P-ISSN: 2618-0723
E-ISSN: 2618-0731

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 7; Issue 5; May 2024; Page No. 34-41

Received: 03-02-2024
Accepted: 11-04-2024

Indexed Journal
Peer Reviewed Journal

Impact of disruptive technologies on transforming Indian agriculture

[1]Samik Kumar Pradhan, [2]Ajay Kumar Prusty, [3]Dibyashakti Priyadarshi, [4]Akhila Badavath, [5]Samridh Nayak, [6]Subash Chandra Munda and [7]Vemu Sudham

[1, 2, 4] Department of Agricultural Extension Education, M S Swaminathan School of Agriculture, Centurion University of Technology & Management, Gajapati, Odisha, India

[3]RRTTS, Semiliguda, Odisha University of Agriculture & Technology, Odisha, India

[5, 7]Department of Soil Science & Agriculture Chemistry, M S Swaminathan School of Agriculture, Centurion University of Technology & Management, Gajapati, Odisha, India

[6]Department of Agronomy & Agroforestry, M S Swaminathan School of Agriculture, Centurion University of Technology & Management, Gajapati, Odisha, India

DOI: https://doi.org/10.33545/26180723.2024.v7.i5a.597

Corresponding Author: Ajay Kumar Prusty

Abstract

The concept of endogenous and exogenous agricultural disruptive technology is based on the idea and fundamentals of scientific and technological revolution. The process by which a major disruptive core technology innovation is applied to agricultural production propels several technological improvements adopted in production, and this is known as the "agricultural science and technology revolution." We are still in the experimental stage of developing artificial intelligence-based intelligent agriculture technology. Unlike the agricultural equipment, chemical, and green technological revolutions, agricultural scientists do not dominate smart agriculture technology, which is a transboundary application of agricultural technology with intelligent sensing technology at its foundation. Big data and machine learning are two examples of disruptive technologies (DTs) implemented more quickly in the farming industry thanks to the emergence of information and communication technologies (ICTs). Using these innovative and predictive techniques in agriculture is essential to managing hitherto unseen problems like climate change and population growth. Farming has been impacted by various disruptive and emerging technologies, including the Internet of Things (IoT), Artificial Intelligence, Blockchain, Unmanned Vehicles, Decision Support Systems (DSS), and Robotics.

Keywords: Agriculture, artificial intelligence, disruptive technology, internet of things

Introduction

Food security is when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life," according to the United Nations Committee on World Food Security (Voinea *et al.*, 2019) [88]. Studying agriculture is essential since it is essential to the existence of the human species. Throughout history, new and improved technologies have increased agricultural productivity and sustainability (Satapathy *et al.*, 2021) [75]. By 2050, it is predicted that there will be roughly 9.7 billion people on the planet (Bapat *et al.*, 2022) [11]. Food production must expand by 70% to keep up with this population growth. However, due to population growth and climate change, fewer resources are available to provide the necessary food (Giller *et al.*, 2021) [25]. Although using technology in agriculture is essential to raising farm output, a wealth of research indicates that small-scale agricultural producers in developing nations continue to accept technologies at a very slow rate and low levels when it comes to externally marketed technologies (Mizik, 2021) [49]. Local farmers in developing nations who embrace and innovate with technology are frequently linked to modernization and development, which can fundamentally undermine traditional agricultural methods and moral ideals (Rout *et al.*, 2020) [70]. For instance, as society becomes more modernized, there is typically a push towards individuality, market relations, private property rights, and monocropping agricultural systems (Meena *et al.*, 2020) [48]. These shifts may be difficult for communities that value community, indigenous economic relationships, private property rights, and mixed cropping systems.

Disruptive innovation can raise ontological issues with how people live, interact with one another in social and professional contexts, and structure their local economies and communities (Lee *et al.*, 2018) [41]. Consequently, farmers may either reject or adopt new technologies, complicating the technology transfer process (Curry *et al.*, 2021) [14]. The abundance of data from Internet of Things (IoT) devices has made big data techniques possible. The efficiency of many farming operations has improved with the advent of Artificial Intelligence (AI) tools, indicating that data-driven agriculture is a viable strategy to guarantee agricultural sustainability (Spanaki *et al.*, 2022) [82].

Smallholder farmers are expected to be disproportionately affected by climate change (Prusty *et al.,* 2021) [63]. The process by which a major disruptive core technology innovation is applied to agricultural production propels several technological improvements adopted in production, known as the "agricultural science and technology revolution" (Krishnan *et al.,* 2020) [38].

