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Ushering in a new growth wave: From artificial intelligence to agricultural intelligence

pwc

FICCI





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Message from FICCI



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

Technological innovations will play a major role in shaping the future of Indian agriculture. India has witnessed rapid adoption of digital technologies in the last few years and has the second largest internet user base with almost 50% penetration presently. We have more rural internet users than urban users which signifies that the country's digital divide is narrowing fast. The National Strategy for Artificial Intelligence released by NITI Aayog in June 2018 identifies agriculture as one of the focus areas. The Government of India has recently announced landmark initiatives in the agriculture sector. Improvements at the grassroots level due to such enabling policy initiatives will certainly boost artificial intelligence (AI) and digital applications in agriculture.

The benefits of applying AI in the agriculture supply chain are immense with regard to enhancing value at each step through use of reliable and accurate information. Such information enables farmers to take informed decisions and plan their farming activities in a better way. Therefore, in a constantly changing world, stakeholders need to evolve their strategies to effectively use technology for designing customised solutions and build their ability to reach and serve small and marginal farmers in India who have landholdings of less than two hectares and account for about 85% of the Indian farming population. Key trends in AI, namely machine learning, deep learning and computer vision learning, will also provide tools to agribusinesses to support the development and delivery of timely and targeted information and services to make farming profitable.

Use of AI and digital technologies will spearhead the next transformation in agriculture. The benefits of applying of AI in the areas of weather, soil nutrients, pest and disease management, fertigation, market prices, finance and traceability cannot be overstated. Future farms would need such innovations that drive precision and have the potential to impact farmers' livelihood through optimal utilisation of resources and bring in better returns.

Indian agriculture will change a lot in the future. It's time to adopt new age solutions like AI to allow modern farmers to become more economically and environmentally sustainable.

Message from FICCI



Hemendra Mathur
Chairman, FICCI Task Force on Agri Start Ups, and Venture Partner, Bharat Innovation Fund

Digital agriculture has the potential to solve the multidimensional problems plaguing Indian agriculture. Digitisation will have a multiplier effect on improving farmers' access to markets, inputs, data, advisory, credit and insurance. Lack of timely and accurate data has been a major bottleneck in building a demand-driven efficient supply chain. The demand-supply imbalance and volatility in market prices of commodities due to climate change issues have further exposed the vulnerability of the agricultural supply chain.

The only way we can solve these challenges at scale is by capturing and synthesising data to enable decision making by farmers, agri-input/output/processing companies and other value chain players such as banks and insurance companies. Fortunately, access to a wide range of digital technologies has been facilitated in the last few years by numerous AgriTech start-ups. These technologies help track multiple data points along the value chain from pre harvest (input application, area under production, farm boundaries, farmer profile, soil health, hyperlocal weather, crop health, etc.) to post-harvest (quality, grades, traceability and losses, etc.) and all the way to the retail and export market. The data is captured through a combination of multiple devices such as sensors, IOT devices, smart phones, spectrometers, drones and satellite images.

Data-centric models are built on machine learning and artificial intelligence (AI) models, which can predict events such as weather events, pest attacks, harvest and crop yield in advance and with more accuracy. Many AI models also provide immediate, low-cost, affordable, portable and accurate solutions for 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 a disproportionate amount of effort and time on data collection rather than data modelling. We should attempt to build a public ecosystem of data repositories by collating existing data.

In sum, smallholder farming in India can benefit significantly through access to AI models which can help in improving farm economics through increased income, optimised input cost and de-risking through timely data intervention.

I would like to thank the FICCI and PwC teams for their efforts in bringing out India's first report on AI in agriculture and organising the 'International Conference on AI and Digital Applications in Agriculture'.

Message from FICCI



Dilip Chenoy
Secretary General
FICCI

There is growing pressure on agriculture to ensure food and nutritional security for the burgeoning population, which is expected to grow to 10 billion by 2050. Along with the many disruptive technologies being used to achieve this big ask, there has been increased application of artificial intelligence (AI) in agriculture to increase per unit productivity and drive efficiency and integration across the value chain.

Globally, AI applications in agriculture have reached a valuation of USD 852.2 million in 2019 and are expected to reach USD 8,379.5 million by 2030, growing at a CAGR of 24.8%. North America is the biggest market for AI applications in agriculture, while the Asia Pacific region is projected to be the fastest growing region over 2020–30, with a growth rate of 27%.

The Government of India and various other state governments are increasingly promoting usage of AI in agriculture. The National Strategy for Artificial Intelligence by NITI Aayog recognises agriculture as one of the priority sectors for implementation of AI-driven solutions. The Indian AgriTech market is presently valued at USD 204 million, which is estimated to be 1% of the currently addressable market opportunity of USD 24 billion.

AgriTech start-ups and tech giants are taking the lead in promoting usage of AI in Indian agriculture, especially around three major emerging themes – soil and crop health monitoring, predictive analysis and agribots. There has been active collaboration between the Central and state governments and agri start-ups and tech giants to pilot applications of AI in agriculture, establish proofs of concept, relay advisories to farmers and unlock additional value by building traceability.

Amongst a mix of many other strategies, a two-level approach is needed to unlock the true potential of AI application in agriculture. At the macro level, there is a need for creating a database of annotated images of various crops and the diseases that affect them, enhancing last-mile reach through better smartphone and internet connectivity, increasing interoperability of various databases and creating an AgriStack platform. On the other hand, at the micro level, there is a need to raise awareness about applications of AI in agriculture, provide training and demonstrations, and develop channels for dissemination of information (e.g. agripreneurs and FPOs).

We believe application of AI in agriculture will go a long way towards increasing farm productivity and help in enhancing farmer income levels in a sustainable way. We hope this report will encourage more discussion around policy and implementation solutions for promoting AI applications in the agriculture sector.

Message from German Agribusiness Alliance



Julia Harnal
Chairperson, German Agribusiness Alliance, and Vice President, Global Sustainability and Governmental Affairs Agricultural Solutions, BASF SE

Digital technologies and innovations hold enormous potential for the agricultural sector. Besides quality and efficiency gains, digital solutions can help to address a number of challenges in the sector. The environment can benefit from the promotion of sustainable agricultural practices, while the farming community can benefit from better technological and financial inclusion. The challenges of climate change, environmental impact, biological diversity, and value to society need to be urgently taken into account by the agriculture sector. Thus, farmers will increasingly need to supplement their own knowledge with digital technology tools in order to make realistic assessments. These tools will help farmers produce more with less resources (water, land and energy) and make data-driven decisions in real-time. In particular, AI-based products hold the potential to enable farmers to micromanage their crops through tailor-made advice – taking into consideration weather patterns, satellite images and data collected from sensors and cameras mounted on drones or tractors.

With accelerated use of digital technologies, open knowledge platforms and exchanges on best practices, there is an opportunity to scale up joint initiatives and knowledge transfer to support sustainable agriculture and good agronomic practices that are climate-smart and financially viable. Both India and Germany support research, development and deployment of digital solutions in order to drive innovation in the agricultural sector. We are convinced that successful development can only be achieved through close cooperation among all stakeholders – the Government, the private sector, and the research and farming community. The German agribusiness is committed to driving agricultural innovations that benefit farmers and the environment. The knowledge report and the conference on 'AI and digital applications in agriculture: Driving productivity, improving quality, preserving resources' are an important milestone. At the same time, they are a starting point for further Indo-German cooperation on digital innovations for agriculture in the future – to which I am very much looking forward!

Message from PwC



Ashok Varma
Partner and Leader,
Social Sector – GRID
PwC India

We are going through arguably the most difficult period in recent history as the current pandemic has disrupted lives worldwide. The pandemic has impacted India's economy and we are gradually working towards the country's economic revival and growth. Though several sectors such as manufacturing and services have been adversely impacted by the pandemic, the agriculture sector has remained resilient and buoyant, and even grew marginally despite the crisis.

For decades, ensuring food security for the country has been a focus for India's agriculture sector. In the last one decade or so, India has become the ninth-largest exporter of agricultural products and the total value of exported agricultural products **stood at USD 37.4 billion in 2019, accounting for approximately 12.6%**[1] of the total merchandise exports from India . We aspire to be one of the top five agricultural exporting countries in the next decade and simultaneously increase the incomes of farmers, and reduce agrarian distress which continues to be an area of concern for the country.

Relatively small landholdings, diverse soil conditions, the lack of private-sector investments, inadequate value adds, limited penetration of technology and mechanisation, and the lack of credible datasets have resulted in constrained growth and transformation of the sector.

Given this background, we are looking to embrace many innovative production technologies and enhance the sectoral growth using emerging digital technologies such as artificial intelligence (AI), robots and drones.

Emerging digital technologies have the capabilities to enable the development of new and more efficient business models, and ultimately make food systems more productive, sustainable, efficient, transparent and resilient. AI and digital applications in the agri value chain include potential technological interventions such as predictive analytics, data and platforms for price transparency, imaging and AI to monitor crop quality, product traceability, agribots and drones for cultivation/harvesting, crop and soil health monitoring, AI-based primary processing, smart warehouse management, livestock monitoring and management, and smart feeding solutions for fisheries.

In the last few years, there has been a significant increase in the number of technology start-ups working across the entire agriculture value chain in India. This transition can be attributed to the significant opportunity for digitisation that exists in the Indian agriculture landscape, with only 1% of the addressable market currently being tapped. In FY20, Indian agri-food tech start-ups raised USD 1.05 billion through 133 deals, registering a year-on-year growth of 6.4%[2]. Investment activity in India currently has been majorly dominated by supply chain and output market linkages. The future wave of investments is expected to be in core agriculture production value chains.

This knowledge report identifies the opportunities, enablers, trends and concerns in the adoption of digital technology and AI in Indian agriculture. Also, while proposing strategic interventions in this report, we have considered that these technologies need to be customised and adapted as per the specific operational issues such as smaller operational landholdings and the preponderance of small and marginal farmers.

1 http://agriexchange.apeda.gov.in/indexp/reportlist.aspx and PwC analysis
2 https://agfunder.com/research/india-2020-agrifood-startup-investment-report/



Industry messages

Infosys



Nitesh Bansal
SVP and Global Head of Engineering Services
Infosys



Rajeev Ranjan
SVP, Infosys
Board Member,
Infosys JV in Japan

A growing population, shrinking arable land, shortage of labour, increase in per capita consumption and diet pattern changes, rise in greenhouse gas emissions, need for sustainable agriculture practices and a robust agri-supply chain, and adulteration in food products are some of the key challenges in the food security and safety field today. While agricultural domain-specific advancements have addressed the concerns to some extent, digital technologies hold more promise. They are expected to establish an inclusive ecosystem for all stakeholders in the ecosystem.

For a farmer, there are over 40 critical farming activities that need informed decision making to ensure good yield and appropriate return on investment. Growers are challenged by insufficient quality agri-inputs, decision making on critical crop growth stages, produce marketing, weather unpredictability, role of different intermediaries such as commission agents, shortage of labour, loans, and insurance facilities.

Easier and quicker access to real-time data such as weather, crop characteristics, soil data, disease or pest data and telemetric data is a significant development. New and emerging technologies such as IoT, drones, mobility, cloud computing, big data, remote sensing, artificial intelligence, machine learning, image analytics and processing, blockchain, and agri-bots are another. Together, these two trends can transform traditional agriculture into data-driven precision farming for profitable and sustainable agriculture. Digital marketplaces similar to commodity exchanges, digital means of quality testing of fresh fruits and vegetables, produce aggregation analytics, smart weighbridges, and price discovery are critical aspects that can benefit from the use of technology.

The main factors fuelling the digital transformation are the availability of affordable hardware (sensor and other communication devices), farm equipment and integrated software to address of stakeholders' needs, adequate extension services to enhance technology adoption and trust, availability of master data, the willingness of agribusinesses to invest, strong support from universities and research institutes, and favourable government policies. In fact, growers, research institutes or universities, Government and AgTech companies must collaborate to accelerate innovations and adoption in digital agriculture. We also need to utilise domain-specific solutions from other parts of the world to develop solutions specific to Indian conditions.

The COVID-19 pandemic has accelerated the need to adopt relevant technological interventions to manage multiple aspects across the agricultural value chain. Digital farming promises increased farm productivity, optimum and sustainable use of time and resources, and better visibility of information.

Infosys is at the forefront of bringing digital interventions to the agricultural domain. We have partnered with agricultural universities to develop domain-intensive solutions. Using the latest IT technologies and research support, Infosys has built a cloud-hosted 'Infosys Smart Agriculture' platform to enable precision and sustainable farming. The platform enables market connect, digital 'mandis', and contract farming operations aligned with the Government of India's reforms. The smart warehouse features of the platform aim to minimise post-harvest losses and optimise the storage cost of grains. We have helped agri-enterprises to develop domain-intensive solutions such as crop scouting using remote sensing, yield projections, variable rate application, disease identification, a digital procurement platform, and food traceability.

Husqvarna India Products Private Limited



Rajesh Raghavan
Managing Director and Country Manager India
Husqvarna India Products Private Limited

There is no doubt that agriculture is the backbone of India and remains critical for the livelihood of more than 50% of the population. With India witnessing and contributing to an increasing number of technological advancements, it is only natural to bring them together for benefit of this core sector.

It is extremely important to improve crop yields and get better farming results through sustainable ways. As a game changer in other industries, artificial intelligence (AI) is even more significant in both the supply and demand aspects of agriculture. AI and allied digital applications can contribute to sustainable and profitable farming through systems that help in precision farming – right from crop selection to monitoring, and from trade of agricultural products to allied farm mechanisation. Given our commitment to our customers and society in general, Husqvarna Group has been innovating over the last 331 years of its existence. Also sometimes referred to as the world's oldest start-up, we have constantly researched and utilised new technologies to give back to society.

Husqvarna's in-house AiLab has looked into multiple AI-driven concepts and use cases to come up with new business models and offerings to challenge the group towards future proofing and readiness. A few areas of Husqvarna's expertise are machine learning, deep learning, vision systems, audio learnings, natural language processing and generation, nano technology, quantum computing, remote sensing, sensor fusion, hyper-personalisation, etc.

Husqvarna is and has worked on various technologies such as Husqvarna Urban Green Space Index (HUGSI), Green Data Insights and Infrastructure Vegetation Management. These technologies apply satellite data with deep learning techniques on a large scale; capture green data through multiple sources, convert data into valuable insights to understand how to manage vegetation in the most efficient way and reach your goals using less resources; and assesses data to plan vegetation management with greatly improved accuracy and efficiency.

These technologies may be useful to gain insights and are helpful in identifying types of crops grown, to measure and compare growth, to analyse the need for fertilisers and irrigation for crops, to identify diseases and enable precision farming – all of which will help in implementing overall best practices for farming. We invite all different parties for collaboration with the group on various technologies, use cases and business models going forward. We believe there is huge potential for AI to revolutionise agriculture in the days to come.

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Global challenges, local solutions.

The future of farming is in our hands. And it's digital.



Parvathy Chandrasekhar
Commercial Manager India,
xarvio™ Digital Farming Solutions



Dr Puran Mal
Senior Agronomy Specialist, xarvio™ SCOUTING, BASF Digital Farming GmbH

Many of the global farming challenges 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 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 it stands, demand for foodgrains in India is expected to increase by 80% in 2030, compared to the year 2000, according to a report by the Indian Council of Agricultural Research.

In this context, one of the main objectives of Prime Minister Narendra Modi's Digital India campaign is to provide farmers with improved and timely access to greater levels agricultural information. This is to help address key issues of low crop productivity and profitability, given the current yield rates of a mere 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 at 15–25% each year.

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 Indian Central Government's strategic reforms, which aim to double farmers' income from USD 1,481 to USD 2,962 by 2022, work to boost private investments in the agriculture sector to support farmers. It is also great to see technological advancements being leveraged by AgroTech companies in different farming sectors – from supply chain through to finance, farm data and analytics. Digital farm management solutions for risk mitigation, specific crop advisories and delivering agricultural inputs have risen to become a segment with huge opportunities. The increasing penetration of smartphones has enabled such players to trigger increased farm productivity through precision agriculture while decreasing production costs, which has huge implications for sustainability.

Though the future looks bright and promising for new digital agricultural business to bloom 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, the low technological adoption rate in rural India calls for digital business to organise their go-to-market strategies in a different set-up compared to urban India. Strategic partnerships that can deliver solutions to the farmers as a complete package, in comparison to 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 agribusiness, not just for companies but more importantly for billions of Indian consumers who look forward to food being produced in a healthy, environmentally responsible and sustainable manner.

Bayer Crop Science, India



Munish Soni
Head – Strategy & Digital
Crop Science Division of Bayer for India, Bangladesh and Sri Lanka

The agriculture and food sectors are facing multiple challenges. With the increase in global population, there will be a significant increase in the demand for food. The availability of natural resources such as fresh water and productive arable land is becoming increasingly constrained. The demand and supply scenarios will change considerably post COVID-19 and will provide a great opportunity to India.

The agri sector remains critical for livelihoods and employment. It is very important to increase crop productivity and farm income for sustainable agriculture and farmer livelihood. Awareness and adoption of modern agri technologies can help achieve this objective. Technology can also make Indian agriculture more resilient as the capacity to predict various events will improve and farmers can be prepared to take care of these eventualities. With advancements in digital technologies, farmers can be provided with solutions which are relevant for their land and optimise all agri operations.

