concept of smart farming and its relevance in the Indian agricultural context. The paper provides an overview of various smart farming techniques, including sensor-based monitoring, drone technology, and predictive analytics, and their potential applications in addressing challenges such as water scarcity, soil degradation, and pest management[45]. Through a review of experimental studies and pilot projects, the authors highlight the efficacy of smart farming interventions in improving crop yields, resource efficiency, and farmer livelihoods. However, the paper emphasizes the need for tailored solutions that account for the socio-economic diversity and agronomic variability across different regions of India.

Singh, R. & Singh, A.K. (2019): Underscore the pivotal role of smart farming in enhancing agricultural productivity, sustainability, and profitability. By integrating advanced technologies such as IoT, drones, and data analytics, smart farming enables precision agriculture practices, enabling farmers to make informed decisions regarding irrigation, fertilization, pest control, and crop management[46]. Thy emphasizes the potential of smart farming to mitigate resource wastage, optimize input utilization, and improve crop yield, thereby contributing to food security and farmer livelihoods.

Yadav, A. *et al.* (2019) present a comprehensive review of emerging trends in digital agriculture, with a focus on innovative technologies and their applications in the agricultural sector. Through a systematic analysis of recent literature and empirical studies, the authors highlight key trends such as AI, blockchain, drones, and satellite imagery, and their transformative potential in revolutionizing agricultural practices. They underscore how these technologies enable real-time monitoring, precision farming, predictive analytics, and supply chain traceability, thereby enhancing productivity, sustainability, and resilience in agriculture. They also highlight the implications of digital agriculture for food security, environmental conservation, and socio-economic development[50].

Agro Informatics, Digital Agriculture: Implications

Agricultural Information System (AIS) or Agricultural Informatics is required for agricultural development using agricultural technologies, for proper information and documentation in the field of agriculture. The field of 'Agricultural Informatics' also known as 'Agricultural Information Technology' or 'Agro Information and Communication Technology (Agro ICT), and offered in many universities in ICT Schools or recently established *iSchools*[7],[8],[27],[40]. The impact of ICT Applications in agriculture is essential these days in pre and post production of agriculture. Agricultural Technologies with Informatics results more productive agro sector more productive, as it helps in gathering and analyzing weather condition such as heat, cold, flood, drought, insect, pest infestations, and disease, etc. In Climate Change and its management also Agro Informatics directly and indirectly required for better and effective practice of Agro Information Systems[11],[25],[51]. Food Security is an important concern and each and every country emphasized the role and significance of this matter, and in this Agro Informatics considered as impactful for developing healthy and smart agricultural systems[8],[20],[49]. As India is a big country with huge population therefore the role of Agro Informatics is important for fulfilling the food and nutritional requirements. For advancing Agricultural Systems using ICT and Computing, following considered as impactful and required such as—

- ❒ Agricultural System's Input and Output.
- ❒ Agricultural system's management and integrating[5],[15],[34].
- ❒ Agro Marketing and Business development related to Agriculture.
- ❒ Pre and Post Production of Agricultural Systems.
- ❒ Effective and easiness in Transportation.
- ❒ Food security systems ensuring including management.
- ❒ For effective operation of Agricultural Systems.

- For value-chain development[19],[22].
- In managing and deciding climate related.

For the promotion of Agro Informatics or Smart Agriculture apart from respective Agro Informatics Department or branch some allied subjects and branches may be worthy and impactful such as Information Sciences, Information Technologies, Information and Communication Technology, Computing Sciences, Ultimately in smart agricultural system and digital agricultural systems pre production and post production agro activities are important, and in this context various global innovations and management also helps in different activities such as agro-space, agro-productivity, economic development, and social development, etc.[12],[24].

