Redefining agriculture through artificial intelligence: Predicting the unpredictable

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FICCI

Message from FICCI

T R Kesavan
Chairman, FICCI National Agriculture Committee, and
Group President, TAFE Ltd

The agriculture sector occupies an important position in the Indian economy. It is important to modernise the sector so that it grows consistently and enables farmers to reap maximum benefits. It is high time that we convert the various challenges faced by the sector into opportunities. Post COVID, the demand for food and nutrition security has changed. The sector needs to be accordingly positioned to ensure sustainable supply to the country and the world. This will certainly require smart technologies which help in predicting the unpredictable, as the name of the knowledge report highlights.

Indian agriculture is diverse and complex, and any effort to transform the sector must be taken while keeping farmers at the centre stage. Artificial intelligence (AI) and digital technologies can resolve multiple challenges that our farmers are facing. It will be a significant achievement if our farmers could appreciate, adopt and embrace digital technologies for the betterment of agriculture. A new generation of agri start-ups and AgriTechs are investing in digital initiatives and such technologies are used for better monitoring of crops, plant health and precision farming, and deriving appropriate interventions. The underlying benefits of these technologies are that farmers can make informed and cutting-edge decisions. Hence, ensuring a fast-track approach towards the adoption rate of such technologies within the farming community will be crucial for the future.

Such technologies can aid in better food management and reduce losses across the entire value chain – from the farm to the end user – bringing in a big revolution. According to an ICAR-CIPET report, the total volume of losses for all commodities is about INR 92,651 crore.[1] Saving such food loss with the aid of new technologies will also add up to farmers' income.

The Government of India (GoI) is leaving no stone unturned in developing a conducive ecosystem for Indian agriculture. Recently, the GoI made a critical announcement on allowing the use of drones for agricultural operations. Now that the Government is playing its part, the onus is on the other stakeholders to work in tandem so that the benefits of the GoI's policy decisions reach farmers in particular and the value chain in general. The agriculture industry, start-ups, academia, farmers, scientists and regulators all have definite roles to play which will determine the success of such initiatives. The GoI has taken several bold steps in the last few years to modernise agriculture. Such efforts certainly deserve to be applauded.

I congratulate PwC for being our continuous partner whenever we decide to launch a new knowledge-based programme in agriculture. I am sure the second edition of this report will provide readers with fresh perspectives on the usage of AI-based technologies in agriculture.

[1] https://www.researchgate.net/profile/Rajesh_Vishwakarma6/publication/289637983_Assessment_of_Quantitative_Harvest_and_Post-Harvest_Losses_of_Major_CropsCommodities_in_India/links/5690c83b08aed0aed811bae6/Assessment-of-Quantitative-Harvest-and-Post-Harvest-Losses-of-Major-Crops-Commodities-in-India.pdf

Message from FICCI

Hemendra Mathur
Chairman, FICCI Task Force on Agri Start-ups

Indian agriculture has traditionally been impacted by a lack of credible and timely data such as area under production, yield, crop and soil health, and commodity prices. This has caused demand-supply imbalance, volatility in the market prices of commodities and suboptimal or excessive use of natural resources.

The only way we can solve these challenges at scale is by capturing and synthesising data for enabling decision making for farmers, agri input/output/processing companies and other value chain players such as banks and insurance companies. Fortunately, we have access to a wide range of digital technologies developed in the last four–five years by multiple AgriTech start-ups.

These technologies help track multiple data points along the value chain from pre harvest, including input application, area under production, farm boundaries, farmer profile, soil health, hyperlocal weather and crop health, to post harvest, including quality, grades, traceability and losses, all the way to retail and export markets. The data is captured through a combination of multiple devices, including sensors, IoT devices, smartphones, spectrometers, drones and satellite images.

Machine learning (ML) and AI technologies are needed to build data-centric models which can predict any weather event, pest attack, harvest and crop yield with more accuracy. Many AI models also provide immediate, low-cost, affordable, portable and accurate solutions for the measurement of soil moisture, nutrition, crop health, quality assessment, etc.

One of the biggest challenges in scaling AI models is access to good-quality data. Most start-ups spend disproportionate effort and time on data collection rather than data modelling. We should attempt to build a public ecosystem of data repositories by collating already existing data. It is time we build centres of excellence to promote AI tools in agriculture through multidisciplinary approaches involving data scientists, soil scientists, agronomists, meteorologist, hydrologists, etc.

The transformation of Indian agriculture through digitisation is underway, improving farmers' access to markets, inputs, data, advisory, credit and insurance. Smallholder farming in India can benefit significantly by accessing AI models which can guide in improving farm economics through increased income and optimised input cost, and de-risking farming through timely data intervention.

I would like to thank the PwC team for its efforts in bringing out this report which can guide policymakers, industries and start-ups in the development as well as adoption of AI tools in agriculture.

Message from German Agribusiness Alliance

Julia Harnal
Chairperson, German Agribusiness Alliance, and Vice President, Public Affairs, Agricultural Solutions, BASF SE

The world is changing at an unexpected pace today. Disrupted supply chains and societies affected by the pandemic, global food supply under pressure due by the war in Ukraine and extreme weather events induced by climate change are some of the major crises affecting the planet. All these events lead us to the following question – How can we produce food to feed the world's growing population in the future?

Despite these challenging times, the agricultural sector has continued to perform strongly. Digital solutions are surely a real game changer when it comes to enhancing resilience and supporting farmers to produce efficiently and sustainably because agriculture first and foremost means the production of food. However, the pressure on the farming community to fulfil this enormous task has never been as high as it is today.

This central role of the farming community is accompanied by other tasks which are no less important and result primarily from the interaction with nature and the environment. In Germany and India, we are engaged in an intensive debate about how productive agriculture is possible worldwide. We also discuss the possibility of achieving economic and ecological efficiency in agriculture and how digital agriculture can support sustainable transformation, driving productivity, improving quality and preserving resources.

There are many solutions on the table. Relying on accurate, precise and reliable weather data is crucial for successful crop management and production – from planting to harvesting. Additionally, accurate early-season yield prediction is important for farm resource management. Digital solutions can support the use of natural resources, increasing crop quality and yield while reducing costs and lessening environmental impact. The digitisation of the agri and food supply chain can bring much-needed efficiency and transparency to farmers and consumers.

German Agribusiness is committed to driving agricultural innovations jointly with farmers, governments, research institutes and businesses in India. This knowledge report and the second edition of the 'International Summit on Artificial Intelligence and Digital applications in Agriculture' mark an important milestone in the cooperation between India and Germany on digital innovations in agriculture.

I eagerly look forward to great collaboration in the future. Let's make a difference together.

Message from PwC

Ashok Varma
Partner and Leader, Agriculture and Social Sector
PwC India

Farming is one of the riskiest sectors with uncertainty around input prices, weather and climatic conditions, productivity, and final output prices. Traditional farming approaches and processes have not helped farmers with small landholdings to overcome these challenges as they have limited access to information, knowledge and financial resources. We have to utilise the advent of digital transformation in the agriculture sector in this environment of risk and uncertainty.

The need is to keep farmers at the core of AgriTech advancement to augment efficient utilisation of farm resources and technology adoption, eventually improving economic productivity and progressing towards doubling farmers' income as envisaged by the Government of India. Amongst digital technologies, AI and AI-integrated applications can be used for remote sensing and generating weather station data. These, in turn, can be used for predictive analysis and suggesting the time of sowing, scheduling of irrigation, etc. AI-powered pest control can help in crop health management and together with blockchain, AI can be used at market linkage platforms to enhance quality and traceability.

Data is the fundamental input for an AI system to operate with utmost efficiency and it is essential to take a long-term view of aspects like interoperability, data governance, data quality, data standards, security, and privacy, besides promoting open innovation. Encouraging steps have been taken in this direction by the AgriTech ecosystem actors, including the development of a national AgriStack and the InDEA Digital Ecosystem of Agriculture. The Government has also prioritised using Kisan drones, as announced during the presentation of Union Budget 2022–23, along with developing public-private partnerships (PPPs) for high-tech farm services, amongst many others. However, the AgriTech domain faces a number of issues and challenges that needs to be addressed for nurturing and sustaining a conducive ecosystem where machines and advanced technologies augment human capabilities and address the pressing issues affecting Indian agriculture.

Indian agriculture is embracing digital transformation. The present market of digitalisation of agriculture is valued at USD 204 million[2] and further expected to grow exponentially owing to increasing adoption of technologies like AI and remote sensing. The domain of AI/ML has made remarkable strides globally and is expected to account for the largest share in the usage of technology in agriculture. The emergence and growth of more than 1,400 AgriTech start-ups[3] is evidence of India's success story. However, this dynamic ecosystem represents only a fraction of the Indian agriculture and has reached less than 20% of the Indian farmers.

2 https://indiaai.gov.in/article/ai-impact-on-india-how-ai-will-transform-indian-agriculture
3 https://tracxn.com/explore/AgriTech-Startups-in-India

This knowledge report provides an overview of AI in the agriculture ecosystem and identifies the bottlenecks specific to innovation, technology, adoption and application. We have also proposed a strategy for overcoming the identified challenges by employing levers of change, i.e. scale, service and skill through the key drivers of the AgriTech ecosystem – Government and related bodies, technology service providers, including tech giants and start-ups, and research and educational institutions. While offering systemic solutions to the barriers to using AI in Indian agriculture, we have considered the need to move beyond the sporadic AI-enabled solutions and transition to integrated platforms deployed at scale, the impact of which can be measured in real time and local context. We believe India has the potential to outpace countries like Japan, the UK and the US in terms of using AI in agriculture. The current pattern is a testimony to the evolving landscape of AI in Indian agriculture and will pave the way towards India becoming the global hub of such technology.

Industry messages

Amazon

Deepti V Dutt
Head, Strategic Initiatives, Public Sector
Amazon Internet Services Pvt Ltd

Aligned with the hon'ble Prime Minister's goal of doubling farmers' incomes, digital technologies and tools such as smartphones, web and mobile apps, IoT devices and satellite data are helping increase farmers' productivity and earnings, and enabling better decision making. With the current state of technological innovation, it is now possible for a farmer to get personalised advisory tailored to his/her specific farmland, soil type and crop. Such innovations enable farmers to scientifically ascertain the time of sowing, quality and quantity of inputs to be applied, monitor crop growth in real time and access the best markets for their produce after harvesting. Data available through satellite-based remote sensing has proved to be immensely useful for predicting natural disasters that can cause crop damage and has been used to implement Government crop insurance schemes. With the advancement of AI and ML and a simultaneous exponential increase in data (images of crops, pests and produce), farmers can now certify the quality of their produce by just taking a picture of their harvest, thus enabling them to negotiate the right price based on quality. Digital technologies positively impact both sides of the equation as they increase farmers' incomes as well as reduce the uncertainties faced by them.

Digital technologies are not only impacting farmers but also stakeholders in the agricultural value chain. There are more than 500 AgriTech start-ups in India growing at a rate of approximately 25% annually, in line with the GoI's Startup India mission. Most of these start-ups provide digital agriculture solutions ranging from input/output marketplaces, farming as a service, farm-to-fork supply chain services, big data analytics, financial services to farmers using agricultural data, and decision support systems for firms and governments. These start-ups cumulatively raised funding worth USD 250 million in 2019, three times of the amount raised in 2018.[4]

The GoI has also been successful in using digital technology in the agriculture and allied sectors. Remote sensing and data analytics have resulted in quick and trusted crop-yield estimation after natural disasters and subsequently, quicker disbursal of claims under the PM Fasal Bima Yojana. Aadhaar-based authentication and Direct Benefit Transfer (DBT) under the PM-KISAN initiative have led to the elimination of leakages and transfer of benefits directly into the bank accounts of farmers.

It is now time to leapfrog from the extensive, on-ground pilots over the last few years to massive population-scale implementations. This would require an enabling environment that bakes in the ability to experiment and innovate into formal Government contracts, which in turn requires a different thinking for procurement models, including PPP engagements. The second crucial factor for population-scale implementation would be managing the significant volume of data required for AgriTech solutions. Currently, this data is present in silos across multiple Government entities that are at different levels of system maturity and digitisation. There needs to be a concerted effort to ensure the adoption of the right and scalable technology that allows an unpredictable volume and variety of data to be accessed by a large number of innovators in a secure and open manner. Both these factors would need rethinking and innovating on technology, processes and institutional frameworks.

[4] https://www.ibef.org/blogs/agritech-start-ups-the-ray-of-hope-in-indian-agriculture

Nurture.farm

Dhruv Sawhney
Chief Operating Officer and Business Head at nurture.farm

The agriculture industry is on the cusp of a change which is evolving, gradual and transformational. But most importantly, the change has to be inclusive for it to be effective.

We have taken a giant leap in building technologies that can help solve the problems across the agri value chain, covering the pre-sowing, sowing, cultivation, harvest and post-harvest stages. However, we haven't been able to drive any sustainable impact in fighting climate change and soil degradation, or make the agri economy viable.

Smallholder farmers own 470 out of 570 million farms worldwide.[5] They don't have the requisite capital, lack the skills to use technology, or are unaware of the solutions available to help them farm better and drive profitability.

More than 70% of the farmers worldwide lack access to proper capital, two-thirds of them struggle to use technology and more than 50% are not aware of the existing solutions.

We need to work together to educate, train and scale our efforts to deliver the benefits of digitalisation, AI, farm mechanisation, and ML to farmers.

We need to open up the agri ecosystem by enabling more PPPs and private-research institute partnerships, collaborating to solve data challenges and partnering with government bodies to build knowledge repositories that act as a single source of truth. We need to invest in building location-agnostic AI models, opening doors for cross compatibility between devices, developing coherent and inclusive agricultural policies and supporting the development of a network of digital-transformation enablers, advisors and experts that work with farmers on the ground level. These enablers will help them upskill, engage with them, solve their queries, offer advisory and ensure that good agricultural practices are followed during cultivation.

Ensuring digital adoption, enabling smallholders with know-how and fostering shared economy models at scale will allow us to leverage information and communication technology (ICT), blockchain, IoT, AI and ML. We will be able to deliver impact and solve food and agricultural problems, and farmer and consumer issues. Using technologies will also enable stakeholders across the value chain to contribute towards building an agri ecosystem that's viable, self-sufficient, and sustainable.

[5] https://ourworldindata.org/smallholder-food-production

Xarvio

Shiva Prakash THM
Commercial Operations, India
xarvio® Digital Farming Solutions
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Many of the global farming challenges that we face – an increasing world population, effects of climate change, growing public expectations concerning environmental practices and the limitations of natural resources – exert pressure on agricultural communities to produce more quantities of affordable quality food in a socially responsible and sustainable manner.

While these challenges are shared by many countries, some are more critical to India's future, particularly within the next ten years. As per a report by the Indian Council of Agricultural Research (ICAR), the demand for foodgrains in India is expected to increase by 80% in 2030 compared to that in 2000.[6]

In this context, one of the main objectives of the GoI's Digital India campaign is to provide farmers with improved and timely access to greater levels of agricultural information. This will help address key issues of crop productivity and profitability, given the current yield rates of 2.4 tonnes per ha for rice and 3.15 tonnes per ha for wheat. Furthermore, it will mitigate the effects of overall potential crop production loss to diseases, weeds and pests, which is estimated to be at 15–25% each year.[7]

Therefore, now is the time to explore and identify what methods, products, organisations and services can collectively provide a holistic solution to the challenges cited. This is where innovative technology can play an even greater role, paving the way for Indian agriculture to not only meet its forecasted demand for food but do so sustainably.

We are already starting to see the impact and success of new technologies in India, which is very encouraging. The GoI's strategic reforms, which aim to double farmers' income from USD 1,481 to USD 2,962 by 2022, inspire private organisations to invest further in the agriculture sector to support farmers. It is also great to see technological advancements being leveraged by AgriTech companies in different farming sectors, from supply chain to finance, farm data and analytics. Digital farm management solutions for risk mitigation, specific crop advisories and delivering inputs have become segments with huge opportunities. The increasing penetration of smartphones has increased farm productivity through precision agriculture while decreasing production costs, which has huge implications for sustainability.