Digital innovations and technologies may solve some of the problems which Indian agriculture has been grappling with. Disruptive digital technologies such as blockchain, internet of things, artificial intelligence, remote sensing, imaging technologies and drones for precision spraying and imaging can transform Indian agriculture. The spread of mobile technologies can help reach millions of farmers, which was earlier not possible as physical outreach was not cost-effective. This is the prime reason why extension services remained accessible to a small set of farmers.

Digital can also integrate smallholder farmers with smaller tradable quantities. Digital platforms can be leveraged to supply quality inputs to farmers, provide them a customised, real-time and data-driven decision support system, marketplace for their finance and mechanisation, and meet their produce-selling requirements. Digital technologies can also help farmers optimise their input usage and manage aspects like residue management and food certification. It will not only reduce their cost but also improve marketability of their produce.

A lot of start-up capital, both financial as well as intellectual, is being invested in digital agriculture. The need of the hour is customising these solutions for smallholder farmers, developing effective and scalable go-to-market models, and handholding farmers to put these technologies into practice. Once they experience these technologies and see the benefits, the adoption rates will increase significantly.

Corteva Agriscience



Dr Aruna Rachakonda
Marketing Director–
South Asia
Corteva Agriscience

The Government of India has a vision of doubling farmers' income by 2022. For realising this vision, increasing the efficiencies of the agriculture supply chain, enhancing agricultural production and modernising farming techniques are very important. Digital agriculture is emerging as one of the most efficient ways to create smart agriculture supply chains in India and globally.

By applying smart digital solutions, farmers can better monitor their crops, and enhance the scope of raising their farm incomes. By use of AI and digital technologies, farmers can also take informed decisions and implement the best practices in their field. However, the small farm sizes of less than a hectare and given the fact that more than 70% percent of farmers being small and marginal in India, scaling digital agriculture innovations in country will be challenging. Thus, for such solutions to succeed in our country, the focus should be on customisation and creating low-cost technologies affordable by the majority.

Dhanuka Agritech



R.G. Agarwal
Group Chairman
Dhanuka Agritech Ltd.

Artificial intelligence (AI) and digital applications have a huge role to play in improving ground-level issues of farmers. One important sector where such technologies can play a big role is disease control and pest management.

India is still at a nascent stage as the use of pesticides/ha of crop is 300 g, which is one of the lowest in the world as compared to other countries such as the USA (5–7kg), Japan (12 kg), China (13 kg), Taiwan and Vietnam. The 37th Standing committee of the Ministry of Chemicals and Fertilizers in 2002 estimated crop losses of INR 90,000 crore in India. Application of digital technology can certainly empower farmers, reduce crop losses and help the country achieve the vision of doubling farmers' income and transforming India into a USD 5 trillion economy.

While pest control cannot be completely automated, technology can certainly help. AI has huge potential in agriculture and can be applied to make pest control safer, quicker and more cost-efficient for farmers through the use of drones. The high-definition cameras on drones can help in detecting threats as small as a single insect. This technology enables farmers to catch issues early and stop the spread before it becomes an epidemic.

We are making all possible efforts to connect to maximum farmers through FPOs by adopting digital technologies. We understand that extension services by use of modern technologies will be the most impactful tool to empower farmers with knowledge. It's time to unleash the full potential of AI and digital technologies for Indian agriculture. Towards this end, we have also invested in farmer-centric IT-based endeavours, which are helping farmer communities as a large number of farmers use smartphones.

Olam



Shanoj Chandroth
VP – Head of Digital Technology and Innovations
Olam Information Services Ltd.

Artificial intelligence (AI) in agriculture is helping farmers to improve their efficiency and reduce the negative impact on the environment. The agriculture industry strongly and openly embraced AI into its practices to make a big impact in agriculture. AI is shifting the way our food is produced and has helped in reducing agricultural sector's emissions by 20%.

Digitalisation and breakthrough technologies such as apps, big data, image-based analytics, connected devices, field sensors, and the internet of things are being used to reimagine ways of working for farmers and customers. AI-driven solutions are leveraged to rapidly estimate the count and weight of different types of cocoa beans and classify coffee cherries to accelerate the quality assessment process at buying stations. In addition, a dedicated solution has been developed to detect diseases in the chilli crop which can be extended to other crops. Our AI solutions runs on a mobile app. Once an image is clicked and submitted, the deep learning algorithm qualifies the diseases and provides a response about the nature of the disease and its remedy.

Olam has been on the forefront of using technology based on AI and satellite imagery for improving the farming and procurement practices in various places. We are clearly aware that digital technologies will create opportunities for new ways of doing business. Through digital transformations, we aim to create a sustainable impact on stakeholders – including farmers, suppliers, customers and employees.

Disclaimer:
The messages from industry players included in this report are personal opinions of the industry experts

Executive summary





Executive summary

The agriculture sector accounts for 16.5% of India's gross domestic product (GDP). The value of agriculture and allied activities rose to INR 27.56 lakh crore in FY19 from INR 20.93 lakh crore in FY15.[1] In FY19, India was the ninth-largest exporter of agricultural products and the total value of exported agricultural products **stood at USD 37.4 billion, accounting for approximately 12.6%** of the total merchandise exports from India.[2]

Although self-sufficiency and food security continue to be critical components of the sector due to the increasing population and rapid urbanisation, there is also a focus on increasing farmer profitability, especially through enabling ecosystem and government initiatives. In addition, it is important to keep pace with the global food and agriculture trends that call for inclusion of emerging technologies, research and development, and innovation.

While India's agriculture sector has been acclimatising to the changing economic and market conditions steadily, there is a need to set the agenda for the next level of growth and transformation. On the one hand, the sector is being driven by factors such as a growing population and increased demand for agriculture and food products, an enhanced focus on doubling farmers' income and a growing aspiration to become a major agri exporter at the global level. On the other hand, the overall ecosystem is being constrained by certain systemic challenges which are leading to reduced resource use efficiency and farm incomes. Small and fragmented landholdings, lower yield compared to global benchmarks, uncertainties and risks involved in traditional farming (e.g. instinct-based decision making) are some of the challenges faced by the agriculture sector.

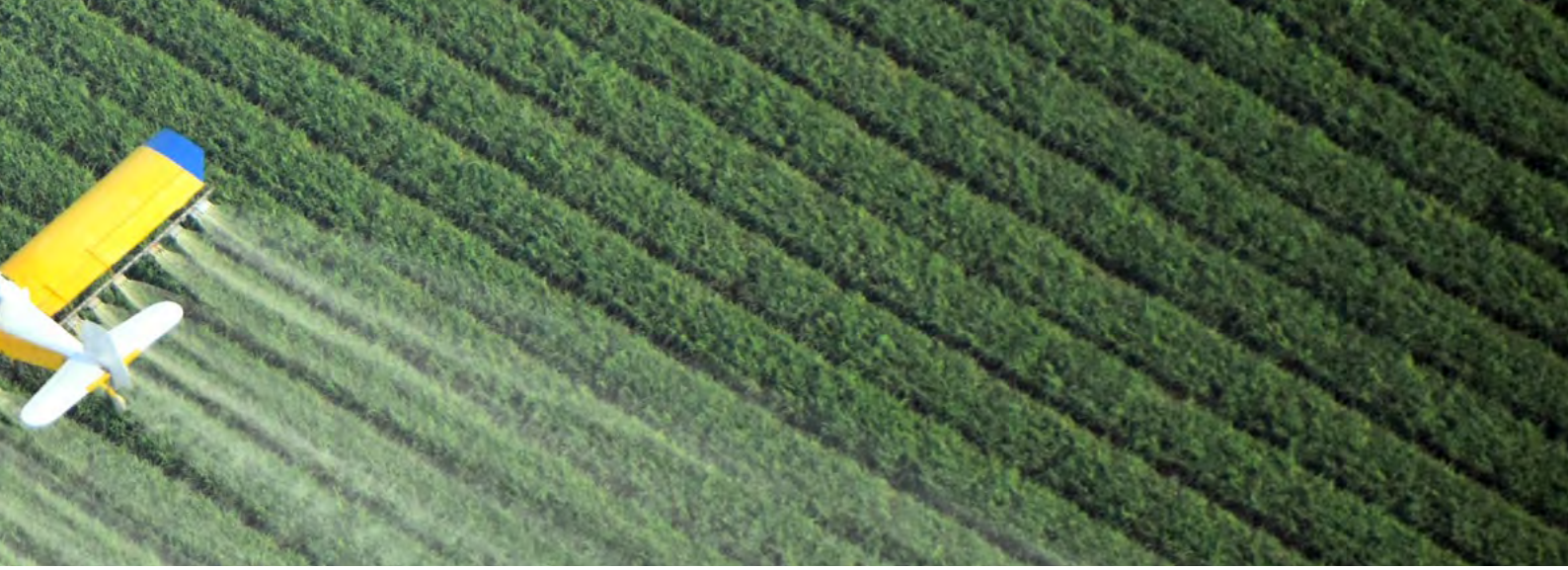
Given the complexity of the sector, digital technology could play an important role in optimising resource-use efficiency and reducing labour cost, thereby resulting in improved farm incomes. Digital solutions such as artificial intelligence (AI) have the potential to help the sector achieve its dual goals of raising the incomes for smallholder farmers and strengthening the sector's competitiveness through data-driven decision making. An industry estimate suggests that digital farming and connected farm services can impact 70 million Indian farmers, adding approximately USD 9 billion to farmer incomes in 2020.[3]

Tech enablement, along with increased connectivity at the farm level through precision techniques, usage of AI and cloud computing for crop and soil monitoring, predictive pest infestation analysis, agri robotics and smart supply chain solutions, etc., will help drive efficiency and value addition across the agricultural value chain. With the increased emphasis on Agriculture 4.0 and 5.0, avenues for the integration of digital, AI and related applications have been identified across the agricultural value chain – from pre-production to retailing or marketing.

AI could be useful across several areas such as agri-predictive analytics and machine learning (ML), data and platforms for price transparency, imaging to monitor crop quality, traceability solutions, agribots and drones for cultivation/harvesting, crop and soil health monitoring, AI-based primary processing, smart warehouse management, livestock monitoring and management, and smart feeding solutions for the fisheries sector.

In India, the applications of AI, cloud computing and related technologies in various agricultural activities across multiple stages of the agri value chain are at a very nascent stage. Currently,

1 Central Statistics Office, Ministry of Statistics and Programme Implementation, Govt. of India
2 https://pib.gov.in/PressReleasePage.aspx?PRID=1650021
3 http://employmentnews.gov.in/newemp/MoreContentNew.aspx?n=Editorial&k=30225



the market size of agri tech, including AI-based agri innovation start-ups in India, is estimated to be worth USD 204 million. This is approximately 1% of the currently addressable market opportunity worth USD 24 billion.[4]

A number of existing and upcoming agri-based start-ups are using AI-based innovations, thereby disrupting the traditional methods of farming. These organisations are using methods such as precision farming, equipment rentals, supply chain aggregation and cloud-based analytics for decision making. In FY20, Indian agri-food and AgTech start-ups have raised USD 1.05 billion[5] through 133 deals, registering a year-on-year (YoY) growth of 6.4%. **Investment activity in India is primarily dominated by supply chain and output market linkage AgTech**.

The rapid adoption of digital technologies in the last one-and-a-half decade can be attributed to internet penetration, the availability of affordable data services, proliferation of feature phones as well as budget smartphones and the rise of innovative digital services. Internet users in India are spread across urban and rural areas. In 2019, the number of users in urban and rural areas stood at 205 and 227 million respectively, with the number of internet users in rural India growing at 18% per annum.[6] These are promising numbers to drive AI in agriculture. The Central Government, as well as the state governments, have been driving AI adoption in agriculture through different polices and schemes.

AI needs to be customised and adapted to the Indian agriculture sector's operational issues such as lower operational landholdings and preponderance of small and marginal farmers to unleash its true potential. It must also find ways to tackle the longer gestation period and existing digital divide in the farming community. A few robust and systemic steps are required to strengthen the implementation of AI in Indian agriculture.

The most important requirement of implementing large-scale AI solutions in the Indian agriculture sector is to build an AI-enabling infrastructure by developing a country-specific super platform to address information asymmetry. This will lead to AI being used at its highest capacity for effective, accessible and affordable solutions. The next key solution is capacity building and upskilling the agrarian community on digital technologies and AI. Effective collaboration and linkages amongst the public and private sectors can catalyse the usage of AI for farmers. It is also important to implement an effective dissemination strategy for farmers. For implementing solutions which are socially embedded and disruptive in nature, direct business-to-farmer channel is ideal. AgTech companies or tech giants can enable business firms to transact directly with farmers. Such solutions in the current Indian context may include advisory services that farmers can receive on their mobile phones via messages. On the other hand, for solutions which will not be affordable to single farmers or require technical expertise, there would be a need for intermediaries such as channel partners, which may include Farmer Producer Organisations (FPOs) and AI entrepreneurs.

A synthesis between AI technology and the social and policy dimensions of the Indian agriculture sector will help in socially embedding this enabler and realising the sector's full potential.

4 https://government.economictimes.indiatimes.com/news/technology/indias-agriculture-technology-can-grow-to-24-1-billion-in-5-years-report/77971911
5 https://agfunder.com/research/india-2020-agrifood-startup-investment-report/
6 https://cms.iamai.in/Content/ResearchPapers/2286f4d7-424f-4bde-be88-6415fe5021d5.pdf

01

Agenda for the next level of agriculture growth and transformation

Indian agriculture: Current status and enablers

With a contribution of **16.5% to India's GDP**,[7] agriculture plays a crucial role in the economy, largely because of the employment opportunities the sector provides and food security it guarantees to 1.3 billion Indians. The value of agriculture and allied activities rose to **INR 27.56 lakh crore in FY19 from INR 20.93 lakh crore in FY15**.[8] In FY19, India was the **ninth-largest exporter of agricultural products in the world and the export value of agricultural goods stood at USD 37.4 billion, accounting for approximately 12.6%** of the total merchandise exports from India. Despite the COVID-19 pandemic, agriculture and allied activities continued to perform well and the sector's contribution to the country's GDP was much better compared to that of others.The sector registered a growth rate of **3.4% at constant prices in the first quarter of FY21, as compared to 3% during the same period in FY20**.[9] The key enabling features of the Indian agriculture ecosystem are presented below:

Prominent position in global agriculture

India is the largest producer of spices, pulses, milk, tea, cashew and jute, and the second-largest producer of wheat, rice, fruits and vegetables, sugarcane, cotton and oilseed. It has the world's largest livestock population of approximately **512 million**. Currently, India is the world's fourth-largest producer of agrochemicals.

Rise in agriculture exports

India has witnessed extraordinary growth in farm output which has helped it transform itself from an import-dependent nation to a self-sufficient one. As a result, the contribution of agriculture exports has increased from 8.5% in FY10 to 12.6% in FY19, with external demand from regions such as the Middle East and Australia.[10]

Record foodgrain production

As per the second advance estimates for 2019–20, the total foodgrain production in the country is estimated to be at a record **291.95 million11 metric tonnes (MT), which is higher by 6.74 million MT** compared to the foodgrain production of 285.21 million MT achieved during 2018–19.

Farm mechanisation[12]

India is one of the largest manufacturers of farm equipment such as tractors, harvesters and tillers. India accounts for nearly **one-third** of the overall global tractor production. But farm mechanisation in India remains low at about **40%**, compared to about **60% in China** and approximately **75% in Brazil**.

Favourable policy environment

With an enhanced focus on the **Jan-Dhan, Aadhar and Mobile (JAM)** trinity and the Direct Benefit Transfer (DBT) scheme implemented through the **Pradhan Mantri Kisan Samman Nidhi Yojana (PM-Kisan)**, the Government of India (GoI) is committed to promoting digitalisation in agriculture while ensuring an effective and faster subsidy distribution mechanism. Digital agriculture is also an important theme under the yield enhancement and technology and innovations component of NITI Aayog's 'Doubling Farmers' Income by 2022' policy.

Recent policy reform announcements on removal of stock limits through the Essential Commodities (Amendment) Ordinance, 2020, liberalisation of the sale of produce across the country, and formalisation of contract farming are expected to provide a stimulus to the sector by encouraging private sector investments and help achieve the Government's aim of doubling farmers' income by 2022. Such enabling policy reforms are expected to encourage the private sector and technology providers to bring in new technology and transform the entire sector.

In addition to the enabling features of Indian agriculture, there are a few sectoral drivers and constraints that are shaping the overall ecosystem and leading to a paradigm shift in the agriculture sector. Indian agriculture has been acclimatising to the changing economic and market conditions, thereby enabling the development of new business models and making food systems more productive, sustainable, efficient, inclusive, transparent and resilient.

The following key imperatives are driving the transformation agenda for Indian agriculture.

