Agriculture 4.0
Towards Agri-Tech Revolution

India has immense potential to transform its agriculture and allied sectors into a powerhouse of growth and prosperity. By adopting digital technologies like artificial intelligence, blockchain, the internet of things, big data analytics, robotics, etc., farmer incomes could be increased, while simultaneously ensuring food security for the growing population. This is possible by leveraging these technologies for precision agriculture, reducing wastage, enhancing climate resilience, improving market linkages, and revolutionising farm economics.

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The agriculture sector employs 42.3% of India's workforce and contributes around 18.2% to the country's GDP. However, the sector faces challenges like low productivity, high monsoon dependence, small landholdings, post-harvest losses, and volatility in farm incomes. Nearly 89.4% of farmers own less than 2 ha of land. Crop yields in India are 20-60% lower than global averages. For instance, rice yield in India is 3.85 t/ha compared to 6.57 t/ha in China. Around 52% of farming is rainfall dependent, making agriculture highly vulnerable to climate change impacts. Post-harvest losses ranged from 0.92% to 15.88% depending on the crop and commodity across the agricultural value chain. The livestock sector, which accounts for 30.23% of agricultural GDP and employs millions of people, also need help with issues like lack of nutritious fodder, inadequate infrastructure for animal health, and supply chain constraints, etc.

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Despite these challenges, India has immense potential to transform its agriculture and allied sectors into a powerhouse of growth and prosperity. By adopting digital technologies like artificial intelligence, blockchain, the internet of things, big data analytics, robotics, etc., farmer incomes could be increased, while simultaneously ensuring food security for the growing population. This is possible by leveraging these technologies for precision agriculture, reducing wastage, enhancing climate resilience, improving market linkages, and revolutionising farm economics. The use of data, connected tools, and contemporary digital technologies to increase agricultural operations' production, sustainability, and efficiency is known as 'digital agriculture.'

Idea of Digital Agriculture

Over the years, digital agriculture in India has evolved from basic information and communication tools to more advanced and integrated systems. Today, the focus is on real-time monitoring, data-driven planning, modern technologies, and strong decision-support systems. The scope of the idea of digital agriculture, which we envisage to bring the next Agri-Tech Revolution, can be broadly understood through two complementary paradigms:

1) **SmartFarm Digitisation**, and
2) **SmartAgriSphere Digitisation**

The first one, i.e., SmartFarm Digitisation refers to the direct deployment of digital technologies at the farm level, enabling farmers to make data-driven decisions and manage their fields with precision. This includes tools such as IoT-based soil and crop sensors, drones for imaging and spraying, automated irrigation systems, and mobile-based farm management platforms. These technologies help transform traditional farms into tech-integrated, responsive production units, enhancing productivity, resource-use efficiency, and climate resilience. It is, in essence, the digitisation of the farm itself.

Whereas, SmartAgriSphere Digitisation encompasses the wider digital ecosystem that supports agriculture without being physically embedded in the farm. This includes satellite-based remote sensing for crop monitoring, weather forecasting systems, blockchain-enabled supply chains, digital platforms for market access, credit, insurance, and subsidies. These interventions operate at a systemic level, enhancing governance, improving transparency, and enabling precision services across the value chain. They represent the digitisation around the farm, creating an intelligent, interconnected agricultural ecosystem that benefits farmers indirectly but significantly.

Together, these two layers of digitisation, i.e., SmartFarm at the ground level and SmartAgriSphere at the systemic level, form the foundation of a modern, resilient, and technology-enabled agricultural sector. While the former empowers individual farmers, the latter strengthens the broader institutional and infrastructural framework in which agriculture operates. Both are essential for realising the vision of a digitally transformed Indian agriculture. While there is no water-tight separation between the two levels of digitisation, they complement each other in their objectives.

