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Digital disruption in Indian agriculture: Startups, emerging technologies, and path to sustainable farming

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Abstract

Agricultural sector in India is experiencing a major shift as digital technologies like Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) converge to redefine traditional farming methods. These innovations are not just minor upgrades, they are fundamentally changing how crops are grown, livestock is managed, and food supply chains operate. Startups are playing a crucial role in this transformation by turning advanced research into real-world, scalable solutions. This paper explores how AI, ML, and IoT contribute to precision agriculture, better resource management, more accurate yield forecasts, early detection of diseases and pests, efficient supply chains, and sustainable farming practices. Startups are driving this change by developing new business models and technologies that tackle key challenges faced by farmers and agribusinesses. While the benefits are clear, obstacles remain, including high costs, concerns over data privacy, and unequal access to digital tools. Looking ahead, the sector is likely to see deeper adoption of AI-driven tools, smarter sensor networks, and greater automation, all while addressing climate resilience and food security in an evolving agricultural landscape.

Keywords: Agri-tech, artificial intelligence, machine learning, IoT, precision agriculture, sustainability

1. Introduction

Modern agriculture is experiencing a digital revolution fuelled by Artificial Intelligence (AI), machine learning (ML), and Internet of Things (IoT). These innovations are replacing conventional farming with smarter, data-driven approaches that enhance productivity and sustainability across crop cultivation, livestock management, fisheries, and supply chains. AI mimics human decision-making to boost crop output, improve pest management, and streamline supply chains. Using computer vision, smart sensors, and predictive analytics, it enables precise weather forecasting, optimal planting strategies, and real-time crop health monitoring (Assimakopoulos *et al.*, 2024) [6]. As a branch of AI, ML leverages historical data to forecast trends in farming. Techniques like supervised and unsupervised learning help predict yields, optimize water use, and detect diseases by analyzing real-time and past datasets (Arya, 2024) [4]. IoT networks comprising sensors, actuators, and cloud platforms—gather real-time data on soil, weather, and crop conditions. This enables automated monitoring and informed decision-making for efficient farm management. The combination of IoT and AI drives precision agriculture by collecting and analyzing field data like soil moisture,

livestock health etc. to automate responses and minimize manual input. This integration enhances resource efficiency, reduces waste, and strengthens resilience against climate challenges, transforming farming into a data-backed science (Sharma & Shivandu, 2024) [25]. Agri-tech startups in India are using all these technologies to tackle the key challenges faced by farmers and agribusinesses.

India has fostered the world's third-largest startup ecosystem, with agri-tech startups playing a pivotal role in transforming agriculture through AI, IoT, drones, and blockchain (PIB, 2025) [21]. Government initiatives like the Digital Agriculture Mission enhance tech adoption, while the Start-Up India initiative and Atal Innovation Mission provide funding, mentorship, and IP protection (Startup India Portal, 2025). The Startup20 Engagement Group under India's G20 presidency further strengthens global startup collaboration (G20, 2023) [11].

Agri-tech investments in India surged by 215% in 2024, reaching \$2.5 billion, capturing 68% of developing markets' funding (AgFunder, 2025) [2]. Despite challenges like fragmented supply chains, schemes like the Start-Up IP Protection Scheme and Technology Innovation Hubs empower startups across growth stages—ideation,

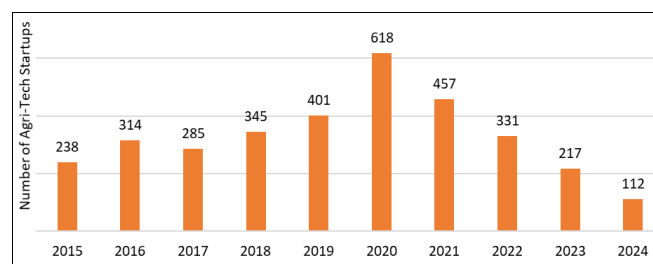
scaling, and diversification (Nuthalapati *et al.*, 2020) ^[19]. With 13,705 agri-startups registered under Startup India, the sector remains a key driver of innovation and economic growth.