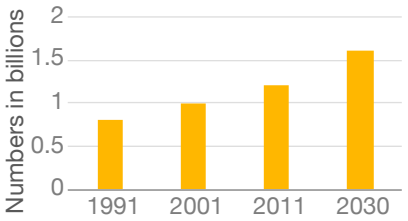
7 https://pib.gov.in/PressReleasePage.aspx?PRID=1601252
8 Central Statistics Office, Ministry of Statistics and Programme Implementation, Govt. of India
9 https://pib.gov.in/PressReleasePage.aspx?PRID=1650021
10 http://agriexchange.apeda.gov.in/indexp/reportlist.aspx and PwC analysis
11 http://agricoop.nic.in/sites/default/files/pocketbook_0.pdf
12 http://ficci.in/spdocument/23154/Online_Farm-mechanization-ficci.pdf

Factors driving sectoral transformations

1. Growing population and rising demand for agricultural and food products

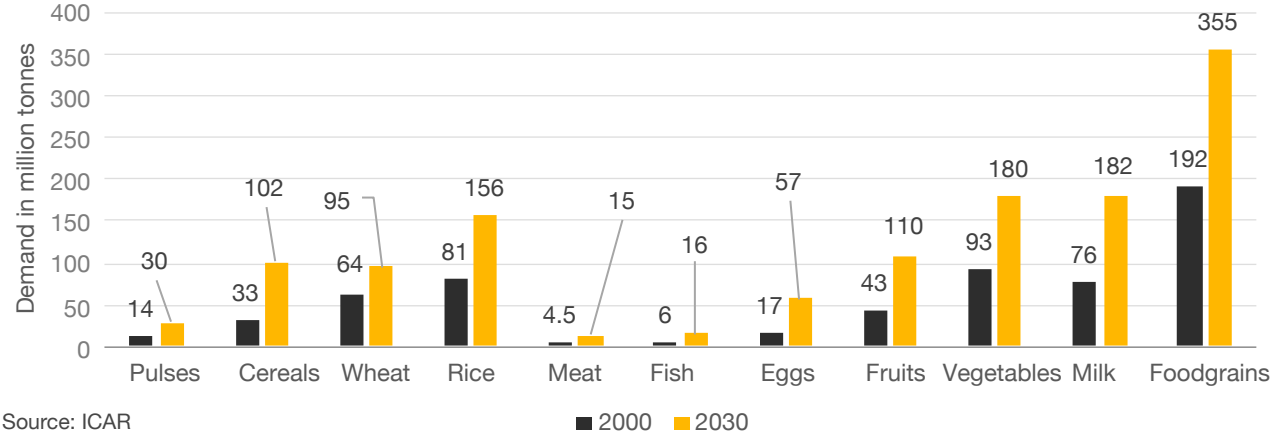
India is the second-most populous country in the world and accounts for **18%** of the global population. India is expected to surpass China's population by 2027.[13] While the population of India is forecasted to grow at a CAGR of 2% from FY00 to FY30, the demand for key food grains will see a corresponding increase at a CAGR of 3%. **As per estimates by the Indian Council for Agricultural Research (ICAR), the demand for foodgrains would increase from 192 million tonnes in 2000 to 345 million tonnes in 2030.**[14]

India's population trend



Source: United Nations

Demand for key foodgrains in 2030



Source: ICAR

2. Focus on doubling farmers' income

In India, the issue of low agricultural productivity vis-à-vis global benchmarks is a result of multiple challenges in the agricultural value chain, including small and scattered landholdings, lack of assured irrigation facilities, institutional credit, tenancy issues, inadequate food processing and supply chain infrastructure, and low availability and adoption of technology.

Doubling Farmers' Income[15] is the flagship programme of the GoI, which aims to double the income of farmers by 2022 while creating an optimum remunerative agricultural value chain ecosystem for farmers. As per All India Rural Financial Inclusion Survey (NAFIS)[16] conducted by the National Bank for Agriculture and Rural Development (NABARD) in 2015-16, the average agricultural household income was INR 8,931 per month in 2016–17, which is a mere 39% increase from 2013. These figures highlight the need for reforms. It is estimated that that for farmers' income to double between 2015–16 and 2022–23, the annual growth rate would need to be 10.41%. The following areas have been identified to accelerate growth:

- improvement in productivity
- resource use efficiency or savings on cost of production
- increasing cropping intensity
- diversification towards high-value crops
- increasing in farmer income through non-farm occupations linked to the agriculture and allied sectors
- improvement in terms of trade for farmers and better price realisation.

13 UN's department of Economic and social affairs (UN – DESA), 2018
14 https://icar.org.in/files/ICAR-Vision-2030.pdf
15 Doubling Farmers' Income: NITI Aayog
16 https://www.nabard.org/PressReleases-article.aspx?id=25&cid=554&NID=43

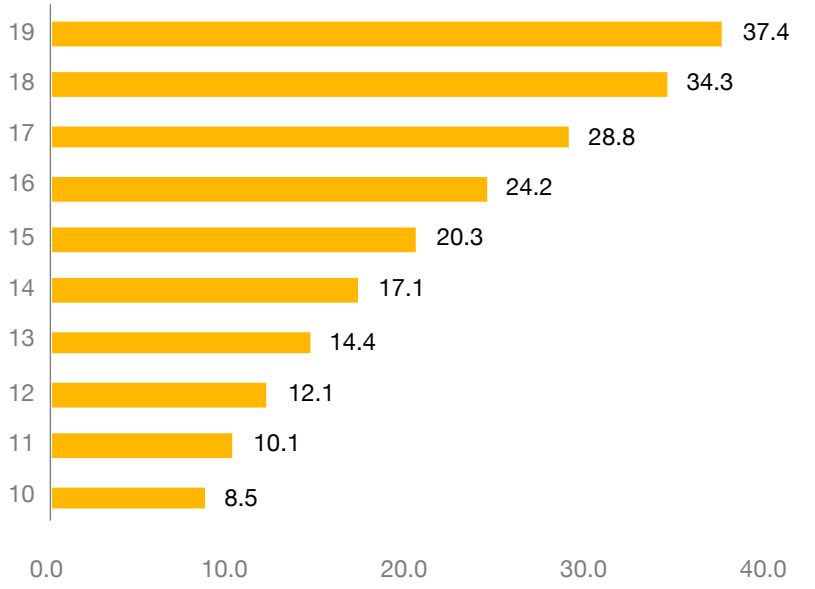
3. Aspiration to become a major exporter of agricultural and allied products

India is among the 15 leading exporters of agricultural products in the world. **Total agricultural exports from India grew at a CAGR of 17.86% over FY10–19 to reach USD 37.4 billion in FY19.**[17]

As per the Draft Agriculture Export Policy, 2018, the GoI is aiming to increase India's agricultural export valuation to **USD 60 billion by 2022.**[18] Marine products, buffalo meat and rice are India's largest agricultural export items in terms of value. Spices, cotton, oil products, tea and coffee are some of the other major agricultural export items.

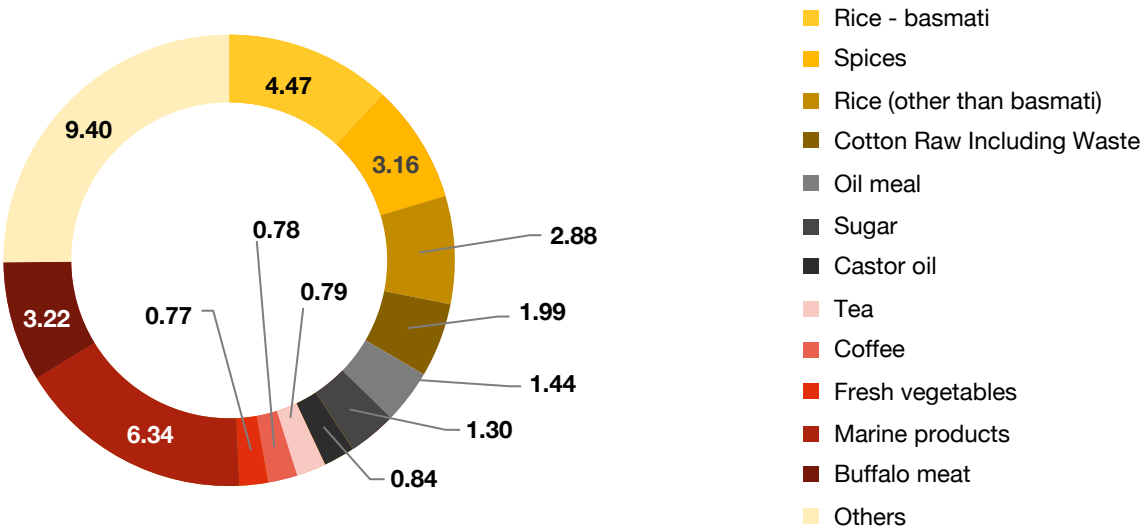
India can increase its share of agricultural exports, especially to European markets, by reducing sanitary and phytosanitary (SPS) rejections and improving the traceability of supply chains. **Digitisation and technology** interventions can play transformative roles in streamlining the export supply chains and unlocking growth potential.

Trend in agricultural exports from India (in USD billion)



Source: Ministry of Commerce, World Trade Organization, Union Budget 2016, Agricultural and Processed Food Products Export Development Authority (APEDA) and PwC analysis of Indian exports

Key agricultural and allied sector exports from India in FY19 (in USD billion)



Source: Ministry of Agriculture and Farmers' Welfare, and APEDA

The three factors discussed above – increasing population and rising demand for agricultural and food products, focus on doubling farmers' income and boosting exports – have created the conditions for a large technology-led transformation in agriculture.

17 Economic Survey of India 2019-20; Farm mechanization: Ensuring a sustainable rise in farm productivity and income, FICCI 2019; PwC analysis

18 Farm mechanization: Ensuring a sustainable rise in farm productivity and income, FICCI 2019

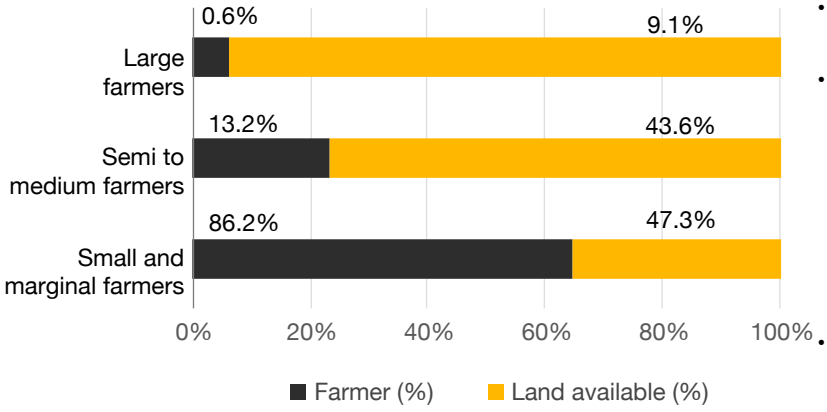
Some of the key constraints impeding the growth and transformation of the sector are discussed below.

Key constraints limiting the true potential

Identifying and addressing the challenges outlined in this section will be critical for realising the growth potential of Indian agriculture.

Small and fragmented landholdings

Farmer categories based on landholdings



Source: Industry estimates and PwC analysis of agricultural landholdings in India

- The average landholding size in India is 1.08 hectares (ha).
- About 86.2% of the country's farmers are small and marginal who cultivate 47.3% of the country's arable land. 13.2% are semi-medium farmers cultivating 43.6% of the land while the rest 9.1% of the land is being cultivated by 0.9% of the farmers who belong to the large category.
- Fragmented landholdings result in **poor bargaining power and reduced price realisation** of agri produce. Farmers are unable to benefit from the economies of scale which hampers the adoption of new technologies and practices.

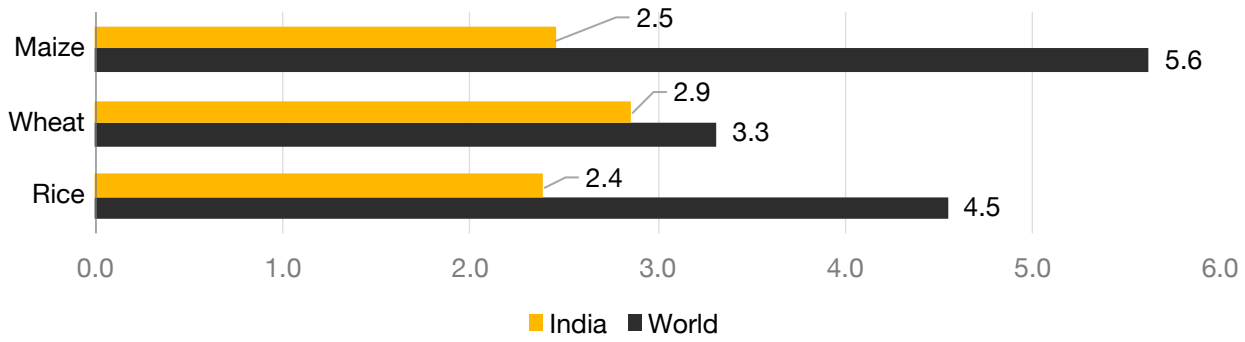


Lower yield as compared to global benchmarks

Since its independence in 1947, India has come a long way in terms of increasing agricultural production and productivity. But there is still a huge gap between India's agricultural productivity and global benchmarks.

Despite the high levels of production, agricultural yield in India is lower than that of other large agri-producing countries.

Comparative analysis of major foodgrains produced in FY 2016–17 (India vs global) in terms of yield (tonnes per hectare)



Crop	Area (in million ha)			Production (in million tonnes)			Yield (in tonnes/ha)		
	Global	India	Contribution (%)	Global	India	Contribution (%)	Global	India	Ratio (India/global)
Rice	163	44.5	**27.3**	741	106.5	**14.4**	4.5	2.4	**0.53**
Wheat	220	30.4	**13.8**	729	87	**11.9**	3.3	2.9	**0.88**
Maize	185	10.2	**5.5**	1040	25	**2.4**	5.6	2.5	**0.45**
	568	85.1	**15.0**	2510	218.5	**8.7**			

Source: USDA FAS and PwC analysis of agricultural production and productivity

- Although, India assumes significant importance in terms of acreage of key foodgrains, productivity is low. The contribution percentage of key foodgrains in acreage terms is 15%, but the production contribution is only 8.7 %.
- Rice and maize yields in India are about one-half of the global yield.
- There is considerable scope for increasing productivity in Indian agriculture through improved production technologies.

Uncertainties and risks in traditional farming practices

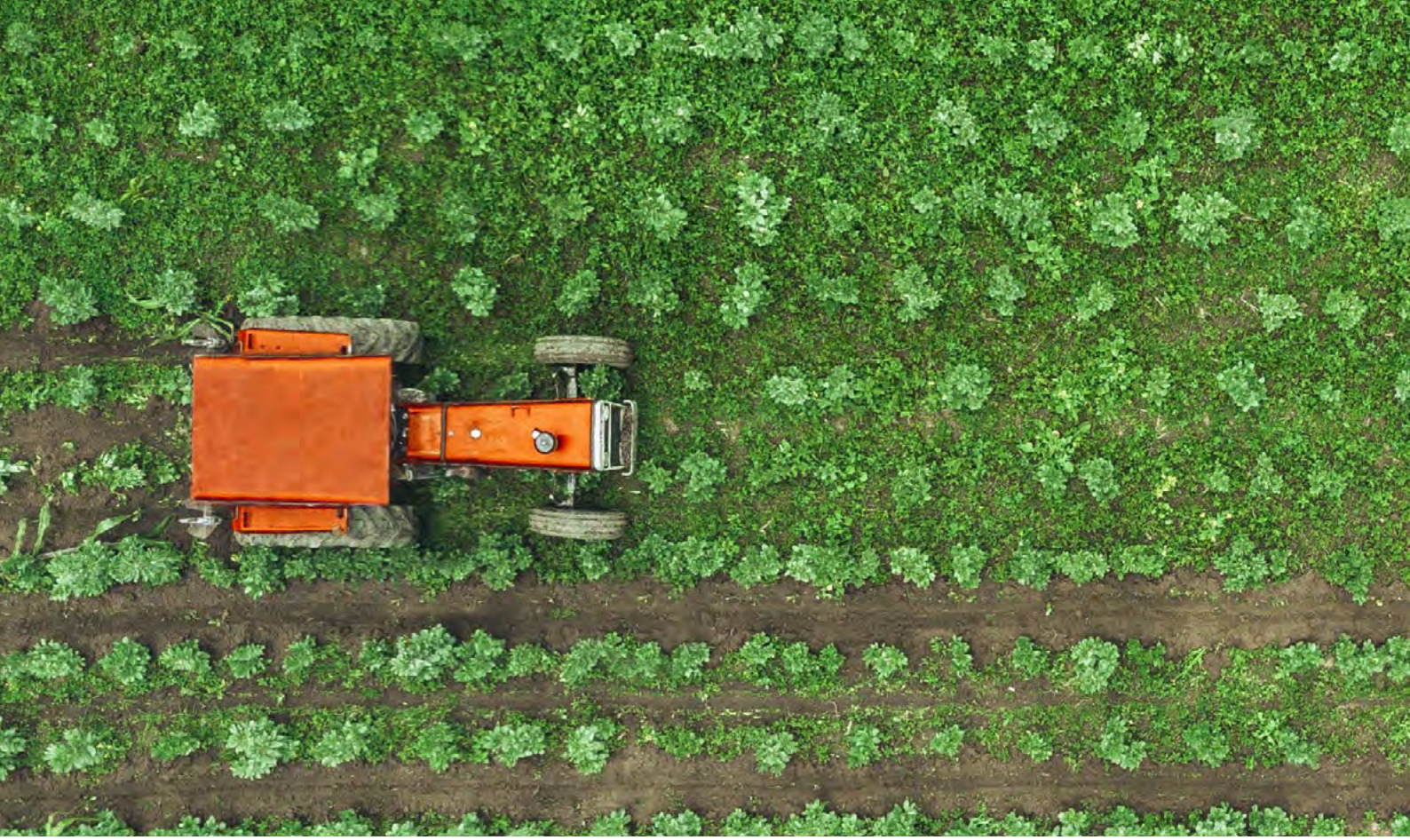
Isolated instances of farm distress in India have been reported in the last several years due to factors such as:

- fluctuating agricultural growth rate
- variability in commodity prices due to the globalisation of value chains
- unpredictable changes in monsoon rainfall and adverse impact of climate change
- structural inefficiencies in the domestic agricultural markets.

