

International Journal of Agriculture Extension and Social Development

Volume 7; Issue 12; December 2024; Page No. 30-36

Received: 09-09-2024
Accepted: 14-10-2024

Indexed Journal
Peer Reviewed Journal

How smart technologies in agriculture are revolutionizing farming practices

¹Lakhan Lal Meena, ²Madhumita Jena, ³Mayuri Sing Sardar, ⁴Uma Pradhan and ⁵Ajay Kumar Prusty

^{1, 2, 3, 4}Krishi Vigyan Kendra, Odisha University of Agriculture & Technology, Bhubaneswar, Odisha, India

⁵MS Swaminathan School of Agriculture, Centurion University of Technology & Management, Odisha, India

DOI: <https://doi.org/10.33545/26180723.2024.v7.i12a.1376>

Corresponding Author: Madhumita Jena

Abstract

Smart agriculture technology are transforming farming techniques to solve the problem of feeding an expected world population of 9.7 billion by 2050. These modern technologies incorporate sensors, automation, artificial intelligence, and data analytics, changing old processes into efficient, data-driven, and sustainable agricultural systems. This article covers the ecosystem of smart technologies in agriculture, including major components such as networked hardware, sophisticated software, and integration systems that allow flawless coordination of agricultural activities. Precision agricultural applications, including crop monitoring, soil health analysis, and automated irrigation, illustrate the influence of these technologies on enhancing productivity and resource management. With breakthroughs in robotics and big data analytics, the smart agricultural industry is altering the workforce, investment plans, and security measures to facilitate wider technology adoption. Furthermore, continuing research in new technologies, such digital twins and blockchain, reveals future trends that promise to boost food security and environmental sustainability. Ultimately, smart agricultural technologies offer a key transition toward sustainable, resilient farming techniques required for addressing the world's expanding food needs.

Keywords: Agriculture, automation, data analytics, precision farming, smart technology

Introduction

The challenge of feeding 9.7 billion people by 2050 is being addressed by smart agriculture technologies, which transform traditional farming methods into data-driven, efficient, and sustainable operations. These technologies combine sensors, automation, artificial intelligence, and data analytics to create intelligent farming systems. Farmers can now monitor crop health remotely, optimize irrigation schedules, predict weather patterns, and make informed decisions based on real-time data (Liang & Shah, 2023) ^[17]. This comprehensive guide explores the ecosystem of agricultural technologies, their practical applications, and their impact on the future of farming.

Smart Technology Ecosystem

The smart technology ecosystem in agriculture represents a sophisticated network of interconnected components working in harmony to revolutionize farming practices. This ecosystem combines advanced hardware, intelligent software, and seamless integration systems to create a comprehensive farming management solution.

Hardware Components

Smart agriculture technology relies on a robust hardware infrastructure, including sensor networks that collect data on soil moisture, temperature, pH levels, and nutrient content. This system includes IoT-enabled tractors, environmental monitoring sensors, drone systems, smart irrigation meters, and field-mounted weather stations (Paul *et al.*, 2022) ^[19]. Each device operates autonomously and maintains wireless

connectivity, ensuring reliable performance in challenging agricultural environments.

Software Solutions

Modern farming relies on advanced software platforms that transform raw data into actionable insights. Cloud-based management systems are the core of smart agriculture operations, providing data analytics, process sensor data, informed decision-making, mobile applications, remote monitoring, predictive modeling, forecasting, proactive management, resource planning, and improved efficiency (Channe *et al.*, 2015) ^[5]. These solutions utilize artificial intelligence and machine learning algorithms for precise farm management recommendations.

Integration Systems

Smart agriculture technology is a powerful tool that integrates hardware and software components to coordinate agricultural operations. It creates a unified platform that connects field sensors, processing units, and user interfaces, enabling real-time data flow and automated responses to changing conditions. The integration systems prioritize cybersecurity measures, ensuring reliable communication and utilizing standardized protocols for data transmission (Hasan *et al.*, 2023) ^[7]. They also facilitate scalability, allowing farmers to expand their smart technology infrastructure as needed. This comprehensive ecosystem provides farmers with detailed insights, enabling them to make data-driven decisions that optimize productivity and conserve resources.