With the above backdrop, the study has been undertaken with the objectives of assessing the present status of agritech startups using AI, ML and IoT in their innovation, reviewing various applications of these technologies in agriculture and allied sciences and studying some of the successful cases of agri-tech startups using AI, ML and IoT.

2. Market Landscape and Investment Trends in Agri-tech Startups

The Indian Agri-tech sector has witnessed remarkable growth over the past decade, with both the number of startups and funding seeing significant increases. Between 2015 and 2024, the sector evolved from a niche industry to a major driver of innovation in agriculture.

In 2015, 238 Agri-tech startups were incorporated, focusing primarily on supply chain solutions and digital marketplaces (Figure 1). By 2016, this number grew to 314, supported by government initiatives like Startup India. The following years saw accelerated growth, with startups reaching 285 in 2017 and 345 in 2018, driven by advancements in precision farming and IoT-based solutions. The COVID-19 pandemic in 2019 further boosted digital adoption, pushing the number to 401 new startups that year. The sector continued its upward trajectory, with 618 startups in 2020—marked by the emergence of unicorns like DeHaat—and 331 in 2022. Despite a global funding slowdown, 2023 saw around 217 new startups, with a strong focus on climate-smart technologies. In 2024 around 112 new startups, fuelled by AI and machine learning innovations were incorporated.



Source: Tracxn database

Fig 1: Year wise number of Agri-tech startups incorporated in India (2015-2024)

Funding trends mirrored this growth. In 2015, Agri-tech startups raised approximately \$50 million (Figure 2), with early-stage deals like AgroStar's \$4 million Series A. Investments climbed steadily, reaching \$558 million in 2016 and \$118 million in 2017, as venture capital firms like Omnivore and Accel increased their focus on the sector. The year 2018 saw funding hit \$442 million, with notable deals such as CropIn's \$12 million Series B. Pre-pandemic, 2019 recorded \$380 million in investments, while 2020 surged to \$593 million as startups like WayCool secured \$40 million. The peak came in 2021, with a staggering \$1.2 billion raised, including DeHaat's \$150 million Series E. However, 2022 brought a correction, with funding dropping to \$934 million, followed by a further decline to \$505 million in 2023 as investors prioritized profitability. For 2024, funding

could reach \$462 million, with AI-driven solutions attracting major interest.

The post-2020 consolidation and reduction in both new startup incorporations and overall funding volumes can be attributed to three critical macroeconomic and structural factors:

Transition from Hyper-Growth to Unit Economics

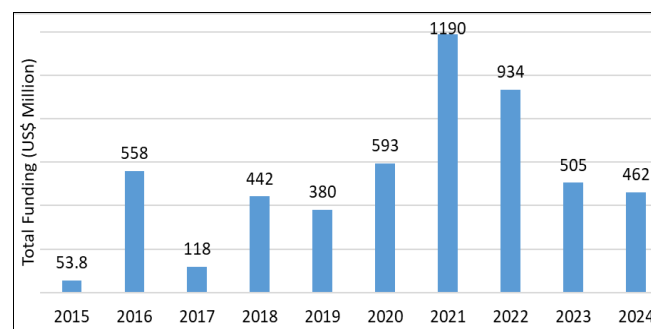
The period of 2019–2021 was characterized by an extraordinary influx of global venture capital and pandemic-driven urgency for digital supply chains. Post-2021, a prominent market correction occurred where venture capital firms adjusted their mandates away from rapid expansion via cash-burning customer acquisition. Investors sharply pivoted toward long-term path-to-profitability and robust unit economics, resulting in elongated due diligence cycles and a drop in overall funding volumes (AgFunder, 2025; Nuthalapati *et al.*, 2020) ^[2, 19].