Public, commercial, and civil society organizations strive to empower and uplift rural populations through creative technical techniques to transform agriculture and rural people (Saha *et al.,* 2024) [72]. Disruptive agriculture technologies offer many advantages that revolutionize traditional farming practices (Prusty & Mohapatra, 2021) [63]. Precision agriculture employs GPS, sensors, drones, and AI to optimize resource allocation, enhancing crop yields while minimizing inputs like water and pesticides (Yadav *et al.*, 2022) [89]. Vertical farming allows for urban agriculture, reducing transportation needs and utilizing space more efficiently. Robotics and automation streamline planting and harvesting, reducing labour costs and addressing shortages (Kabir *et al.,* 2023) [32]. Genetic engineering produces resilient crops, enhancing yields and reducing reliance on chemical pesticides. Blockchain ensures transparency in the food supply chain, fostering trust and fair compensation for farmers (Kamilaris *et al.,* 2021) [34]. IoT devices provide real-time data for informed decision-making, optimizing resource use and crop quality (Sahoo *et al.,* 2021) [73]. Big data and predictive analytics enable farmers to forecast yields and manage risks effectively (Liang *et al.*, 2023) [43]. Agri-Fintech solutions facilitate access to credit and insurance, empowering small-scale farmers (Chaudhary & Suri, 2022) [13]. Cultured meat technology offers a sustainable alternative to traditional livestock farming, addressing environmental and ethical concerns. These innovations collectively enhance efficiency, productivity, sustainability, and resilience in agriculture, contributing to global food security and economic development (Adisa *et al.*, 2024) [1].

Internet of Things (IoT)

IoT is a well-recognized technology that has shown value in practically all the top industries in the cutthroat globe (Ahmad *et al.,* 2021) [4]. IoT has profoundly affected all sectors of business, education, industry, health, and agriculture (Ayaz *et al.,* 2019) [9]. The agricultural industry has significantly benefited from investments made in agricultural IoT by most developed nations. IoT can allow sensors and devices to gather information about a farm's physical characteristics (Elijah *et al.*, 2018) [20]. The Internet of Things capabilities, namely intelligent data processing and real-time device connectivity, allow it to enhance agricultural methods. IoT data analytics makes it easier to solve problems and make decisions with less human error by recognizing trends in data and extracting fresh information on livestock health, crop development, and other improvements to the process (Sinha & Dhanalakshmi, 2022) [81]. Green IoT strategies and techniques, such as network size reduction, selective sensing application, hybrid network architecture implementation (Arshad *et al.,* 2020) [8], and adoption of privacy-oriented blockchain technologies with consensus algorithms (Ferrag *et al.*, 2020) [21], can be taken into concern to save energy consumption in IoT and lower carbon footprints.

Integrating Internet of Things (IoT) technologies in India's agriculture sector has significantly improved efficiency and sustainability. Farmers in Maharashtra use IoT-enabled sensors to monitor soil moisture levels and crop health in real time, enabling precise irrigation scheduling and optimisation of water usage (Mujawar *et al.,* 2024) [52]. In Punjab, IoT devices help farmers make informed decisions about crop management practices (Khanna & Kaur, 2023) [37]. In Karnataka, IoT-enabled wearable devices track cattle health and behaviour, enabling early disease detection and improved breeding practices (Mohanty *et al.*, 2024) [50]. IoT-driven market linkages provide farmers real-time market prices and demand trends, enabling better crop selection and distribution strategies. The strategic integration of IoT technologies in Indian agriculture has shown tangible benefits, including enhanced resource efficiency, improved yield predictability, and market connectivity (Yadav *et al.,* 2022) [89]. These examples demonstrate that IoT is important to the modernization and sustainability of agriculture in India.

Artificial intelligence (AI)

Computer science's artificial intelligence (AI) allows machines and computers to make decisions similarly to humans (Sarker, 2022) [74]. Machine learning (ML) algorithms teach computers and other devices to make intelligent decisions independently (Tyagi & Chahal, 2022) [86]. These algorithms fall into four main categories: reinforcement, semi-supervised, unsupervised, and supervised. AI can carry out tasks like disease and pest identification agricultural and livestock monitoring more efficiently. By preparing for extreme weather and market swings, farmers can reduce their risk using predictive modelling (Alibabaei, 2023) [6]. Modern state-of-the-art models have produced encouraging findings, suggesting that additional studies in the field using more sophisticated AI instruments can aid in closing the gap in food production (Rejeb *et al.,* 2022) [69]. Artificial intelligence (AI) can analyse soil and water and identify potential pests, weeds, and diseased plants. This allows for the timely application of fertilizer, pesticides, and irrigation techniques to plants requiring treatment, reducing yield loss and boosting farm output (Javaid *et al.,* 2023) [29]. AI-generated data can be shared among farms to create a farming community that will improve agricultural practices in the area. However, there is still no such extensive library of AI-derived data and insights for farm operators (Singh *et al.*, 2023) [80].

Farmers in Punjab, Maharashtra, Telangana, Karnataka, and Tamil Nadu are using AI-powered crop monitoring systems to optimize farming practices. These systems use satellite imagery and weather data to provide insights into crop health, aiding in informed irrigation, fertilization, and pest control decisions (Elbehri *et al.,* 2021) [19]. In Maharashtra, AI-based pest and disease detection systems help farmers identify signs of pest infestation or disease outbreaks early, improving crop health and reducing crop losses (Ahale *et al.,* 2024) [3]. In Telangana, precision agriculture techniques powered by AI are revolutionizing farming practices. They use sensors, drones, and AI algorithms to tailor inputs to specific crop needs, maximizing crop yields while conserving resources and minimizing environmental impact,

making agriculture more sustainable (Rao, 2023) [66].