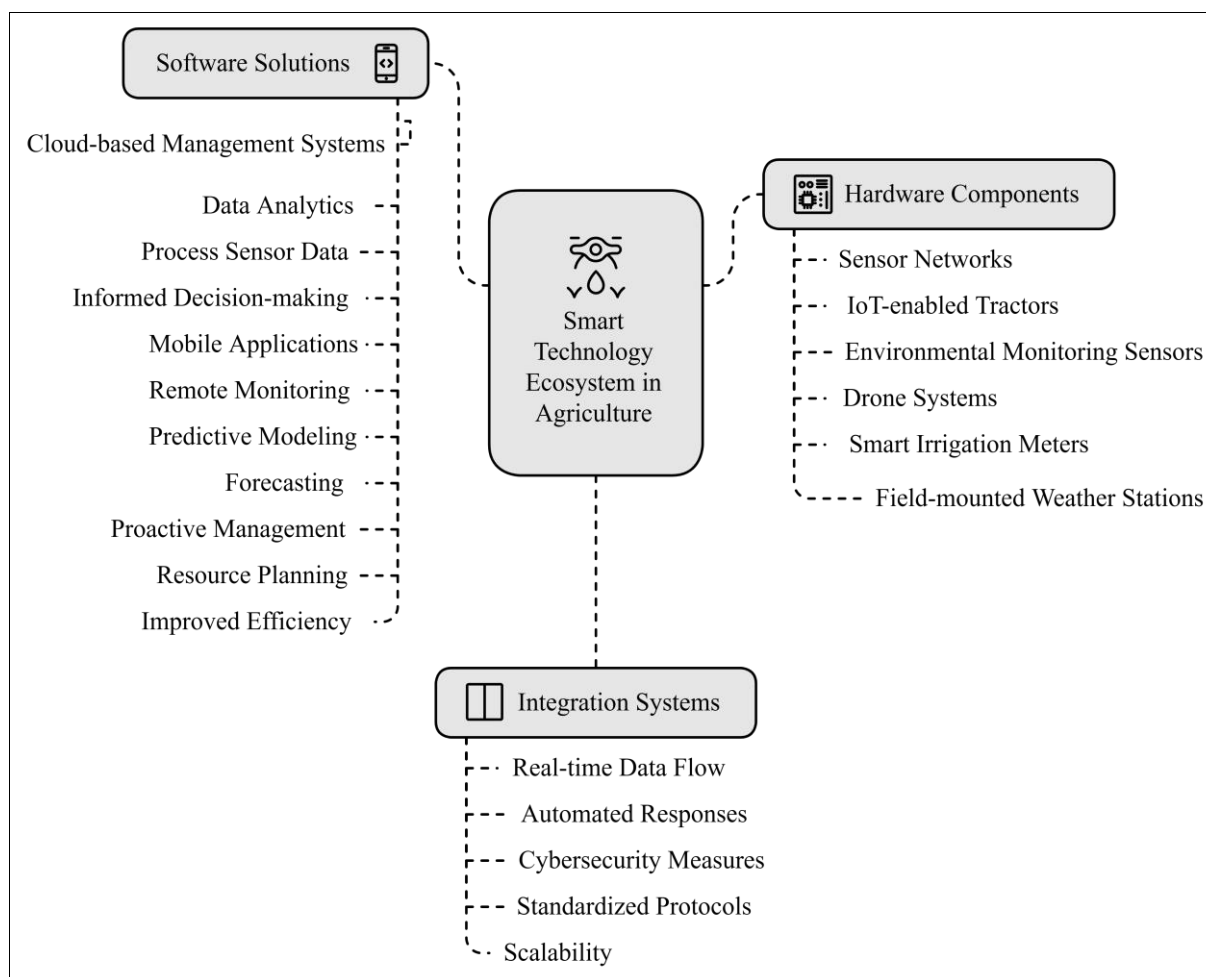


Fig 1: Smart technology ecosystem in agriculture

Precision Agriculture Applications

Precision agriculture applications utilize advanced technology to transform traditional farming into a data-driven science, demonstrating the practical implementation of smart technologies for improved productivity and sustainability (Tantalaki *et al.*, 2019) ^[34].