Global "Funding Winter"

Geopolitical uncertainties, rising global inflation, and aggressive interest rate hikes by central banks restricted the flow of cheap international capital, driving a global funding slowdown across developing markets (AgFunder, 2025) ^[2]. This macro liquidity squeeze disproportionately impacted capital-intensive sectors like agritech, which require sustained financial runway to manage high upfront equipment costs, overcome structural adoption barriers, and navigate limited access to traditional credit lines (Ahmad *et al.*, 2024; Dhillon & Moncur, 2023) ^[3, 8].

Shift to Deep-Tech and Climate-Smart Pivots

Early agritech cohorts focused heavily on low-margin marketplace and basic market-linkage models. As these segments saturated, the post-2022 landscape reflected a structural pivot toward complex hardware-software integrations (Assimakopoulos *et al.*, 2024) ^[6]. These include specialized artificial intelligence tools, micro-language models optimized for climate resilience, and advanced field sensor networks (Forrester, n.d.; Mansoor *et al.*, 2025) ^[10, 14]. These deep-tech solutions demand extensive research, development, and pilot validation before incorporation, which naturally moderated the raw velocity of new startup creation while shifting the sector toward long-term technological maturity (Adadi & Berrada, 2018; Sharma & Shivandu, 2024) ^[1, 25].



Source: Tracxn database

Fig 1: Year wise Funding received by Agri-tech startups incorporated in India (2015-2024)

3. Applications of AI, ML, and IoT by Agri-tech Startups across Agri and Allied Sciences

The integration of AI, ML, and IoT is revolutionizing various facets of agriculture and allied sciences, leading to high levels of precision, efficiency, and sustainability.

3.1 Precision Crop Management and Yield Optimization

Recent studies demonstrate how AI, ML and IoT technologies enable real-time crop monitoring by synthesizing data from multiple sources including satellite imagery, drone surveys, and IoT soil sensors (Sharma & Shivandu, 2024) ^[25]. Farmers now receive hyper-localized recommendations for planting schedules and input applications, fundamentally changing decision-making processes.

Yield prediction accuracy has improved dramatically through machine learning models that analyze multi-year weather patterns combined with current canopy health data. Studies have reported prediction accuracy improvements exceeding 85% for wheat crops in Punjab when using these systems. Pest management has similarly evolved, with computer vision systems achieving 92% accuracy in early blight detection according to recent trials (Ashfaq *et al.*, 2024) ^[5].

Water conservation represents another critical advancement. Studies have found 58-63% reductions in water usage through AI-optimized irrigation systems. These solutions dynamically adjust based on soil moisture sensors and evapotranspiration rates (Sengupta *et al.*, 2021) ^[23]. Post-harvest applications show equal promise, with automated quality sorting systems reducing post-harvest losses by 30% in pilot programs (Das *et al.*, 2025) ^[7].

3.2 Smart Livestock Management

The integration of AI, ML and IoT technologies is also revolutionizing livestock management by enabling real-time health monitoring, behaviour analysis, and precision feeding. Wearable sensors equipped with AI capabilities detect subtle physiological and behavioural changes in animals, facilitating early disease diagnosis and reducing mortality rates (Sharma, 2025) ^[26]. IoT-based tracking systems continuously monitor location, activity patterns, and feeding behaviours, allowing farmers to identify optimal breeding periods and detect anomalies like reduced appetite or lameness (Kaur & Virk, 2024) ^[13]. AI-driven breeding optimization enhances genetic selection and reproductive outcomes, improving herd quality. Smart feeding systems leverage predictive analytics to adjust feed composition and schedules, maximizing milk yield and weight gain while minimizing waste. Digital phenotyping combines genomics and AI to refine poultry health monitoring, boosting both productivity and animal welfare (Neethirajan, 2023) ^[17]. These innovations collectively enhance sustainability and operational efficiency in modern livestock farming.