6 https://icar.org.in/files/Vision-2050-ICAR.pdf
7 https://www.business-standard.com/article/news-ani/india-loses-15-25-pct-potential-crop-output-due-to-pests-weeds-diseases-116072000250_1.html

Though the future for new digital agricultural businesses looks bright and promising in India, there are many considerations. The huge geography and different linguistic zones of the country make the delivery of customised and local solutions to farmers a mammoth task. Additionally, there is huge scope to improve the technological adoption rate in rural India which calls for digital businesses to organise their go-to-market strategies in a different set-up compared to urban India. Strategic partnerships that can deliver solutions to farmers as a complete package rather than fragmented approaches may elevate the value of the agribusiness ecosystem. For example, the partnership between an entity that recommends crop-protection products to another entity that specialises in last-mile logistics could be a symbiotic relationship that, in the end, eases and improves the life of a farmer.

Ultimately, the time is ripe to invest in Indian agribusinesses, not only for companies but also, more importantly, for billions of Indian consumers who look forward to food being produced in a healthy, environmentally responsible and sustainable manner.

Corteva Agriscience

Vedika Kapoor
Head of Government and Industry Affairs – South Asia
Corteva Agriscience

The COVID-19 pandemic has caused considerable damage globally for almost two years. This calls for better preparedness across all sectors and agriculture is no exception. It's time to usher in another revolution that enhances the efficiency of the sector and makes it resilient. An appropriate solution to the issues affecting the sector lies in embracing AI and digital solutions across different segments of the agricultural value chain. The use of such new-age technologies for precision agriculture and predictive analysis, particularly for real-time data on weather, soil moisture and plant health, can certainly be a big game changer in the times to come. However, such technologies should be user friendly, convenient, and easy to maintain and operate by small and medium farmers.

The GoI's Digital Agriculture Mission for 2021–2025 gives ample importance to AI, remote sensing, GIS technology, among others. Implementation of the India Digital Ecosystem of Agriculture (IDEA), which lays down a framework for AgriStack, shall contribute towards effective planning and improving the efficiency of the agriculture sector as a whole. We also commend the GoI for continually conceptualising different policies with a focus on enhancing the use of drones in the agriculture sector. In a recent Government announcement, registered pesticide formulations, which are otherwise permitted to be sprayed manually by knapsack sprayers, have been provisionally approved for commercial use through drones for a period of two years. A series of such positive reforms towards modernising Indian agriculture have been taken by the Government in the last few months and will certainly accelerate the pace of agricultural development in the country.

AI-based models built to provide early warning systems for pest attacks, better data analytics and resource management through IoT, image processing for identifying and detecting diseases, and ML models built using satellite imagery data for plant health mapping and acreage estimation are some of the promising AI-powered solutions. This indicates that connecting the digital ecosystem to the country's agricultural strategies is imperative to make our farmers competitive and our agricultural value chain more resilient.

We congratulate the PwC and FICCI teams for bringing out the latest edition of this knowledge report and are certain that it will benefit the industry.

Bayer Crop Science, India

Simon Wiebusch,
Country Head – Bayer CropScience Division in India, Bangladesh and Sri Lanka

As with every other sector, technology has redefined agriculture over the past decade and brought about several changes in farming. A rise in world population and decline in arable landmass mean that we will have to produce more food with fewer resources to ensure global food security. These changes are driving farmers and agri companies to explore new methods and technologies to optimise each agricultural process and operation – from field spraying to growing cycles and crop health.

We are convinced that Indian agriculture will collectivise and digitise to become more sustainable. AI is an important enabler as it can emerge as a useful tool to help farmers improve efficiency, enhance crop yields and reduce costs. AI and ML can have a far-reaching impact in several areas of agriculture. Farming is a complex task and keeping track of several agricultural processes is a constant challenge. However, AI-powered solutions can simplify the processes by providing real-time insights into how various factors impact productivity with a significant upside for both smallholders and progressive farmers.

A data-centric approach can also reap benefits for farmers and agri solutions companies by helping them gauge how financially successful a crop cycle has been. For farmers, it empowers them to take critical decisions based on insights, supporting higher crop yields and increased incomes. A combination of analytics from real-time sensor data and monitoring through drones can be a game changer for smallholder farmers and product development companies as well.

Drones equipped with computer-vision AI can automate the spraying of pesticides across fields. With access to real-time data, the spraying can be more effective and precise in terms of the area and the quantity to be sprayed. This can result in huge savings for smallholder farmers as using such technologies not only means improved yields that translate into higher incomes but also better health and quality of life for our farmers.

Technology will also help address another critical aspect of agricultural operations related to labour shortage. AI-based applications and smart mechanisation tools can play a huge role in providing significant value to farmers to address the increasing labour shortages in agriculture.

The implications and benefits of AI in agriculture can and will be vast and far reaching for a country like India. But we must recognise the fact that we are a nation of smallholders and collectivisation will be critical to bringing in economies of scale and making technology accessible to our farmers. If we can make it viable, AI has the ability to be a game changer and help us become a more food-secure country.

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Executive summary

Agriculture remains a high-priority sector of the Indian economy, accounting for the livelihoods of around **58%**[8] **of the country's population**. It also occupies a prominent position in the global economy and contributes **11.9% of the gross value added (GVA) in global agriculture (USD 3,320.4 billion),**[9] second only to China. The supply-and-demand analysis for food reflects that in spite of a 50% increase in crop production in the last ten years,[10] the rate of increase of food production will not be sufficient enough to feed the increasing global population which is projected to reach approximately ten billion by 2050[11]. Thus, the agriculture industry's productivity needs to be accelerated.

Technology has become critical in driving all major global economies forward. All sectors, including agriculture, are innovating to address complex problems. India, being one of the largest economies in the world, is no exception and witnessing a huge technological transformation since the last two decades. Flagship programmes like 'Digital India' and 'Startup India' have resulted in the country becoming the third-largest start-up ecosystem in the world, growing at a year-on-year (YoY) rate of 12–15%.

Though agriculture in India is at a transitory juncture, with a focus on integration of technologies for better operations, the sector still faces several challenges across the value chain. These challenges require **disruptive interferences** which can be provided by technological solutions. The entire system needs to adapt to a holistic approach which can be built upon indigenous and traditional farming knowledge integrated with **transformative smart farming practices,** including adoption of artificial intelligence (AI) tools and techniques. Adoption of AI technologies will pave the way for higher production with the optimum utilisation of available resources and facilitate predictive analysis, crop health management, enhance quality and traceability, etc.

The adoption of innovative and transformative smart farming practices in the country is gradually becoming a major trend. **Smart and technology-driven resource management, modernisation of agri supply chains, climate risk mitigation strategy, digitising farm collectives as farmer producer organisations (FPOs), emergence of a start-up ecosystem and Government initiatives in digital farming** are some of steps being taken to encourage smart farming practices.

From the global market point of view, smart agricultural systems and technologies, including AI and machine learning (ML), are showing remarkable growth with the investment and expenditure trends expected to **triple by 2025 to USD 15.3 billion**, out of which **AI technologies alone are projected to grow at a compound annual growth rate (CAGR) of 25.5%**[12]**.** Within **AI interventions, internet of things (IoT) enabled agricultural (IoTAg) monitoring** is considered to be the fastest-growing technology segment, projected **to be worth USD 4.5 billion by 2025.**[13]

The **global market size for AI in agriculture stood at USD 852.2 million in 2019 and is expected to reach USD 8,379.5 million by 2030**, exhibiting a **CAGR of 24.8%**[14] during the forecast period (2020–2030). This market growth is propelled by increasing penetration of IoT in the agriculture industry with implementation of data generation through sensors and aerial images for crops, leading to an increase in crop productivity through deep-learning technology.

Further, technology advancements in recent years are reengineering both the upstream and downstream segments of the agri value chain. Cutting-edge technologies in AI such as **IoT, ML, cloud computing, statistical computing, deep learning, virtual reality (VR) and augmented reality (AR)** are enabling the sector to overcome the challenges of productivity, quality, traceability and carbon emission with enhanced profitability.

8 https://icar.org.in/files/state-specific/chapter/3.htm
9 https://www.indiaglobalbusiness.com/analyses/in-focus/digitalisation-has-brough-a-fresh-breath-to-indias-agricultural-culture
10 Ourworlindata.org
11 https://blogs.worldbank.org/opendata/worlds-population-will-continue-grow-and-will-reach-nearly-10-billion-2050
12 https://www.forbes.com/sites/louiscolumbus/2021/02/17/10-ways-ai-has-the-potential-to-improve-agriculture-in-2021/?sh=5434484e7f3b
13 https://www.forbes.com/sites/louiscolumbus/2021/02/17/10-ways-ai-has-the-potential-to-improve-agriculture-in-2021/?sh=5434484e7f3b
14 https://www.globenewswire.com/news-release/2020/11/03/2119577/0/en/AI-in-Agriculture-Market-Research-Report-By-Type-Technology-Application-Global-Industry-Analysis-and-Growth-Forecast-to-2030.html

Drones or unmanned aerial vehicles (UAVs) are being predominantly used in the agriculture sector. Kisan drones are likely to bring change through accurate weather forecasts and secure, precise crop analytics which are AI enabled and accessible. Multi-spectral and imaging features of drones can aid crop stress monitoring, assess a plant's growth stage, yield prediction and help in delivering fertilisers, herbicides and water. Drones can also help assess **crop health, weed infliction, pests and infections status, and suggest judicious use of chemicals to address these issues**. Hence, drone technology can help enhance the efficiency and consistency of crop management along with making it cost effective. There has been considerable development in the usage of drones in the agriculture sector. The Government of India (GoI) has also made a few important announcements towards the use of drones in the agriculture sector, and the notification of Drone Rules, 2021, launch of the drone Production Linked Incentive (PLI) scheme and introduction of a single-window Digital Sky Platform are some of the important steps taken by the GoI. As the agriculture sector of the country develops further, the usage of drones in farming methods is predicted to grow with many start-ups investing in low-cost drones which can support farmers, enhance their knowledge and generate employment for the rural youth.

The GoI has been continually formulating and implementing policies and schemes to promote digital transformation in agriculture with increased impetus on supporting the ecosystem players, including agri-based start-ups. The Government is also enabling an institutional ecosystem for AgriTech start-ups through incubators/accelerators. It has adopted the theme of **'AI for All'** and laid down broad recommendations for nurturing the AI ecosystem in India through the NITI Aayog.

Despite the progress in creating and nurturing an AI-enabled ecosystem, the agriculture sector faces a number of issues and challenges that need to be addressed for facilitating a smooth transition. The major challenges with the **innovation and technology aspects** of AI in the agriculture sector are **limited pool of AI and sectoral expertise, existing gaps in public AI research, poor data quality and lack of access to data, lack of coordination and cross-border collaboration**. The **adoption and application aspects** of AI in agriculture have **limitations in terms of achieving scale, IoT devices, data annotation, data security and privacy, and technical understanding**.

In the context of Indian agriculture, AI technologies need to sustain diverse and locally relevant practices that not only learn from local knowledge systems but also enable innovation along the entire value chain. This report proposes a **3S strategy** by employing the levers of **scale, skill and service** to transform AI into agri intelligence, leading to widespread adoption of the technology in the ecosystem through the collaborative efforts of key actors as drivers of change. **Scale** can be achieved through regulatory, policy and awareness, and capacity-building interventions. **Skill** can be achieved via revising the agricultural education curriculum to include AI as a topic, establishing AgriTech innovation centres in public-private partnership (PPP) modes and enhancing outreach through the network of agricultural universities (AUs) and Krishi Vigyan Kendras (KVKs). Finally, better **service** can be provided through building simple farmer-friendly systems, establishing sustained partnerships and increasing investment in low-cost, open-source cloud-based platform solutions. These levers driven by the Government, research and educational institutes and private players, including start-ups, will result in **enhanced adoption**, **an improved innovation ecosystem**, **increased access to the latest technologies** and **better sector-specific application.**

1. Emerging need for AI in agriculture

Emerging need for AI in agriculture

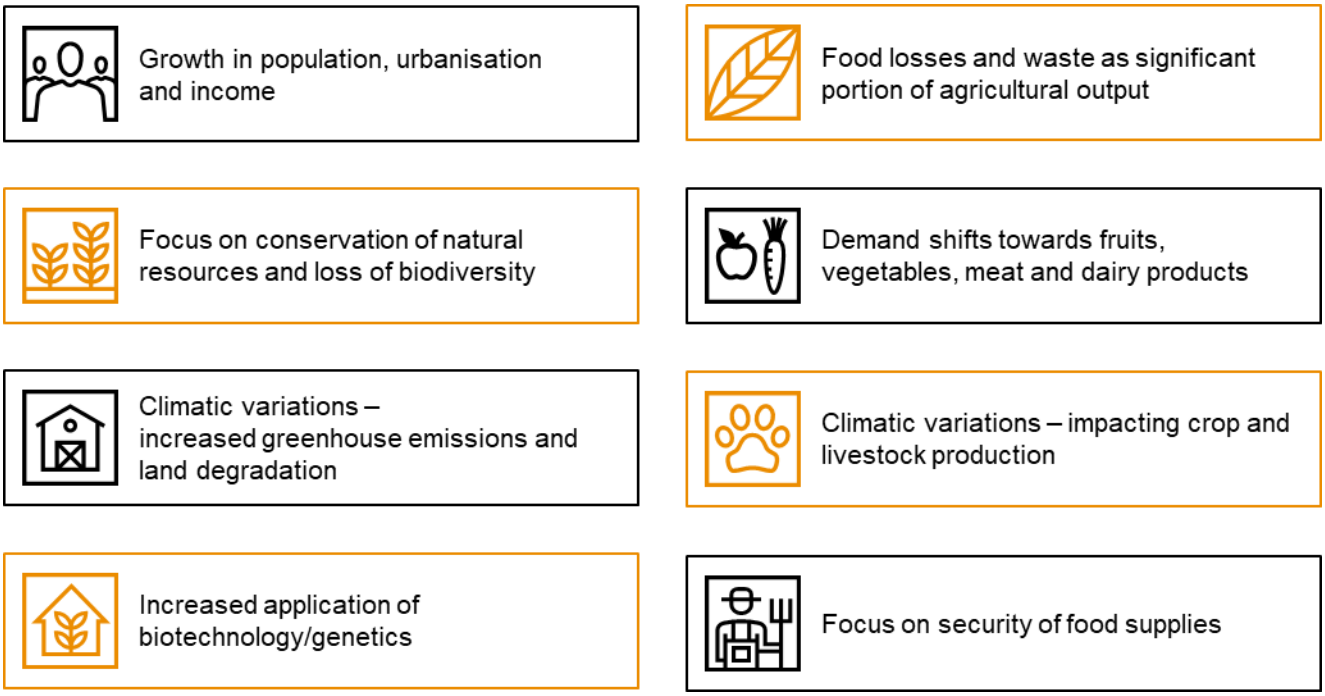
1.1. Existing agri scenario analysis – key trends and high-level transformations

Agriculture is presently experiencing a catalytic transformation. The sector is imbibing and adopting innovative technologies to enhance the efficacies of farming operations, thereby enhancing yield. These technologies operate to apply data science and analytics to each component of the agricultural value chain and eventually optimise its delivery efficacy.

The supply-and-demand analysis for food reflects that in spite of a 50% increase in crop production in the last ten years,[15] the rate of increase will not be sufficient enough to feed the burgeoning global population which is projected to reach approximately ten billion by 2050.[16] As per a UN report, 60 million people globally[17] remain undernourished at present compared to 2014, thus creating the need to accelerate the agriculture industry's productivity.

Various global trends are influencing the overall sustainability of food and agricultural systems, and creating the need for transformation in the agricultural ecosystem.

Major global trends necessitating the need for increasing farm productivity



Source: UN DESA, Fitch analysis and PwC analysis

Note: 68% of the global population is projected to live in urban areas by 2050 as the cumulative global GDP witnesses a 130% growth between 2016–2050. Around 14% of the food produced in the world is lost between farm gate and retail points, and by 2025, 35.3% of household budgets will be spent on food and drinks, up from 33.2% in 2005.

15 Ourworlindata.org
16 https://blogs.worldbank.org/opendata/worlds-population-will-continue-grow-and-will-reach-nearly-10-billion-2050
17 https://www.un.org/sustainabledevelopment/hunger/#:~:text=Current%20estimates%20show%20that%20nearly,achieve%20Zero%20Hunger%20by%202030.

Indian agriculture system

Agriculture remains a high-priority sector of the Indian economy, accounting for the livelihoods of around 58% of the country's population. Indian agriculture also occupies a prominent position in the global economy and makes up for 11.9% of global agriculture's GVA of USD 3,320.4 billion,[18] second only to China. The sector broadly comprises farming (crops and horticulture) and forestry, livestock (milk, eggs and meat), and fisheries.