SmartFarm Digitisation

SmartFarm Digitisation includes a wide range of technologies that support precision farming, such as artificial intelligence, drones, remote sensing, blockchain, and control systems. These tools help farmers adopt climate-smart practices at their farms and promote sustainable agriculture. The embedding of digital technologies on farm level, for example, drone adoption in Indian agriculture, remains relatively low as compared to countries like Japan and South Korea, where adoption rates exceed 60%. Whereas, in China, the usage of drones in agriculture is widespread, more than United States. Apart from this, China has developed and implemented various IoT-based systems for monitoring and controlling crop diseases and insect pests, particularly in rice and orchard settings. In India, about 30-35% of crops are damaged due to pest infestation of crops. Further, climate change is projected to significantly increase pest attacks in agriculture, with each degree celsius rise in temperature potentially leading to a 10-25% increase in yield losses due to insect pests, which is alarming. Another significant concern is the overuse of water for irrigation in Indian agriculture. Data indicates that irrigation, particularly from groundwater, is extensive, with 70-80% of farmers relying on it. Inefficient irrigation practices have led to various problems like water-logging, salinity, and declining water tables. Approximately 17% of groundwater blocks in India are classified as overexploited, with 5% being critically depleted, according to the Central Groundwater Board. Another 14% are categorised as semi-critical, meaning they are experiencing significant depletion. The use of sensors in agriculture, particularly for precision irrigation, can significantly reduce water requirements in India, potentially by up to 50%. Similarly, IoT-based sensors can collect data on various macro and micronutrients in the soil. Optical sensors can be used to apply the liquid, granular or gaseous fertilisers in the field, which automatically dispense fertilisers in optimum quantities, saving from overuse of fertilisers. Weed mapping can be done with the help of drone and image processing technologies. If this is further equipped with GPS, it can create a weed map, after which automatic spraying of weedicides can be done based on precision requirements. A smartphone can be the easiest and one-stop tool to conduct, control, and monitor these operations. Smartphone, a device in the day-to-day life of most of us, is equipped with so many sensors that can be utilised in the most versatile possible ways. For example, the camera can help in taking pictures of soil and plant leaves for calculating leaf area index. The picture taken can be sent for further investigation to remote centres. The GPS can be used to identify the exact location of problems in the field. The accelerometer in smartphones can help in setting up an alarm as per requirements. The gyroscope can identify movements in the farmer's field. The farmer can ensure the traceability and authenticity of seeds using his smartphone if the seed package is embedded with such information in a QR code.

On the ground, these automation technologies help reduce physical labour by using AI tools for analytics, robotic weed control, drone-based spraying, and efficient irrigation systems. Around 90% of Indian

farmers cite the availability of labour as a challenge. Thus, technology can help in addressing the challenge of labour availability in agriculture, but also reduce the disguised unemployment in Indian agriculture. However, to address this, it would be imperative that the agricultural labour force becomes skilled in technology operations and they are equipped with the technical know-how required for the Next-Generation Agriculture Revolution that we are envisaging.

In India, approximately 85.5% of households possessed at least one smartphone. Around 86.3% households in India have access to the internet within the household premises. In the age group 15-29 years, around 95.5% of persons who own a mobile phone in rural areas own a smartphone. This widespread adoption of smartphones in India offers a massive opportunity to achieve the goal of making *'every farm a SmartFarm.'* This is just the ideation of digital agriculture in the field.

SmartAgriSphere Digitisation

This refers to building a supportive ecosystem of backward and forward linkages for the agri-value chain, which is going to indirectly and ultimately benefit the farmer. For example, blockchain technology can make supply chains more transparent by ensuring traceability from farm to fork. QR code-based systems help confirm the quality and origin of products, increasing trust and boosting the export potential of agri, dairy, and livestock goods. Direct linkages between farmers and buyers through online platforms and digital marketplaces can help farmers get better prices and reduce their dependence on middlemen. Artificial intelligence platforms can deliver hyperlocal, crop-specific advisories on weather changes, pest risks, and good farming practices. These advisory services can play a big role in helping farmers cope with climate change and build long-term resilience.

Geo-tagging of agricultural assets can support better farm planning and risk management. Through remote sensing and satellite imagery, soil moisture, crop health, and pest or disease outbreaks can be monitored, and suitable advisories may be disseminated at the village, block, and district levels, which would help in timely intervention.

Livestock productivity can also be improved by tracking animal health, feed quality, and early signs of disease. This reduces losses and improves farm income. In the dairy sector, automation can improve quality assurance by reducing manual handling and operational losses.

In the fisheries sector too, digital technologies can support efficient planning by providing weather updates, price trends, and market information. Mapping of water bodies, tracking of the fisheries value chain, and digital commerce platforms can further connect fishers directly with buyers. The mapping of fishing zones and the monitoring of marine ecosystems can help in reducing the risks involved in fishing activities, advising the fishermen on locating a good catch of fish, and at the same time ensuring that fishing is done in a sustainable manner.