In Karnataka, AI-driven market analysis and price prediction systems help farmers make better decisions on crop selection and marketing strategy. These systems analyze market data and trends, providing insights into demand-supply dynamics and price fluctuations, enabling farmers to optimize planting schedules and selling strategies (Redhu *et al.,* 2022) [67]. In Tamil Nadu, robotic farming technology powered by AI is gaining traction among progressive farmers. These systems reduce the need for manual labour and increase productivity, helping farmers overcome labour shortages and improve overall farm efficiency. As AI continues to evolve, its potential to revolutionize Indian agriculture will only grow (Senthilkumar *et al.,* 2023) [76].

Blockchain

One type of distributed ledger technology is blockchain (DLT). A distributed ledger technology, or DLT, is a technology that keeps track of transactions in a distributed manner across multiple nodes (Pandey *et al.,* 2023) [58]. Blockchain technology makes new channels of communication between supply chain participants possible. It is a dispersed, unchangeable ledger that records every exchange of digital assets over a network. Allowing traceability for food products purchased and keeping an eye out for contamination can also increase food safety (Rehmani, 2021) [68]. Blockchain has been utilized in the global food and agriculture industry for several purposes, including farmer land registries, tracing the provenance of humanitarian goods, minimizing waste for small cooperative farmers, and guaranteeing that it reaches its intended users (Kamilaris *et al.,* 2021) [35]. Blockchain has the potential to introduce the idea of agriculture insurance, in which pricing can adjust based on crop harvest status, and secure information can be sent down the supply chain, improving financial assistance and easing the burden on farmer operators (Kamalakshi & Naganna, 2021) [33]. Several possible benefit categories are offered by the application of blockchain to supply chain traceability: an expansion of the market based on quality assurance, Price increases, and value capture depending on consumer value is distributed via smart contracts to supply chain participants (Agrawal *et al.,* 2023) [2].

Blockchain technology is revolutionizing the agricultural sector in India by enhancing transparency, efficiency, and sustainability. Companies are establishing traceable supply chains for agricultural products, ensuring authenticity, quality, and safety (Chandan *et al.,* 2023) [12]. Blockchain platforms provide pricing and payment transparency, addressing price manipulation and delayed payments. Smart contracts automate agreements between farmers and buyers, streamline processes, and reduce disputes (Li *et al.,* 2023) [42]. Blockchain is also improving crop insurance and risk management practices by providing transparent records of weather conditions, crop yields, and insurance policies. Other applications include streamlining the supply chain of agricultural inputs, creating blockchain-based marketplace platforms, and managing land records for smallholder farmers (Omar *et al.,* 2023) [56]. These cases demonstrate the potential of blockchain technology to revolutionize agriculture in India, promoting transparency, efficiency, and sustainability throughout the value chain.

In India, blockchain technology is being utilized to address several issues related to agriculture, including transparent supply chains, equitable pricing and payment policies, effective insurance procedures, and direct relationships between farmers and buyers. Using a tamper-proof ledger to record transactions, FarmPay in Maharashtra guarantees sugarcane farmers justice and transparency in pricing and payments (Shaktawat & Swayamprava, 2024) [77].

Farmer producer organizations (FPOs) in Karnataka are automating sales contracts for organic produce by utilizing blockchain-powered smart contracts (Lalitha *et al.,* 2022) [40]. By storing information about weather patterns, agricultural yields, and insurance plans on a blockchain, CropChain increases the effectiveness of crop insurance procedures in Telangana (Pandey & Sen, 2022) [59]. Blockchain technology is used by online marketplaces such as AgriMart in Tamil Nadu to link farmers and buyers directly, removing the need for middlemen and guaranteeing fair prices for agricultural products (Dash *et al.,* 2021) [15]. These illustrations show how blockchain technology is used in several states to empower farmers and improve the agricultural industry's sustainability (Mukherjee *et al.,* 2022) [53].

Unmanned vehicles

Unmanned Vehicle technology represents a significant innovation with the potential to revolutionize traditional manual agricultural practices (Pathak *et al.,* 2020) [61]. Agricultural businesses worldwide use this technology more frequently to modernize farming (Duncan *et al.,* 2021) [18]. Drones are remotely piloted aircraft systems (RPAS) that have a propulsion system, programmable controller, satellite navigation system, automated flight planning features, and the ability to carry a payload for completing a task like cameras, spraying systems, etc. (Gupta *et al.,* 2013) [28] Unmanned aerial vehicle/systems (UAV/UAVs) and unmanned aircraft systems (UAS) are two additional acronyms that are frequently used interchangeably; nonetheless, RPAS is the most official and global way to refer to such system (Pathak *et al.,* 2020) [61]. A drone, short for "Dynamic Remotely Operated Navigation Equipment," is a flying device that can operate autonomously using autopilot control and GPS coordinates along a predetermined route (Ajmera *et al.,* 2022) [5]. Alternatively, it can be manually operated using radio signals through a remote control or smartphone applications (Maddikunta *et al.,* 2021) [45]. With so many sensors, drones can find objects invisible to the human eye. As a result, drones can provide real-time, more precise, trustworthy, and objective information with fewer mistakes and higher detail (Molina *et al.,* 2012) [51]. Drones can be used in various agricultural applications like field and Soil analysis, Planting of Seed Pods, Crop monitoring, Identification of weeds, Crop Spraying, Irrigation, Crop health monitoring, and protecting the field from animal damage.