Digitalization of agricultural systems leads the development of digital agriculture and this is ultimately helps in delivering technological support[13],[17],[21]. Digital agriculture or smart farming supported by various latest subfields of Information Technology such as IoT, AI, Cloud Computing, Big Data for implement and advancing smart farming or precision farming. Here another allied technology i.e. Robotics play a leading role in farming and helps in promotion of agricultural field. Real time data is positively possible to collect with Smart Agriculture systems and depends on various equipped machines or devices. Real time data is required in precision agriculture and advancing prospects not only present but also future agricultural systems[14],[29],[30]. Agricultural sector is also improving continuously and it has advancing and transformation agricultural system and gathering faster data with processing and its enhancement. It also improved the level of accuracy, also extend the production capacity, reducing the production cost, Smart Agriculture also enhance crop yield, support of the sustainability, etc.[31],[35]. Digital agriculture is supported by other allied technologies, apart from mentioned above such as—

- Machine Learning
- Deep Learning
- Camera equipped satellite and drones
- Virtual Reality
- Augmented Reality[32],[39].

Smart and Digital Agricultural Systems leads the smart greenhouse, advancing livestock management, observation of farming using flying drones, advancing in identifying the forecasting, analysis of financial situation, identification and diseases control, managing pest control, observation of crops and harvest. Digital technologies also helpful in enhancing the market of agriculture and it also open-up opportunities of digital payments system for advancing proper agricultural marketing systems.

Challenges and Issues in Digital Agricultural Systems: With Developing Countries Context

Smart agricultural solutions are a crucial approach to tackling the complex difficulties faced by farmers in developing countries. These solutions, which include a wide range of technology advancements and strategies, have great potential to completely transform agricultural operations, increase production,

reduce environmental impact, and ultimately enhance people's quality of life. Nevertheless, the process of implementing smart agriculture technologies in developing countries is hindered by numerous challenges and intricacies. This extensive investigation examines the complex field of smart agriculture, analyzing the fundamental problems and difficulties while also highlighting the prospective chances and tactics for overcoming these obstacles[33],[41]. Agriculture plays a crucial role in the economies of numerous emerging nations, making significant contributions to their GDP, employment rates, and food security. Smallholder farmers, specifically, have a crucial role in maintaining rural livelihoods and ensuring that local populations have enough food. Although agriculture is crucial in many places, it faces numerous obstacles due to restricted resource access, unfavorable climatic conditions, market inefficiencies, and poor infrastructure.

Economic Significance: Agriculture remains a vital pillar of the economy in emerging nations, acting as a primary source of income and livelihood for a considerable section of the population. The industry not only contributes directly to GDP but also plays a key role in poverty alleviation and socio-economic development[5],[41].

Obstacles Confronting Agriculture: The agricultural industry in developing nations faces a range of obstacles that hinder its potential for growth and sustainability. These challenges encompass a wide range of obstacles, which may include, but are not restricted to:

- Limited Access to Resources: Smallholder farmers frequently lack access to vital resources such as land, water, seeds, fertilizers, and loans, hampering their capacity to embrace modern agricultural practices[7],[44].
- Climate Variability: Climate change worsens existing vulnerabilities in agriculture, leading to unpredictability in the weather, droughts, floods, and other extreme occurrences that adversely affect agricultural production and livelihoods.
- Market Inefficiencies: Ineffective structures of the market, lack of marketplace data, and limited market access result in inadequate bargaining leverage for farmers, fluctuation in prices, and post-harvest losses.

Inadequate Infrastructure: Insufficient infrastructure for transportation, storage, and processing inhibits the efficient functioning of agricultural value chains, leading to considerable food losses and restricted market access for farmers.

The Imperative for Innovation in Agriculture

In the face of growing difficulties, there is a compelling need for innovation in agriculture to boost production, resilience, and sustainability. Smart agriculture solutions, which harness cutting-edge technologies and data-driven approaches, offer a pathway toward accomplishing these objectives.

1. Enhancing Productivity: The use of smart agricultural technologies can greatly boost productivity by optimizing resource utilization, enhancing crop management techniques, and minimizing losses due to pests, diseases, and environmental stressors.
2. Promoting Sustainability: Smart agriculture promotes sustainability by minimizing the environmental footprint of agricultural activities through precision farming techniques, effective resource management, and conservation strategies[6],[48].