Owing to the aforementioned reasons and other factors such as labour migration and decreasing water tables, the cost of cultivation has gone up, resulting in decreased farm income. **Technology, especially digital technology, can play an important role in optimising resource-use efficiency and reducing labour cost, thereby resulting in improved farm income**.

In addition to the sectoral challenges, **instinct-based decision making is another constraint limiting resource-use efficiency and per-unit productivity**. Many of the critical farming decisions are still taken based on guestimates and hearsay across the states. Critical decisions such as the amount of fertiliser to be used and when to sow, irrigate and harvest the crops are often taken on the basis of experience and instinct. While such field and practical experiences are crucial, the unscientific actions are detrimental to the larger cause of agriculture. Such actions result in low crop yields, regardless of whether a field is irrigated or rainfed. These challenges have further got accentuated due to **COVID-19 pandemic**, affecting all the segments of the food system, from primary supply to processing to trade, as well as national/ international logistics systems, impacting the intermediate and final demand.

Given the complexity of the sector, digital solutions such as AI, have the potential to help the agriculture sector meet its dual goals of raising income for smallholder farmers and



strengthening the competitiveness of the sector through data-driven decision making. An industry estimate suggests that digital farming and connected farm services can impact 70 million Indian farmers, adding USD 9 billion to farmer incomes in 2020.[19] It is well understood that agriculture should be a key priority area for the deployment of AI technologies as it can impact maximum lives and livelihood.

Digital and AI-driven agriculture: Advancing towards intelligent farming

Globally, agriculture is witnessing technological advancements mainly aided by increased connectivity at the farm level through precision farming techniques, usage of AI and cloud computing for crop and soil monitoring, predictive pest infestation analysis, agri-robotics and smart supply chain solutions, etc., to drive efficiency and value addition across the value chain.

India has also been looking forward to adopting digital and AI-based data-driven solutions to bring resource efficiency and effectiveness into the agriculture value chain.

With the impending launch of 5G technology and increased smartphone penetration in rural India (it is estimated that **30 million farmers own smartphones[20]**), Agriculture 4.0 and 5.0 will be playing transformative roles in the Indian agriculture sector.

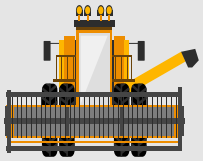
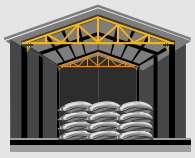
Agriculture 4.0 is based on precision agriculture principles. Farmers will be using systems and technologies that generate data in their farms and that data will be processed to help them take proper strategic and operational decisions. In **Agriculture 5.0**, farmers will follow precision agriculture principles and use equipment for unmanned operations and autonomous decision support systems. Robots and AI are expected to play a significant role in Agriculture 5.0.

With the increased emphasis on Agriculture 4.0 and 5.0, avenues for integration of digital, AI and related applications across the agricultural value chain – from pre-production to retailing or marketing – have been identified along with their potential impact.

In the next section, we look at some of the possible intervention areas and their impact on the agriculture sector.

19 https://niti.gov.in/sites/default/files/2019-01/NationalStrategy-for-AI-Discussion-Paper.pdf
20 https://cms.iamai.in/Content/ResearchPapers/2286f4d7-424f-4bde-be88-6415fe5021d5.pdf

Avenues for integration of digital, AI and related applications across the agricultural value chain and their potential impact

	Value chain vulnerabilities	AI-driven solutions	Impact
 **Agricultural inputs**	• Unsustainable use of fertilisers and pesticides leading to lower productivity • Poor access to institutional credit	• Soil monitoring based cropping decision • Interaction history-based e-extension services • FinTech-led credit and insurance services	• Agri-input optimisation • Robust agri-extension • Increased access to credit and insurance
 **Farming practices**	• Unscientific practices leading to increase cost of cultivation • Rising labour costs • Climate change	• Predictive pest management • Drone-led agrochemical spraying • Precision farming – IoT and remote sensing • Smart tractors and agribots	• Robust incident management resulting in decreased crop loss • Decreased cost of cultivation • Increased productivity
 **Harvest and aggregation**	• Increased level of intermediation by a network of aggregators, traders and commission agents • Lack of primary processing at farmgate	• AI-based insurance claim settlement • Real-time yield estimation • Commodity testing solution • Commodity grading/sorting solution • Transaction discovery • Procurement optimisation	• Increased price realisation • Increased rate of claim settlement
 **Storage**	• Poor access to storage capacity at farmgate • Bulk arrival during harvest leads to price volatility	• Smart warehousing and cold storage solution linked to electronic markets • E-WRF (weather research and forecasting)	• Ability to convert the warehouse into a market • Decreased wastage and losses
 **Marketing and trading**	• Lack of price discovery and intelligence mechanism • Disaggregated and disconnected supply chain	• Price information and intelligence mechanism • AgriStack • Transport optimisation • Traceability	• Capturing premium value through traceability • Ease of trading • Informed decision making for marketing

Source: PwC analysis

02

AI and digital applications: Driving optimisation and profitability in the agri value chain

The usage of digital applications in agriculture is growing rapidly with enabling Government policies, increased penetration of smartphones and the internet, affordable cost of agricultural sensors and drones, and the application of AI and cloud computing. Big data, internet of things (IoT), AI, drones and ML are being harnessed for multiple applications such as farmer decision support, precision farming and insurance claims assessment. Investment activity in **digital- and AI-based agri start-ups in India is largely dominated by supply chains and AgTechs working to facilitate agricultural produce marketing, enhance supply chain efficiencies and improve per unit productivity**.

Technology solutions for key challenges faced in the agri value chain

Challenge	Description	AgTech solutions
Volatility in input prices and suboptimal input usages	• Inadequate data on supply-demand of inputs • High dependency of farmers on traditional distribution channels, resulting in non-scientific usage of agricultural inputs • Instinct based decision making	Predictive analytics and machine learning
Poor quality management and traceability	• Traditional models do not offer large-scale quality testing with quick turnaround times • Challenges associated with post-harvest produce handling, quality check and analysis, produce monitoring and traceability during storage and transportation	• Imaging and AI to monitor quality • Traceability solutions
Imaging and AI to monitor crop quality	• Lower realisation rates for farmers due to uncertainty in demand • Higher cost of procurement for retailers due to the numerous intermediaries in the value chain as well as higher wastage • Other supply-demand challenges	Data and platforms for price transparency
Challenges during farm operations	• Poor economies of scale of farm equipment • Equipment breakdown during farm operations • Weather uncertainty	Agbots and drones for cultivation/ harvesting

Source: PwC analysis



In addition to AgTech start-ups, AI and cloud computing in agriculture are largely being championed by global tech corporations.

COVID-19 has given a fillip to technology usage across key sectors of the economy. Digitisation is emerging as a key trend in Indian agriculture and will have high relevance in the post-COVID era. Post COVID, the key themes of support areas in agriculture that would witness notable digital interventions (including AI) in the medium term have been identified and presented as below:

Impact of technology post COVID-19

#	Pillar	Theme	Pre COVID-19	Future (mid-term)
1	Demand	Growing market demand for better traceability	Low visibility into origins of agro produce	Increased productivity
2	Resources	Increase in labour productivity in the agriculture sector	Low productivity	Higher productivity
3	Supply	Predictive models and technology will improve crop yield	Low crop yield	Improved crop yield enabled by technology
4	Supply	Enhanced collaborations and linkages to promote research and development (R&D)	Low R&D spend	Higher R&D spend though collaborations
5	Supply	More efficiency in extension mechanism for dissemination of information to farmers	Low efficiency in agriculture extension mechanism	Improved efficiency in agriculture extension mechanism

Source: PwC analysis of data from the report 'Full Potential Revival and Growth - Charting India's medium-term journey'

A detailed assessment of the presence of AI, cloud and related technologies in agri and allied value chains is presented below.

Monitoring crop and soil health

- It involves monitoring of crops and soil through computer vision and deep learning by capturing and processing data through drones, sensors, GPS chips, etc.
- It helps in generating customised advice that is helpful in optimising resource use – i.e. irrigation, fertilisers, pesticides etc. – to decrease the cost of cultivation and increase the yield through timely detection of stress, crop hostility, etc.
- Early detection of crop infestation as well as crop health assessment is crucial in ensuring good agricultural yield. Any stress linked to weed, insect and fungal infestation as well as climate change and nutrient deficiencies must be detected early to enable farmers to mitigate these threats.
- Artificial intelligence can be applied to predict current sowing time and provide advisories on pest and input control. This can help in ensuring increased yield and thereby farm income by ensuring necessary stability for agricultural communities. High-resolution weather data, remote sensing data, AI technologies and AI platforms can be used to monitor crop health and other parameters like production and provide holistic and necessary insights to farmers.
- Soil health monitoring is a mechanism that can help farmers take decisions about crops based on soil structure (e.g. when and what to sow, amount of nutrient application). Image recognition and deep learning based models have enabled distributed soil health monitoring without the need for laboratory testing infrastructure.
- Integration of AI solutions with data signals from remote satellites as well as local images captured on agricultural fields helps in generating relevant insights for farmers, enabling them to take immediate action to restore soil health.

Predictive analysis

- It involves the formulation of predictive models and digital intelligence using a host of agriculture and allied sector parameters, including market prices, input and output linkage trends, satellite data and image sensing.
- It finds usage across the agricultural value chain, including credit and insurance, FinTech and logistics.
- It helps to generate contextualised advice and enables decision making for actors across the value chain, including farmers, agri-input suppliers, agri-produce marketing organisations and credit and insurance companies.
- Climate change has made forecasts for crop yields more important as farmers cannot depend only on traditional knowledge. More accurate weather forecasts could enable farmers to pick the optimal days for planting or harvesting. AI techniques apply reinforcement learning on past predictions and actual outcomes. Data is fed into an algorithm that uses deep learning techniques to learn and make predictions based on past weather data to aid in weather forecasting.

Agricultural robotics and drones

- The gradual shift in employment focus around agricultural activities addresses major pain points of the current agricultural system which is heavily labour oriented, especially in the Indian context.
- It includes the development of autonomous and smart devices, and machineries that could undertake various agricultural activities like sowing, irrigation, spraying herbicides and harvesting.
- Agriculture robotics – also known as agribots – is now becoming popular due to labour shortages and the increased need to feed the global population. Agribots automate tasks for farmers, thereby increasing the efficiency of production and reducing the industry's dependency on manual labour. This includes assisting farmers with activities such as harvesting picking, seeding, spraying, pruning, sorting and packing.
- Drones are equipped with multi-spectral and photo cameras that can monitor crop stress, plant growth and predict the yield. This saves both time and labour efforts as farmers are not required to physically go out and check on a crop. The more advanced drones can carry and deliver payloads like herbicides, fertilisers and water.
- A robot drone tractor decides where to plant, when to harvest and how to choose the best route for crisscrossing the farmland. These robots reduce the usage of pesticides, herbicides, fertilisers and water.

AI-based primary processing

- There is a growing demand for standardisation of agri produce, especially for fruits and vegetables, for aiding smooth trading operations both nationally and internationally.
- AI is already being utilised for automating grading and sorting operations. Deep learning and advanced image processing techniques are used for viewing images and pictures, thus ensuring food quality.

Warehouse management

- With an increased focus on farmgate-level trading activities, the connectedness of agri infrastructure, especially farmgate and other agricultural warehouses, will play a critical role in converting farmgate into a robust market.
- With the advent of recently announced agri reforms, i.e. **the Farming Produce Trade and Commerce (Promotion and Facilitation) Ordinance, 2020, the Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Ordinance, 2020, and the Agri Infrastructure Fund under the Aatmanirbhar Bharat Yojana**, it is envisaged that farmgate level activities will further scale up.
- Installing sensors in warehouses can warn farmers about any condition that may result in the spoilage of agri commodities.
- E-negotiable warehousing receipts can enable farmers to sell their produce across the country without worrying about transporting it first.

AI application in supply chain management

- **Trading:** AI and related technologies can be utilised for transforming aggregation, trading and marketing of agri commodities by developing digitally enabled platforms for stakeholders. These platforms enable interaction and collaborative measures, which in turn ensures transparency and accountability in the system and for associated stakeholders.
- **Logistics:** AI has a significant role to play in agri supply chains, including route optimisation and supplier management. Integration of AI-based software has made transportation of agricultural produce easier and increased consumer satisfaction by utilising technologies such as smart sensors and GPS.
- **Traceability:** With the increasing globalisation of the food system, food traceability and safety have become more important than ever. Traceability of agri inputs, especially seeds, is very important as the spurious seeds which are available in the market have a negative impact on agricultural productivity. AI, cloud computing and related technologies are playing transformative roles in establishing traceability across the agri value chain.

Ag-FinTech

- Digital technologies are also playing the role of crucial enablers to provide affordable financial solutions to farmers.
- Ag-FinTech organisations are capturing farmer-level data through various sensors and other mediums, and utilising such data to develop customised credit scores for farmers. Such credit scores enable banks and other financial institutions to provide affordable credit and insurance to farmers.

Livestock monitoring and management

- AI and related technologies enable farmers to track their grazing animals remotely with the help of cameras and collars placed on them.
- Digital tags provide farmers with relevant data on their livestock's health, mating patterns and food intake.
- Such applications have helped farmers in establishing the traceability of their products, thereby enabling them to sell their produce at premium prices.

Smart feeding solutions in fisheries

- Feeding cost is one the most biggest costs in fish rearing, so optimisation in this area always means better profitability. Currently, feeding strategies are often arbitrary and based on observation or intuition.
- AI and data analytics can be used to fine-tune feeding strategies, thereby optimising feeding costs in fish rearing.

03

Market scenarios and investment trends in AI and digital applications in agriculture

Digital agriculture involves the **use of ICT and data ecosystems to support the development and delivery of timely, targeted information and services to make farming profitable and sustainable while delivering safe, nutritious and affordable food to all**. The following are the market scenarios and key investment trends in AI and digital applications in agriculture globally and nationally.

Global scenario and investment trends

Industry estimates suggest that the use of AI and analytical tools in agriculture has the potential to generate an annual economic value of up to **USD 486.3 billion globally**.[21] This potential market is currently being steered by a robust ecosystem of multiple stakeholders, including AgTechs, tech corporations, agricultural input and output companies, ICAR research institutions and the Government. This ecosystem has been driving the implementation of emerging technologies and applications such as IoT, AI-based data-driven farming, chatbots, drone technology and precision agriculture to increase per unit productivity levels while maintaining cost efficiency.

Globally, the market size of AI in agriculture stood at **USD 0.85 billion in 2019**, and it is expected to reach **USD 8.4 billion by 2030**, with a CAGR of **24.8%**. Precision agriculture and farm management is the largest category within the AI and related technology segment, wherein predictive analysis is the fastest growing subcategory.[22]

Globally, **monitoring** will be the highest revenue-generating segment among IoT-based agriculture services. **Crop health monitoring** will be the highest revenue-generating application, followed by livestock and animal health monitoring. It has been estimated that by 20205, the monitoring segment will have **a market share of 69%, with an economic value of USD 4.5 billion**.[23] It is estimated that around 12 million agricultural sensors will be installed by 2023, and that an average farm would generate about **5 lakh data points per day**, which can be used to improve yield and maximise profits.[24]

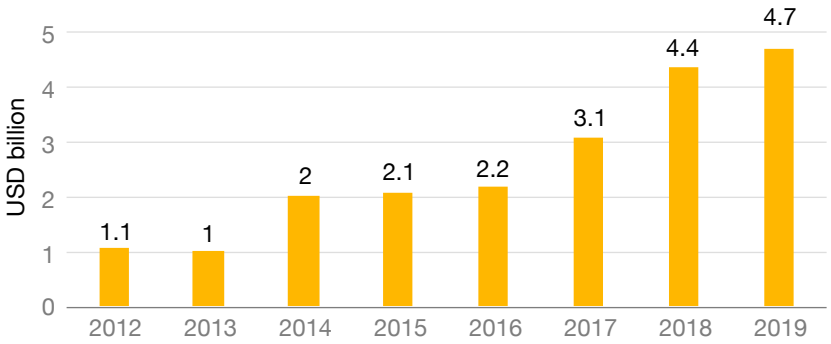
Market potential of drones

Agribusinesses are deploying drones/robots to obtain real-time data on many aspects of farming operations. A combination of aerial and land perspectives/images are being captured using multi-spectrum cameras and sensors installed on agricultural drones/robots. By 20205, the market revenue from this segment is estimated at USD 850 million.[25]



21 Artificial intelligence for agriculture in New Zealand; AI Forum, New Zealand
22 https://www.psmarketresearch.com/market-analysis/artificial-intelligence-in-agriculture-market
23 https://www.researchandmarkets.com/reports/5027859/iot-in-agriculture-market-outlook-and-forecasts
24 https://www.businessinsider.com/smart-farming-iot-agriculture?IR=T
25 https://www.globenewswire.com/- India-Digital-Transformation-Market-to- Reach-710-Billionby-2024-P-S-Intelligence

Investment trends in global farm tech from 2012– 2019 (in USD billion)



Globally, farm-tech[26] start-ups have raised USD **4.7 billion** in 2019 through 695 deals, with the largest deal valued at USD 205 million. The sector has witnessed 940 unique investments in farm-tech companies deploying AI and related technologies in the agricultural value chain in 2019.