Farmers in India are increasingly using drones to improve productivity, precision farming, and crop monitoring. High-resolution cameras and sensors are being used in Punjab to track crop health and identify pests and illnesses early on. This enables farmers to locate stressed or infested areas and implement focused measures, such as using pesticides or

modifying irrigation (Sharma *et al.*, 2021) [78]. Drones are utilized in Maharashtra to gather data on crop health, soil moisture content, and nutritional deficits as part of precision agriculture procedures. Farmers may increase crop yields and resource efficiency by making educated decisions regarding irrigation, fertilizer, and other inputs using artificial intelligence algorithms to produce actionable information (Phade *et al.*, 2023) [62].

Drones are utilized in Telangana to spray fertilizer and insecticides from the air in large-scale farms, limiting the use of chemicals and lowering pollution levels in the environment. This method lowers labour expenses, guarantees efficient management of pests and diseases, and enhances worker safety (Mandla *et al.*, 2021) [47]. In Karnataka, where uneven land parcels and land fragmentation are frequent problems, drones are also employed for mapping and surveying purposes (Pandey *et al.*, 2022) [59]. Coastal farmers are using drones in Tamil Nadu to measure soil salinity and saltwater intrusion in their farms so they may apply the proper remedial methods (Mandal *et al.*, 2021) [46].

Drone usage in Indian agriculture is revolutionizing the industry by providing farmers with cutting-edge tools for land management, precision farming, pest control, and crop monitoring (Srivastava, 2022) [83]. As drone technology develops and becomes more widely available, it has the potential to drastically transform Indian agriculture and address important issues like food security and environmental sustainability (Khan *et al.*, 2021) [45].

Decision Support Systems (DSS)

By supporting farmers, directing them to accurate information, aiding in decision-making, and outlining the optimal course of action for a particular scenario, decision support systems (DSSs) bring value to the efficient operation of farming techniques (Naud *et al.*, 2020) [54]. Efficiency can be significantly increased by making production guidelines and knowledge available to the farm (Prusty *et al.*, 2020) [64]. It offers a method for ensuring sustainability by letting farmers choose different crops for a given area (Javaid *et al.*, 2022) [30]. Mobile device access makes the system more palatable to farmers and helps them through the growing process (Dickson & Amannah, 2023) [17]. DSS offers remote monitoring that combines intelligent sensing and intelligent irrigation systems to monitor variables, including water efficiency, moisture content, and temperature. The study highlights the significance of hydroponic farming, which permits farming in inappropriate soil and water conditions, as a smart agricultural technique (Suebsombut, 2021) [84].

Indian agriculture is changing thanks to Decision Support Systems (DSS), which offer farmers customized recommendations. DSS systems evaluate information on crop growth stages, weather patterns, and soil health in Punjab, a region known for its wheat and rice farming, to produce insights that may be used. Through web portals or mobile apps, farmers can obtain this advice, which will increase yields and resource efficiency (Anser *et al.*, 2020) [7]. DSS technologies integrate data from soil moisture sensors, weather forecasts, and crop water requirements to optimize irrigation practices and water usage in Maharashtra, a state with a high concentration of sugarcane farming. Using these technologies, farmers may save water resources and cut crop costs by determining when and how much irrigation is necessary. Additionally, DSS platforms offer warnings and advisories regarding circumstances of water stress, allowing for prompt action to reduce crop losses (Saggi *et al.*, 2022) [71].

Using market prices, agronomic models, and historical climatic data, DSS systems help farmers in Telangana choose and plan their crops by suggesting appropriate crop kinds and planting times (Pal *et al.*, 2023) [16]. By reducing the risks brought on by market volatility and climate change, these instruments increase the resilience and profitability of farms. DSS platforms combine information from agricultural health monitoring systems, satellite images, and pest surveillance networks to detect pest outbreaks and disease hotspots in real-time in Karnataka (Vennila, 2022) [87]. Farmers can limit crop losses by implementing timely interventions and receiving alerts and advisory messages on disease management techniques and pest control measures (Panda, 2020) [57].

Robotics

The combination of mechanical, electrical, and computer engineering is known as robotics, and it allows for the creation of machines that can carry out complicated tasks using pre-programmed instructions (Bandari & Schmidt, 2021) [10]. Originally, robots were presented as a cutting-edge remedy for industrial processes. The trend of using robots in various industries agriculture, space exploration, logistics, health, and defence, to name a few is growing as technology progresses and reduces the cost and size of robots while increasing computer capacity (Javaid *et al.*, 2021) [29]. Farm owners can oversee and control their operations from the comfort of their own homes thanks to robots. Disposable robots can readily do dangerous tasks, such as working at heights and with chemicals (Ng & Mahkeswaran, 2021) [55]. Additionally, the agriculture industry's adoption of robotics opens up employment opportunities for robotics engineers and technicians. However, IoT, AI, and global positioning systems must be combined to create efficient robots (Licardo *et al.*, 2024) [44].