3.3 Advanced Fisheries and Aquaculture

The aquaculture sector is also undergoing a transformative shift through the adoption of IoT, AI, and machine learning technologies, significantly enhancing operational efficiency, fish health management, and environmental sustainability. IoT-enabled sensors now provide continuous, real-time

monitoring of critical water parameters including pH, temperature, and dissolved oxygen levels, enabling immediate corrective actions when deviations occur (Shete *et al.*, 2024) ^[27]. AI-driven automated feeding systems utilize computer vision to analyze fish feeding behaviour, optimizing feed distribution schedules to minimize waste while maximizing growth rates. Advanced disease detection systems leverage machine learning algorithms to identify health anomalies early by analyzing behavioural and physiological data patterns, allowing for timely interventions that reduce mortality rates. Biomass estimation has also been revolutionized through non-invasive computer vision and sonar technologies, providing accurate, real-time data on fish populations and growth metrics (Ramírez *et al.*, 2024) ^[22]. Furthermore, these smart systems integrate renewable energy solutions and cloud-based analytics to reduce the ecological footprint of aquaculture operations, optimizing resource use while maintaining high productivity standards. Together, these innovations are setting new benchmarks for sustainable and efficient aquaculture practices globally.

3.4 Optimizing Food Processing and Supply Chains

The implementation of AI and IoT technologies are enhancing quality control, reducing waste, and improving traceability. Advanced predictive models powered by machine learning now accurately assess product shelf life while optimizing operational workflows, with IoT sensors providing real-time monitoring of storage conditions to ensure compliance with stringent safety standards. Supply chain efficiency has markedly improved through AI-driven demand forecasting and logistics optimization, particularly for perishable goods, where timely delivery reduces spoilage rates by up to 30% according to recent studies (Das *et al.*, 2025) ^[7]. Machine vision systems have become indispensable for contaminant detection, significantly lowering foodborne illness risks, while behavioural analytics help processors align production with evolving consumer preferences. Blockchain integration has emerged as a game-changer, creating immutable records from farm to retail that enhance transparency; several agri-tech startups now offer complete product journey visibility, building consumer trust in food origins and handling practices. These technological synergies are setting new benchmarks for safety, efficiency, and sustainability across global food networks.

3.5 Robotics and Automation in Farming

Modern agriculture has entered a new era of productivity and sustainability through the widespread adoption of robotic systems and automation technologies. Autonomous farming equipment like self-driving tractors and drone-assisted monitoring systems are solving critical labour shortages while executing field operations with unprecedented accuracy. Precision planting robots now utilize advanced GPS guidance and AI-driven analytics to optimize seed placement, achieving perfect spacing and depth for maximum germination rates (Senthilkumar, 2025) ^[24]. Perhaps most remarkably, computer vision-equipped weeders can distinguish crops from invasive plants with 95% accuracy, enabling targeted mechanical removal or micro-spray applications that have reduced herbicide usage

by up to 80% in pilot programs (Espejo *et al.*, 2020) ^[9]. These intelligent systems continuously gather vital field data through multispectral sensors, providing farmers with real-time insights into crop health and soil conditions. Beyond productivity gains, agricultural robots follow optimized routes to prevent soil compaction and apply nutrients with surgical precision, significantly reducing environmental impact while maintaining crop yields.

4. Case Studies of Leading Agri-tech Startups: Technologies, Business Models, and Key Impacts

4.1 Ninjacart: Supply Chain Optimization and Market Linkage

Technology/Business Model: Ninjacart operates as an innovative B2B platform that bridges farmers directly with commercial buyers through advanced digital solutions. The company employs artificial intelligence and machine learning to predict demand patterns, optimize delivery routes, and minimize post-harvest losses. Its integrated ecosystem features multiple services: Ninja Mandi facilitates wholesale transactions, Ninja Kisan supports farmers with agronomic advice, Ninja Kirana serves retail needs, while Ninja Global expands market access internationally. The platform's proprietary algorithms analyze vast datasets from IoT devices and mobile applications to streamline the entire supply chain.