Though agriculture in India is at a juncture of transition with a major focus on integration of technologies for better operations, the sector is still mired with several challenges across the value chain. These challenges, along with the need to increase food demand, are bound to make the agricultural system unsustainable, forcing it to operate while sustaining high environmental costs and huge wastage of produce.

The figure below summarises some of the major challenges faced by the Indian agricultural system.

Major challenges faced by the Indian agriculture system

1	Small and marginal farmers (86% of farmers own <2 ha of land, causing unsustainable farm incomes and poverty
2	Unsustainable farming practices, resulting in soil degradation and water stress
3	Unorganised and fragmented systems with existence of multiple levels of intermediaries and middlemen across the agricultural value chain
4	Limited access to technology, inputs, credit, capital and market, etc.
5	High-input, resource-intensive farming systems causing massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions
6	Lack of datasets at farm, farmer and sector levels, leading to higher cost of services
7	Gaps in market linkages, challenges in price discovery for farmers and price volatility in the market
8	Challenges in financial and digital inclusivity
9	Lack of food processing, logistics and warehousing infrastructure close to farm gates, increasing wastage
10	Poor farm mechanisation due to affordability challenges

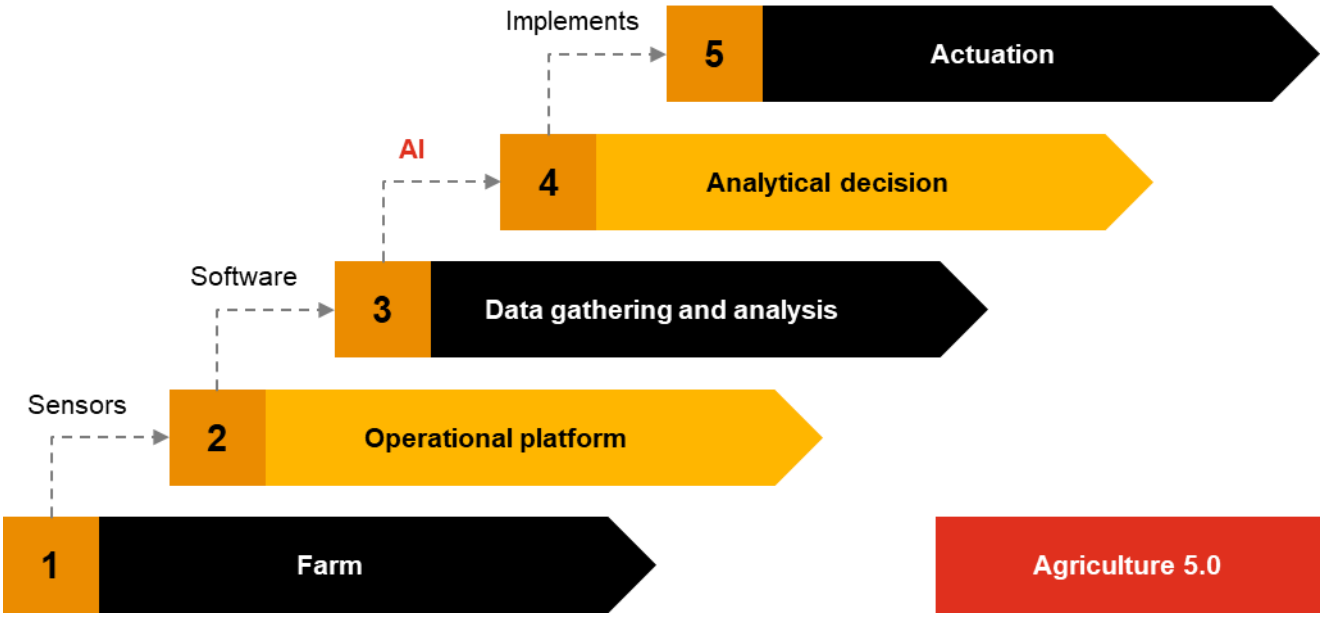
Source: Market survey and PwC analysis

[18] https://www.indiaglobalbusiness.com/analyses/in-focus/digitalisation-has-brough-a-fresh-breath-to-indias-agricultural-culture

The challenges mentioned above clearly indicate the need for disruptive interferences which allow for interventions via technological solutions. The agricultural system needs to adapt to a holistic approach which can be built upon indigenous and traditional farming knowledge by integrating it with **transformative smart farming practices.**

The Agriculture Information Management System (AIMS) developed by the National Informatics Centre (NIC) has experienced multiple stages in the process of transformation to bring about the most beneficial smart farming solutions.

Transformative smart farming practices



Source: Pradhan Mantri Krishi Sinchayee Yojana

The above-mentioned global and national trends further reiterate the urgent need of increasing farm productivity and AI tools and technologies have an important role to play. Adoption of AI technologies will pave the way for higher production with the optimum utilisation of available resources.

Integrating AI with other applications provides an AI-leveraged model for the farming ecosystem. AI can be combined with remote sensing and weather station data, and used for predictive analysis and suggesting the time of sowing, scheduling irrigation, crop health management through AI-powered pest control, and combining AI and blockchain at market linkage platforms to enhance quality and traceability.

There are some major trends in the Indian agriculture system which are leading to the **adoption of innovative and transformative smart farming practices in the country**. Discussed below are six major **trends** that are paving the way for such **transformation**:

1. **Smart and technology-driven resource management**: Water management is one of the most important initiatives in terms of optimum utilisation of resources. Such initiatives range from watershed management to drip irrigation. The GoI has focused on this extensively and started the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) with a total allocation of INR 50,000 crore[19] (from 2015–16 to 2019–20) for a period of five years. As a part of the allocation, INR 4,000 crore has been earmarked under the Per Drop More Crop programme of the PMKSY for improving irrigation efficiency. Geotagging of assets under the scheme can be monitored through the Bhuvan app for better implementation across the country. Similarly, the Fertiliser Monitoring System (FMS) software is introduced to monitor the movement of fertilisers at different stages across the value chain. Relevant information such as rate of concession on fertilisers, maximum retail prices (MRPs), dispatch details, fertiliser receipts and company details are provided on the website.

[19] www.pmksy.gov.in

2. **Modernisation of the agri supply chain:** Integration in the agriculture sector is enhancing with better connects in the value chain, access to the global market and along with environmental concerns, food safety and quality, animal welfare regulations are also increasingly impacting the sector. To minimise the supply chain losses, efforts are being put to enhance the efficacy of operations by focusing on critical factors such as quality, traceability, logistics and distribution. Smart/responsible sourcing technologies are used through predictive market demand forecasting using AI and prescriptive intelligence for route optimisation is obtained using AI/ML. Also, data-driven simulation modelling of food systems and quality with traceability are maintained by using AI-integrated systems.

3. **Climate risk mitigation strategy**: Several initiatives are being taken to create a climate risk mitigation strategy as India suffers from huge crop losses owning to the erratic weather conditions in the country. Solutions for early warning systems are playing a vital role in estimating and minimising risks incurred due to sudden climate-change scenarios. Automatic weather stations (AWS) are examples of one such initiative. They consist of weather and lightning sensors, rain gauge and data loggers to measure the atmospheric conditions and provide prior weather-related information for production planning.

4. **Preponderance and digitising farm collectives as FPOs:** Farmer producer organisations (FPOs) are formed when individual small and marginal farmers come together and engage in farming operations and businesses as members of an aggregated body. FPOs help in creating opportunities for better credit facilities, insurance terms, post-harvest management (PHM) infrastructure for quality management, precision agriculture solutions for better crop management, etc.

5. **Emergence of a start-up ecosystem**: A number of start-ups working on different aspects of digital/smart agriculture have been founded. There is scope for more incubation and funding support for these start-ups. The global AgriTech market grew by 35.4% between 2019–2020 and is further projected to grow between 2020–27 at a CAGR of 12.1%.[20] India is also growing in this segment along with China and the US. The GoI is supportive of technology adoption and has invested in more than 300 AgriTech start-ups during 2019–20, totalling to INR 3,150 crore.

6. **Government initiatives in digital farming:** Adoption of innovative technologies is becoming one of the major driving forces for increasing productivity and promoting agricultural development. In addition to growing focus on technological adoption for increasing production, productivity and farm incomes, policies for agricultural development are also being emphasised. The Government has initiated multiple projects based on new technologies like AI, blockchain, remote sensing and geographic information system (GIS), drones and robots through a digital mission for 2021–2025. The Ministry of Agriculture has signed a memorandum of understanding (MoU) for pilot projects with many of the major industry players in the digital market. The GoI is also focusing on digitising farmers' data with the India Digital Ecosystem for Agriculture (IDEA) initiative. This National Farmers Database is an 'AgriStack' with a collection of technologies and digital databases of farmers and other stakeholders in the agriculture sector. It includes digitised land records and other relevant information for farmers. Such digitised farmer endowment data facilitates in providing benefits under various schemes such as the Pradhan Mantri Kisan Samman Nidhai (PMKSNY) and Pradhan Mantri Fasal Bima Yojana (PMFBY). A lot of data collected through these systems has information of different aspects of agriculture and enhances the possibility of implementing AI technologies in farming systems.

   Thus, it is observed that the Indian agricultural ecosystem is in the process of infusing technologies aiming at enhancing the incomes of farmers. These innovations are driven by the Fourth Industrial Revolution and comprises technologies such as AI, ML, IoT, big data, drones and blockchain, and aimed at bringing rapid and large-scale changes to increase efficiency and productivity of the sector.

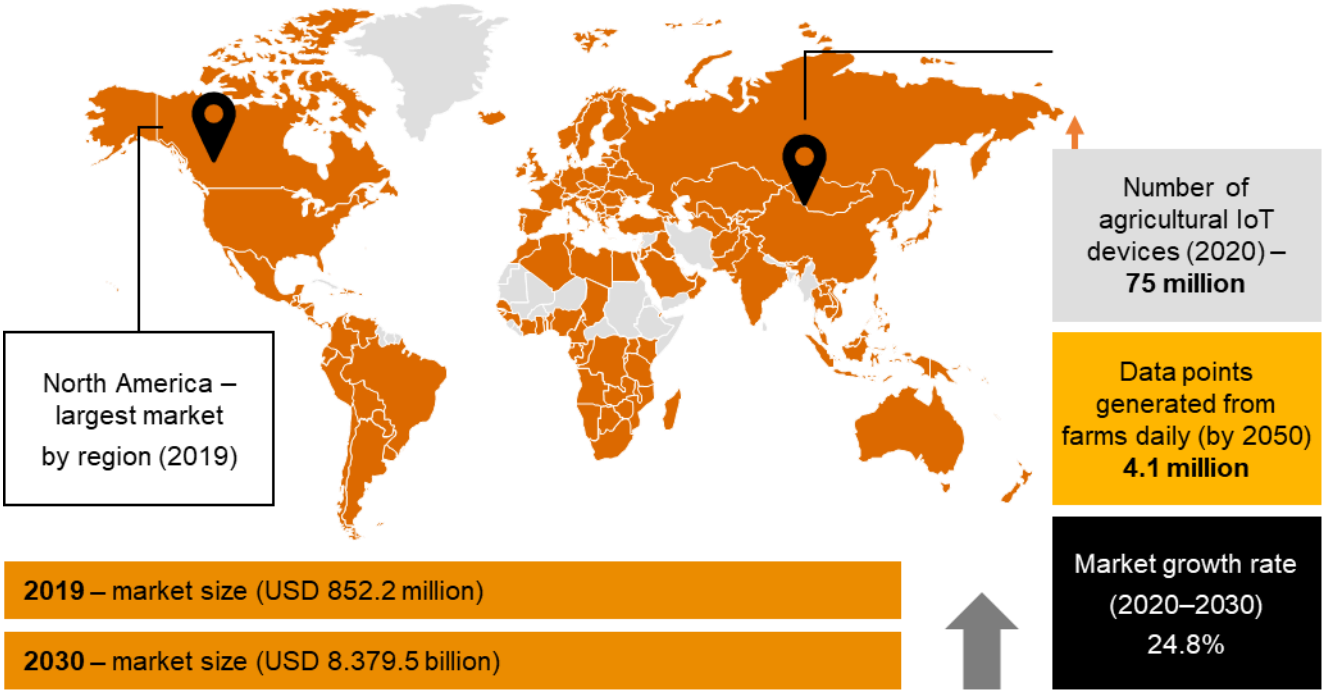
[20] https://www.globenewswire.com/news-release/2021/03/24/2198497/0/en/Agritech-Market-Forecast-to-2027-COVID-19-Impact-and-Global-Analysis-By-Type-and-Application-and-Geography.html

Global markets of AI technologies

Globally, smart agricultural systems and technologies, including AI and ML, are showing remarkable growth with the investment and expenditure trends expected to triple by 2025 to USD 15.3 billion. Out of this, AI technologies alone are projected to grow at a CAGR of 25.5%.[21] AI, ML and IoT sensors provide real-time data for algorithms to improve crop yields, increase agricultural efficiencies and reduce input production cost. Within AI interventions, IoT-enabled agricultural (IoTAg) monitoring is the one which is considered to be the fastest-growing technology segment and projected to reach USD 4.5 billion by 2025.[22]

The global market for AI in agriculture stood at USD 852.2 million in 2019 and is expected to reach USD 8,379.5 million by 2030, growing at a CAGR of 24.8%[23] during the forecast period (2020–2030). This market growth is propelled by increasing penetration of IoT in the agriculture industry with implementation of data generation through sensors and aerial images for crops, leading to increase in crop productivity through deep-learning technology.

Global market for AI in agriculture



Source: Industry reports and PwC analysis

[21] https://www.forbes.com/sites/louiscolumbus/2021/02/17/10-ways-ai-has-the-potential-to-improve-agriculture-in-2021/?sh=5434484e7f3b

[22] https://www.forbes.com/sites/louiscolumbus/2021/02/17/10-ways-ai-has-the-potential-to-improve-agriculture-in-2021/?sh=5434484e7f3b

[23] https://www.globenewswire.com/news-release/2020/11/03/2119577/0/en/AI-in-Agriculture-Market-Research-Report-By-Type-Technology-Application-Global-Industry-Analysis-and-Growth-Forecast-to-2030.html

Major components of AI applications in agriculture

With the emergence of AI as a leading technology solution towards improving productivity, agriculture is slowly getting digitalised with focus on the following three areas.

1. Agricultural robotics
2. Soil and crop monitoring
3. Predictive analytics

Farmers are increasingly using robotics, sensors and soil sampling to gather data which is stored on farm management systems and allow for better processing and analysis. The availability of such agricultural data is paving the way to deploy AI in agriculture.

Different AI technologies have also been divided into different categories, depending on the type, technology and industry. Amongst these three categories, the fastest-growing segments are the service segment in the type category, predictive analysis in the service category and precision farming in the industry category. The figure below further analyses the three fastest-growing segments.

Types of AI application systems

Service segment	Predictive analytics	Precision farming
Fastest growing in type category	**Fastest growing in technology category**	**Largest application category in industry**
High requirement for proper installation, maintenance and training services among farmers and other industry stakeholders Increasing demand for support, maintenance and training services by farmers who are deploying the AI technology	Highest CAGR for AI in the agriculture market Increasing demand for advanced analytics solutions that analyse real-time weather conditions, soil moisture and plant health, and provide deep insights into improving yield and crop quality	Largest size in the AI in agriculture market (2019) Increasing need for optimum yield production from limited available resources as well as reducing the cost of crop production and increasing the capabilities of IoT devices for field mapping and irrigation management

Source: P&S Intelligence

The list below includes details of all digital technologies used across agri value chains from pre-production to marketing and up to consumer experience.