Indian agriculture is using robotics to automate labour-intensive jobs, increase productivity, and solve issues, including labour shortages and growing input costs. Mechanized farming is prevalent in Punjab, where robotic sowing and transplanting methods are becoming more and more popular (Gautam *et al.*, 2023) [22]. With their precision seeders and transplanters, these devices can plant seeds or seedlings consistently and accurately, saving effort and guaranteeing ideal plant spacing (Syed *et al.*, 2019) [85]. Robotic pruning systems are being implemented in Maharashtra to automate vineyard management procedures. These systems use vision and sensor systems to recognize and prune grape plants according to predetermined standards. This preserves the productivity and quality of the vineyard while saving time and labour (Kukreti *et al.*, 2023) [39].

Robotic weeders are utilized in Telangana's rice paddies in place of manual labour or chemicals to control weeds. By enabling the distinction between crops and weeds, machine learning algorithms and computer vision can save labour costs and chemical usage while enhancing crop yields and

soil health (Ghosh *et al.*, 2023) [24]. Robotic milking systems are transforming the dairy farming industry in Karnataka by automating the milking process, permitting voluntary milking of cows, doing away with the requirement for manual labour, and providing round-the-clock milking without the need for human intervention (Gopakumar & Deka, 2020) [26]. Robotic egg collection systems are being used in poultry farms in Tamil Nadu to automate the processes of collecting and sorting eggs. This reduces labour expenses and lowers the possibility of egg contamination or breakage (George, 2024) [23]. Robots in Indian agriculture is changing customary agricultural methods and spurring innovation in several fields, such as crop, dairy, and poultry farming (Gulati *et al.*, 2021) [27].

Conclusion

Given the increasing demand on land and water resources, the agriculture sector needs to modernize its methods. Data-driven initiatives offer one way to guarantee sustainability. ICTs and Disruptive Technologies in automating and optimizing agricultural processes, and illustrated how disease prevention, monitoring, and automated seeding and harvesting may all contribute to smart farming's ability to increase crop yields. While both IoT and AI are potent technologies on their own, their combination known as the Artificial Intelligence of Things (AIoT) has the potential to alter a wide range of farming operations and procedures significantly. The green 5G-AIoT has the potential to create a massive network of interconnected smart devices that are dependable, energy-efficient, and capable of self-monitoring, self-correcting, and self-healing. This could redefine the future of the agriculture industry and other industries, as well as transform businesses across industries. The technology is paired with the newest fifth generation (5G) wireless technology and environmentally friendly technology.

Reference

1. Adisa O, Ilugbusi BS, Adewunmi O, Franca O, Ndubuisi L. A comprehensive review of redefining agricultural economics for sustainable development: Overcoming challenges and seizing opportunities in a changing world. World J Adv. Res Rev. 2024;21(1):2329-2341.
2. Agrawal TK, Angelis J, Khilji WA, Kalaiarasan R, Wiktorsson M. Demonstration of a blockchain-based framework using smart contracts for supply chain collaboration. Int. J Prod Res. 2023;61(5):1497-1516.