Crop Monitoring Systems

Advanced crop monitoring systems use satellite imagery and IoT sensors to provide farmers with valuable insights into crop health and development. These systems can detect early signs of stress, disease, or nutrient deficiencies, leading to significant benefits such as reduced water usage, pesticide application, yield improvement, resource efficiency, and optimization in livestock management (Kumar *et al.*, 2024) ^[12]. Wearable devices, such as collars and tags, continuously monitor vital parameters, enabling real-time location tracking, behavioral pattern analysis, and automated health alerts (Aleluia *et al.*, 2022) ^[2]. These systems have shown remarkable efficiency in detecting health issues up to 48 hours before symptoms appear,

reducing treatment costs and improving herd health outcomes.

Soil Health Analysis

Soil analysis is a crucial aspect of modern agriculture, combining portable sensor technology with advanced data analytics to provide real-time insights into soil conditions. Smart soil monitoring systems measure critical parameters like moisture content, nutrient levels, and pH balance, enabling precise fertilizer application and irrigation management (Srivastava *et al.*, 2020) ^[33]. Smartphone-based analysis tools have democratized access to advanced soil testing capabilities, allowing farmers to perform rapid field assessments using specialized sensors. This technology improves operational efficiency and sustainability metrics, creating a comprehensive framework for modern farming operations (Hauashdh *et al.*, 2024) ^[9]. As smart technologies continue to evolve, they continue to improve existing functionalities to meet the growing demands of agricultural production.

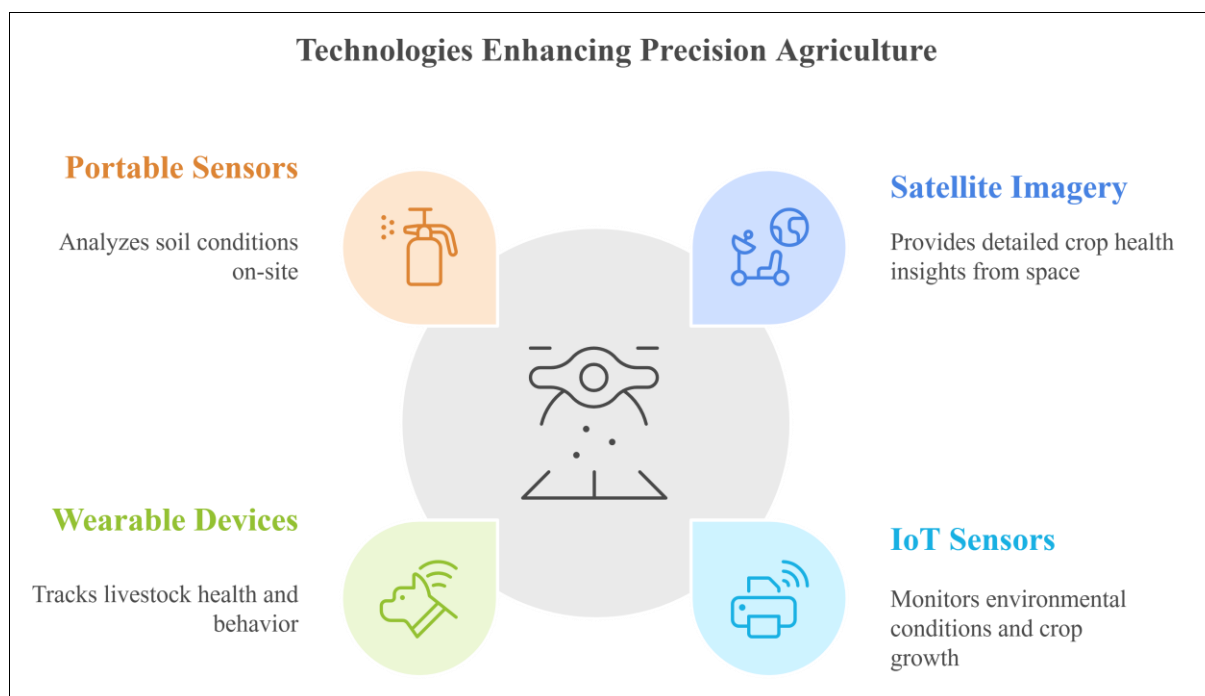


Fig 2: Technologies enhancing precision agriculture

Automation and Robotics

Automation and robotics are revolutionizing agriculture by transforming traditional practices. The agricultural robotics market is expected to grow from \$4.9 billion in 2021 to \$11.9 billion by 2026, showcasing the rapid adoption of these smart technologies (Sharma & Shivandu, 2024) ^[31].