Major digital technologies

IoT	IoT is used in intelligent farming with various sensors for light, humidity, soil moisture, temperature, crop health monitoring, etc. • Data collection by farm sensors like autonomous vehicles, wearables, button cameras, robotics and control systems • Aerial and ground-based drones for irrigation, assessing crop health, spraying, monitoring and field analysis • Geofencing using wireless IoT sensors and livestock tracking to monitor cattle healthcare • Predictive analytics for rainfall, temperature, soil, humidity, etc. • Innovative greenhouse with the aid of IoT devices and monitors, doesn't require human intervention
GIS	Used to analyse complex spatial data like rainfall , topography, soil elevation, slope aspect, wind direction, flooding and erosion. Some excellent use cases of GIS in the agriculture industry trends for 2022 are: • irrigated landscape mapping • crop health assessment • irrigation amendment analysis • land degradation assessment studies • erosion remediation • efficient drainage elevation model.
AI/ML and data science	These technologies contribute towards and benefit the farmers by proven data analysis and predictions, Crucial agricultural data collected by IoT devices and ML algorithms are processed and channelised with data science. Real-time use cases of AI/ML and data science in agriculture are: • predicting yield and quality assessment • predictive analytics for crop sustainability • using ML to eliminate weed by recognising species of plants/crops • detection of crop infections and diseases • intelligent harvesting and pricing decisions • prevention of wastage and meeting demands • autonomous robots for herding cattle.

Blockchain	Helps farmers ensure the safety of their crops, preventing theft and fraud, efficiently managing the supply chain, and balancing the food ecosystem. The real-time use cases of blockchain technology in agriculture are: • food traceability • transparency in the food supply chain • agricultural insurance for farmers • e-commerce for agri trades • agricultural subsidies.
Automation	Machine performing agricultural operations acknowledges farm automation/smart farming and eases out the workload on human resources. Drones, custom tractors, watering motors, harvesters are some of the modern technologies used for automation in agriculture.

AI-/ML-led technologies are being used in agriculture for various innovations, some of which are mentioned below:

1. Crop monitoring

Drone-based crop monitoring is being used worldwide to address drought and other harmful environmental phenomenon affecting agriculture. The 3D imaging from drones is being utilised to predict soil quality, farm patterns and parameters, diseases and pest infestations, etc. Drone-based chemical spraying on crops is also prevalent as it has been analysed that the pace of spraying increases by five times compared to other machineries. However, care must be taken to avoid groundwater penetration of chemicals. Improving nutrient quality of the grains, for example, through XRF Analyzers to assess mineral content in grains, grain analyser to digitise grain seed quality and establish traceability and hyperspectral Imaging to predict nutrient concentration in leaves over developmental stages.

2. Robotics in agriculture

The usage of robotics has improved productivity and resulted in higher yields in agricultural systems. Around 90% agrochemical usage can be achieved by using weeding and spraying robots. Using camera for guidance and laser, robots can remove weeds without any human involvement as they are capable of navigating crop rows by themselves. Utilising robots in plant transplanting is bringing in more efficient methods compared to traditional ones. Robots are also being used for fruit picking and nut harvesting.

3. RFID sensors and tracking

Radio frequency identification (RFID) sensors are used to track food from source for consumers. Such sensors create an end-to-end traceability trail for a product, thereby enhancing trustworthiness and product conformance for fresh and quality produce.

Adoption of AI technologies has also led to the emergence of two unique and innovative farming practices.

Regenerative agriculture

Farming practices that increase soil carbon sequestration are regenerative in nature. This method focuses on the rejuvenation and biodiversity of soil and soil distribution, and revives the soil for the upcoming cropping period.

Farmers undertake the following practices while implementing regenerative agriculture:

- Reducing tillage
- No-till farming
- Crop rotation
- Planting cover crops

These methods enable sequestration and make the farms act as a carbon sink.

Controlled environment agriculture

This practice enables effective farming even under fluctuations and extremities due to climatic variations.

The farming technique saves energy, identifies pests and diseases, maximises production space, and increases margins and profits.

Considering the potential of digital farming techniques, it can be assumed that digital transformation will drive the future of agriculture and empower farmers. They will have access to crops with better yields, improved and efficient farming methods and be free from worrying about environmental concerns. With our ever increasing population and the additional pressure of ensuring food availability for all, technology must be taken advantage of, which, in turn, will lessen the burden on our farmers as well.

1.2. Need for AI-led agri disruptions

As per a study by the Food and Agriculture Organization (FAO), a mere 5% additional land will come under cultivation worldwide by 2050.[24] Crop production will continue to be under pressure and food production will have to increase by 60% to feed an additional two billion people. However, traditional methods are not enough to handle this huge demand. This is driving farmers to find newer ways of increasing production and reducing waste.

India's agriculture sector, which is worth USD 370 billion, continues to be the mainstay of the country's economy and supports the livelihood of more than 40% of the population, contributing 19.9% (FY 2021)[25] to the national GDP. However, structural and operational deficiencies stall the sector's productivity growth. Thus, to strengthen the sector structure and increase productivity, the system is in dire need of integration of technology-aided practices and operations. It also requires reforms which are resilient enough to fasten easy adoption, scalability and sustainability of operations. The introduction and use of AI become critical to adopt these technological interventions.

AI is steadily emerging as a part of the agriculture industry's technological evolution. AI-powered solutions envision to improve farming efficiencies and also enhance the marketability of produce in terms of quality as well as access. AI technologies are facilitating complex and routine tasks involving huge person hours. Such technologies operate to gather and process big data on a digital platform, analyse it for getting the best course of action, and even initiating the required action when combined with other technology.

The figure below analyses the major drivers for the need of AI in agriculture.

Drivers for AI in agriculture

Growing demand for agricultural produce	Increasing need for real-time livestock monitoring	Surging utilisation of drones in the agriculture industry	Rising adoption of IoT
• Demand for agricultural products majorly driven due to the rising disposable income, rapid urbanisation, and changing consumption habits of the increasing population • Focus has increased for leveraging AI in order to increase the overall productivity	• Advanced AI solutions such as facial recognition for livestock and image classification incorporated with body condition score and feeding patterns • Possibility of individually monitoring all behavioural aspects of a herd • Machine vision helps to recognise hide patterns, monitor water and food intake and record behaviour and body temperature	• Used for monitoring the health and growth of crops • Used for scanning soil health, assisting in irrigation schedules, estimating yield data, and applying fertilisers • Enhanced Government focus on the Indian drone market is expected to help it become worth USD 6.69 billion in the next five years	• IoT enables to monitor farm conditions and infrastructure remotely which helps reduce time on field, labour efforts and investment capital • The global IoT in agriculture market was valued at USD 21.99 billion (2021) and is expected to grow with a CAGR of 10.1% to reach USD 35.55 billion by 2026

Source: P&S Intelligence

[24] https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf
[25] unctad.org

Need for AI-led disruptions with available solutions

AI-enabled farm business models can help meet the rising global food demand along with supporting an inclusive and sustainable agri system. These will mainly lead to the following three developments of:

1. Enhancing resilience in farming methods
2. Reducing cost of quality inputs and services, and enhancing the input-output profitability ratio
3. Enhancing the access to domestic and global markets for even smallholder farmers

The table below analyses the AI-led solutions for some of the critical needs in the farming sector:

Sr. no.	Need of AI disruption	Areas of concern	AI-led solutions
Pre- production related parameters			
1	Judicious use of pesticides	• India is the leading producer of pesticides in Asia and produces around 900,000 tonnes of agrochemicals annually. Paddy (26–28%) and cotton (18–20%) are the top crops in terms of agrochemical usage. • Only 2% of the pesticides sprayed reach their target species. • In spite of large-scale usage of pesticides, 14% of crop value is lost due to pests and overuse of pesticides causes insecticide resistance and pest revival, resulting in higher input costs. • In addition, the system also lacks a strong authentic input advisory service.	• AI can calculate pest density from pest trap images. • It can measure the economic threshold level (ETL) and recommend advisory on application timing, type and quantity, so as to optimise the pesticide application.
2	Smart irrigation management	• In India, 53% of the cultivable land is monsoon dependent and irrigation efficiency is merely at 38%. • Agriculture accounts for 70% of freshwater withdrawal. • The deployment of micro irrigation facilities is only at 12%.	• AI-led disruption can provide short- and long-range forecast for tracking water availability from surface, ground and soil moisture. • AI can aid in village-level water budgeting by analysing water demand, surplus and deficit regions, and balancing budgets.

Sr. no.	Need of AI disruption	Areas of concern	AI-led solutions
			• It can also help in real-time crop stress identification and monitoring, and accordingly planning irrigation scheduling.
3	To tackle labour challenges	• Shortage of agricultural workers is a problem across the country. • Insufficient resources are available for large-scale agricultural businesses to handle the day-to-day operations and the security and monitoring of farms.	• AI- and ML-based agribots, robotics and smart tractors create practical options for many remote agricultural operations. • Robotics can be used by big agribusinesses for securing the large segments of crop plantations in case of remote locations. • The operating costs for fertiliser distribution can be kept in check with self-propelled robotics based machinery and also lead to improved yields. • Robots doing bulk harvesting help improve the size of the yield and reduce waste from crops being left in the field.
4	To provide farm and climate related information	• Lack of availability of information about soil, nutrient status, temperature and other weather conditions. • Increased unjustified usage of resources. • Creates a situation of poor/delayed decision making due to the unavailability of data and information.	• AI helps to map the status of soil micronutrients, temperature, moisture data along with pest historical reports and crop images. • Micro weather data and forecast can be gathered using AI technologies.
5	For crop health management – smart insurance	• Smart insurance requires efficient transactions between multiple stakeholders such as farmers, central and state governments, and insurance companies. • The present system faces many hurdles in effective operations such as delayed payments to farmers, lack of proper details of insured farmers, untimely payment of premium to insurance companies, lack in transparency of crop cutting experiment (CCE) and insurance underwriting at the gram panchayat level and not the farm level.	• With authentic availability of data, insurance companies can improve the efficiency and risk cover. • The insurer and the farmer both benefit from the weather-based policy built on the data-based insurance coverage. Crop signatures and other tools can predict the impact of weather conditions and yields as well. • The precise level of a crop's growth and potential loss can be measured by the insurer.

Sr. no.	Need of AI disruption	Areas of concern	AI-led solutions
			• Smart insurance ensures a streamlined claims process.
Post-production related parameters			
6	To prevent post-harvest losses in storage and transportation	• A significant portion (24–40%) of produce gets wasted as a result of long transit times, temperature fluctuations and contamination.	• AI-led predictive systems can result in predicting storage conditions and also come up with preventive measures to be taken to avoid stored food getting rotten. • The usage of robots and machines has resolved the challenge of labour availability for harvesting crops such as strawberries and tea, hence reducing the post-harvest losses.
7	Poor traceability of origin	• As produce moves through the supply chain, information on its origin and transit is lost. Buyers may need to ascertain the veracity of specific single-origin varieties of produce or to trace back the origin of produce in the event of food-safety risk or to make assertions about following sustainable production and sourcing practices. However, they are unable to do so due to the absence of traceability systems.	• Traceability of produce cultivated by farmers can be strengthened with technology via developing quality and quantity record systems which will stipulate the harvested produce, its transportation to market/destination, price, etc. All this information will be difficult to tamper with in the value chain. • Further, food safety is also catered to through a technology-based food traceability system as it can tackle contamination and avoid produce wastage right from the point of origin.
8	Limited market transparency	• Farmers, intermediaries and buyers find it difficult to locate and connect with each other. • Often, buyers resort to substandard and cost-ineffective supply centres to fulfil their demand, and farmers similarly settle for suboptimal pricing for their produce. • This limits farmer value capture and creates value-chain inefficiencies.	• AI helps in improving market access by creating digital connection platforms. • It also enhances the reach and quality of information related to quality, price and the availability of markets.

Thus, the key objectives of emerging technology interventions in agriculture include the following:

Pre-production	Production	Post production
• Improving productivity and efficiency through farm mechanisation and optimum utilisation of resources • Financial and digital inclusivity	• Facilitating input market linkages • Digitalising records through farm management • Precision agriculture enhancing yield by up to 30%	• Better connected farm-to-market supply chains • Safety and trust in food systems • Managing food wastage through digital enablement • Introducing quality management and traceability of storage and logistics infrastructure • Facilitating output market linkages

Real-time monitoring of environmental impact

Smart risk management of nature-related uncertainties

Thus, AI provides the opportunity to plug several pain points that exist across the agriculture sector's value chain, thereby expanding the market potential. Leveraging technology in India's agriculture sector can create opportunities for investment through modernising and introducing systemic efficiencies.

The table below details how AI can help achieve effective agriculture by contributing to critical areas.

AI-integrated practices in agriculture

Decision support	Marketplaces	Logistics & infrastructure	Financial services
Analytical support and software for farm operations	E-market platforms for inputs purchase and output sales	Digitised management for optimisation of farm produce to markets	Digitised credit and insurance services

Livestock solutions	Irrigation and water management	Robotics & automation
Traceability, increased yield, nutrition, disease and breeding management	Smart Irrigation with sensors and digitised scheduling	Satellite and weather data analytics optimization of resources

Source: PwC analysis

01 Farm management/field monitoring

- The digital checklist for agricultural farm management is an integrated platform to give decision makers access to information and tools to track daily activities on a farm. With this, farmers can get a better overview of their fields.
- Real-time video feeds help in identifying animal or human breaches in the farm. An alarm is sounded immediately, resulting in prevention of accidental crop destruction. This also helps in checking on break-ins or burglaries at remote farm locations.
- Technology for pest management as drone data using information from field sensors can be used to improve plant health by safeguarding from pests and diseases. Using infrared camera data from drones combined with sensors on fields that can monitor plants' relative health levels, pest infestations, etc.
- Digital farm management has grown remarkably worldwide at a CAGR of 9.9% (2020–2021). Field mapping, which results in enhanced accuracy in planting, spraying and harvesting schedules has seen the largest growth.

02 Yield monitoring and estimation

- AI and ML through real-time sensor data and visual analytics data from drones can enhance the efficacy of yield prediction.
- The technologies have also enabled utilising information through sensor data about various farm-related indicators to analyse the growth pattern of crops.
- Crop yields can be optimised using advice generated from combining massive data by ML.
- Through yield mapping technology, the potential yield rates of a field can be mapped before the start of a vegetation cycle.
- Potential soil yields can also be predicted using various ML technologies to evaluate mapping, conditioned data from sensors and drone-based data of soil features as colour.
- With accurate yields, farmers will be better equipped to get buyers for the harvested produce and reduce wastage, thereby enhancing income. Furthermore, yield monitoring technology will help farmers be informed about variety selection for next year and yield potential.

03 Data integration

- Data management software allows farmers to leverage data for different parameters such as soil, moisture and weather, for better decision making. The data can also be used in real time to fulfil need-based requirements such as knowing and changing the depth of sowing based on available moisture.
- It is important in the long term for the digital ecosystem of agriculture to consider aspects like data governance and data security along with interoperability and privacy of information.

04 Drone technology and aerial imaging

- Drones are autonomous aircraft that fly over a certain area.
- They are used for aerial imaging and better management of fields.
- Satellite imaging and drone technology allow farmers to see crop variations and issues that are hard to spot from the ground.
- The data used with precision agriculture technology helps farmers to enhance the profit of their operations through better farm management.

05 Price forecasting

- Price forecasting technologies for crops based on yield rates support in laying out an efficient pricing strategy for the total yield produced.
- Prior information regarding quality and the amount of produce improves the bargaining power for various government organisations and private firms as well as farmers to get better prices.
- It also helps in understanding the price elasticity curve for a given crop in consideration with the total demand, thus helping in formulation of pricing strategy.

06 Irrigation monitoring technologies/water management

- AI contributes to areas of finding irrigation leaks, optimising efficacy and measuring effectiveness.
- The optimal amount of water required for a particular crop to get optimal yield is calculated using the linear programming method.
- Supervised ML algorithms are ideal for ensuring that fields get enough water to optimise yields and minimise waste.

07 Livestock management

- **Livestock health monitoring techniques** include monitoring critical signs, food intake and activity level on a daily basis to ensure livestock health. This is one of the fastest-growing parameters of AI and ML in agriculture.
- It helps farmers understand dietary requirements, health and boarding conditions of the livestock.

08 AI- and ML-based technologies

- AI- and ML-based smart tractors, agribots and self-propelled robots are used for large-scale agricultural businesses. These technologies provide security around the entire perimeter of farms in remote locations and also distribute fertilisers on each row of crops, thereby optimising operating costs and ultimately improving yields.

These emerging technologies have the potential to enhance productivity and efficiency across all stages of the agricultural value chain, boosting farmers' incomes, increasing farm productivity while reducing waste, and enhancing supply-chain efficiency, transparency and sustainable resource use.