Impact

The platform has demonstrated significant economic benefits, increasing farmer incomes by 20% compared to traditional markets while ensuring next-day payments. Logistics costs plummeted from ₹10.1 to ₹1.95 per kilogram between 2016-2022, achieving 80.7% efficiency gains. Retail partners save approximately ₹80,000 annually through combined direct and indirect savings. Currently serving 800,000+ farmers and 100,000+ retailers across 120 cities, Ninjacart has disrupted conventional distribution channels by removing intermediaries, thereby creating a more transparent and equitable marketplace (Ninjacart Impact Report, 2023 & Singh, 2024) ^[28].

4.2 Cropin: Farm Management and Predictive Intelligence

Technology/Business Model: Cropin delivers AI-powered farm management solutions that integrate IoT sensors, cloud computing, and predictive analytics to optimize agricultural operations. Its comprehensive platform features a Management Information System (MIS) for real-time data visualization and decision support, while the innovative Cropin Sage module employs specialized AI models, including a Micro Language Model (μ -LM) designed for climate-resilient farming practices.

Impact

The platform has achieved global scale, digitizing 16+ million acres and serving 7+ million farmers across 102 countries. Independent studies verify its 300% return on investment, with measurable improvements including 5% higher yields, 15% reduced pesticide use, and 5% water savings. In potato cultivation, the technology boosted solid content by 1.5%, generating €410/hectare in added value. Through its digital advisory services, Cropin has enhanced

productivity for over 1,000 smallholder farmers, demonstrating the tangible benefits of precision agriculture technologies (Medium, 2020 & Forrester, n.d.) ^[15, 10].

4.3 Fasal: Precision Farming and Resource Efficiency

Technology/Business Model: Fasal's innovative IoT-SaaS platform harnesses AI to transform horticulture through its three-phase "Sense-Analyze-Act" methodology. The system deploys field sensors to collect real-time microclimate data, while its mobile application delivers customized irrigation, fertilization, and pest management recommendations. The platform offers tiered solutions ranging from basic farm-level intelligence to advanced enterprise systems capable of autonomous irrigation control.

Impact

Field trials demonstrate Fasal's significant resource efficiency gains, including 60% reduction in pesticide expenditure and 20-25% water savings across multiple crops. Farmers report consistent yield improvements of 10-40%, with notable cases showing 20% production increases for chili and brinjal cultivators. Cumulatively, the platform has conserved over 9 billion litres of water while reducing chemical inputs, directly addressing sustainability challenges in intensive horticulture (Verma, 2018) ^[30].

4.4 Intello Labs: Quality Assessment and Supply Chain Automation

Technology/Business Model: Intello Labs leverages artificial intelligence and computer vision to revolutionize quality assessment across agricultural supply chains. Their technology suite digitizes quality evaluation for fresh produce, spices, and nuts, enabling data-driven pricing while minimizing food waste. The comprehensive solution includes Intello FruitSort for automated grading, Intello Pack for precision packaging, and Intello Track for blockchain-enabled traceability. Their flagship Praman platform serves as an AI-powered agricultural commodities exchange, standardizing quality metrics across the industry.

Impact

The company's solutions demonstrate tangible supply chain improvements, reducing manual quality checks by 80% while decreasing food rejection rates by 30%. Their Praman exchange platform currently processes \$40 million monthly in transactions, with projections reaching \$100 million, indicating strong market adoption. By introducing objective quality standards, Intello Labs has enhanced trust between growers, processors, and retailers while reducing post-harvest losses by an average of 15% (Ghosh & Sengupta, 2021; Omnivore Fund 2, 2024) ^[12, 23, 20].

4.5 AgroStar: Farmer Advisory and Input Access

Technology/Business Model: AgroStar operates as an integrated agricultural platform combining AI-driven advisory services with input supply chain optimization. The solution features the "AgroStar Agri-Doctor" mobile application which utilizes machine learning for crop disease diagnosis through image recognition and provides personalized farming recommendations. The platform offers a curated selection of 200+ agricultural products accessible through multiple channels, complemented by its global

produce brand 'Kimaye' that connects farmers to international markets.