3. Ahale S, Rakhonde G, Bhateja S, Kuppuraj J, Mishra S. Disease and Pest Control Through Advance Technology. In: Artificial Intelligence and Smart Agriculture: Technology and Applications. Singapore: Springer Nature Singapore; 2024. p. 437-459.
4. Ahmad T, Zhang D, Huang C, Zhang H, Dai N, Song Y, *et al*. Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. J Clean Prod. 2021;289:125834.
5. Ajmera D, Saroliya M, Arora P. Unmanned Aerial Vehicles (UAVs). Int. Res J Innov Eng. Technol. 2022;6(1):22.
6. Alibabaei K. Application of Artificial Intelligence algorithms to support decision-making in agriculture activities; c2023.
7. Anser MK, Hina T, Hameed S, Nasir MH, Ahmad I, Naseer MAUR. Modeling adaptation strategies against climate change impacts in integrated rice-wheat agricultural production system of Pakistan. Int. J Environ Res Public Health. 2020;17(7):2522.
8. Arshad R, Zahoor S, Shah MA, Wahid A, Yu H. Green IoT: An investigation on energy saving practices for 2020 and beyond. IEEE Access. 2017;5:15667-81.
9. Ayaz M, Ammad-Uddin M, Sharif Z, Mansour A, Aggoune EHM. Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. IEEE Access. 2019;7:129551-129583.
10. Bandari VK, Schmidt OG. System-Engineered Miniaturized Robots: From Structure to Intelligence. Adv Intell Syst. 2021;3(10):2000284.
11. Bapat S, Koranne V, Sealy MP, Shakelly N, Huang A, Sutherland JW, *et al*. Cellular agriculture: an outlook on smart and resilient food agriculture manufacturing. Smart Sustainable Manuf. Syst. 2022;6(1):1-11.
12. Chandan A, John M, Potdar V. Achieving UN SDGs in food supply chain using blockchain technology. Sustainability. 2023;15(3):2109.
13. Chaudhary S, Suri PK. Agri-tech: Experiential learning from the Agri-tech growth leaders. Technol. Anal Strat. Manag. 2022. p. 1-14.
14. Curry GN, Nake S, Koczberski G, Oswald M, Rafflegeau S, Lummani J, *et al*. Disruptive innovation in agriculture: Socio-cultural factors in technology adoption in the developing world. J Rural Stud. 2021;88:422-431.
15. Dash L, Rout S, Mishra U, Sahoo G, Prusty AK. Insecticidal genes in pest management. Ann Romanian Soc Cell Biol. 2021;25(6):5601-5608.
16. Deb Pal B, Kumar S, Patan EK. Investment planning to minimize climate risk in agricultural production: an optimization model for a semi-arid region in India. Climate Policy. 2023;23(4):477-494.
17. Dickson MS, Amannah CI. Augmented IoT Model for Smart Agriculture and Farm Irrigation Water Conservation. Int. J Intelligence Sci. 2023;13(4):131-163.
18. Duncan E, Abdulai AR, Fraser ED. Modernizing agriculture through digital technologies: Prospects and challenges. In: Handbook on the human impact of agriculture. 2021. p. 138-161.
19. Elbehri A, Chestnov R. Digital agriculture in action: Artificial intelligence for agriculture. Food & Agriculture Org. 2021.
20. Elijah O, Rahman TA, Orikumhi I, Leow CY, Hindia MN. An overview of Internet of Things (IoT) and data analytics in agriculture: Benefits and challenges. IEEE Internet of things J. 2018;5(5):3758-3773.
21. Ferrag MA, Shu L, Yang X, Derhab A, Maglaras L. Security and privacy for green IoT based agriculture: Review, blockchain solutions, and challenges. IEEE Access. 2020;8:32031-53.
22. Gautam PV, Mansuri SM, Prakash O, Pramendra, Patel A, Shukla P, *et al*. Agricultural Mechanization for Efficient Utilization of Input Resources to Improve Crop Production in Arid Region. In: Enhancing Resilience of Dryland Agriculture Under Changing