2. Analysing the AI landscape

Analysing the AI landscape

2.1. The AI landscape: Different actors and beneficiaries

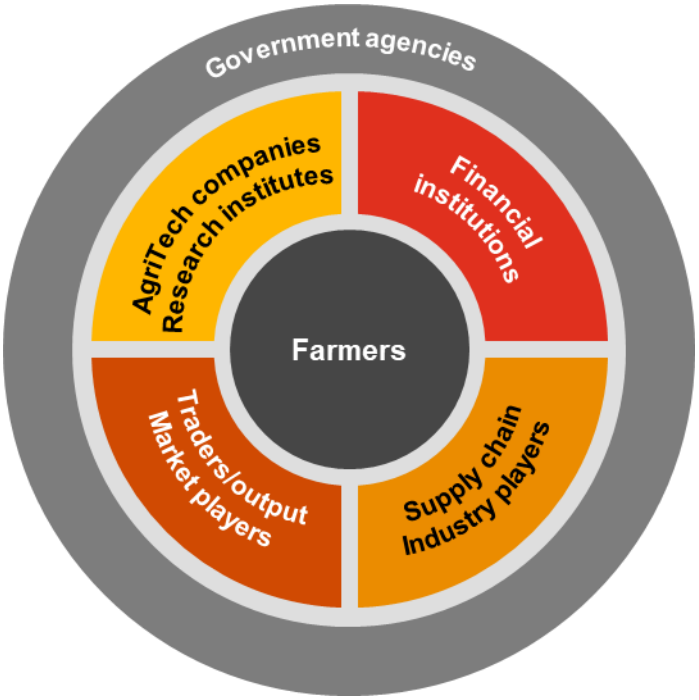
Technological transformation of agriculture systems requires a holistic approach, including the involvement and support of multiple stakeholders across the value chain. There are multiple internal and external factors that define the pace of adoption of AI-led innovative disruptions.

Across the value chain, technological innovations are impacting both producers/farmers as well as consumers. The farmer-centric approach positions the farmers as the fulcrum of all strategies and innovations, envisioning to enhance the income of the producers by adoption of these technologies.

On the other hand, the consumer approach aims to provide quality produce to the customers and the technologies are aligned towards automated quality management, traceability and market tools for appropriate the pricing of produce.

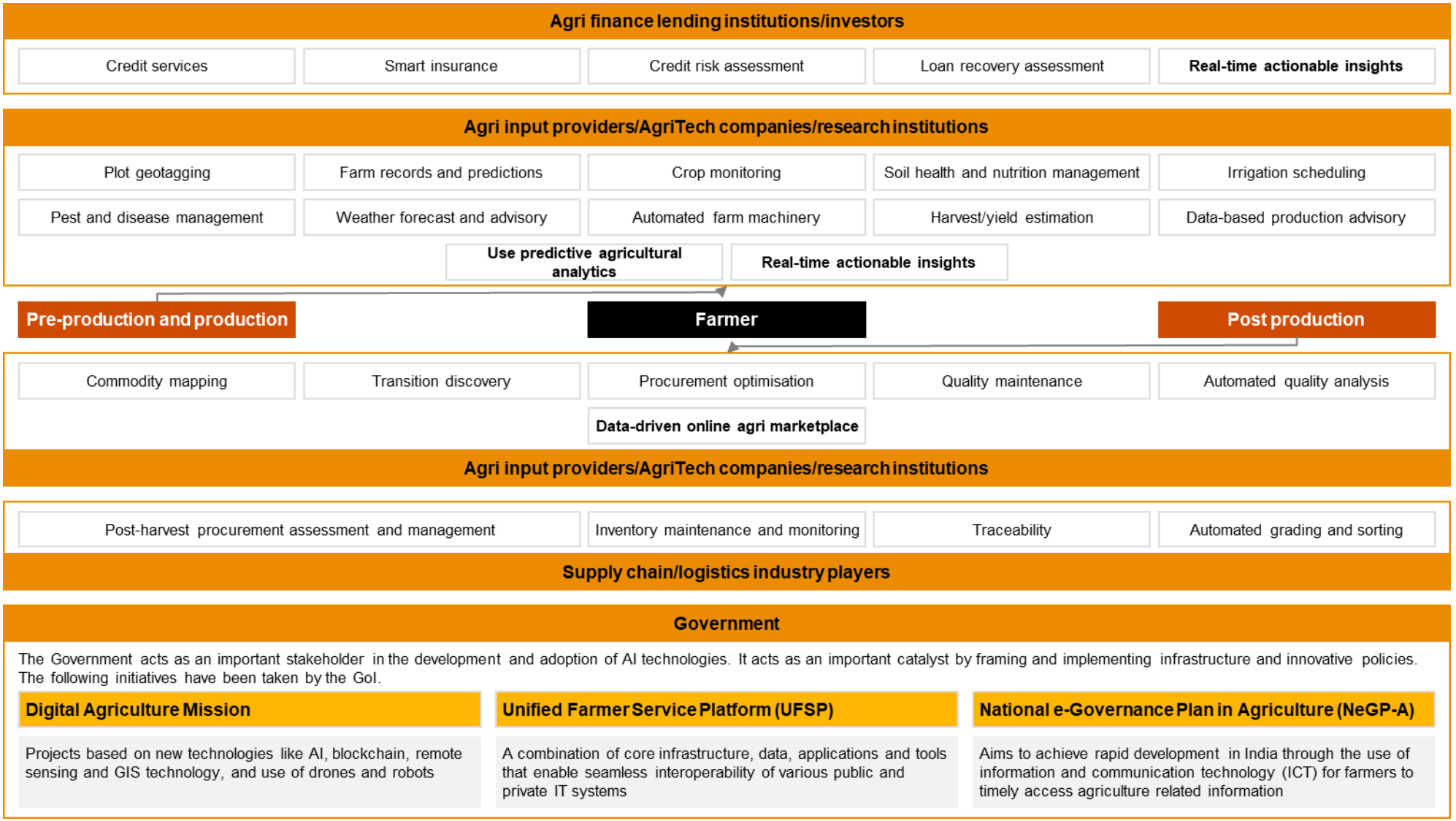
Major components for AI interventions

Farmer-centric components	Customer-centric components
• Optimum resource utilisation	• Quality products
• Quality production	• Enhanced accessibility of products
• Post-harvest management	• Traceability
• AI-integrated marketing platforms	• Fair pricing
• Automated price discovery	• Product conformance



The AI landscape presents a framework for all major stakeholders involved in the integration of technological innovation in agriculture. These include agri industries, start-ups, technology innovators, input and output industry players, supply chain actors and Government organisations which put farmers at the centre of adoption of these technologies.

The figure below depicts the AI landscape.

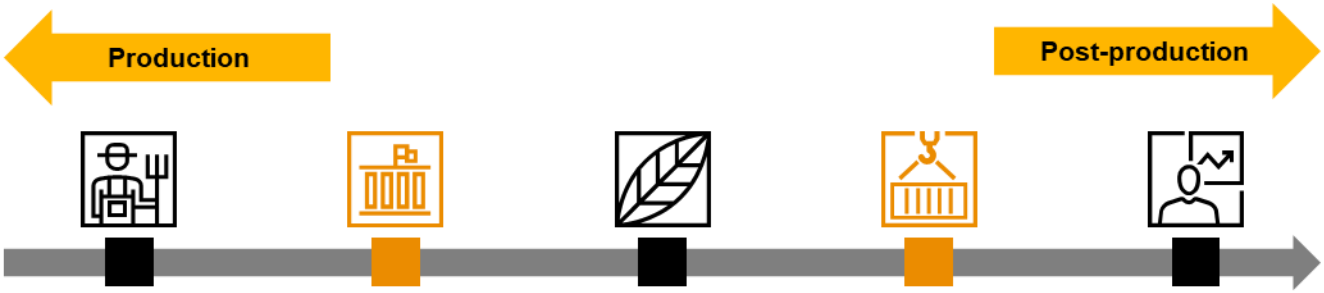


Source: PwC analysis

Role and involvement of stakeholders

AI-enabled technological interventions impact and benefit different stakeholders, from farmers to different agents operating across the value chain, such as input providers, AgriTech players, supply chain actors, traders and other marketers. These stakeholders use AI technology solutions for different operations, starting from on-time weather advisory for sowing to enhancing the quality of produce through traceability mapping to optimising the cost-effectiveness of the processes in the system.

Benefits of AI for different stakeholders across the agri value chain



Farmers	Agri finance LIs/investors	Input/AgriTech companies/ research institutions	Supply chain/logistics industry players	Traders/output market players
• Focused efforts for long-term sustainable farming through use of AI tools • Adoption and promotion of the used technologies • Need infrastructural, both physical and digital, as well as policy support for enhancing adoptability and scalability	• Enhanced access to credit services for farmers • Increased use of blockchain based automated crop insurance platforms • Use of blockchain-powered warehouse receipt finance	• Use of predictive analysis to enhance the efficacy of production • Informed advisory and decision backed by data and analysis by AI tools • Precision farming solutions and advisory services segment registered a growth of approximately 17% during FY 2020	• Enhancing supply chain operational efficacy by minimising storage and transition losses • Automated logistics and cloud-based storage facilities	• Transition discovery – real-time data analysis on multiple data-streams along with crowd-sourced data from producer/buyer marketplaces and transporters • AI-enabled digital market platforms for enhancing reach and profitability • Focus on product quality and traceability

Source: PwC analysis

Apart from these internal value chain stakeholders, the Government, funding organisations/incubators and capacity building organisations also play a major role in the integration of AI technologies by providing the required policy support, capital investment and skill building respectively for enhancing their application, scalability and sustainability for the overall benefit of the farming community.

2.2. Geographical and value chain spread of AIs – national and international

Geographical spread of AI in agriculture

Monitoring will be the highest revenue generating segment among IoT-based agriculture applications

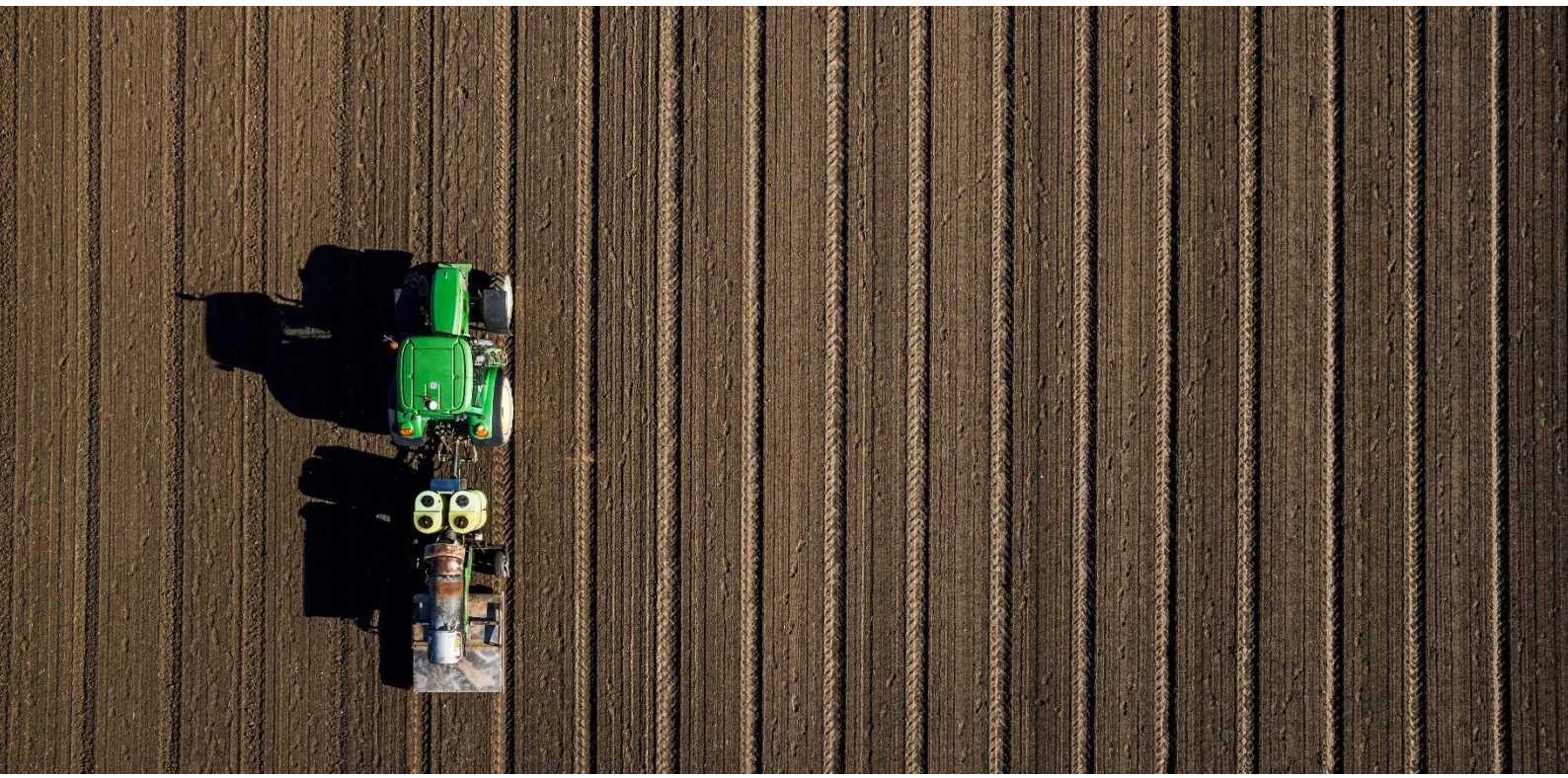
Precision farming is expected to witness the highest CAGR in the AI-in-agriculture market application

ML is expected to register the largest share in the technology domain in the AI-in-agriculture market

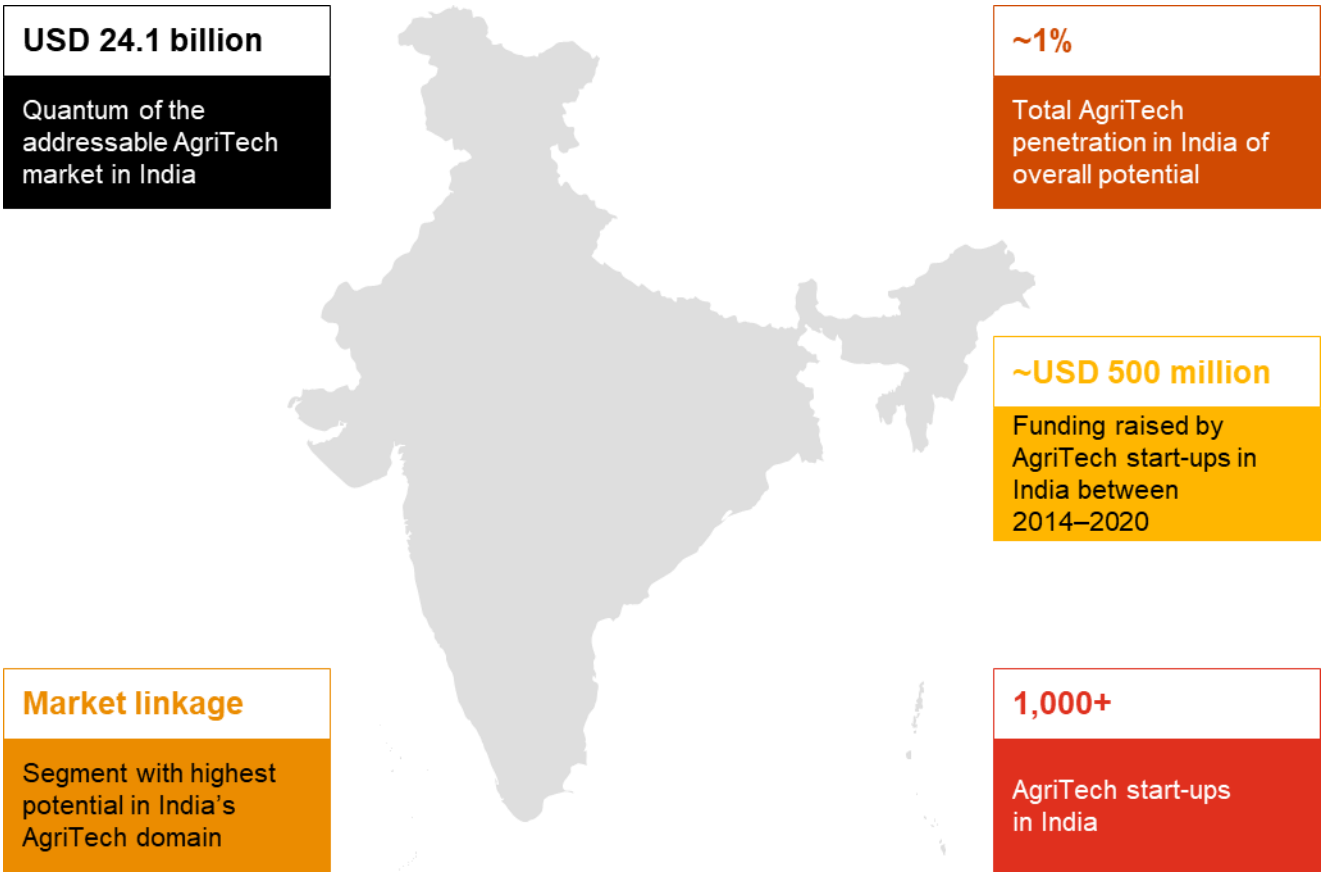
AI-as-a-service is projected to be the fastest growing segment by offering in the AI-in-agriculture market

Source: PwC analysis

AI was first attempted to be used in agriculture in 1985 and since then, the usage of such technology has come a long way. AI in agriculture is expected to be worth USD 4 billion worldwide by 2026.[26] The market for AI in agriculture is globally divided into six major regions – North America, Europe, Asia Pacific, the Middle East and Africa, and South America. Of these, North America has emerged as the largest market for AI in agriculture owing to early adoption of advanced technologies for different agricultural practices. Further, the largest civil funding programme on robotics was introduced by the European Union (EU) that prioritises agri-food as one of the four application areas for the robotics programme in Horizon 2020 (EU's research and innovation funding program with a budget of nearly EUR 80 billion). The EU has strongly focused on digitising the agriculture sector by implementing Internet of Food and Farm 2020 (IoF2020), DEMETER, Agricultural Interoperability and Analysis System (ATLAS) and SmartAgriHubs with an investment of EUR 80 million.[27] In recent years, Latin America and the Caribbean have witnessed an increase in technological innovation in the AgriTech domain across the food and agriculture sector. Countries like China and India are also increasingly adopting AI and ML in agriculture at a massive rate. In 2019, the Asia Pacific region stood next to North America in the AgriTech market with a revenue share of 29.68% which is expected to grow continuously owing to the ongoing technological revolution in the agri-food industry.