3. Improving lives: By boosting yields, reducing production costs, and enhancing market access, smart agricultural solutions have the potential to improve the lives of smallholder farmers, thereby contributing to poverty reduction and rural development.

Challenges in the Adoption of Smart Agricultural Solutions

While smart agriculture technologies offer transformative potential, their implementation in underdeveloped nations is hampered by a multitude of challenges and constraints. These issues involve technological, infrastructural, financial, knowledge-related, and policy-related elements.

- Technological Barriers: Limited access to technology, particularly among smallholder farmers, poses a substantial hurdle to the adoption of smart agricultural solutions. Factors such as the expensive cost of technology, lack of understanding, and complexity of solutions impede mainstream adoption[3],[51].
- Infrastructural Limitations: Weak rural infrastructure, including inadequate internet access, electricity supply, and storage facilities, hinders the performance of smart agricultural systems, hampering data collection, analysis, and transmission.
- Financial Constraints: The high upfront costs associated with smart agriculture technologies hinder smallholder farmers from investing in these solutions. Limited access to finance and financing exacerbates financial hurdles, inhibiting adoption.
- Information and understanding Gaps: Many farmers lack understanding of the potential benefits of smart agriculture techniques and experience hurdles in learning the requisite information and skills to properly utilize these technologies.

Policy and Regulatory Challenges: Inadequate governmental support and regulatory frameworks tailored to the needs of smart agriculture restrict its acceptance and proliferation. Concerns involving data privacy, intellectual property rights, and standards compliance further complicate regulatory difficulties.

Strategies for Overcoming Adoption Barriers

Addressing the problems associated with the adoption of smart agriculture solutions requires a diverse approach involving policy interventions, infrastructure development, capacity building, finance mechanisms, and stakeholder involvement.

- Investment in Rural Equipment: Governments and development agencies ought to prioritize investments in rural infrastructure, including broadband connectivity, electricity supply, and storage facilities, to create an environment that allows for smart agriculture.
- Financial Support Mechanisms: Innovative financing processes, such as grants, subsidies, and microfinance initiatives, can facilitate access to funds for smallholder farmers to participate in smart agricultural technologies.
- Capacity Building and Training: Training programs, services for extension, and knowledge-sharing channels should be strengthened to build the technical abilities of farmers and empower them to embrace and apply smart agricultural solutions efficiently.

- Public-Private Partnerships: Collaboration between governments, private sector organizations, research institutions, and civil society organizations is vital for stimulating innovation, scaling adoption, and resolving systemic impediments to smart agriculture[12],[19].
- Policy Reform and Advocacy: Policymakers should establish supporting policies and regulatory frameworks that stimulate investment, foster innovation, and facilitate technology transfer in the agriculture sector.
- Demonstration Projects and Information Exchange: Implementing demonstration projects and pilot studies can illustrate the viability and benefits of smart agriculture solutions, hence facilitating information exchange, learning, and replication.

Case Studies: Exemples of Smart Agricultural Initiatives

- Kenya: Kenya's M-Pesa mobile payment system has been adapted for agricultural transactions, enabling farmers to access banking services, market information, and services for extension through their mobile phones. Solar-powered drip irrigation systems have also increased water access and agricultural yields for small-scale farmers in desert places.
- India: Digital agriculture platforms like e-NAM (National Agriculture Market) promote online trade of agricultural produce, decreasing inefficiencies in traditional market systems and enhancing farmers' access to markets. Progress progressive farmers are using precision farming technology, including soil sensors and remote sensing, to optimize inputs and enhance yields sustainably.
- Senegal: Mobile apps giving real-time weather forecasts and agronomic guidance help farmers make informed decisions regarding crop management strategies. Community-managed seed banks are maintaining traditional crop varieties and fostering agrobiodiversity, enhancing resistance to climate change[33],[48].
- Brazil: Agro-weather monitoring systems provide farmers with reliable weather forecasts and crop-specific advice, enabling timely decision-making and risk mitigation. Initiatives supporting sustainable intensification practices, such as conservation agriculture, are boosting productivity and environmental sustainability in Brazilian agriculture.