Climate: Interdisciplinary and Convergence Approaches. Singapore: Springer Nature Singapore; 2023. p. 689-716.
23. George AS. Humanoid Robots as Poultry Partners: Enhancing Welfare through Collaboration on the Farm. Partners Universal Int. Res J. 2024;3(1):183-199.
24. Ghosh S, Yadav DK, Ronanki S, Yeasin M, Bhargavi B, Das K, *et al*. Weed Management in Dryland Agriculture. In: Enhancing Resilience of Dryland Agriculture Under Changing Climate: Interdisciplinary and Convergence Approaches. Singapore: Springer Nature Singapore; 2023. p. 411-440.
25. Giller KE, Delaune T, Silva JV, Descheemaeker K, van de Ven G, Schut AG, *et al*. The future of farming: Who will produce our food? Food Security. 2021;13(5):1073-1099.
26. Gopakumar CP, Deka RP. Standard operating procedures for managing pig breeding farms. 2020.
27. Gulati A, Zhou Y, Huang J, Tal A, Juneja R, Gulati A, *et al*. Innovations in Production Technologies in India. From Food Scarcity to Surplus: Innovations in Indian, Chinese and Israeli Agriculture. 2021. p. 23-82.
28. Gupta SG, Ghonge DM, Jawandhiya PM. Review of unmanned aircraft system (UAS). Int. J Adv. Res Comput. Eng. Technol. (IJARCET) Volume. 2013;2.
29. Javaid M, Haleem A, Khan IH, Suman R. Understanding the potential applications of Artificial Intelligence in Agriculture Sector. Adv. Agrochem. 2023;2(1):15-30.
30. Javaid M, Haleem A, Singh RP, Suman R. Substantial capabilities of robotics in enhancing industry 4.0 implementation. Cogn Robotics. 2021;1:58-75.
31. Javaid M, Haleem A, Singh RP, Suman R. Enhancing smart farming through the applications of Agriculture 4.0 technologies. Int. J Intell. Networks. 2022;3:150-164.
32. Kabir MSN, Reza MN, Chowdhury M, Ali M, Samsuzzaman, Ali MR, *et al*. Technological trends and engineering issues on vertical farms: a review. Horticulturae. 2023;9(11):1229.
33. Kamalakshi N, Naganna. Role of blockchain in agriculture and food sector: a summary. In: Convergence of Internet of Things and Blockchain Technologies. Cham: Springer International Publishing; 2021. p. 93-107.
34. Kamilaris A, Cole IR, Prenafeta-Boldú FX. Blockchain in agriculture. In: Food Technology Disruptions. Academic Press; 2021. p. 247-284.
35. Kamilaris A, Cole IR, Prenafeta-Boldú FX. Blockchain in agriculture. In: Food Technology Disruptions. Academic Press; 2021. p. 247-284.
36. Khan N, Ray RL, Sargani GR, Ihtisham M, Khayyam M, Ismail S. Current progress and future prospects of agriculture technology: Gateway to sustainable agriculture. Sustainability. 2021;13(9):4883.
37. Khanna A, Kaur S. An empirical analysis on adoption of precision agricultural techniques among farmers of Punjab for efficient land administration. Land Use Policy. 2023;126:106533.
38. Krishnan A, Banga K, Mendez-Parra M. Disruptive technologies in agricultural value chains. Insights from East Africa. Working paper. 2020;576.
39. Kukreti T, Sharma B, Singh SP, Arora S, Uniyal D, Agrawal Y, *et al*. Journal of Agriculture and Food Research. Journal of Agriculture and Food Research. 2023;14:100814.
40. Lalitha N, Viswanathan PK, Vinayan S. Institutional strengthening of farmer producer organizations and empowerment of small farmers in India: Evidence from a case study in Maharashtra. Millennial Asia. 2022.
41. Lee M, Yun JJ, Pyka A, Won D, Kodama F, Schiuma G, *et al*. How to respond to the fourth industrial revolution, or the second information technology revolution? Dynamic new combinations between technology, market, and society through open innovation. J Open Innov Technol Market Complexity. 2018;4(3):21.
42. Li K, Lee JY, Gharehgozli A. Blockchain in food supply chains: a literature review and synthesis analysis of platforms, benefits and challenges. Int J Prod Res. 2023;61(11):3527-3546.
43. 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.
44. Licardo JT, Domjan M, Orehovački T. Intelligent Robotics-A Systematic Review of Emerging Technologies and Trends. Electronics. 2024;13(3):542.
45. Maddikunta PKR, Hakak S, Alazab M, Bhattacharya S, Gadekallu TR, Khan WZ, *et al*. Unmanned aerial vehicles in smart agriculture: Applications, requirements, and challenges. IEEE Sensors J. 2021;21(16):17608-17619.
46. Mandal UK, Mandal S, Lama TD, Burman D. Innovative Approaches for Agriculture in Coastal Fragile Ecosystem in India. In: Innovations in Agriculture for a Self-Reliant India. CRC Press; 2021. p. 421-464.
47. Mandla VR, Chokkavarapu N, Peddinti VSS. Role of Drone Technology in Sustainable Rural Development: Opportunities and Challenges. In: International Conference on Unmanned Aerial System in Geomatics. Cham: Springer International Publishing; 2021. p. 301-318.
48. 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.
49. Mizik T. Climate-smart agriculture on small-scale farms: A systematic literature review. Agronomy. 2021;11(6):1096.
50. Mohanty AK, Rao TK, KS MH, Agme R, Gogoi C, Velu CM. IoT Applications for Livestock Management and Health Monitoring in Modern Farming. Educ. Admin: Theory Pract. 2024;30(4):2141-2153.
51. Molina P, Colomina I, Vitoria T, Silva PF, Skaloud J, Kornus W, *et al*. Searching lost people with UAVs: the system and results of the close-search project. Int. Arch Photogramm Remote Sens. Spatial Inf. Sci. 2012;39:441-446.
52. Mujawar RY, Lakshminarayanan R, Jyothi AP, Patnaik S, Dhayalini K. IoT-Enabled Intelligent Irrigation System with Machine Learning-Based Monitoring, for Effective Rice Cultivation. Int. J Intell. Syst. Appl. Eng. 2024;12(11s):557-565.
53. Mukherjee AA, Singh RK, Mishra R, Bag S.