[26] https://www.marketsandmarkets.com/Market-Reports/ai-in-agriculture-market-159957009.html
[27] https://digital-strategy.ec.europa.eu/en/policies/future-farming



Source: PwC analysis

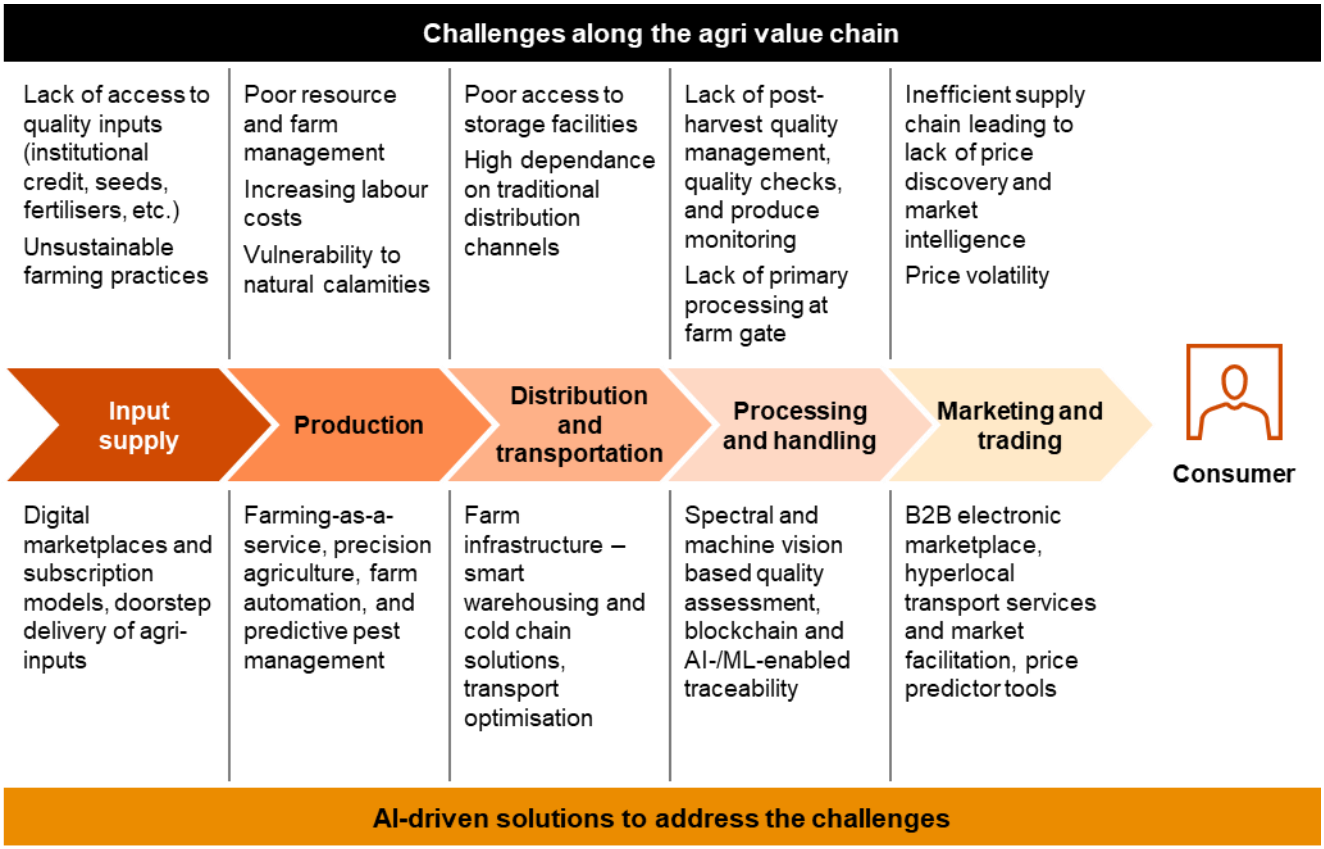
India's increasing population is leading to a rising demand for food production and has resulted in enhanced investment in the AgriTech sector. The country has registered a YoY increase of 87% in the total funding growth corresponding to increase in total deal value from USD 133 million in 2018 to USD 249 million in 2019.[28] In the last few years, the AgriTech sector has witnessed unprecedented growth along with rising interest from venture capital (VC) investors. In 2021, the number of upstream (pre-harvest) deals in the AgriFoodTech sector surpassed the downstream (post-harvest) deals. This momentum can be attributed to enhanced internet access, rising smartphone penetration, business-to-farmer (B2F) agri-input marketplaces, rural FinTech businesses, and farm-to-fork consumer brands. However, this dynamic ecosystem represents only a fraction of the Indian agriculture set-up and has reached less than 20% of the Indian farmers. Majority of the AgriTech models currently operational in India are supply-chain oriented and using such models is relatively easier for entrepreneurs and VC investors. However, due to the burgeoning emergence of a number of start-ups which are disrupting traditional methods of farming, the agriculture sector offers a lot of potential to develop and absorb deep technologies, including digital tech (sensors, IoT, blockchain, ML and image processing applications). In the coming years, this untapped segment is expected to grow and be adopted on a larger scale while overcoming innovation and early-adoption challenges.

[28] https://www.globenewswire.com/news-release/2021/04/16/2211431/28124/en/Global-Agritech-Market-Report-2021-Market-was-Valued-at-17-442-7-Million-in-2019-and-is-Projected-to-Reach-41-172-5-Million-by-2027.html

Value-chain spread of AI in agriculture

Recent technological advancements are reengineering both the upstream and downstream segments of the agri value chain. Cutting-edge technologies in AI such as IoT, ML, cloud computing, statistical computing, deep learning, VR and AR are enabling the sector to overcome the challenges of productivity, quality, traceability and carbon emissions while ensuring enhanced profitability.

Overview of value-chain spread of AI in agriculture



Source: Inc42 and PwC analysis

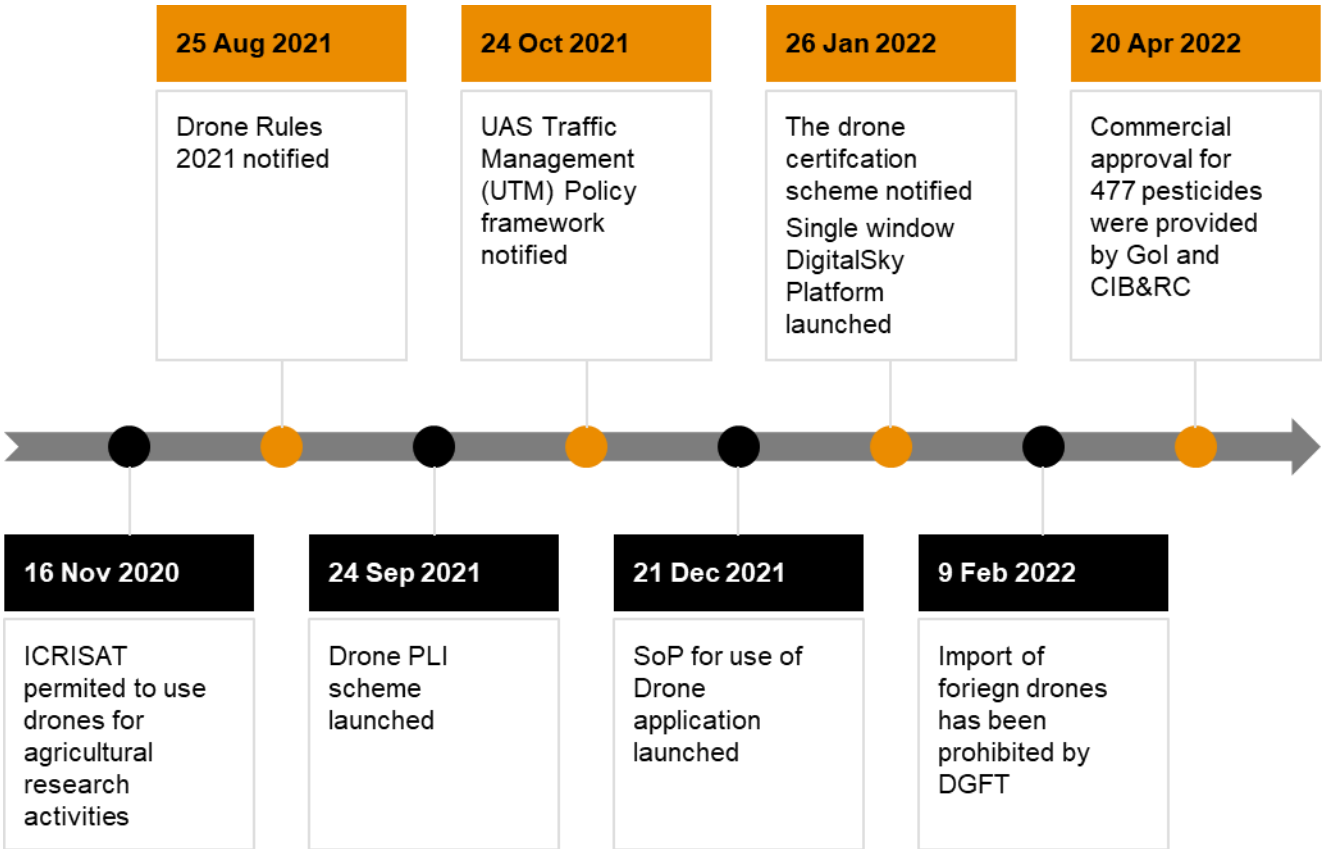
2.3. Drone technology: An enabler for agri services

Drones or unmanned aerial vehicles (UAVs), which were traditionally used mainly for surveillance, are creating solutions to manpower shortage in agriculture and also enabling judicious application of pesticides and fertilizers. The hon'ble PM of India launched 100 kisan drones to different parts of the country on 19 March 2022 and stated that drones are marking a new chapter in the direction of modern farming.[29] They can be used to provide accurate weather forecasts and secure and precise crop analytics (soil assessment, irrigation planning yield assessment and damage assessment).

Agri drones = Weather forecast + secure + AI-enabled + accessible + low-cost maintenance

2.3.1. Drone usage regulations by the Government

A National conference on "Promoting Kisan Drones: Issues, Challenges and the Way Ahead" was organised as part of Azadi Ka Amrit Mahotsav on 2 May 2022 by the Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmer Welfare, Government of India. The various initiatives taken by the Central Government towards promoting usage of drones in agriculture sector were shared during the conference. From November 2020 onwards, there has been considerable development in drone usage regulations. Following this, important announcements and notifications for the use of drones have been made and are highlighted below.



Source: PwC analysis

[29] https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202231124201.pdf

2.3.2. Drone technology and its application in agriculture

The multispectral imaging features of drones can help in crop stress monitoring, growth stage assessment of plants and yield prediction. Moreover, these drones can carry and spray fertilisers, herbicides and water over crops. Another application of drone technology includes the assessment of crop health by identifying weed growth, pests and infections, and suggesting appropriate and relevant use of chemicals to fight such infestations. Therefore, drone technology can enhance the efficiency and consistency of crop management, facilitating precision farming and reducing manpower requirement, making it a cost-effective practice. The features and application of drones are highlighted below**.**

Utility of agri drones

Soil, weather and field analysis: Drones may be used for efficient field planning, weather forecasts, evaluating terrain conditions, determining moisture and nutrient content and fertility of the soil.

Geofencing and crop monitoring: Thermal cameras present in drones can detect and guard fields from external damages. For effective crop and field surveillance, farmers can take active measures based on real-time information.

Plantation: Drones can help in planting trees and crops. This technology will save labour and fuel and help safeguard environment too.

Livestock management: By making use of sensors that have high-resolution infrared cameras, drones can help monitor and manage livestock. These cameras can also help detect a sick animal and swiftly take action accordingly.

Crop spraying: Drones have reservoirs that can be filled with fertilisers and pesticides for spraying on crops in considerably lesser time as compared to traditional methods.

Check crop health: Drones can monitor the soil and crop health with the help of infrared mapping.

Judicious use of chemicals: Drones detect signs of pest attacks and provide accurate data regarding the degree and range of the attack, thereby limiting the use of pesticides, insecticides and other chemicals.

Application of drones

1	**Analysing the area**	Establishing a boundary, analysis of the area, and then uploading the technical GPS information into the drone's navigation system
2	**Using autonomous drones**	Drones independently follows flight patterns into their already established system to collect required data
3	**Uploading the data**	Post data capturing through the multispectral sensor/RGB sensor, data is processed through software for further analysis and interpretation
4	**Output**	Post data collection, it is processed and formatted into a simple information outlay for farmers; 3D mapping is normally used to display the informative data

Source: PwC analysis

Challenges in using drone technology

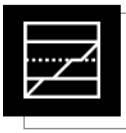
Adoption of drone technology in the agricultural sector has paved the way for precision farming. Many start-ups using drone technology are trying to increase the scale of operations and enhance technology standards and productivity at reasonable prices. However, the costs associated with drone technology (although cost effective in a larger perspective, farmers may find it expensive to buy the necessary technology), lack of trained manpower to operate drones and restrictive policies limit the application of this technology in our country.

Challenges to adoption of drones

Major challenges

High initial cost: Agriculture drones equipped with software, imaging sensors, hardware and tools cost nearly INR 10 lakh and above, and financing of the same from banks is a challenge for farmers.

Connectivity issue: Internet connectivity is required for smooth drone functioning, which becomes an additional recurring expense.



Data transfer speed: The data transfer speed of drones is slow. An extended delay can result in loss and damage.[30]

Weather dependent: Drones can only function during good weather conditions.[31]

Skill and digital literacy dependency: It can be difficult to operate and maintain a drone until correct knowledge and skills are acquired. Digital literacy is a must to operate drones. Farmers find themselves dependent on drone operators, which hinders the adoption of drone technology.[32]

Flight time and range: Kisan drones, with their high payloads, have a low flight time, ranging from 20–60 minutes. This limits the coverage area of the drones.