Agricultural Robots

Smart agricultural robots are revolutionizing farming operations with their precision and efficiency. These autonomous systems perform complex tasks that traditionally required manual labor, such as harvesting, seeding, planting, maintenance, weeding, pruning, and crop monitoring. They also offer high-resolution NDVI imaging for crop health assessment, ultra-low volume spraying for efficient chemical application, millimeter-accurate field mapping for precision planning, and real-time data transmission for immediate decision-making (Pathak *et al.*, 2020) ^[18]. The implementation of drone technology has demonstrated up to 5% increase in crop yields through improved monitoring and rapid response to field conditions (Alexandris *et al.*, 2021) ^[3].

Automated Irrigation Systems

Smart irrigation automation is a significant advancement in water resource management, utilizing advanced sensors and control mechanisms to optimize water distribution in agricultural operations. This results in 20-30% water conservation compared to traditional methods (Hassan *et al.*, 2023) ^[8]. The integration of smart agriculture technology allows real-time adjustments based on soil moisture levels, weather forecasts, and crop requirements. These systems minimize waste and reduce operational costs. Robotics, drone technology, and automated irrigation enable farmers to manage larger operations with greater precision and efficiency (Prusty & Mohapatra, 2021) ^[20]. These technologies continue to evolve, incorporating artificial

intelligence and machine learning to adapt to changing agricultural needs.

Data Management and Analytics

The digital transformation of agriculture relies on effective data management, as smart technologies generate vast amounts of information, making it the cornerstone of modern farming operations.

Big Data in Agriculture

Agricultural big data, generated through field sensors, satellite imagery, and smart machinery, transforms traditional farming practices by enabling real-time crop monitoring, yield prediction, resource allocation, early detection of plant diseases, and weather pattern analysis. Implementing smart agriculture technology has shown significant returns, with organizations reporting productivity increases of 15-20% through data-driven decision-making (Huang *et al.*, 2018) ^[10].

Cloud Computing Solutions

Cloud infrastructure is crucial for agricultural data management, providing scalable storage and processing capabilities. It ensures continuous data accessibility and robust security protocols. Cloud architecture supports real-time processing, immediate response to field conditions, scalable storage, remote access, mobile monitoring, automated backup, and data security (Mir, 2024) ^[16]. Edge computing complements cloud solutions by processing time-sensitive data directly in the field, enabling rapid response to critical farming conditions.

Analytics Platforms

Agricultural analytics platforms use artificial intelligence and machine learning to transform raw data into actionable insights. These platforms offer four levels of analytical capability: descriptive, diagnostic, predictive, and prescriptive

(Ahmed *et al.*, 2021) ^[1]. These capabilities have revolutionized decision-making processes, providing farmers with precise recommendations for irrigation scheduling, fertilizer application, and harvest timing (Tripathy *et al.*, 2021) ^[28]. Modern analytics platforms also incorporate visualization tools to present complex data in intuitive formats, enabling quick identification of patterns and anomalies. Advanced analytics have improved resource efficiency, with some operations reporting up to 30% reduction in water usage and 25% decrease in fertilizer application. Data security is crucial in agricultural analytics, with robust encryption protocols and access controls to protect sensitive farm information. The average cost of agricultural data breaches exceeds INR 372.76 million, emphasizing the importance of comprehensive security measures in data management systems.

Smart Farm Security

The integration of smart technologies in agriculture presents both opportunities and vulnerabilities, necessitating comprehensive security measures to protect farm assets and data in the era of digitization.

Cybersecurity Measures

The agricultural sector faces cyber threats that can compromise farm operations and sensitive data. To protect against these threats, smart agriculture technology requires robust cybersecurity frameworks. These include advanced encryption, regular security assessments, network segmentation, continuous monitoring systems, and incident response protocols. Protected systems show 85% fewer security breaches.