Source: AgFunder 2019, PwC analysis

Indian scenario and investment trends

India is home to some of the top tech unicorns in HealthTech, EduTech, FinTech, TravelTech, AgriTech, etc. Although the Indian digital sector is expected to **contribute USD 1 trillion to the grand vision of a USD 5 trillion economy by 2025**,[27] its potential contribution to the digital economy is considered to be much higher and far-reaching. The following are some of the key facts and projections related to India's start-up ecosystem in India:

Particulars	2014	2019	2025
Tech start-ups[28]	3,100	9,300	16,743
Unicorns[29]	5	24	95–105
Cumulative value of tech start-ups[30]	USD 10–20 billion	USD 95–101 billion	USD 350–390 billion
Market value of core digital services industry[31]	-	USD 200 billion	USD 710 billion
Smartphone user base[32]	170 million	354 million	1,100 million
Total number of internet[33] connections	251.59 million	687.62 million	1,198 million

In India, applications of AI, cloud computing and related technologies in various agricultural activities across multiple stages of the agri-value chain are at a very nascent stage. Currently, the market size of AgriTech, including AI-based agri innovation start-ups in India is estimated to be **USD 204 million** or around 1% of the currently addressable market opportunity worth **USD 24 billion**.[34]

The AgriTech segment, including AI-based innovations, in India is witnessing the emergence of a number of start-ups which are disrupting traditional methods of farming through precision farming, equipment rentals, supply chain aggregation and cloud-based analytics for decision making. **In FY20, Indian agri-food tech start-ups raised USD 1.05 billion through 133 deals, registering a year-on-year growth of 6.4%.**[35]

Big data, IoT, AI, drones and ML are being harnessed for multiple applications, such as farmer decision support, precision farming and insurance claims assessment. **Investment activity in India is largely dominated by supply chain and output market linkage AgTech**.

27 https://www.meity.gov.in/writereaddata/files/india_trillion-dollar_digital_opportunity.pdf
28 https://thenextweb.com/in/2015/07/05/india-the-worlds-fastest-growing-startup-ecosystem/ https://www.startupindia.gov.in/content/sih/en/international/go-to-market-guide/indian-startup-ecosystem.html
29 NASSCOM - Indian Tech Start-up Ecosystem – Leading Tech in the 20s – Edition 2019 (page 93)
30 NASSCOM - Indian Tech Start-up Ecosystem – Leading Tech in the 20s – Edition 2019 (page 93)
31 https://www.globenewswire.com/- India-Digital-Transformation-Market-to- Reach-710-Billionby-2024-P-S-Intelligence
32 https://www.techcircle.in/2014/05/29/india-had-third-largest-smartphone-base-with-117m-users-in-2013-to-grow-45-in-2014-marymeeker-report
33 TRAI - Indian Telecom Services Performance Indicator Report (as on March 2014 and September 2019)
34 https://government.economictimes.indiatimes.com/news/technology/indias-agriculture-technology-can-grow-to-24-1-billion-in-5-years-report/77971911
35 https://agfunder.com/research/india-2020-agrifood-startup-investment-report/

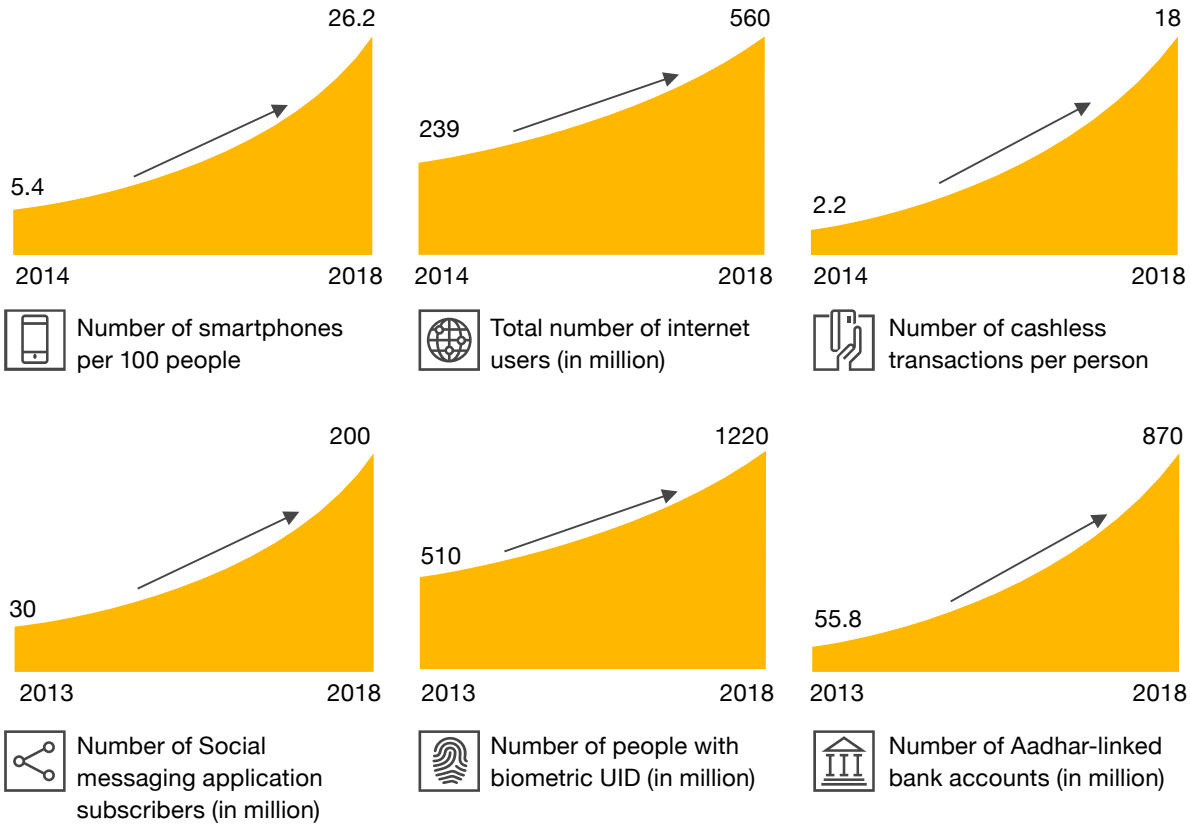
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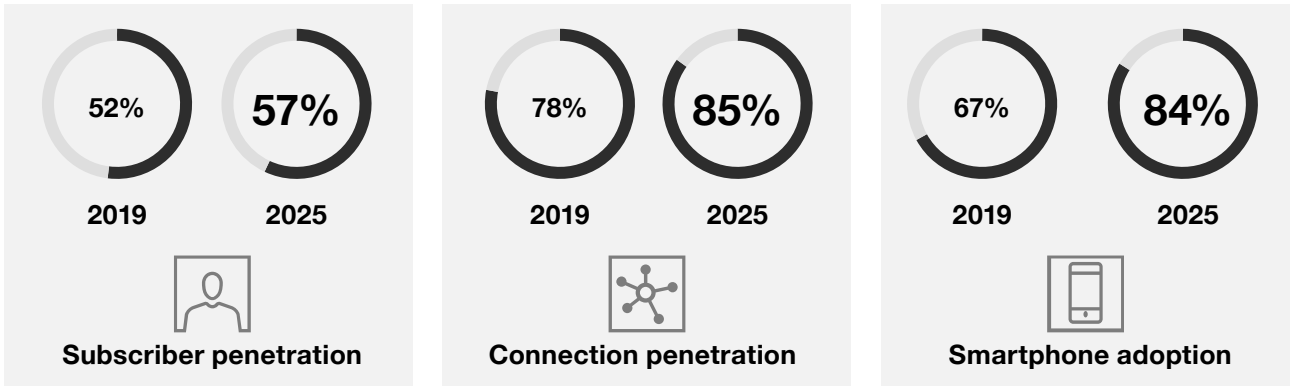
Enablers of AI in India's agriculture sector

Access to digital technologies is important not only for urban consumers but also for farmers and rural communities. Farmers and agri-preneurs without reliable access to quality IT infrastructure and technology could face a disadvantage with respect to most aspects of their farming activities, business and livelihood.

Reducing the digital divide through increased smartphone and internet penetration

Key indicators showing a declining digital divide in India from 2014–2018 and future trends





Source: Industry estimates and PwC analysis



India has witnessed rapid adoption of digital technologies in the last one-and-a-half decade. This growth may be attributed to **internet penetration, availability of affordable data services, proliferation of feature phones as well as budget smartphones, and the rise of innovative digital services**. With almost 50% penetration today, India has the world's second largest internet user base,[36] and the country's digital divide is narrowing fast.

It is forecasted that connection penetration will increase to 85% by 2025 from the current level of 78%, while smartphone adoption is forecasted to reach to 84% by 2025 from its current level of 67%. It is also estimated that 4G penetration would increase to 82% from the current level of 56%.23

Internet users are spread across both urban and rural areas in India. In 2019, the number of users in urban and rural areas stood at 205 and 227 million respectively, with the number of users in rural areas increasing at 18%per annum.[37]

Supportive technologies promoting applications of AI and digital applications

The development of enabling technologies and their commercialisation are crucial for mainstreaming of AI applications in agriculture. These technologies include unmanned aircraft systems (UAS), often referred to as drones, IoT-based sensors, remote image sensing and proximal sensing etc. When combined together, these technologies enable use of big data, AI and cloud computing to drive efficiency and profitability at each stage of the agricultural and allied value chain.

UAS/unmanned aerial vehicle (UAV)/ drone-based farming: Widening AI applications in agriculture

The use of drones in Indian agriculture is increasing, with multiple AgTech start-ups and agri-input companies providing these services to farmers.

The intelligent use of UAV technology can help fight highly mobile invasive pests such as fall armyworm (FAW) and desert locusts more efficiently and effectively, and reduce the cost of cultivation while maintaining agricultural productivity. The following are some broad application of drones in agriculture:

- **Crop health monitoring:** Routine surveillance using high-resolution, geo-referenced, orthomosaic 2D maps, spectral imagery and visual imagery can capture the growth cycle and assess crop health, enabling the swift detection of any potential problems as well as assessment of damage to contain crop losses. Site-specific crop damage reports can be generated for appropriate action.
- **Soil health assessment:** Soil quality can be monitored using parameters such as soil moisture through remote sensing, which can help in developing fertility maps and planning for more optimal crop rotation or irrigation.
- **Improved resource utilisation:** Ascertaining areas within a field that are most fertile or that require additional water/fertilisers or chemicals can help farmers to optimise their resource utilisation.

36 https://economictimes.indiatimes.com/tech/internet/internet-users-in-india-to-reach-627-million-in-2019-report/articleshow/68288868.cms
37 https://cms.iamai.in/Content/ResearchPapers/2286f4d7-424f-4bde-be88-6415fe5021d5.pdfç

Consolidation and expanding presence across the value chain

The development of AI solutions that can meet the static and dynamic knowledge needs of farmers and improve their agri-based practices and decisions are driven by larger and more established private players. These companies are engaged, or are looking to engage directly, with farmers in the precision agriculture segment and can afford resource-intensive investments to consolidate the value chain.

These initiatives are set to receive a boost in India with the Government's recently announced landmark agri-marketing reforms under the Aatmanirbhar Bharat Yojana, i.e. **the Essential Commodities (Amendment) Ordinance, 2020, the Farming Produce Trade and Commerce (Promotion and Facilitation) Ordinance, 2020, and the Farmers (Empowerment and Protection) Agreement on Price Assurance and Farm Services Ordinance, 2020**. These reforms are aimed at transforming agricultural marketing, allowing contract farming and removing stock limits on essential commodities. Increased farm gate activities due to such enabling initiatives will certainly spur the adoption of AI and digital applications in agriculture.

Enabling policy environment and government initiatives

The GoI has been very proactive in understanding the role AI could play in transforming Indian agriculture. Various policy initiatives have been undertaken to support agri start-ups promoting AI-based and digital innovations, their early uptake and successful operations. The salient features of such policy interventions are presented below.

Sr. no.	Name of scheme	Salient features
1	Startup India[38]	Startup India is a flagship initiative of the Government of India, and aims to build a strong ecosystem to nurture innovation and start-ups, drive sustainable economic growth and generate large-scale employment opportunities in the country. Through this initiative, the Government aims to empower start-ups to enable them to grow through innovation and design. The Startup India initiative is based on the following three pillars: • simplification and handholding • funding support and incentives • industry-academia partnership and incubation.
2	Atal Innovation Mission (AIM)[39]	The Atal Innovation Mission (AIM), which includes Self-Employment and Talent Utilization (SETU), is the Government of India's flagship programme to promote a culture of innovation and entrepreneurship across the country. Its objective is to serve as a platform for the promotion of world-class innovation hubs, start-up businesses and other self-employment activities, particularly in technology- driven areas. It has two core components: • promotion of entrepreneurship through SETU • innovation promotion – to provide a platform where innovative ideas are generated. AIM provides a grant-in-aid package of INR10 crore to every Atal Incubation Centre for a maximum of five years, to cover its capital and operational expenditure in running the centre.

38 https://www.startupindia.gov.in/
39 https://aim.gov.in/



Sr. no.	Name of scheme	Salient features
3	NewGen Innovation and Entrepreneurship Development Centre (NewGen IEDC)[40] under the National Science & Technology Entrepreneurship Development Board (NSTEDB)	The Government's NewGen IEDC start-up programme has been implemented in educational institutions. A maximum of 20 new projects are supported in a year and the Government provides one-time, non-recurring financial assistance up to a maximum of INR25 lakh to the institution to meet the cost of its establishment, furnishing of cubicles for start-ups, purchase of PCs with printers, library books, journals, laptop, multimedia projector, 3D printers, etc.
4	Dairy Entrepreneurship Development Scheme promoted by NABARD[41]	• 25% of the project cost as back-end subsidy restricted to a maximum of 10 animals, subject to a ceiling of INR15,000 per animal for establishing a dairy unit (INR6 lakh maximum) • 25% of the project cost as back-end subsidy restricted to a maximum of 20 calves, subject to a ceiling of INR6,000 per animal for establishing a dairy unit (INR5.30 lakh maximum)
5	Venture Capital Finance Assistance (VCA) Scheme promoted by Small Farmers' Agri-Business Consortium[42]	Capital assistance depends on the cost of the project, location and the promoter's status. It is in the form of interest-free venture capital assistance up to INR50 lakh or 26% of the promoter's equity, whichever is lower.
6	Aspire (MSME)[43]	Aspire has been launched by the Government to set up a network of technology and incubation centres, and to promote start-ups for innovation and entrepreneurship in rural and agriculture-based industries.

Among other government initiatives, NITI Aayog has brought out the **National Strategy for Artificial Intelligence[44] in June 2018**, identifying key priority areas in health care, agriculture, education and other sectors. In agriculture, **farm productivity, farm income enhancement and reduction of wastage** have been identified as targets for AI-led innovations, with a new thrust on **farming as a service (FaaS)**.

40 https://www.startupindia.gov.in/content/sih/en/government-schemes/newgen-innovation-and-entrepreneurship-development-centre.html
41 https://www.nabard.org/content.aspx?id=591
42 https://www.startupindia.gov.in/content/sih/en/government-schemes/venture-capital-scheme.html#:~:text=Ministry%20of%20Agriculture%20and%20Farmers,for%20implementation%20of%20the%20project.
43 https://aspire.msme.gov.in/ASPIRE/Home.aspx
44 https://niti.gov.in/sites/default/files/2019-01/NationalStrategy-for-AI-Discussion-Paper.pdf



National Strategy for Artificial Intelligence: NITI Aayog

NITI Aayog recognises agriculture as one of the priority areas for implementation of AI-driven solutions. To meet the plethora of challenges in the agriculture value chain, it identifies key challenges that can be met and resolved with digital and AI-based solutions. These challenges include inadequate access to credit and information, decreased fertility of the soil, pest infestations, changing cropping pattern, wastage in supply chain and an incompetent market discovery mechanism. Identifying major areas where digital technology can be applied, it delineates tech-enabled agri-extension, precision farming using IoT and remote sensing data, predictive pest management and real time forecasting of yields as key areas for immediate intervention.