Misuse of drones: Drones can be misused to violate people's privacy and illegally transfer information.[33]

Safety concerns: In densely populated areas, drones pose a risk as system malfunctioning or hacking of the device can lead to ground impact and subsequent damage.

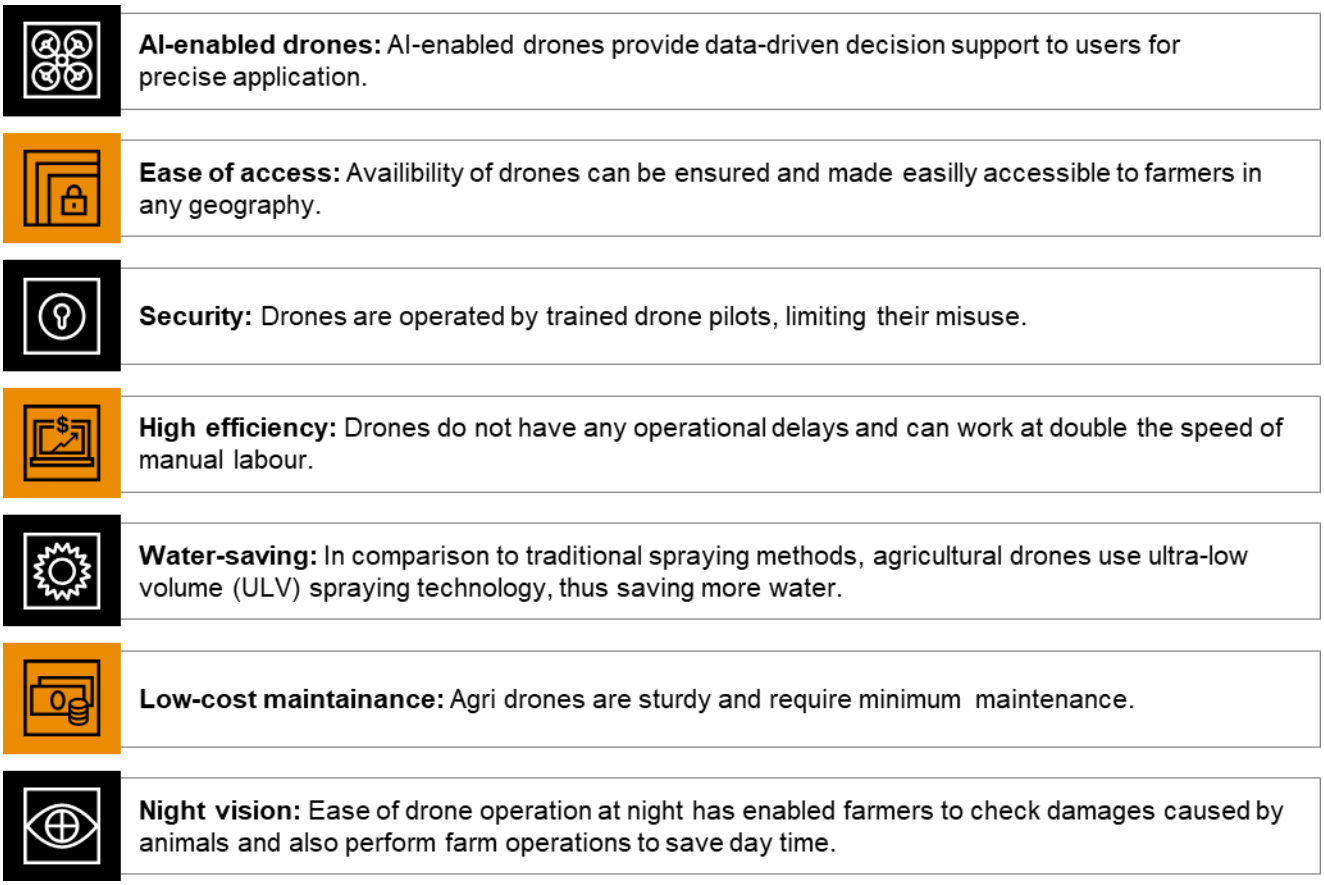
Vulnerable to attacks by animals/birds: An attack by animals or birds can damage drones.

30 https://www.equinoxsdrones.com/blog/10-major-pros-cons-of-unmanned-aerial-vehicle-uav-drones
31 https://tropogo.com/blogs/application-of-drones-in-agriculture-in-india
32 https://www.irjet.net/archives/V8/i5/IRJET-V8I5155.pdf
33 https://roboticsbiz.com/agricultural-drones-in-india-challenges-and-bottlenecks/

2.3.3. Scope for drones in the agri sector

Indian farmers now have options for improving efficiency of crop management systems with the use of farm automation, precision agriculture, customised weather, crop, farm, and marketing advisory, and other such advanced farming techniques. Drones are increasingly gaining popularity in agriculture, particularly for producing real-time field maps, monitoring the status of crops (including health and yield), evaluating germination, predicting agricultural productivity, assessing ploughing quality and monitoring the overall land environment.

Scope of drone applications



Source: PwC analysis

2.3.4. Future prospects

Five million tonnes of foodgrains need to be added to India's food basket each year to feed its growing population.[34] In this context, precision agriculture is proving to be a key enabler of crop management across the globe, and this trend is likely to play out in India too.

Since most farmers in India have small landholdings, the only way to increase productivity and production of foodgrains is through disruptive technologies. Drones are futuristic and transformative, and can play a crucial role in making farming more smart, productive and precise. A recent notification by the Directorate General of Foreign Trade (DGFT), which prohibits the import of foreign drones, will prove to be a boon for indigenous manufacturers. This will, in turn, create more employment opportunities for start-ups and the youth of the country. It is estimated that approximately 45 lakh employment in service sector[35] (18 lakh direct employment and 27 lakh indirect employment i.e., training, after sales, spares etc.) will be generated. A recent notification by DGFT prohibiting import of foreign drones will be a boon for indigenous manufacturers and approximately 50 lakh additional employment may be created by indigenous manufacturers.

[34] https://economictimes.indiatimes.com/news/economy/agriculture/who-will-pay-for-the-kisan-drone/articleshow/89530562.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

[35] https://farmech.dac.gov.in/revised/2023/Presentations%20for%204%205%202022/Session%202%20-6%20ANGRAU%20-Nat%20Conf.%20MoA%2002.05.2022%2010.00%20a.m..pptx

Union Budget 2022–23 laid emphasis on Kisan drones, including PPPs for high-tech farming services. FPOs, farmer cooperatives and other state-governed institutions are now eligible to access grants up to 75% of the cost of drone demonstrations, which involves demonstrating the drone technology usage in agricultural fields. Contingency expenditure of INR 6,000/ha has also been provisioned for hiring of drones for demonstration by implementing agencies.[36]

Several AgriTech companies and FPOs/farmer cooperatives are offering drones as a service to marginal farmers at significantly low costs. With the growth of the agricultural sector in India, it is expected that the use of drones in farming will also increase. This increase in adoption of drone technology can be attributed to the many start-ups that are investing in low-cost drones to provide support to farmers, enhance their knowledge and generate employment for the rural youth.

To get the maximum benefit out of drone technology in this sector, more mature transformations are required, taking into consideration the rising population, farmers' requirements, operational aspects, small landholdings, etc. The future will bring in more developed practices using drone technology and may result in more changes in the sector as a result.

According to a recent study, the global drone market within the agricultural sector would grow at a CAGR of 35.9% and be worth USD 5.7 billion by 2025.[37]

2.3.5. Success stories: Drone applications in India

Case 1: Pazhayannur in Thrissur, Kerala
Major challenge: The paddy farmers of **Pazhayannur in Thrissur** were facing the following problems: 1. low production of paddy 2. high cost of fertilisers 3. labour shortage.
Impact of drone application in a 50-acre paddy field
1. **Increase in yield:** Earlier, the production was limited to around 1–2 tonnes of paddy/acre; the use of drone technology increased it to 2.75–3 tonnes/acre. 2. **Efficient use of inputs**: Drones have resulted in reducing the water usage by 10 litres/acres, i.e. up to 80%, when compared to around 50 litres/acres previously. 3. **Less damage**: Manual spraying caused considerable damage to paddy plants at a large scale. The use of drones prevented such damage.[38]

[36] https://www.hindustantimes.com/india-news/modi-launches-100-agricultural-drones-across-the-country-101645294860662.html
[37] https://www.marketsandmarkets.com/Market-Reports/agriculture-drones-market-23709764.html
[38] https://theworldnews.net/in-news/drones-to-reboot-farming-activities

Case 2: Barabanki, Uttar Pradesh
Major challenge: Farmers were facing issues related to late blight identification.
Impact of drone application on potato and peppermint crops
1. **Efficient use of inputs:** An AgTech firm helped peppermint farmers to save nearly INR 3,620 per acre by making use of drones to apply agri inputs with precision. 2. **Increase in yield:** The productivity of peppermint oil increased from 50 kg/acre to 70 kg/acre. 3. **Preventive measures:** Potato farmers were able to diagnose major diseases like late blight as soon as they affected their plants and take preventive measures. 4. **Increased profits:** The judicious use of inputs provided by drone technology significantly increased the profit margin.[39]

2.4. Government interventions and intent

The GoI has been continuously formulating and implementing policies and schemes to promote digital transformation in agriculture with increased impetus to support the ecosystem players, including agri-based start-ups. Owing to the conducive ecosystem, AgriTech funding has gained substantial momentum with good investments despite the COVID-19 pandemic. The Government is also enabling an institutional ecosystem for AgriTech start-ups through incubators and accelerators. Some effective instances of these in India's AgriTech chain are presented below:

Sr. no.	Key Government incubators/accelerators for AgriTech in India[40]	Description
1	**AGRI UDAAN**	India's first food and agribusiness accelerator organised by NAARM, a-IDEA and IIM-A, CIIE in partnership with Caspian Impact Investment and supported by the Department of Science and Technology (GoI)
2	**Pusa Krishi**	An agriculture innovation hub nurturing agri start-ups and incubators under the Ministry of Agriculture and Farmers' Welfare (GoI) for the biggest agribusiness incubation scheme, RKVY-RAFTAAR
3	**Association for Innovation Development of Entrepreneurship in Agriculture (a-IDEA)**	A technology business incubator hosted by the National Academy of Agricultural Research Management (ICAR-NAARM), Hyderabad, and supported by the NSTEDB, DST & BIRAC, DBT of GoI
4	**Innovation Hub (iHub)**	An agribusiness incubator launched by ICRISAT and the Department of Science and Technology (GoI) to support agricultural tech entrepreneurs, scientists, and technology experts

[39] https://icar.org.in/file/9084/download?token=mroXPrVC
[40] https://www.researchgate.net/publication/334442335_Agritech_Startups_The_Ray_of_Hope_in_Indian_Agriculture

Sr. no.	Key Government incubators/accelerators for AgriTech in India[40]	Description
5	**AgriTech Startup Accelerator CIE, Hyderabad**	AgriTech start-up accelerator programme by IIIT Hyderabad and National Institute of Agricultural Extension Management (MANAGE) to identify, support and facilitate idea-stage enterprises using the latest technologies and innovations to solve agriculture-specific issues

The GoI, through its think-tank wing, NITI Aayog, laid down broad recommendations for nurturing the AI ecosystem in India, with the theme of 'AI for All'. In 2018, NITI Aayog released the National Strategy for Artificial Intelligence (NSAI) that identifies the key focus sectors for promoting AI: (i) promotion of research, (ii) skilling and reskilling of the workforce, (iii) facilitating the adoption of AI solutions and (iv) the development of guidelines for 'responsible AI'. Further, to design the blueprint for digital agriculture named the India Digital Ecosystem of Agriculture (IDEA), the Department of Agriculture, Cooperation and Farmers Welfare (DoAC&FW) constituted a task force and working group consisting of domain and technology experts in 2019. The IDEA architecture is derived from InDEA 2.0, an ongoing initiative of the Ministry of Electronics and IT to develop a set of reference architecture patterns for designing ecosystem architectures for various ministries and states. The IDEA architecture includes the core, common and reference building blocks relevant to the agricultural sector.[41] This initiative clearly demonstrates the GoI's vision towards elevating the Indian agricultural sector by leveraging cutting-edge technologies. In addition to devising strategies and policies, the GoI has introduced numerous digital and AI-enabled platforms for facilitating access to Government-sponsored interventions in the agricultural sector. A few such initiatives are highlighted below:

Sr. no.	Platform[42]	Description
1	**National Agricultural Market (eNAM)**	eNAM is a pan-India electronic trading portal supported by the GoI which networks the existing Agricultural Produce Market Committee (APMC) mandis to create a unified national market for agricultural commodities.
2	**mKisan**	Developed and maintained by the Ministry of Agriculture, this portal provides information, services and advisories, preferences related to agricultural practices, and locations to cultivators via SMS in their local language.
3	**Kisan Suvidha application**	An initiative of the National Informatics Centre (NIC), this app provides services and information relevant to farmers on a single platform, including various schemes and services of Central and state governments.
4	**Soil Health Card portal**	A web and smartphone-based application, designed and developed by the NIC, Ministry of Information and Technology (MeitY), it provides information on the nutrient status of various soils along with fertiliser dosage application in local units in 22 different languages and five dialects.

41 https://agricoop.nic.in/sites/default/files/IDEA%20Concept%20Paper_mod31052021_2.pdf
42 https://www.enam.gov.in/web/, https://www.meity.gov.in/writereaddata/files/MeitY_AR_English_2020-21.pdf

Sr. no.	Platform[42]	Description
5	**Kisan Rath**	A mobile-based app developed by NIC, MeitY, it enables farmers/traders to hire transporters for transporting agri produce. KisanRath is integrated with eNAM.
6	**Farm Machinery Solutions (FARMS)**	It is a mobile app for connecting farmers and custom hiring centres (CHC) owners with facilities such as renting agricultural machinery, booking custom hiring services, and selling and purchasing second-hand farm machinery and equipment.
7	**KisanMitr**	This is a national digital platform for farmers launched by the office of the Principal Scientific Advisor for providing insights and recommendations to farmers based on data from Government departments.

Need for disaggregated data

As the vital ingredient for driving digital intelligence, data is constantly in demand. However, data as a resource remains underdeveloped in India. To fuel AI-based agriculture advisory, there is a need for disaggregated data owing to the localised nature of the country's agricultural sector. Given the increasing use of sensors and other devices, there are several avenues where the data volume is expected to rise quickly. A generic categorisation of the different kinds of data generated by R&D agencies in operation in the agricultural sector would be as follows:

- **Scientific/experimental/survey/lab/field data:** All India Coordinated Research Project (AICRP) trial data, production and productivity; soil and water, diagnostic; animal health; fishing, etc.
- **Georeferenced data:** Weather data, remote-sensing imageries, etc.
- **Live-streamed images/data:** Sensors on fields and crops; GPS and sensor units on tractors/machines, UAVs or drones, radio frequency identification (RFID) based traceability systems; administrative data, agricultural farm records (revenue departments), subsidies, credit details (financial institutions), input supply and use (agribusiness industries), agriculture, livestock, fisheries census data
- **Socioeconomic data:** Commodity and market data, price and sales data
- **Social media/internet/Government schemes:** Extension services through social media, Government web portals – PM Kisan portal, direct benefit transfer, soil health card, crop insurance, Kisan credit card, Kisan call centres
- **Open Government data platform:** https://data.gov.in.

In view of the huge amount of data that is being generated across the agri value chain by a multitude of players and probable use case scenarios, the GoI has introduced many policies and guidelines regarding data management. However, accessing and sharing of data by the formal institutions handling the same is still at the basic level. In order to establish a digital ecosystem of agriculture, it is necessary to take a long-term view of aspects such as interoperability, data governance, data quality, data standards, security and privacy, apart from promoting open innovation.[43] There is a need for a single policy instrument that covers all these aspects and an architecture that formulates an enforcement mechanism to ensure that the principles are adopted across the board – by both the public and private sectors.