Physical Security Systems

Modern farm security involves advanced surveillance and monitoring capabilities, including AI-powered cameras, perimeter monitoring, 24/7 access control, entry management, 90% unauthorized access reduction, thermal imaging, night surveillance, enhanced detection, motion sensors, and intrusion detection (Mahato & Neethirajan, 2024) ^[14]. These systems integrate with smart agriculture technology, providing real-time monitoring and automated responses to security threats, even in challenging weather conditions or low-light environments (Rout *et al.*, 2020) ^[24].

Data Protection Protocols

Agricultural data protection is crucial for safeguarding sensitive farm information and ensuring operational efficiency. Modern frameworks address three key aspects: data ownership and control, privacy compliance, and security implementation. These include clear definitions of data ownership rights, transparent data sharing agreements, controlled access to sensitive information, and regular privacy impact assessments (Saha, Prusty, & Nanda, 2024) ^[25]. The agricultural sector has seen a 40% reduction in data breaches due to comprehensive protection protocols (Gupta *et al.*, 2020) ^[6]. Physical and digital security systems work together to create a robust security ecosystem, allowing seamless and secure operations. Implementing these measures has shown significant benefits, including reduced insurance costs and enhanced operational reliability.

Workforce Impact and Training

Smart technologies in agriculture are transforming the workforce, requiring new competencies and creating new career opportunities. A comprehensive approach to workforce development and training is crucial for successful adoption (Meena *et al.*, 2020) ^[15].

Skill Requirements

Smart agriculture technology has revolutionized farming, necessitating a unique skill set that combines traditional knowledge with modern technical expertise. Today's agricultural professionals must master a combination of competencies, including technical skills, data interpretation, decision-making, resource optimization, management expertise, leadership, team coordination, implementation of new technologies, digital literacy, software operation, mobile applications, daily operations, and monitoring (Yu *et al.*, 2023) ^[37]. Agricultural education has evolved to meet these demands, with comprehensive training programs focusing on developing both theoretical knowledge and practical skills in smart agriculture technology (Satapathy *et al.*, 2021) ^[30]. These programs provide hands-on experience in field crop management, precision agriculture techniques, livestock monitoring systems operation, data analytics, and environmental sustainability practices. These programs are particularly beneficial for small-scale farmers, enabling them to compete effectively in the modern agricultural landscape while promoting sustainable farming practices.

Job Market Changes

The agricultural sector is experiencing significant employment shifts due to the reshaping of traditional roles by smart technologies. This transformation has created new positions and modified existing ones, leading to a dynamic job market. Key trends include a rise in demand for technical specialists in system maintenance, data analysis, and technology implementation, as well as biotechnology research and genetic engineering positions (Xu *et al.*, 2018) ^[36]. Environmental sustainability experts are also in high demand as the industry prioritizes eco-friendly practices. Additionally, agricultural educators and consultants play a crucial role in bridging the knowledge gap between traditional farming practices and modern technologies (Prusty *et al.*, 2020) ^[15]. Female participation in agricultural leadership has grown significantly, with women taking on prominent roles in innovation and technology implementation (Raney *et al.*, 2011) ^[22]. This trend is supported by targeted training programs and initiatives promoting gender diversity in the sector.

Investment and Funding

Financial support is crucial for implementing smart technologies in agriculture, with significant investment from public and private sources. This transformation has been driven by strategic funding initiatives and innovative investment approaches.

Government Initiatives

Governments worldwide are investing in agricultural modernization through various funding programs, including digital agriculture programs, clean technology funds, sustainable farming, and innovation support. Notable

programs include India's National e-Governance Plan in Agriculture (NeGPA) and the World Bank Group's Climate Change Action Plan (2021-2025), which support AI, machine learning, and blockchain implementation in agriculture, resulting in increased farmer income and reduced emissions (Balkrishna *et al.*, 2024) ^[4].

Private Sector Investment

Private investment in agricultural technology has seen a 20-fold increase in recent decades, with corporate investors accounting for 23% of total investment. This surge has benefited sectors like precision agriculture, agricultural biotechnology, and farm management software, demonstrating strong private sector confidence in smart farming solutions. The investment landscape includes early-stage startup funding, corporate venture capital, strategic partnerships, and research and development investments.