Although the idea of smart agri warehousing is gaining momentum, which includes usage of sensors to

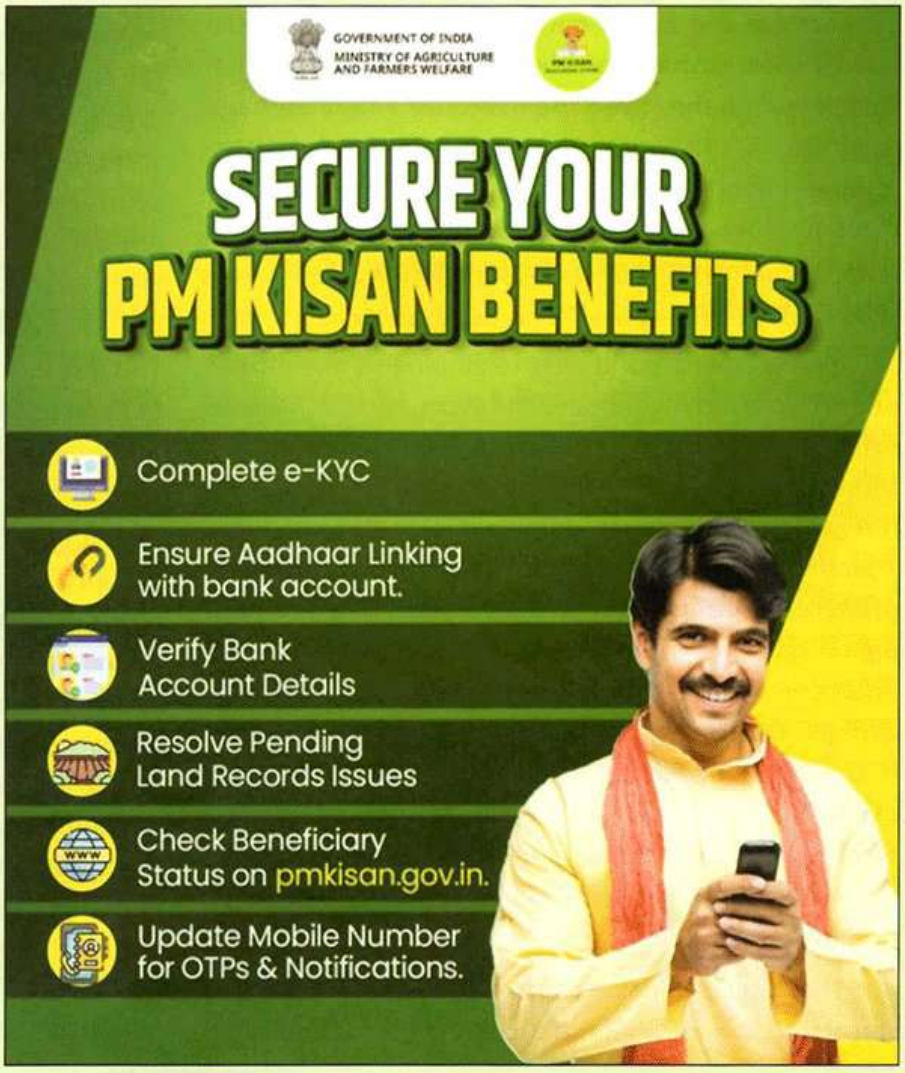
monitor parameters such as temperature and humidity (so as to effectively minimise losses); the adoption of this idea in India is yet at a minuscule and nascent stage.

Agri Stack India: Digital Agriculture for Policy Planning, Implementation, and Monitoring