Key constraints for development of AI-based solutions in agriculture	Government support outlined in national strategy
Data for training for AI algorithms	Creation of domain-specific annotated data sets; data standards; improved access for existing data
Computation of infrastructure required for storage, training and inference	AIRAWAT cloud computation platform to enable AI solution developers to train algorithms affectively and host large 'common good' data sets
Domain-specific expertise to design solutions	ICTAIs/CORE to promote inter-sectoral linkages; Moonshot programmes to guide innovation

Digital and AI-based platforms promoted by GoI

Cyber Agro-Physical Systems (CAPS): The ICAR, with its 113 research institutes and 716 KVKs, has geared up to enhance the competitiveness of farming in India to make it a viable, self-sustaining and internationally competitive enterprise through the digital agricultural platform CAPS. CAPS, while integrating the use of sensors with computers, satellite imagery, supercomputing facility for research, will also help to reduce uncertainty and risk in agricultural operations through AI-enabled farmers' advisories for critical agricultural operations and climatic events.

Ekikrit Krishi Shiksha Takniki Ayaam: New digital applications have been developed to bring Indian agriculture in line with the Digital India theme. The Department of Agricultural Research and Education (DARE) launched the agricultural education portal Ekikrit Krishi Shiksha Takniki Ayaam (EKTA) and set up an integrated online management information system, developed nine mobile apps for mango, e-kalpa, oil palm (English, Hindi and Telugu), pomegranate, onion and garlic, black pepper and mushroom cultivation and two mobile apps for the farming community (Kisan Suvidha and Pusa Krishi).

mKisan: KVKs, through the mKisan portal, provided SMS services to 612.95 lakh farmers on improved farming practices such as climate-smart agriculture, low carbon farming, and System of Rice Intensification (SRI), for various crops and allied enterprises as well as weather-based advisories and information on various Government schemes.

Key state-specific initiatives to promote application of AI in agriculture

In addition to the GoI, state governments have also undertaken several initiatives to promote AI, cloud computing and digital applications in agriculture.

State	Initiative[45]
Karnataka	• Karnataka has partnered with a leading multinational technology company for agricultural produce, price-related information and intelligence using predictive modelling. • SAMRAKSHANE is an end-to-end e-governance solution to handle crop insurance under the Pradhan Mantri Fasal Bima Yojana (PMFBY) programme and the Modified Weather Based Crop Insurance Scheme (MWBCIS). It coordinates with the Karnataka State Natural Disaster Monitoring Centre (KSNMDC) to compute weather-related data and compensation based on term sheets under the MWBCIS.
Uttar Pradesh	• The Government of Uttar Pradesh is collaborating with the Bill and Melinda Gates Foundation (BMGF) and the Tata Trust to set up the Indian Agritech Incubation Network at IIT-Kanpur.
Punjab	• PAGREXCO has partnered with a budding AgTech start-up for application of AI-powered technology to enable traceability in the potato seed supply chain and thereby pre-immunise it.
Maharashtra	• Maharashtra has launched the Maha AgriTech project that is aimed at utilising and promoting application of satellites and drones to solve various agrarian problems.
Telangana	• The Government of Telangana has launched AI in its agricultural innovation programme in collaboration with C4IR, the global economic forum.
Delhi	• Recognising the importance of AI, IIT Delhi has established its School of Artificial Intelligence.

45 https://niti.gov.in/writereaddata/files/document_publication/NationalStrategy-for-AI-Discussion-Paper.pdf

05

Constraints in AI adoption in Indian agriculture

While application of AI in making Indian agriculture future ready seems promising, there is long way to go for actualisation of benefits. There are multiple challenges that hinder adoption of AI-driven solutions for agriculture. The main bottlenecks and challenges are given below:



Operational 01



Investment 02



Infrastructural 03



Policy-related advisory 04



Operational 01

Small landholding sizes: In India, the average land holding size is comparatively smaller than that in other countries, and stands at less than 2 ha. Moreover, 33% of farm households in India own less than 0.4 hectares of land. Consequently, it is not commercially viable for small and non-contiguous farms to own applications individually, since this would not be cost-efficient.

Diverse soil conditions and cropping patterns: Due to the diversity in agri-climatic conditions and differing soil types, various cropping systems have evolved across the country over a period of time. Accommodating these variable conditions and to achieve scale, it is therefore difficult to develop geographical and crop-based customized AI technologies or products.

Blanket approach to assessment of technology-related requirements and dissemination: While developing AI-based applications for Indian farmers, it is important to consider the adoptability and accessibility of such technology. Most solutions using AI and related technologies are not localised and are unable to meet geographical, socio-cultural and demographic-related needs in India. This results in their inadequate rate of adoption and dissemination.



Investment 02

In order to collect and interpret large sets of reliable data for precise AI-based solutions, collaborations with multiple sources and stakeholders are required. However, the involvement of various sources and development of customised AI solutions involves significant technical expertise and investment in capital. This tends to increase the cost of adoption of such technology.

Long gestation period: Adoption and penetration of technology is a very slow process. This diminishes investors' interest. Data input from satellites are analysed to issue advisory to farmers. At times, this data is not localised enough to have a positive impact on agriculture. For instance, weather forecasts may be provided at a district or block level, but may not always be accurate in the case of small and marginal farm holdings in remote parts of the districts. Moreover, current satellite-based technologies for acquisition of data from farms are too expensive for small farmers in India who cannot afford these.

Deployment-related constraints: Equipment with proven technologies is largely deployed by service providers due to the inadequate last-mile reach of start-ups. It is very difficult for new age technologies to reach farmers due to lack of connectivity. This, in addition to the fact that farmers lack trust in technology, results in a low adoption rate. Looking at the statistics, India has around 120 million farmers, of this number 30 million use smartphones. Therefore, approximately 75% farmers, who do not have access to smartphones, cannot take advantage of AI-based solutions such as those for monitoring of crop health, predictive analytics with respect to sowing, use of fertilisers, irrigation, etc. IoT sensors for monitoring soil composition, temperature, moisture, cattle movement, etc.

Infrastructural 03

Digital divide: The digital divide in India is rapidly decreasing with the increase in smartphone usage and internet penetration. India is among the top three global economies in its number of digital consumers and the digital divide is narrowing fast in the country. However, although there are various enabling measures and programmes being undertaken by the Government, digital literacy and adoption of technology are still significantly inadequate in rural areas.

Weak synergy and limited collaboration among various stakeholders: griculture is multi-dimensional in nature. There are multiple government departments and actors (public and private) at the state, district, block and panchayat levels. Multiple actors such as (but not limited to) the Indian Meteorological Department (IMD), state agricultural universities and private sector companies provide advice to farmers, on the basis of which the farmers take strategic decisions on preparation of land, sowing or transplanting as well as use of fertilisers, agrochemicals, irrigation, etc.

Due to the low level of synergy and collaboration among these entities and/or departments, different agencies or entities may issue different advisories for the same geographic area at the same time, based on their predictive models. This could confuse the farmers and prevent them from taking the right decision at the right time.

Lack of quality and reliable data sets: An AI-based decision-making system is as good as the underlying data. AI modelling relies on several input data points such as topography, soil, weather, seed types, cropping practices, diseases and pest patterns that all have an impact on each another. Moreover, some of the data is not publicly available, and what is available needs a detailed review to satisfy the key attributes required, such as volume, variety and veracity. Traditionally, these data pools have been maintained by public agencies. Furthermore, data, including farm output, which is collected manually and not by using scientific methodologies, is often unreliable for important decision-making.

Policy-related advisory 04

Regulatory and policy issues

At the farm level, AI-based advisory provided to farmers may not be fully executable due to misalignment of policies or on-the-ground conditions. Digital technology initiatives such as the promotion of the Electronic National Agriculture Market (e-NAM) platform for agro-commodities with digital assaying, grading and online payment options for auction of commodities, which comprise important sources of data, have not yet gained traction yet. Challenges may arise with the implementation of the recently announced sectoral reforms, if the issues faced are not properly addressed. The three farm bills brought in by the GoI aim to promote private sector investment and contract farming practices by diluting the monopolistic roles of traditional markets and market regulators. Agricultural trade in coming years is therefore likely to steadily emerge beyond the Agricultural Produce Market Committees (APMCs). With the APMCs increasingly disintermediating from the supply chain, it is envisaged that the e-NAM system embedded in the APMC architecture will be disseminated to a larger national agri-marketing MIS system. This upcoming system however needs significant effort to enable real-time and authentic marketing data capture and analysis.

06

Strategic interventions to promote AI adoption

With the rising penetration of the internet and smartphones and the impending launch of 5G, India is poised to develop an enabling ecosystem for rapid adoption of AI and related technologies in agriculture.

Along with a conducive policy environment, agri start-ups, agri value chain players, tech corporations and the Government are taking proactive measures to collaborate with entities to enable effective dissemination of AI and related technologies and significant increase their last mile reach. In this background paper, FICCI and PwC have formulated some strategic interventions to promote adoption of AI in agriculture. These are presented below.



Infrastructure enablement 01



Capacity building and skill upgradation 02



Collaborations and linkages 03



Ensuring effective dissemination 04



01

Infrastructure enablement: Strengthening of infrastructure for effective decision-making

In the existing situation there are multiple sources of information stacked at different levels, it is crucial to bring the information at one source for providing valuable and precise AI based solution.

Development of country-specific platform to address asymmetry in information

A large number of digital platforms already exist in the current agri tech ecosystem. The Ministry of Agriculture and Farmers Welfare (MoA&FW), GoI, operates around 80 portals, and state departments and universities operate around 800 portals. These cover almost all the aspects of the agriculture value chain and have a reasonable level of geographic granularity.

Since the relevant data is often in silos, it is imperative that these multiple data points or knowledge portals are aggregated into a single integrated agriculture platform. This platform can be supplemented with the appropriate intelligence to provide customised and tailor-made advisory to farmers through mobile apps or secure, structured and supplementary service data text-messaging services, which currently have a wide reach. To harness the true value of precision agriculture, multiple data providers who have hitherto collected and provided information in silos need to be brought together to consolidate agricultural data. Data from new and upcoming avenues such as drones, satellites and digital payment should be incorporated as a part of this integrated platform for it to be a true one-stop solution for all information on agriculture in India.

Making optimal use of AI data for effective, accessible and affordable solutions

The rising challenges of financing, selling produce or trading options to farmers can be attributed to the lack of data or their inability to access data in a usable form. However, data from sources such as digitised land records, photographs of standing crops, evidence of digital payments and receipts, etc., can help to solve this issue. Data points can be fed into a credit risk assessment algorithm, which can accurately assess farmers and their produce to provide them easy finance options and ease payouts of insurance settlements, loan recoveries, etc.

Information sources, such as satellites, drones and weather-related data can be combined with the results of crop-cutting experiments to improve the accuracy of forecasts through improved data capture frequency and rationalise the cost of a number of crop-cutting experiments in different areas.



02

Capacity building and upgrading of skills

Establishment of skill development centres for training on AI tools

For farmers to adopt and implement new methods of digital and AI-based farming-related practices across the value chain of the agriculture eco-system, it is important to upgrade existing hands into skilled ones.

- Government extension officials are among the important and critical stakeholders for enablement of timely adoption of AI application in agriculture. Training and capacity-building-related support is however required to sensitise them about the various benefits accruing from adoption of AI in agriculture as well as the inherent challenges faced in the procedure.
- Some initiatives such as the establishment of Skill Development Centres (SDCs) would support the creation of AI-preneurs and AI-sakhi experts in the market. Such SDCs will not only support farmers through effective dissemination and training on AI-based applications in agriculture, but will also help them develop related training modules, train trainers and conduct agri AI workshops.

Improving digital literacy among farmers

Although digital literacy is a concern in the Indian farming community, system and solution designers also need to be more imaginative in designing solutions and interfaces that are socially embedded and localised in relation to soci0-cultural and agronomic contextualities. Low digital literacy among farming communities is a major impediment for adoption of AI and related technologies in agriculture. An increase in digital literacy will significantly increase the social embeddedness of technological solutions.

Hence, building digital literacy among farmers should be viewed as a public good and appropriate measures, both systemic and programmatic, should be taken to increase digital literacy in farming communities.

- Programme-related measures taken by the Government to increase digital literacy[46]
- **National Digital Literacy Mission:**[47] The Ministry of Electronics and IT, GoI, has launched a programme to achieve the objectives of the National Policy on IT, 2012, to make at least one person in every family digitally literate. In collaboration with 614 training partners, around 12 million people have been trained and around 6 million certified under NDLM since 2014.
- **Pradhan Mantri Gramin Digital Saksharta Abhiyan (PMGDISHA):** PMGDISHA aims to cover a six crore rural population. So far, a total of 1.47 crore candidates have been enrolled under the scheme, of which 1.43 crore candidates have been trained and 74.5 lakh candidates have been certified.

46 India's Trillion Dollar Digital Opportunity, Ministry of Electronics and IT, GoI
47 https://pib.gov.in/PressReleseDetail.aspx?PRID=1506002



03

Collaborations and linkages

Transformation of the existing ecosystem by fostering linkages and collaborations among private and public agencies would play a crucial role in the creation of an effective support system.

- **Fostering linkages among private players and public-private partnerships:**Such linkages would not only provide easy access to information for farmers, but would also enable dissemination of information at affordable prices to farmers. Companies with digital competencies and access to crucial data sets have already made inroads into the AI space in agriculture via public-private partnerships with state agencies and governments, as well as with AgTechs and agri-based organisations. Digital companies, especially tech giants, have realised the need to harness the true potential of digital farming through collaborations and partnerships with agri start-ups or agri-based organisations. AI tech giants,

  AgTech start-ups and agri sub-sector-specific companies producing seeds, fertilisers, etc., are increasingly coming together to synergise and build innovative solutions for farmers.

- **Fostering linkages between private players and state agriculture universities:** Digital agriculture is being actively promoted by the World Bank, the ICAR and the funded National Agricultural Higher Education Project (NAHEP). One of the partner State Agricultural Universities (SAUs) of the NAHEP, the Mahatma Phule Krishi Vidyapeeth in Rahuri (Maharashtra) has collaborated with a private player and developed digital solutions and technologies to improve the efficiency of irrigation and enable timely assessment of soil health. For innovation in irrigation, the 'IoT-based Auto Phule Irrigation System (PIS) propounds irrigation without human intervention, based on sensors. After they adopt the Auto PIS technology, farmers can provide the precise amount of water required to their fields, and thereby save electricity, water and labour costs. This will ultimately increase the productivity of crops and improve the health of the soil. The 'Phule Soil Moisture Sensor' helps farmers gauge the condition of soil through moisture sensors and determine its need of nutrition, irrigation, etc. These innovations have benefited more than 6,000 farmers in Maharashtra.



04

Ensuring effective dissemination

Categorisation for effective dissemination of digital technologies

In order to formulate strategies aimed at effective dissemination of digital technologies in agriculture and allied activities among farming communities, it is very important to analyse digital technology from the socio-economic and cultural standpoint.

We need to factor in the socio-cultural dynamics of a farming community in order to convert AI and cloud computing applications in agriculture – moving from 'artificial intelligence' to 'agricultural intelligence'. In this regard, the categorisation given below helps to classify digital technologies.