Funding Opportunities

The agricultural sector offers various funding opportunities through international climate finance and multilateral development banks. The Green Climate Fund and Global Environmental Facility provide significant support for climate-smart agriculture initiatives, focusing on sustainable farming practices and technology adoption (Sahoo, Wani, Rout, *et al.*, 2021) ^[27]. Bilateral development assistance is a dominant source of international public finance, supporting capacity development and institutional strengthening. Agricultural Clean Technology programs, such as Canada's recent investment in variable rate technology, provide direct funding to farmers for adopting smart technologies. The private sector plays a crucial role through responsible investment practices, guided by frameworks like the Principles for Responsible Investment in Agriculture and Food Systems (CFS-RAI) (Requelme & Afonso, 2023) ^[23]. Organizations like FAO promote dialogue between private sector companies and small-scale producers, ensuring balanced development of agricultural technology ecosystems (SAHOO, WANI, DASH, *et al.*, 2021) ^[27]. Domestic government budgets are a significant portion of public investment in agriculture, often exceeding international funding sources, enabling access to global climate financing and implementing comprehensive national agricultural technology strategies.

Future Trends and Innovations

The global smart farming market, valued at INR 1261.51 billion in 2022, is expected to reach INR 2764.27 billion by 2027, demonstrating a remarkable CAGR of 16.99%, reshaping the agricultural landscape.

Emerging Technologies

Digital twins and generative AI are revolutionizing agricultural innovation by creating virtual replicas of farming environments. These technologies improve resource allocation, predict crop yield, and enhance decision-making. The integration of IoT devices with smart agriculture technology is expected to reach INR 2812.01 billion by 2032. These systems enable real-time monitoring and automated response mechanisms, transforming traditional farming practices into data-driven operations. The IoT market in agriculture is projected to reach INR 2812.01

billion by 2032.

Research Developments

Agricultural research is rapidly advancing to address global challenges, with regenerative agriculture emerging as a key focus. Key developments include carbon farming for soil health, precision aquaculture systems for sustainable protein production, advanced crop genetics for resilience, and smart irrigation solutions (Saha, Prusty, Nanda, *et al.*, 2024) ^[25]. The use of 5G technology, artificial intelligence, and machine learning is revolutionizing agricultural equipment, enabling yield optimization and reduced operational costs through automated precision farming practices (Somashekar *et al.*, 2024) ^[32].

Industry Predictions

The agricultural sector is set to undergo significant transformation, with experts predicting a 70% increase in food production by 2050. This is driven by the rapid adoption of smart farming technologies, which are expected to reduce greenhouse gas emissions by nearly 20%. The precision farming market is expected to grow to INR 2848.87 billion by 2032. Vertical farming and indoor agriculture solutions are gaining prominence, particularly in urban environments, using advanced environmental controls and AI-driven optimization (Kabir *et al.*, 2023) ^[11]. Blockchain technology ensures transparency and traceability throughout the supply chain. Agriculture 4.0 is a paradigm shift, focusing on autonomous farming systems, AI-powered decision support systems, integrated sensor networks, and predictive analytics for resource optimization (Mishra & Mishra, 2024) ^[17]. Cloud-based software solutions are expected to capture a significant market share, offering reduced energy consumption, enhanced data storage capabilities, and cost savings (Satapathy *et al.*, 2020) ^[29]. The agricultural workforce is evolving, with increasing demand for specialists in data analytics, robotics, and precision farming techniques. The adoption of digital agriculture technologies is expected to accelerate due to the need for sustainable farming practices and improved food security.

Conclusion

Smart technologies have revolutionized agriculture by enabling data-driven, efficient, and sustainable practices. These advancements aim to feed the growing global population while optimizing resource usage and minimizing environmental impact. Key developments include smart technology ecosystems that combine sensors, automation, and AI for precise farming decisions. Precision agriculture applications improve crop yields and resource efficiency, while robotics and automation systems reduce labor requirements and increase operational accuracy. Data management platforms provide actionable insights for informed decision-making, while advanced security measures protect both physical assets and digital information. Workforce development programs prepare agricultural professionals for technology-driven roles. Agricultural technology investments are growing, with research in regenerative agriculture, vertical farming, and precision systems pointing towards a sustainable future. These innovations not only represent technological

advancements but also promote environmental stewardship, laying the foundation for sustainable agriculture for future generations.