Impact

The platform has achieved significant scale, serving 9 million+ farmers and delivering 10 million+ advisory sessions. Digital transformation has dramatically improved service efficiency - cloud-based solutions now handle thousands of daily queries in 4-5 minutes each, compared to traditional systems managing only 100 consultations taking 30-50 minutes. By establishing direct manufacturer procurement channels, AgroStar reduces input costs by 15-20% for farmers while improving access to quality products (The CSR Universe, 2025) ^[29].

5. Challenges and Considerations for Adoption

While AI, ML, and IoT offer transformative potential for agriculture, several critical barriers hinder widespread implementation. These challenges span technical, economic, data-related, and social dimensions, requiring comprehensive solutions for sustainable adoption.

5.1 Technical Barriers

The integration of smart farming technologies faces multiple technical obstacles. Sensor reliability remains problematic, with environmental factors and manufacturing inconsistencies causing inaccurate soil, nutrient, and crop health readings (Mansoor *et al.*, 2025) ^[14]. Data integration proves equally challenging, as agricultural systems generate heterogeneous information from drones, satellites, and field sensors that lack standardized formats. Rural connectivity gaps further complicate deployment, with many farming regions lacking the robust broadband needed for real-time IoT functionality. Additionally, the "black box" nature of many AI algorithms creates transparency issues, reducing farmer trust in algorithmic recommendations (Adadi & Berrada, 2018) ^[1].

5.2 Economic and Financial Hurdles

Cost presents a major adoption barrier. Smallholder farmers often cannot afford the substantial upfront investment required for sensors, drones, and automated machinery (Ahmad, 2024) ^[3]. Limited access to credit and financing options exacerbates this challenge, despite potential long-term benefits. Agricultural startups similarly struggle to secure funding for technology development and scaling (AgFunder, 2025) ^[2].

5.3 Data-Related Concerns

Effective AI implementation depends on abundant, high-quality agricultural data, which remains scarce for many crops and regions (Mishra & Srivastava, n.d.) ^[16]. Data privacy and security risks also deter adoption, as farms generate sensitive operational information vulnerable to exploitation.

5.4 Human and Social Factors

Farmer scepticism and resistance to change persist, particularly among those unfamiliar with digital tools. The technical complexity of these systems creates knowledge gaps, requiring extensive training programs. Moreover, the digital divide disproportionately affects small-scale

producers, as most technologies cater to industrial operations, exacerbating inequality in the sector (Dhillon & Moncur, 2023) ^[8].

6. Conclusion and Recommendations

The integration of AI, ML, and IoT technologies is revolutionizing Indian agriculture, enabling data-driven decision-making that enhances productivity, sustainability, and resilience across crop cultivation, livestock management, and supply chains. Agri-tech startups like Ninjacart, Cropin and Fasal have demonstrated the transformative potential of these technologies, delivering measurable benefits such as 20–40% yield improvements, 60% reductions in pesticide use, and 80% logistics cost savings. However, challenges like high implementation costs, rural connectivity gaps, data privacy concerns, and farmer scepticism persist, particularly for smallholders. Addressing these barriers requires collaborative efforts to improve digital infrastructure, provide targeted training, and develop affordable, farmer-centric solutions.

Looking ahead, the sector's growth will hinge on scalable innovations—from AI-powered predictive analytics to autonomous robotics—that balance efficiency with equity. Government initiatives like the Digital Agriculture Mission and Startup India are critical enablers, but sustained progress demands private-sector engagement, standardized data protocols, and inclusive design. By prioritizing these measures, India can harness Agri-tech's full potential to build a food system that is not only more productive but also equitable and climate-resilient, ensuring long-term food security for its farming communities.

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