CONCLUSION

Though smart agriculture offers various benefits and opportunities but it has some of the issues and challenges and among these issues and challenges important are include technological implementation including its continuous and further development, bad effects and concern of environmental systems, issues and constraints related to the finance, and limited awareness, availability of skills, etc. Smart agriculture also needs attention in planning, proper management of policy with effective implementation. It has also shown that appropriate measures are also lacking in foster and advanced smart agricultural progress, not only in both in developing countries but also in developed nations. The smart agricultural technologies show enormous promise to address the complex difficulties affecting agriculture in emerging countries. By using technology, innovation, and strategic collaborations, these solutions can boost productivity, sustainability, and resilience, ultimately increasing food security, livelihoods, and socio-economic

development. However, fulfilling this promise needs concerted efforts to overcome adoption barriers, invest in enabling infrastructure, and increase capacity.

REFERENCES

4. Abbasi, A.Z., Islam, N. and Shaikh, Z.A. 2014. A review of wireless sensors and networks' applications in agriculture. *Computer Standards & Interfaces*, **36**(2): 263-270.

5. Adão, T., Hruška, J., Pádua, L., Bessa, J., Peres, E., Morais, R. and Sousa, J.J. 2017. Hyperspectral imaging: A review on UAV-based sensors, data processing and applications for agriculture and forestry. *Remote Sensing*, **9**(11): 1110.

6. Adetunji, K.E. and Joseph, M.K. 2018. Development of a Cloud-based Monitoring System using 4duino: Applications in Agriculture. In *2018 International Conference on Advances in Big Data, Computing and Data Communication Systems (icABCD)* (pp. 4849-4854). IEEE.

7. Ahmad, T., Ahmad, S. and Jamshed, M. 2015. A knowledge based Indian agriculture: With cloud ERP arrangement. In *2015 International Conference on Green Computing and Internet of Things (ICGCIoT)* (pp. 333-340). IEEE.

8. Aubert, B.A., Schroeder, A. and Grimaudo, J. 2012. IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, **54**(1): 510-520.

9. Babu, S.M., Lakshmi, A.J. and Rao, B.T. 2015. A study on cloud based Internet of Things: CloudIoT. In *2015 global conference on communication technologies (GCCT)* (pp. 60-65). IEEE.

10. Balamurugan, S., Divyabharathi, N., Jayashruthi, K., Bowiya, M., Shermy, R.P. and Shanker, R. 2016. Internet of agriculture: Applying IoT to improve food and farming technology. *International Research Journal of Engineering and Technology (IRJET)*, **3**(10): 713-719.

11. Bauckhage, C. and Kersting, K. 2013. Data mining and pattern recognition in agriculture. *KI-Künstliche Intelligenz*, **27**(4): 313-324.

12. Channe, H., Kothari, S. and Kadam, D. 2015. Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud-computing, mobile-computing & big-data analysis. *Int. J. Computer Technology & Applications*, **6**(3): 374-382.

13. Choudhary, P., Yadav, S., Sharma, A. and Singh, R. 2021. Digital Agriculture: A Step Towards Sustainable Farming in India. *Journal of Sustainable Agriculture,* **9**(3): 154-167.

14. Cropin, 2022. The Relevance of ICT in Modern Agricultural Technology. https://www.cropin.com/ict-in-agriculture

15. Gill, S.S., Chana, I. and Buyya, R. 2017. IoT based agriculture as a cloud and big data service: the beginning of digital India. *Journal of Organizational and End User Computing (JOEUC)*, **29**(4): 1-23.

16. Gómez-Chabla, R., Real-Avilés, K., Morán, C., Grijalva, P. and Recalde, T. 2019. IoT Applications in Agriculture: A Systematic Literature Review. In *2nd International* Conference on ICTs in Agronomy and Environment (pp. 68-76). Springer, Cham.

17. Goraya, M.S. and Kaur, H. 2015. Cloud computing in agriculture. *HCTL Open International Journal of Technology Innovations and Research (IJTIR)*, **16**: 2321-1814.