[43] https://agricoop.nic.in/sites/default/files/IDEA%20Concept%20Paper_mod31052021_2.pdf

Augmenting the existing data ecosystem

Augmenting the existing data ecosystem to drive AI in agriculture

Public sector

- A national data marketplace with checks and balances for data access and use
- Integration of agriculture reform and AI policy under 'AI for All' mandate
- Policies on upgrading extension services and training field personnel to implement public AI solutions at the farm level
- Formulating transparency frameworks for countering data-driven monopolisation

Private sector

- Development and implementation of scalable solutions
- Prolonged sustainability of IT solutions
- Customised application of AI/ML research tools and innovations
- Integration of support services across key functions
- Leveraging of international experience and converting R&D to on-ground implementation

Partnerships/collaborations

- Creation of open materials, tools and technologies and sharing of such tools with the ecosystem
- Promoting awareness, access and affordability of responsible AI knowledge materials, tools and technologies

Source: PwC analysis

3. Understanding the bottlenecks

Understanding the bottlenecks

In spite of the progress that has been made in creating and nurturing an AI-enabled ecosystem, the domain faces many issues and challenges that need to be addressed to facilitate a smooth transition from legacy systems to advanced machines and technologies that can augment human capabilities. Although AI application has witnessed an upward trend in India – outpacing that in countries like Japan, the UK and the US – it is still at a nascent stage in the country. This is especially the case in the agricultural sector owing to a multitude of bottlenecks posed by the sector. Some of these challenges are discussed below.

3.1. Innovation and technology aspects

1. **Limited pool of AI and sector expertise:** As an emerging technology, AI requires highly skilled and trained professionals. With the rising demand for AI-based systems, companies are hiring data scientists and analysts for various business needs. However, the demand for skilled experts far outstrips the supply. Globally there are less than 10,000 professionals with the necessary skills to tackle serious AI-related issues across all domains; this also makes hiring them highly competitive.[44]

2. **Existing gaps in the public AI research:** In India, the current R&D initiatives in AI are limited to a few institutions, such as the Indian Institutes of Technology (IITs), with a closely knit pool of 50 to 70 principal researchers, out of which very few are involved in agriculture-related AI innovations. Though India ranks third globally in bringing out research publications in AI, it trails behind world leaders such as China in terms of practical application.[45] Resource and administrative bottlenecks, siloed approaches to research in academia and inadequate computing infrastructure and lack of categorised and quality data are some of the challenges in AI research in India.

3. **Low data quality and lack of access to data:** AI-enabled technologies rely heavily on data to produce meaningful results. Thus, data quality is the cornerstone for the success of such solutions. Further, many datasets are disaggregated and not easily accessible. As a majority of agriculture data (e.g. on landholdings, research data, crop sown area and survey data) lies with the Central and state governments, many start-ups have to actively engage in creating data baselines and pools[46] for ensuring the efficacy of their systems. For instance, one of the AI-enabled start-ups operating in the agri-food domain engages a huge workforce to visit various locations and collect data by photographing commodities and feeding in this information through smartphones. As the development of complex AI solutions demands large volumes of highly diverse datasets, it will be difficult for small and mid-sized start-ups to scale up such resource-intensive efforts. Moreover, such efforts end up engaging critical resources that may otherwise be used for R&D purposes.

4. **Lack of coordination and cross-border collaboration:** Globally, AI technologies are being upgraded at a very fast pace. However, in the event of multiple regulations or a lack thereof, the transfer of such knowhow and/or technological resources to other geographies poses a challenge. To fill such innovation and technology gaps, it is important to leverage data sharing to support ML and responsible development, thereby facilitating collaboration with other nations and the development of innovative solutions. Moreover, AI is a capital-intensive undertaking, requiring hi-tech hardware devices and machinery, most of which is currently not available domestically. The existing policy imposes a high import duty on IoT devices, thus impeding research and innovation. Therefore, there is a need to establish policies and collaborations that will enable easy and incentivised procurement of IoT devices and relevant technologies.

[44] https://www.nytimes.com/2017/10/22/technology/artificial-intelligence-experts-salaries.html
[45] https://www.thehindu.com/sci-tech/science/india-ranks-third-in-research-on-artificial-intelligence/article26030596.ece
[46] https://www.researchgate.net/publication/344603754_Taking_Stock_of_Artificial_Intelligence_in_Indian_Agriculture

3.2. Adoption and application aspects

Considering the multifaceted application of AI in agriculture, it only seems logical to implement this technology across the agri value chain. However, there are several challenges related to adoption, application and scalability which need to be addressed in order to derive maximum benefits from this technology:

1. **Limitations in achieving scale:** The current industry trends suggest that a majority of the players and start-ups in the agri value chain are operating in the downstream or midstream segment for market linkages and value-added innovations. These segments include e-grocery/online retail and services like assaying and grading, optimisation of logistics, certification, and standards development, etc.,[47] and are present in controlled environments that offer assured returns. In contrast, the existing agriculture market is highly fragmented, and onboarding of farmers is highly resource intensive. Large corporations have an advantage over start-ups in the market due to their brand value. As a result, farmers are locked into a relationship of dependence and domestic innovation is hampered.

2. **Limitations of IoT devices:** In real agricultural environments as opposed to demonstrations in a contained environment, the devices installed to capture data for AI are exposed to a number of adverse conditions such as heavy rain, high humidity, extreme temperatures, strong winds and wildlife (rodents, birds, etc.) that can easily damage the electronic circuits or disrupt their normal functionality. To this end, it is imperative that the devices used in India are not only durable enough to withstand field conditions but also self-sustainable in order to work reliably for long periods without human intervention.

3. **Limitations of data annotation:** As quality of data plays a key role in AI technologies, it is important to have good datasets to help build an accurate learning and prediction system. However, the availability, standards, accessibility, security, sovereignty, quality, authenticity and disambiguation of agricultural data is a challenge that affects the applicability of AI systems. Further, because agriculture is a dynamic sector in terms of climate, crop specificity, etc., it requires quick actionable knowledge. This necessitates a system that is capable of coping with a large amount of data and functional across heterogenous devices. The AI devices used in agriculture need to be interconnected and interoperable across various data ownership platforms.

4. **Concerns related to data security and privacy:** The data resources on which AI technologies work are generated from a vast number of sources and often carry sensitive personal details. With increasing usage of AI-enabled technologies, threats like cyberattacks and data leaks may cause farmers serious problems. Further, the entry of large agribusiness corporates with extensive resources at their disposal may pose a threat to farmers' autonomy and impact their livelihoods.

5. **Lack of digital literacy:** As AI adoption in agriculture is still at a nascent stage, it is important to familiarise farmers with the relevant technologies in order to improve their output. In the absence of digital literacy, especially among small and marginal farmers, people are sceptical about technology adoption, thus hindering the scalability of such technologies. To trigger a gradual shift in the adoption behaviour of farmers, it is important to reduce information asymmetry with respect to AI systems and alleviate the trust issues and apprehensions of farmers by helping them develop their skills. Doing so will eventually lead to improved and sustained adoption of AI-enabled technologies in agriculture.

[47] https://www.researchgate.net/publication/344603754_Taking_Stock_of_Artificial_Intelligence_in_Indian_Agriculture

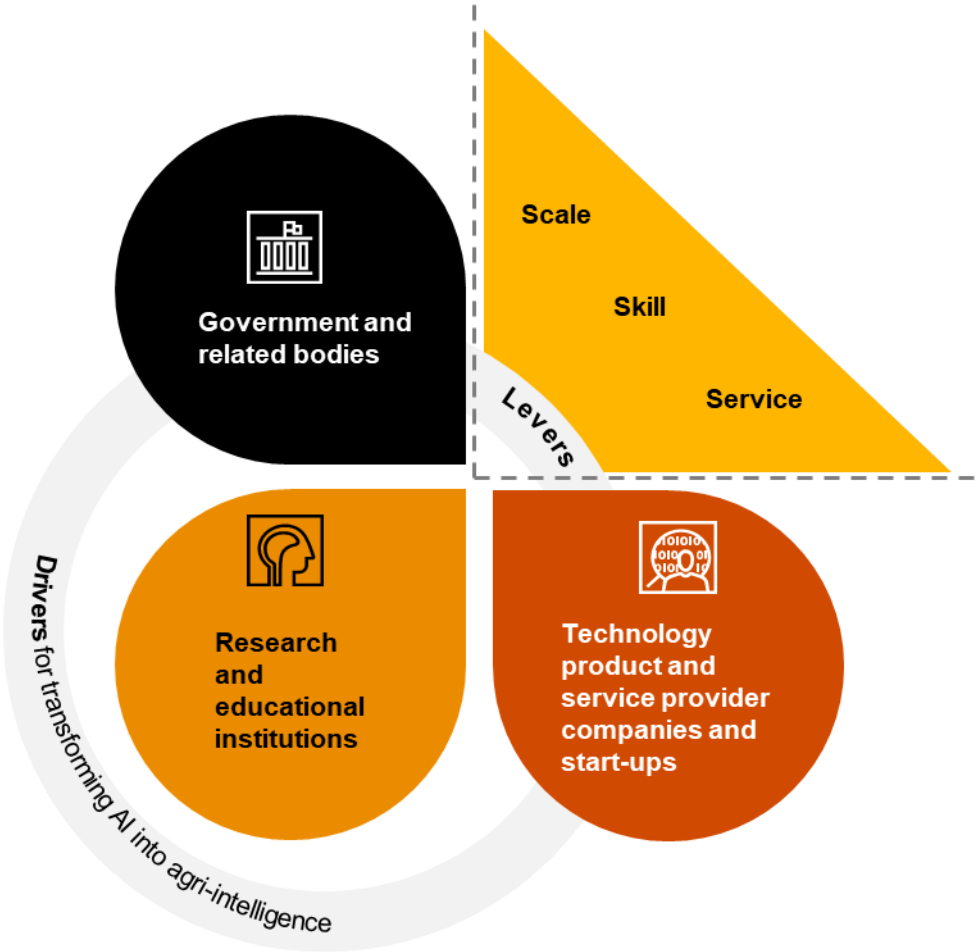
4. Transforming AI into agri intelligence

Transforming AI into agri intelligence

The entire AI ecosystem in India is moving at an accelerated pace with improved technologies and enhanced use cases. The current state is testimony to the ripening AI landscape in India, which will spur India's growth and enable it to become the AI hub of the world.

In the context of Indian agriculture, AI technologies need to sustain diverse and locally relevant practices that not only learn from local knowledge systems but also enable innovation along the entire value chain. As there are a multitude of actors in the agri value chain it is important to improve farm productivity and support farmers in making data-enabled decisions using AI. Therefore, for the agricultural sector to grow, there is a need for concerted efforts from all the key actors within the sector – the Government, technology product and service provider companies and start-ups, and research and educational institutions. We propose a **3S strategy** that uses the levers of **scale, skill and service** to transform AI into agri intelligence, leading to widespread adoption of the technology in the agri ecosystem through the collaborative efforts of key actors as drivers of change.

Commissioning the 3S strategy for transforming AI to agri-intelligence



Source: PwC analysis

Government and related bodies

Due to the scale of the Government programmes and initiatives, and heavy dependence on farmers for participation in the agri value chain – from input procurement to post-harvest management – it is extremely critical for Government agencies to undertake the promotion of AI-enabled technologies in agriculture. To this end, Government interventions must strengthen the AI-enabled agri-ecosystem by undertaking the following steps:

- **Regulatory interventions:** India's national AI strategy recognises that a 'one size fits all' approach to AI regulation is not practical, as the risks depend on the use cases and deployment context. A risk-based approach that evolves with time and encourages innovation while safeguarding consumers' interest must be used to regulate AI systems. Currently, there are no specific regulations on AI or ML in India; however, the existing IT acts and regulations are applicable across this domain. Therefore, there is a need for policies that enhance trustworthiness of AI and regulatory standards with checks and balances, as reflected in a NITI Aayog strategy report – National Strategy for Artificial Intelligence.[48] Further, it is crucial to ensure that AI systems are inclusive and non-regulatory. Therefore, laws and regulations that promote unbiased, dependable, open, safe and inclusive data sharing must be formulated for the integration and dissemination of data.

- **Policy interventions:** The Government needs to play a lead role while ensuring effective operationalisation of AI technologies and their application in agriculture. To do so, policy interventions are required in order to streamline procurement, promote accountable data sharing, build development and deployment frameworks for AI systems, and incentivise research and innovation along with cross-border collaborations to catalyse the exchange and adoption of frontier technologies. Additionally, by inviting PPPs and encouraging innovative localised solutions, the Government can create a conducive environment that fosters growth among Indian start-ups. A few such initiatives are being taken in this direction, one of which includes the development of a national 'AgriStack' in collaboration with private sector companies.

- **Awareness and capacity-building interventions:** As AI is a rapidly evolving domain, there is an urgent need for awareness and capacity building both within the Government agencies and among consumers. To address this, a focused training curriculum can be introduced in sector-specific educational institutions to create awareness on the need and capabilities of AI. This curriculum will help in overcoming trust issues, building practical expectations and staying abreast of global developments, while also promoting informed investments in the sector. Similarly, upskilling interventions with focused collaborations at the sector level can help in building marketable and adaptable skills, thereby reducing the threat of unemployment due to adoption of AI-enabled technologies.

Technology product and service provider companies and start-ups

India has a rich and diverse portfolio of AI efforts undertaken by the private sector. However, the interventions are mostly limited to the downstream segments of the agri value chain. The use of AI in the pre-harvest or production stages remains limited to sensors, RFID and other basic IoT devices, even though these stages require critical optimisation pertaining to soil, crop, nutrient and crop quality. To overcome this barrier, sporadic AI-enabled solutions need to be converted into integrated platforms. These platforms then must be deployed at scale such that the impact is measurable in real time and in the local context. Establishing sustained partnerships with agribusiness companies and tech giants may provide customised solutions through robust platforms at scale and with minimal risk. To address the rising concerns around ethical and responsible AI use cases and data monopolisation by big corporates, assigning accountability to a member of the leadership within the organisation will ensure compliance with standards and guidelines and alignment with the company strategy. As AI-enabled solutions have low provability and viability, AI has been labelled as a 'black box' as people are sceptical about its functioning. This is especially true in the case of small and marginal farmers who lack awareness about technology. Therefore, there is a growing need for organisations to build trust by making AI explainable, provable and transparent. Further, to overcome barriers to adoption, simple user-friendly systems need to be developed that equip farmers with the right balance of equipment, information and market access, thereby enabling higher profits. This calls for increased investment in low-cost, open-source cloud-based platform solutions that allow interoperability across various agri value chain platforms.

[48] https://www.niti.gov.in/sites/default/files/2021-02/Responsible-AI-22022021.pdf

Research and educational institutions

A strong research and development base for technology innovations is essential for building a strong AgriTech environment. In India, industry-university partnerships have been the usual norm for expanding the talent pool for enabling industrial growth and technological innovation. However, with an increasing number of AI-enabled technologies, the existing knowledge and awareness is spreading beyond R&D labs and research institutions. To fill the current skill gap in the sector, there is a need to revise the education curriculum and include a programme on AI and go beyond technology institutions for the increased sensitisation. Further, the vast network of agricultural universities and KVKs could play a key role in increasing access to the existing knowledge on AI in agriculture. Efforts need to be made to establish AgriTech innovation centres in the PPP mode for piloting and roll out AI-enabled innovative solutions. Moreover, the capacity of existing statistical agencies to collect and process AI-compatible publicly available data can be increased. To promote responsible AI, the existing ethical guidelines and enforcement structures for research in India could be augmented and extended to AI research in addition to clinical and biomedical research.

Possible impact

The implementation of the 3S strategy through the drivers detailed above could help in removing the bottlenecks across adoption, application, innovation and technology in the deployment of AI in the agri value chain. Policy, regulatory and awareness interventions by the Government could lead to the achievement of the required scale for wider adoption of AI in the agricultural sector. Further, interventions by product and service provisioning companies and start-ups are expected to have the maximum impact through the services lever. However, these will also have a medium-intensity impact via the scale and skill levers. Companies and start-ups are expected to positively affect skills as uptake of services and/or products will require awareness generation among the target population. There is also a growing need for start-ups to prove scalability in order to attract investors as well as create a market network. This will have a direct bearing on increased adoption. Research and educational institutions, through their updated curriculum and R&D, will lead to skill development and create a conducive ecosystem for technology advancement and adoption.

Drivers	Levers	Impact intensity	Impact areas
Government and related bodies	Scale	●	Enhanced adoption Improved innovation ecosystem Increased access to latest technologies Improved sector-specific application
	Skill	●	
	Service	◑	
Technology product and service provider companies and start-ups	Scale	◑	
	Skill	◑	
	Service	●	
Research and educational institutions	Scale	○	
	Skill	●	
	Service	○	
● **High**	◑ **Medium**	○ **Low**	

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