References

- Ahmed I, Ahmad M, Jeon G, Piccialli F. A framework for pandemic prediction using big data analytics. *Big Data Res.* 2021;25:100190.
- Aleluia VM, Soares VN, Caldeira JM, Rodrigues AM. Livestock monitoring: Approaches, challenges and opportunities. *Int J Eng Adv Technol.* 2022;11(4):67-76.
- Alexandris S, Psomiadis E, Proutsos N, Philippopoulos P, Charalampopoulos I, Kakaletis G, *et al.* Integrating drone technology into an innovative agrometeorological methodology for the precise and real-time estimation of crop water requirements. *Hydrology.* 2021;8(3):131.
- Balkrishna A, Singh SK, Pathak R, Arya V. E-governance paradigm in the Indian agricultural sector. *Discov Agric.* 2024;2(1):2.
- Channe H, Kothari S, Kadam D. Multidisciplinary model for smart agriculture using internet-of-things (IoT), sensors, cloud-computing, mobile-computing & big-data analysis. *Int J Comput Technol Appl.* 2015;6(3):374-382.
- Gupta M, Abdelsalam M, Khorsandroo S, Mittal S. Security and privacy in smart farming: Challenges and opportunities. *IEEE Access.* 2020;8:34564-34584.
- Hasan MK, Habib AA, Shukur Z, Ibrahim F, Islam S, Razzaque MA. Review on cyber-physical and cyber-security system in smart grid: Standards, protocols, constraints, and recommendations. *J Netw Comput Appl.* 2023;209:103540.
- Hassan M, Kowalska A, Ashraf H. Advances in deep learning algorithms for agricultural monitoring and management. *Appl Res Artif Intell Cloud Comput.* 2023;6(1):68-88.
- Hauashdh A, Nagapan S, Jailani J, Gamil Y. An integrated framework for sustainable and efficient building maintenance operations aligning with climate change, SDGs, and emerging technology. *Results Eng.* 2024;21:101822.
- Huang Y, Chen Z-x, Tao Y, Huang X-z, Gu X-f. Agricultural remote sensing big data: Management and applications. *J Integr Agric.* 2018;17(9):1915-31.
- Kabir MSN, Reza MN, Chowdhury M, Ali M, Samsuzzaman Ali MR, Lee KY, *et al.* Technological trends and engineering issues on vertical farms: A review. *Horticulturae.* 2023;9(11):1229.
- Kumar V, Sharma KV, Kedam N, Patel A, Kate TR, Rathnayake U, *et al.* A Comprehensive Review on Smart and Sustainable Agriculture Using IoT Technologies. *Smart Agric Technol.* 2024;100487.
- Liang C, Shah T. IoT in agriculture: The future of precision monitoring and data-driven farming. *Eigenpub Rev Sci Technol.* 2023;7(1):85-104.
- Mahato S, Neethirajan S. Integrating Artificial Intelligence in dairy farm management-biometric facial recognition for cows. *Inf Process Agric.*; c2024.
- Meena LL, Mohanty BK, Prusty AK, Rout S. Impact of KVK training on farmers of Jagatsinghpur district of Odisha. *J Plant Dev Sci.* 2020;12(6):371-374.
- Mir AA. Optimizing mobile cloud computing architectures for real-time big data analytics in healthcare applications: Enhancing patient outcomes through scalable and efficient processing models. *Integr J Sci Technol.* 2024, 1(7).
- Mishra H, Mishra D. AI for Data-Driven Decision-Making in Smart Agriculture: From Field to Farm Management. In: *Artificial Intelligence Techniques in Smart Agriculture.* Springer; c2024. p. 173-193.
- Pathak H, Kumar G, Mohapatra S, Gaikwad B, Rane J. Use of drones in agriculture: Potentials, Problems and Policy Needs. *ICAR-National Institute of Abiotic Stress Management.* 2020;300:04-15.
- Paul K, Chatterjee SS, Pai P, Varshney A, Juikar S, Prasad V, *et al.* Viable smart sensors and their application in data driven agriculture. *Comput Electron Agric.* 2022;198:107096.
- Prusty AK, Mohapatra BP. Constraints and suggestions perceived by the pulse farmers of Nayagarh district of Odisha. *Int J Plant Soil Sci.* 2021;33(11):09-15.
- Prusty AK, Panigrahi RS, Padhy C, Rout S. Knowledge level of farmers regarding system of rice intensification (SRI) method in Puri district of Odisha. *Indian J Pure Appl Biosci.* 2020;8(3):270-277.
- Raney T, Anríquez G, Croppenstedt A, Gerosa S, Lowder SK, Matuschke I, *et al.* The role of women in agriculture; c2011.
- Requelme N, Afonso A. The Principles for Responsible Investment in Agriculture (CFS-RAI) and SDG 2 and SDG 12 in Agricultural Policies: Case Study of Ecuador. *Sustainability.* 2023;15(22):15985.
- Rout S, Prusty K, Rout S. Participation of Rural Youth in Agriculture and Allied Activities-A Review. *Int J Multidiscip Perspect Health.* 2020;1(1):32-34.
- Saha P, Prusty AK, Nanda C. Extension strategies for bridging gender digital divide. *J Appl Biol Biotechnol.* 2024;12(4):76-80.
- Saha P, Prusty AK, Nanda C, Ray S, Sahoo B. Professional Insights Provided by Women Extension Personnel in Odisha. *Indian J Ext Educ.* 2024;60(3):101-105.
- Sahoo G, Wani A, Rout S, Sharma A, Prusty A. Impact and contribution of forest in mitigating global climate change. *Des Eng.* 2021;4:667-682.
- Sahoo G, Wani AM, Dash AC, Rout S, Tripathy B, Prusty AK, *et al.* Impact of rural activities on biodiversity and ecosystem services. *Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/J Tianjin Univ Sci Technol.* 2021;54:373-393.
- Satapathy A, Prusty AK, Rout DS, Tarania PR, Rout S, Satapathy A, *et al.* Cost of cultivation and income analysis of hybrid maize cultivation in Nabarangpur district of Odisha. *Int J Curr Microbiol Appl Sci.* 2020;11:1540-1548.
- Satapathy A, Satapathy A, Rout DS, Prusty AK, Rout S. Prevalence of protein energy malnutrition among under-five children in Odisha: A review. *J Phytopharm.* 2021;10:272-276.
- Sharma K, Shivandu SK. Integrating Artificial Intelligence and Internet of Things (IoT) for Enhanced Crop Monitoring and Management in Precision Agriculture. *Sensors Int.* 2024, 100292.