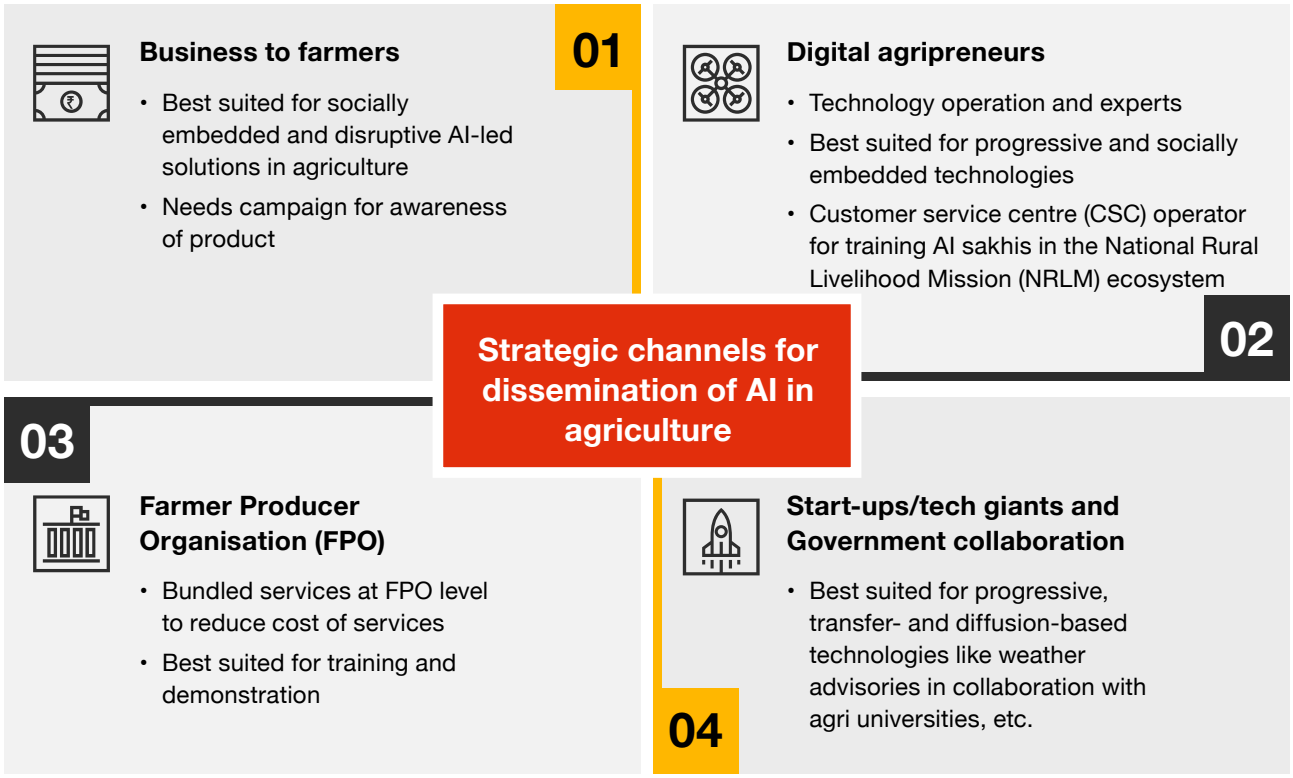
- **Innovation and its implications:** This results in identification of two broad categories of innovation, i.e. social embeddedness-led innovation and transfer and diffusion-led innovation. Socially embedded digital technologies take into account cognitive, emotional and political capacities that individuals who are nurtured in their local social institutions bring to bear on the unfolding of innovation-related efforts. Whereas innovations which are led by transfers and diffusions do not reflect the social understanding of a farming community, and therefore requires additional efforts on training and capacity-building or in adding a layer of intermediaries including CSC operators. For example, **vernacular language-based call centres for agri-extension services are socially embedded**, whereas English language-based mobile application-led extension services in northern Indian states are a classic case of innovation by (knowledge) transfer and diffusion. Socially embedded technologies usually do not require further layers of intermediaries and direct business-to-farmer channels can be developed for its dissemination.

- **Transformation and its implications:** On the basis of transformation, digital technologies are categorised as progressive and disruptive technologies. Disruptive innovation are usually ones that drastically reduce the time, effort or money utilised to conduct an activity. It disrupts the existing socio-political relationship among various actors. For example, a mobile phone is a disruptive technology as it has drastically reduced efforts to communicate by means of hand-written letters. Progressive innovations in the long run lead to overall economic and social gains, and do not

hamper existing socio-political relationships. For example, the **Soil and Crop Health Monitoring Mechanism using AI and cloud computing in the current context of Indian farming community can be considered a progressive transformation**.

Development of a channel for dissemination of AI solutions among farming communities

Slowly but progressively, application of AI and related technologies is shaping up as an input in the agricultural sector, since it is expected have a significant impact on the yield and profitability of farms. While other agri-input including irrigation, seeds and fertilisers have well-developed channels of sales and distribution, development of channels of dissemination of AI and related technologies among Indian farmers are still at a nascent stage. Based on the understanding gained from the framework depicted above, appropriate channels for dissemination of AI and related technologies can be developed. Some e strategic channels are discussed below:



The direct business-to-farmer channel is best suited for solutions that are socially embedded and are disruptive in nature. AgTech companies or tech giants can directly transact with farmers. Such solutions in the Indian context currently may include advisory services that farmers can receive on their mobile phones via messages. Whereas, for solutions that are not affordable for single farmers or require technical expertise, there is a need for development of intermediaries such as channel partners. These could include FPOs, AI entrepreneurs or AI sakhis (women entrepreneurs in the NRLM ecosystem).

In the case of FPOs, bundled farmer-facing services can be provided to a large number of farmers. This would also reduce the cost of such services and make them affordable for individual farmers. Additionally, to channelise effective dissemination of AI-led solutions for agriculture, innovative institutional collaborations can also be established with local institutions such as KVKs, agriculture universities and agriculture colleges. The framework depicted above for dissemination of digital technologies could act as a compass to guide selection of effective channels for dissemination of AI-led technologies in agriculture.

The strategies proposed for widespread adoption of AI in Indian agri-ecosystems are aimed at socially embedding the change, making it a multiplier force and transforming AI to agricultural intelligence.



Case studies

01 Harnessing the power of digital technologies for creating an effective decision support system for farmers

A case study from Corteva Agriscience, India

Core area of operation and a brief description of the problem being addressed by Corteva

Every year, on an average, farmers lose 37% of their rice crop due to severe pest and disease infestation. Farmers usually rely on their past experience or seek advice from fellow farmers/retailers to identify such diseases/pests and take remedial actions. In a majority of the cases, the advice may not be correct. In addition to good crop management, timely and precise diagnosis can significantly reduce further losses. Corteva is providing an AI-based diagnostic solution (powered by Plantix®) through **Corteva's Farmer Connect application**. Using this application, farmers can take a photo of the infected portion of the crop, and get a diagnosis report along with suggested remedial approaches (physical and chemical). This application also suggests farmers to purchase agro chemicals either from e-commerce vendors or nearby retailers (the contact details of nearby retailers are shared through the application).

Corteva's data science team has created the AI-based solution to address the aforementioned challenges. A few AI-based solutions supporting farmers are described below:

1. Remote sensing solution

a. **Acre-next:** Traditionally transplanted rice cultivation is water intensive and direct seeded rice (DSR) cultivation is an alternative to this method. The DSR method reduces water consumption and labour cost, thus increasing the chances of maintaining a higher cost-to-benefit ratio. AI solutions are developed from satellite images to detect DSR rice fields and provide weedicides solutions, along with advisory services to farmers, for ensuring optimum crop yield.

b. **Crop monitoring and acreage estimations:** The ML models are built using satellite imagery data for monitoring major crops like rice and corn for their health mapping and acreage estimation in the target areas for delivering the most appropriate solutions to farmers.

c. **Fall armyworm solutions:** AI-based models are built to provide early warning systems that includes identifying locations that are at a high risk of attack, the most likely time of attack and the stage of crop for recommending agrochemicals usage. The system also suggests the locations of retailers from where farmers can procure products/solutions.

2. Proximal sensing solutions:

a. **Internet of things (IoT):** With the help of sensors and interconnectivity, the IoT in agriculture delivers better data analytics and resource management by providing real-time data of the chemical and physical properties of soil, such as its moisture, nitrogen content, temperature and its pH, weather and resource tracking.

b. **Image processing:** Image processing has helped in identifying and detecting diseases that the field might be affected with. The digital scoring of the damaged area can help in automating the process and reducing labour cost/time to deliver the most appropriate solutions in a timely manner.

Factors likely to drive future growth

In a market research carried out by Corteva, it was found that 80% of India's farmers now own smartphones and are comfortable using them. This enables farmers to rely on using smartphones and digital solutions as their decision support system (DSS). On the other side, most of the private companies in the agriculture sector are working on digital innovation to help farmers take well-informed decisions. Key decisions on crop selection, insurance, farm finance, smart package of practices, crop health monitoring, nutrient tracking, yield estimation and soil health tracking will be driven through digital solutions which will involve the use of big data driven AI. This AI will help in generating an analytical view gathering insights, and providing customised solutions for individual farmers to form the basis of a farmer's DSS.

Corteva plans to use such AI models for future predictions and AI-powered solutions to help farmers protect their crop from possible biotic stresses and adopt recommended prevention measures. Corteva plans to reach up to one million farmers in 2021 and enable them to benefit from the organisation's AI-powered solutions.

Brief outcome/ socioeconomic or technological impact created through Corteva

The surge in the use of smartphone and digital farm solutions has enabled Corteva to play an important role by offering suitable digital solutions to help farmers take better decisions. Their AI-based package of practices has provided advisory services to more than 300,000 farmers. Within a year of its launch, there have been 1,670 instances wherein farmers have diagnosed their infested crop and benefitted by the precise and timely solutions provided by Corteva.

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02 Real-time analytics based digital solution to support farmers in enhancing their income

A case study from Bayer Crop Science Limited, India

Core area of operation and a brief description of problem being addressed by Bayer

Farming has traditionally been based on past practices, experiences and intuitions, and on calendar days or weather events. Digital technologies and AI now make it possible to drive farm interventions based on data, thereby significantly improving the probability of success. Farmers take significant (often uncalculated) risks, hoping for a good outcome. The fortune of farming is dependent upon the weather. Invariably, farmers are not prepared to take care of these eventualities and incur losses. The advisory which is generally provide to them is based on standard POP (package of practice) and does not consider everchanging weather conditions, crop conditions and other factors responsible for development of a crop, and the different types of stresses encountered by a crop.

With analytical models based on AI, Bayer is providing real-time advisory services to farmers and customised services as per individual requirements and conditions of the farmland. These models can visualise the interaction of the weather with crop/soil conditions and can create a real-time output. They can predict crop growth stages, nutrition and irrigation requirements, and pest/disease development. With the help of these insights, farmers can improve their chances of having a good season and reduce costs, and earn better income. Bayer is providing a realistic advisory service and helping farmers to grow more crops in a more professional and sustainable fashion. The solution will optimise their input usage (fertilisers and pesticides) and irrigation. It will also support them with residue management and other aspects of crop management. Timely prediction of various pests and diseases, and effective recommendations to manage them will help farmers reduce crop losses and improve their profitability.

Bayer is currently operating this model in a pilot approach in apple and rice fields. Farmers are being advised on the basis of the outcome of these models. The outcomes have been accurate and gradually the model will cover new crops and geographies.

Factors likely to drive future growth

Weather data is a very critical input for running AI-based models where there is a need to bring in multiple layers of weather data along with the forecasting for each location. Bayer is looking at a combination of virtual weather stations to get the larger volume of data and use various weather sensors to bring in a localised variation in the microclimate.

Going ahead, sensors related to soil parameters, e.g. soil moisture, soil pH, soil electrical conductivity (EC) and soil nutrient content, as well as imaging sensors for monitoring crop issues can be integrated to minimise manual effort, human bias and errors. These IoT-based sensors are required to capture the field reality and validate the hypothesis developed through available multisource crop-related data. One of the essential steps in development of these models is the validation of field outcomes (ground truthing) so that one can further calibrate these models and improve the accuracy level of predictions. The field resources needed to do complete the validation and shorten the development cycle will be critical success factors.

Creating farmer acceptance and demonstrating the benefits of this advisory will be the key to drive usage, especially given the fact that at certain times it will be contrary to their beliefs/historical experiences.

Brief outcome/ socioeconomic or technological impact created through Bayer

The benefits of this development would impact all farmers as they can make informed decisions using a data-driven and dynamic DSS. It helps farmers to prepare in advance and minimise crop losses. It has also helped them to follow crop protection schedules that can help them in managing minimum residue levels in the harvested produce and improve its marketability.

These models also helped Bayer in planning their activities better and optimise human resources, supply chains and other aspects of their business as they have a better visibility of crop development and knowledge of all the stresses that a crop can encounter.

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03 Bridging the information gap in existing agricultural systems via digital technology

A case study from Dhanuka Agritech Limited, India

Core area of operation and a brief description of the problem being addressed by Dhanuka

Dhanuka Agritech is preparing a pilot project to be implemented in one or more districts in India with the aim of doubling farmers' income using the latest technology. The adoption of such technology would ensure the overall increase in productivity and support in establishing market linkages for better remunerative prices for farmers' produce. This project is a collaboration between the state government, researchers from agriculture universities, the Krishi Vigyan Kendra (KVK) and a central team from the Ministry of Agriculture that will help in monitoring the project at periodic intervals to assess the benefits and meet the key objectives.

Dhanuka Agritech will work with FPOs/self-help groups (SHGs) and provide them services ranging from procuring seeds to the marketing of their produce. At the stage of crop management, Dhanuka will train the groups on sowing time, seed rate, land preparation, etc. Using the technology model, they will provide operational support on agro-chemical applications and irrigation schedules, along with the safety precautions to be adopted during the field operations. However, after the harvest, the model will also support farmers in finding better marketplaces for their produce and help in generating better income for them.

Factors likely to drive future growth

Farmers shall be trained through scientific agri extension and knowledge dissemination as a joint collaborative work with the government agencies. The necessary framework shall be prepared to reach out to these farmers by aggregating them and making the right exposure to use latest AI and mobile applications. The framework component includes mobilising farmers through promotion techniques by using the media, identifying the progressive farmers and assigning them the responsibility to communicate with their fellow farmers, taking the help of custom hiring agencies and supporting them to provide farmers with farm equipment and coordinating with the marketplaces under e-NAM, the National Commodity and Derivatives Exchange (NCDEX) and other bulk purchasing agencies.

Brief outcome/ socioeconomic or technological impact created through Dhanuka Agritech

Dhanuka has already demonstrated its private-public partnership (PPP) model in Hoshangabad district, Madhya Pradesh. The district shown improvement in yields due to the scientific approach adopted in agricultural practices. As a result, a 40% yield improvement was observed over the span of four years in the district. The National Productivity Council felicitated the district with the distinction of being the 'Best Productivity District'.

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04 Digital initiative for Healthy and Sustainable Green Cities

A case study from Husqvarna (India) Products Private Limited (HUGSI)

Core area of operation and brief description of problem being addressed by Husqvarna

Modernisation and globalisation are taking a toll on the resources in our existing cities, especially within the domain of sustainability. More than a million people move into cities and urban areas every day globally and the green cover in urban areas is impacted the most. Multiple research on this subject indicates the importance of green covers on human settlements with respect to both physical and mental health and well-being. HUGSI has created awareness on the importance of green cover and also provided tools to enable citizens, organisations and societies for the better creation, management and support of green areas within city limits.

There are a few solutions in this space at the moment but most of them are driven by local government initiatives and lack the potential to be applicable for extended geographical coverage, as well as collaboration and information that is needed across the domain to tackle the issue of green cover effectively. While many initiatives are being taken worldwide for on ground remediation, HUGSI see a lack of tools and processes available in terms of information. There is also a lack of platforms across geographies where data can be shared and digital technology capabilities can be utilised to quickly onboard different stakeholders and let them innovate on real-time information to manage, control and plan green spaces within cities/urban areas.

Factors likely to drive future growth

As the stress of globalisation increases on cities, there is a need to increase the awareness regarding the importance of green space creation, maintenance, support and quality for basic physical and mental health. This would drive governments and organisations to not only be aware but also act on different aspects. HUGSI provides the necessary tools with easy, accurate and timely information, along with future-prediction capabilities to drive both awareness and demand. Millennials can provide some extra impetus as they are not only aware about sustainability implications but can also impact purchase behaviour to a large extent.

Digital solutions which are modularised and easy to implement would be readily acceptable and implemented (for example using API economy) into existing services to benefit from customer exposure and goodwill perspective. These digital solutions can provide real-time information and are inexpensive to scale up. This is a crucial and important aspect, especially when trying to create an impact on a mass audience that includes the different sections of society.

Digital technologies like AI can provide capabilities like predictive information and maintenance where solutions can be designed in a proactive manner rather than trying to fix the issue post sustaining any damage.

Brief outcome/ socioeconomic or technological impact created through HUGSI

HUGSI creates awareness within city/ urban municipalities on how green their environments really are. It also provides easy tools and mechanisms to help people understand their green environments. It uses publicly available datasets to create insights by utilising ML and deep learning technologies.

HUGSI is setting the standards for new ways of working and reporting metrics when it comes to the greenness of urban environment. It also facilitates the creation of friendly and healthy competition between cities on what measures could be taken to make the environment better.

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05 State-of-the-art digital farming solution to bring prosperity in the Indian agricultural ecosystem

A case study from xarvio™ Digital Farming Solutions (powered by BASF)

Core area of operation and a brief description of the problem being addressed by xarvio™

xarvio™ Digital Farming Solutions delivers tailored, state-of-the-art agronomic advice to farmers to increase the efficiency, profitability and sustainability of their agricultural operations.

They offer three digital products, namely Scouting, Field Manager and Healthy Fields. These products are used by farmers in more than 100 countries worldwide. Their goals are to increase farmers' incomes, optimise the use of crop protection products and prevent the degradation of environmental resources due to farming practices. They believe firmly that digital technology has the power to transform agriculture, pushing it towards a more sustainable path.

In India, xarvio's Scouting tool (freely available) enables farmers to detect infield stress by simply taking a photo. Available in six languages, Scouting is used by 1.95 million farmers in the country and this figure is increasing daily. The product is calibrated to recognise diseases and weeds specific to the Indian geography. It also has the capability to analyse leaf damage, so that farmers can monitor plant health and respond to the field stresses that may occur. The product's unique radar feature alerts farmers on incidents of diseases or pests in their surrounding areas. Additionally, their partnership with Agrostar facilitates the delivery of crop protection products to farmers' doorsteps and is especially useful in the current unprecedented times.

Their upcoming product Field Manager will be launched in 2021 and will be a constant companion to the Indian farmer, from the processes of sowing to harvest. It will provide real-time information on weather, sowing and optimal spraying times to improve efficiency, boost crop health, increase crop yield, ensure compliance and support sustainability.