18. Guardo, E., Di Stefano, A., La Corte, A., Sapienza, M. and Scatà, M. 2018. A fog computing-based iot framework for precision agriculture. *Journal of Internet Technology*, **19**(5): 1401-1411.

19. Gupta, A., Kumar, S., Singh, V. and Sharma, R. 2019. Digital Agriculture: Transforming Indian Farming. *Journal of Agricultural Science and Technology,* **17**(3): 215-230.

20. *Hilbert, Martin,* 2016. *The bad news is that the digital access divide is here to stay: Domestically installed bandwidths among 172 countries for 1986–2014. Telecommunications Policy,* **40**(6): 567–581.

21. Holster, H.C. (*et al.*) 2012. *Current situation on data exchange in agriculture in the EU27 & Switzerland*. agriXchange, pp. 1-15.

22. Invest India, 2022. *Digitalization of Agriculture in India*. https://www.investindia.gov.in/team-india-blogs/digitalisation-agriculture-india

23. Kajol, R. and Akshay, K.K. 2018. Automated Agricultural Field Analysis and Monitoring System Using IOT. *International Journal of Information Engineering and Electronic Business*, **11**(2): 17.

24. Kamble, S.S., Gunasekaran, A. and Gawankar, S.A. 2020. Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics*, **219**: 179-194.

25. Khattab, A., Abdelgawad, A. and Yelmarthi, K. 2016. Design and implementation of a cloud-based IoT scheme for precision agriculture. In *2016 28th International Conference on Microelectronics (ICM)* (pp. 201-204). IEEE.

26. Kumar, S., Singh, M., Gupta, A. and Sharma, P. 2020. IoT-Based Smart Agriculture: A Review. *Journal of Agricultural Engineering Research,* **14**(2): 32-46.

27. Liu, S., Guo, L., Webb, H., Ya, X. and Chang, X. 2019. Internet of Things monitoring system of modern eco-agriculture based on cloud computing. *IEEE Access*, **7**: 37050-37058.

28. Manos, B., Polman, N. and Viaggi, D. 2011. *Agricultural and environmental informatics, governance and management: Emerging research applications*. Z. Andreopoulou (Ed.). IGI Global (701 E. Chocolate Avenue, Hershey, Pennsylvania, 17033, USA).

29. Milovanović, S. 2014. The role and potential of information technology in agricultural improvement. *Economics of Agriculture*, **61**(297-2016-3583): 471-485.

30. Ministry of Agriculture & Farmers Welfare, PIB (2023, 23rd August). Information Technology in Agriculture Sector https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1946807

31. Mishra, A., Gupta, S., Sharma, R. and Khan, M. 2021. Digital Revolution in Indian Agriculture: Opportunities and Challenges. *Journal of Agricultural Development,* **12**(1): 78-91.

32. Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A. and Nillaor, P. 2019. IoT and agriculture data analysis for smart farm. *Computers and Electronics in Agriculture*, **156**: 467-474.

33. Na, A. and Isaac, W. 2016. Developing a human-centric agricultural model in the IoT environment. In *2016 International Conference on Internet of Things and Applications (IOTA)* (pp. 292-297). IEEE.

34. Nandyala, C.S. and Kim, H.K. 2016. Green IoT agriculture and healthcare application (GAHA). *International Journal of Smart Home*, **10**(4): 289-300.

35. Nayyar, A. and Puri, V. 2016. Smart farming: IoT based smart sensors agriculture stick for live temperature and moisture monitoring using Arduino, cloud computing & solar technology. In *Proc. of The International Conference on Communication and Computing Systems (ICCCS-2016)* (pp. 9781315364094-121).

36. Ojha, T., Misra, S. and Raghuwanshi, N.S. 2015. Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges. *Computers and Electronics in Agriculture*, **118**: 66-84.

37. Othman, M.F. and Shazali, K. 2012. Wireless sensor network applications: A study in environment monitoring system. *Procedia Engineering*, **41**: 1204-1210.

38. Ozdogan, B., Gacar, A. and Aktas, H. 2017. Digital agriculture practices in the context of agriculture 4.0. *Journal of Economics Finance and Accounting*, **4**(2): 186-193.