32. Somashekar K, Belagalla N, Srinatha T, Abhishek G, Kumar V, Tiwari A, *et al.* Revolutionizing Agriculture: Innovative Techniques, Applications, and Future Prospects in Precision Farming. *J Sci Res Rep.* 2024;30(8):405-419.
33. Srivastava A, Das DK, Kumar R. Monitoring of soil parameters and controlling of soil moisture through IoT based smart agriculture. 2020 IEEE Students Conference on Engineering & Systems (SCES); c2020.
34. Tantalaki N, Souravlas S, Roumeliotis M. Data-driven decision making in precision agriculture: The rise of big data in agricultural systems. *J Agric Food Inf.* 2019;20(4):344-380.
35. Tripathy B, Rout S, Mishra UN, Sahoo G, Pradhan K, Prusty AK, *et al.* Vegetables: A Potential Source of Nutraceuticals. *Ann Rom Soc Cell Biol.*; c2021. p. 17921-17941.
36. Xu LD, Xu EL, Li L. Industry 4.0: State of the art and future trends. *Int J Prod Res.* 2018;56(8):2941-2962.
37. Yu X, Liu W, Qing L, Zhang D. Improving farm cooperatives' performance and sustainability: A study of agricultural managers' competencies based on the grounded theory and the fsQCA methods. *Sustainability.* 2023;15(2):1263.