Digital agriculture is not only essential for promoting smart farming practices but also serves as a powerful tool for data-driven decision-making and evidence-based policy planning. By integrating diverse datasets such as satellite imagery, weather forecasts, soil health records, and market intelligence, farmers can be empowered with comprehensive, real-time insights for informed decision-making. To fully leverage this potential, a national-level platform like Agri Stack may be conceptualised as a Comprehensive Agriculture Management System (CAMS). This system may be built on the robust and transparent financial principles of the Public Finance Management System (PFMS) and Comprehensive Financial Management System (CFMS). Such a system shall encompass strong and secure databases on the backend, and a single window clearance system on the front end. The backend of CAMS should include data on farmers' identity, such as Aadhaar-linked farmer ID, social group, SHG or FPO membership, and details of landless workers. It should also include information on land and assets like geo-tagged land parcels, soil health, water sources, and land ownership or rental status. Cropping and input records should also be maintained, including crop patterns, yield history, use of fertilisers and seeds, and whether the farmer is using organic or natural farming methods. Real-time data such as satellite-based crop health images, weather and pest alerts, and warnings for floods or droughts should be part of the system. It should also contain details of agriculture infrastructure like seed and fertiliser outlets, custom hiring centres, cold storage, warehouses, and transport facilities. Market-related data such as MSP procurement, mandi prices, buyer linkages, and food processing units should also be linked. The system must include details of credit and insurance like Kisan Credit Cards, loan history, and crop insurance coverage under schemes like PMFBY. It should also link government schemes and benefits like PM-KISAN, RKVY, PKVY, and SMAM, etc., and include features for checking eligibility and raising grievances. CAMS should also support digital advisory services. Farmers should receive personalised messages through mobile phones about weather, crop choices, and climate-friendly farming practices. Strong data protection, consent-based access, and real-time dashboards will help ensure transparency and better policy planning. This type of unified and farmer-friendly system can not only improve how agricultural services are delivered across the country, but also be helpful in policy implementation, planning, monitoring, and evaluation at multiple levels of governance, from village to block, district, state, and central levels.

Way Forward

Despite the immense potential of digital agriculture, there are a few important areas that need to be strengthened to fully move towards Agriculture



4.0. One of the key concerns is the limited digital infrastructure in many rural areas. High-speed internet connectivity and better power supply with renewable energy sources shall ease the farmers' access to digital services when they need them. Mobile and broadband coverage is still weak in several remote locations. Another important area is affordability; we need to take steps to make these digital technologies affordable to everyone, so that they become a model of Inclusive Digital Agriculture.

Regulations around new technologies like drones and artificial intelligence are still evolving, which would safeguard the digital revolution from cybersecurity threats. At the field level, extension services need not just to be strengthened but also evolved with Training and Capacity Building (TCB) programmes, to prepare themselves for the revolution and promote digital agriculture effectively. Similarly, several Farmer Producer Organisations, cooperatives and Self-Help Groups are in the early stages of digital adoption. It is equally important to ensure that the benefits of digital agriculture reach all sections of society. Women farmers, tribal communities, and landless workers, should be given special focus in such TCB programmes.

The Government has taken several important steps to promote digital agriculture through flagship schemes such as PM-KISAN, Digital India, Kisan Credit Cards, Soil Health Cards, and the Pradhan Mantri Fasal Bima Yojana, etc. The Digital India programme has brought high-speed broadband connectivity to over 2.5 lakh villages, laying the foundation for precision farming. While these initiatives have created strong momentum, the overall adoption of digital innovations in agriculture still has a long way to go. Continued efforts are needed to improve awareness and digital capacity among farmers, expand access to affordable finance, upgrade rural infrastructure, and develop localised technology solutions suited to the diverse needs of Indian agriculture.

India's vast network of 113 ICAR institutes and 74 agricultural universities and 731 KVKs spread across the country can serve as key enablers for the transfer of technology from lab to land and be a catalyst for this digital transformation in Indian agriculture. Digital technologies usually operate on economies of scale, and these economies of scale are possible to achieve through the vast network of 1,01,524 Primary Agricultural Credit Societies (PACS), 8,875 registered FPOs across the country. The United Nations has declared 2025 the International Year of Cooperatives. This presents a timely and valuable opportunity for India to position its cooperative ecosystem as a driving force behind a modern, digital agri-economy. It is a moment to align our efforts with the national priorities of Digital India, Make in India, Agriculture 4.0, and *Atmanirbhar Bharat*. Looking ahead, it is essential to move from isolated efforts to a nationwide movement for digital agriculture that is inclusive, scalable, and centred on the farmer. The transition to Agriculture 4.0 is not only about technology adoption but also about strengthening rural communities, reshaping agricultural systems, and building resilience across the value chain. With the right vision, coordination and commitment, India can become a global leader in agricultural innovation, where every farmer, regardless of land size, is empowered to thrive in the digital age. ❑