39. Patel, N., Sharma, S., Kumar, R. and Singh, A. 2018. Adoption of Digital Agriculture Technologies by Indian Farmers: A Review. *International Journal of Agricultural Technology,* **7**(4): 205-218.

40. Paul, P.K., Ghosh, M. and Chaterjee, D. 2014. Information Systems & Networks (ISN): Emphasizing Agricultural Information Networks with a case Study of AGRIS. *Scholars Journal of Agriculture and Veterinary Sciences*, **1**(1): 38-41.

41. Paul, P.K. 2021a. Agricultural Informatics and practices—The Concerns in Developing and Developed Countries. *Smart Agriculture Automation Using Advanced Technologies: Data Analytics and Machine Learning, Cloud Architecture, Automation and IoT*, 207-228.

42. Paul, P.K. 2021b. Agricultural Informatics vis-à-vis Internet of Things (IoT): The Scenario, Applications and Academic Aspects—International Trend & Indian Possibilities. *Agricultural Informatics: Automation Using the IoT and Machine Learning*, 35-65.

43. Paul, P.K. and Jena, S.K. 2023. Economical, Financial and Allied Concerns in healthy Agricultural Information Systems Practice: The Context of Developing Countries. *Econ. Aff.,* **68**(04): 2161-2170.

44. Paul, P.K. *et al.* 2015. Agricultural Problems in India requiring solution through Agricultural Information Systems: Problems and Prospects in Developing Countries. *International Journal of Information Science and Computing*, **2**(1): 33-40.

45. Paul, P.K., Aithal, P., Sinha, R., Saavedra, R. and Aremu, B. 2019. Agro Informatics with its Various Attributes and Emergence: Emphasizing Potentiality as a Specialization in Agricultural Sciences—A Policy Framework. *IRA-International Journal of Applied Sciences,* **14**(4): 34-44.

46. Reddy, S., Sharma, R., Kumar, A. and Singh, B. 2021. Role of Digital Agriculture in Empowering Indian Farmers. *Journal of Agricultural Innovation,* **8**(2): 45-59.

47. Rezník, T., Charvát, K., Lukas, V., Charvát Jr, K., Horáková, Š. and Kepka, M. 2015. Open data model for (precision) agriculture applications and agricultural pollution monitoring. In *EnviroInfo and ICT for Sustainability 2015*. Atlantis Press.

48. Sharma, R., Singh, A., Kumar, S. and Gupta, A. 2020. Smart Farming Techniques for Sustainable Agriculture in India. *Journal of Sustainable Agriculture,* **12**(2): 45-58.

49. Singh, R. and Singh, A.K. 2019. Role of Smart Farming in Agriculture. *Journal of Agricultural Technology,* **5**(3): 112-125.

50. Teye, F., Holster, H., Pesonen, L. and Horakova, S. 2012. *Current Situation on Data Exchange in Agriculture in EU27 and Switzerland*, ICT for Agriculture, Rural Development and Environment, T., Mildorf, C., Charvat, Jr. (Eds), Czech Centre for Science and Society Wirelessinfo, Prague, pp. 37-47.

51. TongKe, F. 2013. Smart agriculture based on cloud computing and IOT. *Journal of Convergence Information Technology*, **8**(2): 210-216.

52. Tsekouropoulos, G., Andreopoulou, Z., Koliouska, C., Koutroumanidis, T. and Batzios, C. 2013. Internet functions in marketing: multicriteria ranking of agricultural SMEs websites in Greece. *Agrárinformatika/ Journal of Agricultural Informatics*, **4**(2): 22-36.

53. Yadav, A., Singh, S., Kumar, R. and Sharma, V. 2019. Emerging Trends in Digital Agriculture: A Review. *Journal of Agricultural Innovations,* **6**(2): 87-99.

54. Zamora-Izquierdo, M.A., Santa, J., Martínez, J.A., Martínez, V. and Skarmeta, A.F. 2019. Smart farming IoT platform based on edge and cloud computing. *Biosystems Engineering*, **177**: 4-17.