Application of blockchain technology for sustainability development in agricultural supply chain: Justification framework. Oper Manag Res. 2022;15(1):46-61.
54. Naud O, Taylor J, Colizzi L, Giroudeau R, Guillaume S, Bourreau E, *et al*. Support to decision-making. In: Agricultural Internet of Things and Decision Support for Precision Smart Farming. Academic Press; 2020. p. 183-224.
55. Ng AK, Mahkeswaran R. Emerging and disruptive technologies for urban farming: A review and assessment. In: Journal of Physics: Conference Series. Vol 2003. IOP Publishing; c2021. p. 012008.
56. Omar IA, Jayaraman R, Salah K, Hasan HR, Antony J, Omar M. Blockchain-Based Approach for Crop Index Insurance in Agricultural Supply Chain. IEEE Access. 2023;11:118660-118675.
57. Panda CK. Advances in application of ICT in crop pest and disease management. In: Natural Remedies for Pest, Disease and Weed Control. Academic Press; c2020. p. 235-242.
58. Pandey R, Goundar S, Fatima S, editors. Distributed Computing to Blockchain: Architecture, Technology, and Applications. Elsevier; c2023.
59. Pandey S, Kumari N, Dash SK, Al Nawajish S. Challenges and Monitoring Methods of Forest Management Through Geospatial Application: A Review. In: Advances in Remote Sensing for Forest Monitoring. 2022. p. 289-328.
60. Pandey S, Sen C. Blockchain Technology in Real-Time Governance: An Indian Scenario. Indian J Public Adm. 2022;68(3):397-413.
61. Pathak H, Kumar G, Mohapatra SD, Gaikwad BB, Rane J. Use of drones in agriculture: Potentials, Problems and Policy Needs. ICAR-National Institute of Abiotic Stress Management; c2020. p. 4-5.
62. Phade G, Kishore AT, Omkar S, Suresh Kumar M. IoT-Enabled Unmanned Aerial Vehicle: An Emerging Trend in Precision Farming. In: Drone Technology: Future Trends and Practical Applications. 2023. p. 301-324.
63. Prusty AK, Mohapatra BP. Socio-economic and cultural attributes of pulse farmers of Nayagarh district of Odisha. Pharma Innovation J. 2021;10(5):540-544.
64. 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.
65. Prusty AK, Rout S, Pradhan K, Sahoo G, Meena LL, Dash L. Technology Adoption of Farmers Regarding System of Rice Intensification (SRI) Method in Puri District of Odisha, India. J Tianjin Univ Sci Technol. 2021;54(7):394-405.
66. Rao GBN. Precision Agriculture by Integration of Algorithms and Remote Sensing. Agric Res. 2023;12(4):397-407.
67. Redhu NS, Thakur Z, Yashveer S, Mor P. Artificial Intelligence: a way forward for agricultural sciences. In: Bioinformatics in Agriculture. Academic Press; c2022. p. 641-668.
68. Rehmani MH. Blockchain Systems and Communication Networks: From Concepts to Implementation. Boston: Springer; 2021.
69. Rejeb A, Rejeb K, Zailani S, Keogh JG, Appolloni A. Examining the interplay between artificial intelligence and the agri-food industry. Artificial intelligence in agriculture. 2022;6:111-128.
70. Rout SD, Prusty KA, Rout S. Participation of Rural Youth in Agriculture and Allied Activities-A Review. Int J Multidiscip Perspect Health. 2020;1(1):32-34.
71. Saggi MK, Jain S. A survey towards decision support system on smart irrigation scheduling using machine learning approaches. Arch Comput Methods Eng. 2022;29(6):4455-4478.
72. Saha P, Prusty AK, Nanda C. Extension strategies for bridging gender digital divide. J App Biol Biotech. 2024;12(4). DOI: 10.7324/JABB.2024.159452.
73. Sahoo G, Wani A, Rout S, Sharma A, Prusty AK. Impact and contribution of forest in mitigating global climate change. Des Eng. 2021;4:667-682.
74. Sarker IH. AI-based modeling: techniques, applications and research issues towards automation, intelligent and smart systems. SN Comput Sci. 2022;3(2):158.
75. 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;10:272-6.
76. Senthilkumar K, Boina R, Singh S, Kumar Y, Rao AK, Shrivastava A. Smart Electricity System Enabled By AI. In: 2023 1st International Conference on Circuits, Power and Intelligent Systems (CCPIS). IEEE; 2023. p. 01-07.
77. Shaktawat P, Swaymprava S. Digital Agriculture: Exploring the Role of Information and Communication Technology for Sustainable Development. Ed. Biswajit Mallick and Jyotishree Anshuman published by PMW, New Delhi; 2024. p. 31.
78. Sharma I, Sharma A, Singh I, Kumar R, Kumar Y, Sharma A. Plant disease detection using image sensors: a step towards precision agriculture; c2021.
79. Sharma R, Singh A. Blockchain Technology in the Agricultural Supply Chain: A Case Study of India. In: Handbook of Research on Cyber Law, Data Protection, and Privacy. IGI Global; 2022. p. 87-104.
80. Singh A, Rajput VD, Ghazaryan K, Gupta SK, Minkina T, editors. Nanopriming Approach to Sustainable Agriculture. IGI Global; c2023.
81. Sinha BB, Dhanalakshmi R. Recent advancements and challenges of Internet of Things in smart agriculture: A survey. Future Gener Comput Syst. 2022;126:169-184.
82. Spanaki K, Sivarajah U, Fakhimi M, Despoudi S, Irani Z. Disruptive technologies in agricultural operations: A systematic review of AI-driven Agri. Tech research. Ann Oper Res. 2022;308(1):491-524.
83. Srivastava U. Disruptive technologies: shaping the future of agriculture. J AgriSearch. 2022;9:282-289.
84. Suebsombut P. Adaptive Decision Support System for Smart Agricultural Crop Cultivation to Support Food Safety Standard [Doctoral dissertation]. Université Lumière Lyon2; 2021.
85. Syed TN, Lakhiar IA, Chandio FA. Machine vision technology in agriculture: A review on the automatic seedling transplanters. Int. J Multidiscip. Res Dev. 2019;6(12):79-88.
86. Tyagi AK, Chahal P. Artificial intelligence and

machine learning algorithms. In: Research anthology on machine learning techniques, methods, and applications. IGI Global; c2022. p. 421-446.
87. Vennila S. Use of Information and Communication Technology in Integrated Pest Management. In: Adaptation Strategies for Pest Management in Climate Change Scenarios; c2022. p. 55.
88. Voinea L, Vrânceanu DM, Filip A, Popescu DV, Negrea TM, Dina R. Research on food behavior in Romania from the perspective of supporting healthy eating habits. Sustainability. 2019;11(19):5255.
89. Yadav S, Luthra S, Garg D. Internet of things (IoT) based coordination system in Agri-food supply chain: development of an efficient framework using DEMATEL-ISM. Oper. Manag. Res. 2022;15(1):1-27.