Factors likely to drive future growth

Climate change and the degradation of natural resources is impacting yield increases. Such a situation has created a pathway for the development of modern agricultural technologies to provide solutions that address these issues. Furthermore, an increase in supportive initiatives by the Government of India to improve the economic returns from farms by providing growers with state-of-the-art information is also key towards driving growth in the digitalisation of the agriculture sector. xarvio™ strives to provide farmers with holistic and accurate information at the right time for informed decision making. In order to do so, forging partnerships is a key factor required for the growth of the sector. The start-up ecosystem in India is brimming with innovation and xarvio™ believes that collaboration with a range of businesses and organisations is the right way forward to help achieve the common goals of increasing food production, delivering sustainability and helping to raise the socioeconomic status of the Indian farmer.

Brief outcome/ socioeconomic or technological impact created through xarvio™

xarvio's digital agricultural tools enable farmers to take preventative action to protect their crops from pests, diseases and other infield stresses. Their targeted actions for crop protection result in improved efficiency and higher yields with less inputs. This has direct implications on boosting farmers' incomes while increasing their social mobility and ensuring the sustainable growth of agriculture. xarvio™ is one of the leaders working towards transforming the Indian agriculture industry and the livelihoods of millions of farmers.

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06 Uberisation in agriculture

A case study from FarmERP

Core area of operation and a brief description of the problem being addressed by FarmERP

Growing concerns about climate change and the need for improving quality are among the important factors driving agribusinesses to implement tech-driven automation in agriculture. FarmERP has been working towards the uberisation of agriculture and agribusiness since 2001 and aims towards making them efficient and profitable. Its next-generation farm management technology platform helps users to improve farming by using sustainability, traceability, climate-resilience and food safety. FarmERP's 'Uberization in Agriculture' project is based on the foundation of precision and smart farming. It brings smallholder vegetable farmers in Maharashtra and buyers together through a single platform that makes agriculture predictable and more profitable for farmers.

The project is aimed at making agriculture predictable by solving issues in the three primary areas of farming, i.e. climate change, improving the quality of produce and market linkage. Through this project, FarmERP helped in mapping and tracing the entire agricultural supply chain – from pre-sowing to harvesting, procurement to sales to traceability over a single digital platform. With the use of AI, deep learning, computer vision, soil sensors and satellite imagery analysis, FarmERP helped farmers to uberise their processes and provide climate-smart advice. Buyers can judge the quality of vegetables and the rates can be fixed. FarmERP also enabled disease-related risk prediction vis-a-vis impending pest threats. This ultimately facilitated the intelligent use of pesticides and fertilisers, thereby improving pest control and nutrient management in vegetable crops. Satellite imagery analysis also helped in improving management practices for various factors such as vegetation, biotic stress, abiotic stress and moisture. FarmERP promoted sustainable agricultural practices and climate resilience during the crop production stage by educating farmers through digital advisory services (DAS). Field officers conduct weekly visits to collect research data and make observations. Collective marketing helps to reduce the emission of distributions in the supply chain, which also contributes to climate resilience.

Factors likely to drive future growth

While the COVID-19 pandemic hampered business dynamics for most industries, the agriculture industry remained largely unaffected. The growing demand for food consistently improved the potential for expanding market reach for farmers and agribusinesses in India. The pandemic highlighted the importance of technology in agriculture. However, the lack of prevalence of AgriTech tools for smallholder farmers restricted them from leveraging their full potential. FarmERP has mapped a smallholder vegetable grower's journey from crop production to sales process using technology tools that are more farmer friendly, foreseeing the huge scope for market expansion.

Farmers are increasingly offered the opportunity to employ intelligent farming practices with the help of these emerging technologies. These digital transformations are making farmers understand the market demands with reference to food safety.

The uberisation project also helped them optimise grower activity through a task calendar and manage their expenses as per budget, while maintaining the high quality of the produce. As the entire supply chain, starting from procurement to packing and sales, was digitised, smallholder farmers could achieve greater control over their operations and earn more profit.

Furthermore, innovations in the digital technologies and the AI models that FarmERP has built to solve various problems faced by smallholder farmers need continuous ground reality knowledge and refinement. Team FarmERP is directed towards improving the accuracy of yield predictions, climate-smart advice for irrigation, nutrition, pest and disease management, quality of vegetables, and sustainability analysis.

Brief outcome/ socioeconomic or technological impact created through FarmERP

The project improved profits as well as predictability in vegetable production for smallholder farmers, which ultimately led to an increase in technology adoption and improvement in their socioeconomic status. This project also ensured better farmer-buyer linkage. FarmERP extended its expertise to these farmers to help them understand and measure quality standards expected by the buyers. FPOs and buyers both benefited by meeting demand and supply requirements at both ends. It also enabled farmers to implement precision agriculture to a great extent and improved their decision-making practices through AI-based tools and technologies.

Through the implementation of the project, FarmERP was partially successful in making agriculture highly predictable for smallholder vegetable farmers. With the continual improvements in the accuracy of the models, FarmERP aims to reach higher levels of precision and predictability through AI-driven agriculture.

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07 Utilising digital technologies to address farm-level issues

A case study from ITC Limited, Agri Business Division

Core area of operation and a brief description of the problem being addressed by ITC

E-Choupal 4.0 for chilli value chain development: Most of the farmers cultivating chilli are small farmers and they lack access to good agricultural practices and technologies. The increasing cost of cultivation, labour shortage, erratic distribution of rainfall and crop integrity issues are making chilli farming difficult. On the other hand, the growing awareness of chemical residues has led to consumers demanding safe food products and there are stringent Government regulations on the same. The proposed solution aims to transform the conventional crop-level generic advice to a more customised advice for the farmers. The solution is based on international market demand, climate conditions, soils and current crop conditions, etc., integrating multiple data points from farmers, field monitors, agriculture experts, research and development (R&D) and the Government, using the 'digital crop advisory cum monitoring' module of ITC's e-Choupal 4.0 digital platform supported by an on-ground handholding ecosystem. The objective is to develop a globally competitive crop production system which addresses the key elements of farmer profitability, i.e. farm productivity (lower costs, increased yield and minimised wastage) on the one hand and product quality and integrity (which drives the realisable price and marketability) on the other, in an environmentally sustainable manner. The platform was adopted in the integrated agri extension platform development for chilli value chain development in partnership with the Department of Horticulture, Government of Andhra Pradesh under a PPP model.

Factors likely to drive future growth

In 2019, the digital platform provided contextualised and personalised advice to over 4,000 chilli farmers in four districts of Andhra Pradesh, covering over 12,000 acres. In 2020, it planned to increase its reach to 10,000 farmers (25,000 acres) and further to 40,000 farmers (100,000 acres) by 2023–2024. The digital platform shall further expand the scope, from providing information and agronomy advisory to products and services to the farmers to boost their incomes.

The focus of the e-Choupal 4.0 platform is to collaborate with partners of repute in the agri industry to facilitate the adoption of a package of best practices and the use of inputs in line with quality attributes as required by national and international markets. The platform will be expanded to deliver more products/services to the farmers – pesticide spraying services using drones, farm implements, financial services, remote sensing, rapid quality assaying and market linkage platforms for better price discovery. Apart from delivering agri services, the platform will be expanded to deliver non-agri services too in the future. The platform will be expanded to provide services to farmers of other crops and corresponding geographies, covering wheat, paddy, oilseeds, fruits and vegetables in the near future.

Brief outcome/ socioeconomic or technological impact created through ITC

The intervention created an enabling ecosystem for synergising the expertise of multiple players and service providers across the chilli crop value chain. The efforts to educate and handhold farmers through the digitally driven chilli value chain development has resulted in a 13% crop productivity improvement, and a 27% rise in net returns per acre for the chilli farmers. Efforts in the programme resulted in an increase in the farm gate purchase, from 30% to 62%, thereby providing the farmers with better prices and reducing costs incurred in transport. The 'phygital' model implemented has been an exemplar in utilising digital technologies for value chain development,

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08 AI and digital applications in agriculture

A case study from Infosys Technologies Private Limited

Core area of operation and a brief description of the problem being addressed by Infosys

As a global leader in next-generation digital services and consulting, Infosys has worked with several agricultural enterprises, farm equipment manufacturers, seed manufacturers, fertiliser manufacturers, food and beverage manufacturers, retailers and logistics providers. The organisation helps its clients modernise the business functions and IT systems, and maximise outputs while ensuring environmental sustainability. This is achieved by providing innovative domain and technology solutions across the agricultural value chain – from season planning to post-harvest management.

Providing farmers and enterprises with powerful insights for improving yield

The Infosys Smart Agriculture solution integrates with multiple sensors in the farm to gain insights on soil conditions, weather information, storage systems and trigger irrigation systems for automated irrigation, and optimised water usage. Infosys's drone-based solutions, integrated with RGB and NIR cameras, help in crop scouting. This solution improves yield and encourages sustainable agriculture practices. Infosys developed a precision farming application for a global seed manufacturer using advanced digital technologies like IoT, drones, AI and ML. Infosys is also a part of the Industrial Internet Consortium (IIC), which developed a precision crop management testbed.

Digital solutions for agro machinery

Infosys helps manufacturers in the design and development of next-generation farm equipment. This includes developing planter ECU firmware, simulators and telematics applications that ensure the equipment is IoT-enabled. Infosys is also involved in predictive maintenance and condition monitoring of these critical assets and helps reduce the maintenance cost and equipment downtime.

Implementing cutting-edge technologies with precision and scale

The solutions developed by Infosys are a powerful combination of technologies like IoT, AI/ML, big data and analytics, advanced image analytics, blockchain, mobility and cloud technologies. customisable algorithms, business logic, strong agronomy expertise and agro-university collaboration. As a result, the solutions derive sharper insights to create better agri products, increase process efficiencies, automate and reduce the cost of operations and meet sustainability goals.

Factors likely to drive future growth

Digitisation will play a key role in making technology products farmer friendly and the solutions more effective for agri businesses. The factors that are likely to drive transformation in this field include:

- End-to-end turnkey solutions: Equipment manufacturers can provide one-stop shop solutions to cater to all the needs of the end customer (farmers or dealers).
- Personalised services: Personal touchpoints are provided to end customers (B2C) through customer portals, mobile apps and phone-based customer support.
- Technology adoption: Utilising IoT, 5G and cloud technologies to provide holistic experiences at a greater speed. Appropriate networks and analytics can help a farmer or grower make informed decisions.
- Servitisation: New business models such as pay-per-use can enhance the manufacturer-dealer-end customer relationship by providing much higher value, better flexibility and lower total cost ownership (TCO) for the end customer. With this approach, farmers are entitled to pay for what they use, such as acres ploughed, without owning or leasing equipment.
- Affordable field sensor or equipment integration: Affordable sensors used in agriculture will increase technology adoption. Software, coupled with required hardware, such as sensor nodes and communication gateways, can help in real-time data collection, whereas satellite or drone-based image analytics can help in crop scouting.
- Need for accuracy and timely traceability: Consumers in many parts of the world demand verifiable evidence of traceability as an important criterion of food product quality and safety. Blockchain technologies are widely used for this purpose.
- Sustainable agriculture and innovation: Adopting sustainable farming practices to satisfy today's needs without compromising the ability of the future generations to meet their food demand has become a trigger for IT innovation.

The agriculture industry can adopt the manufacturing industry's Industry 4.0 practices to improve efficiency across the value chain.

Brief outcome/ socioeconomic or technological impact created through Infosys

Over the last few years, Infosys has extensively helped customers with platforms and solutions to improve agricultural yield, reduce costs, increase quality and implement sustainable practices.

Here is an image of Infosys's digital agriculture solution installed to harvest multiple crops across multiple seasons of the year. It is a technical demonstrator and a testbed to build and roll out next-generation agriculture solutions.





In countries like India, tractors and other farm equipment are used for over 50 years. Given the increasing population and lower arable area, it is imperative to use technology to increase yield, reduce water consumption and usage of fertilisers, minimise pesticide usage and make optimal use of the land (which is less than a couple of acres per farmer). By partnering with farm equipment manufacturers, seed manufacturers and cloud providers, Infosys has introduced innovative digital solutions to reduce the burden on the farmer and make agriculture profitable and sustainable.

Additionally, Infosys's CSR initiative, Infosys Foundation, works closely with farmers to provide them agricultural consultancy, loans and ecosystem connect, thus improving their lives. More than 50% of India's livelihood relies on farming. Infosys is driven by its core values to help improve the lives of farmers and make food more affordable for people.

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FICCI provides a platform for networking and consensus building within and across sectors and is the first port of call for Indian industry, policy makers and the international business community.

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At PwC, our purpose is to build trust in society and solve important problems. We're a network of firms in 157 countries with over 276,000 people who are committed to delivering quality in advisory, assurance and tax services. PwC refers to the PwC network and/or one or more of its member firms, each of which is a separate legal entity. Please see www.pwc.com/structure for further details.

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About PwC's Agriculture and Natural Resources team

PwC India has a dedicated and highly experienced team working in the agriculture and natural resources sector which provides advisory services related to agriculture and agribusiness management, long-term transformational project implementation, food processing, agricultural credit, agri policy, impact assessment, performance improvement, commodity trading, integrated resource management, farm inputs and agri infrastructure. Part of the Government Reforms and Infrastructure Development (GRID) practice, the group consists of graduates and postgraduates in agriculture, agribusiness management and natural resources, with extensive experience in various aspects of the agriculture sector, including advisory in the agriculture and food domain, supply chain management, public private partnerships, policy advocacy, agri economics, agri retail, agri marketing, farm inputs and banking.

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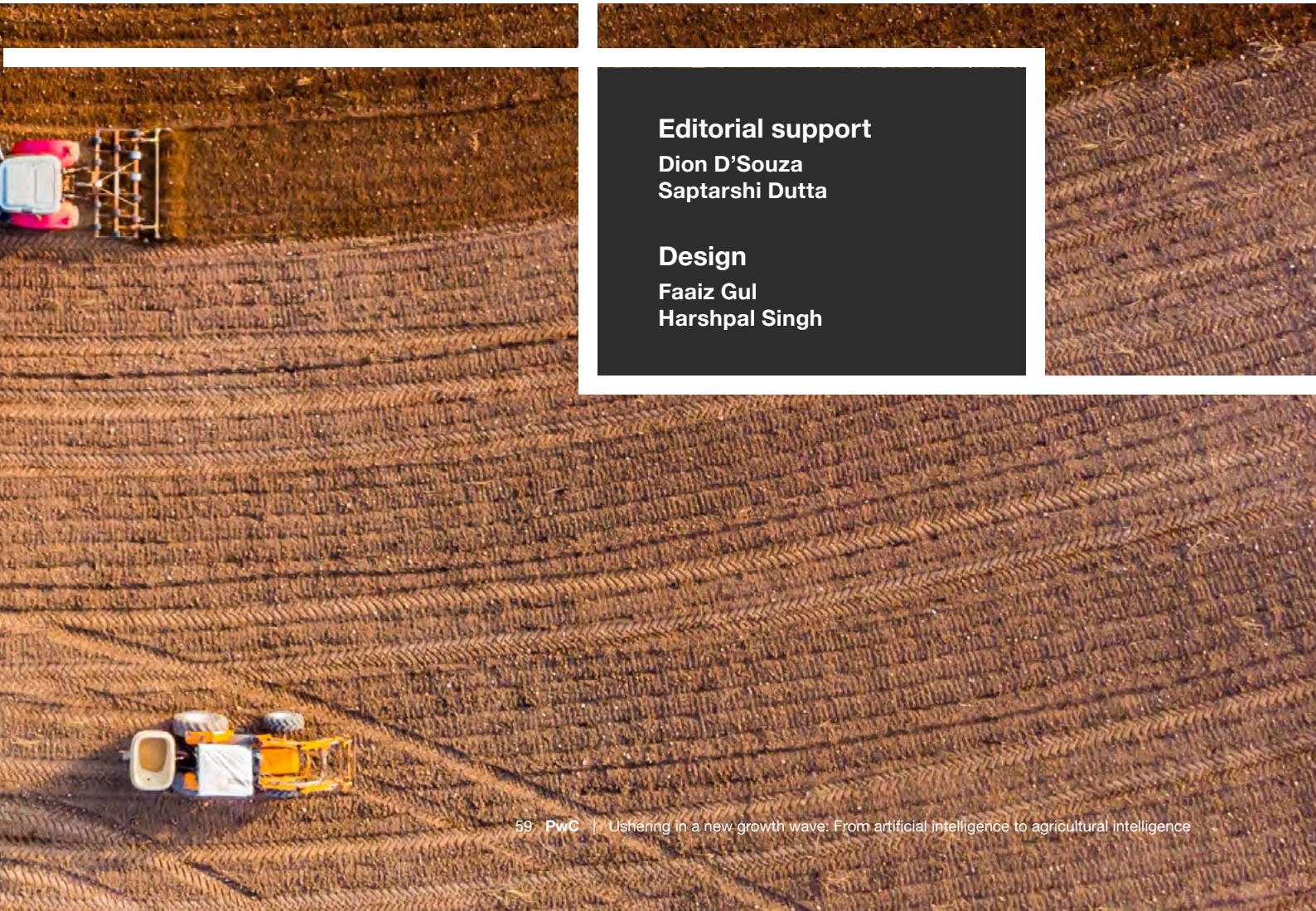
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