

AGRICULTURAL TECHNOLOGY

in India

Innovating for a Greener Tomorrow



Like in all other parts of human life, technology and a fusion of digitized systems are increasingly being used to manage agricultural processes. Technology has historically played a crucial role in India's agriculture, particularly since 1965. Driven by the concerns about food security, India successfully translated the vision of self-reliance in agriculture into reality with the help of a robust agricultural science & technological ecosystem comprising high-yielding seeds, irrigation, and intensive use of associated inputs. Since then, the agriculture sector across the globe has further witnessed an emergence previously unheard-of and innovative use of existing technology.

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1. What are the prevalent technological applications being used and developed in the agriculture sector?

- Agricultural technology, also known as “agri-tech,” encompasses a broad range of disciplines and devices that improve agricultural output.
- It includes a wide range of tools, equipment, techniques, and systems designed to improve various aspects of agricultural practices, including **crop production, livestock management, and farm operations.**

1.1 Prevalent technological applications in the agriculture sector

Table 1.1. Technological Applications in Agriculture

Farm management and monitoring technologies

- Includes use of technologies like sensors, IoT (Internet of Things), remote sensing, Global Positioning System (GPS), Geographic Information System (GIS), wearables, cameras and drones in combination with big data analysis, Artificial intelligence, machine learning etc. to enable **data collection and analysis for monitoring of health indicators** of soil and livestock, pests, climatic conditions etc.
- E.g., **Precision Agriculture (PA) utilizes GIS and data analysis** to for precise management of inputs, such as water, fertilizers, pesticides, and seeds, based on the specific needs of different areas within a field or farm.

What's new?

Connected cows: Wearable sensors are developed for cows to monitor health and increase productivity. E.g., Connecterra, a Dutch company, makes Fitbit-style necklaces that monitor a cow's movement and feeding habits which can be used to detect health problems.

Mechanisation of agricultural activities

- Includes **labour-saving technologies**, such as manned and automated tractors, seed drills, harvesters, combines, mechanised trawlers etc. to **perform mechanical tasks** like sowing, harvesting, weed removal, fertilizer and pesticide application etc.

What's new?

Agricultural robots are being developed for automation of agricultural processes like sowing, transplanting, harvesting, etc. through. E.g., Harvest CROO, a robotics startup, has developed an advanced strawberry-harvesting robot.

Biotechnology and Genetically modified organisms

- Utilizes technologies such as genetic engineering, molecular markers, molecular diagnostics, vaccines, and tissue culture to **enhance genetic potential of plants and animals.**
- E.g., **Bt cotton** is a genetically modified pest resistant cotton variety.

What's new?

Lab-grown meat — or cultivated or cell-based meat — is being developed from animal cells and grown, with the help of nutrients like amino acids, in massive bioreactors.

Digitalization of Agri Logistics and other extension services

Utilises technologies such Application Programming Interfaces (APIs), Artificial Intelligence, machine learning, blockchain, etc. to **manage forward and backward linkages** in the agricultural sector in an organized and sequential manner.

What's new?

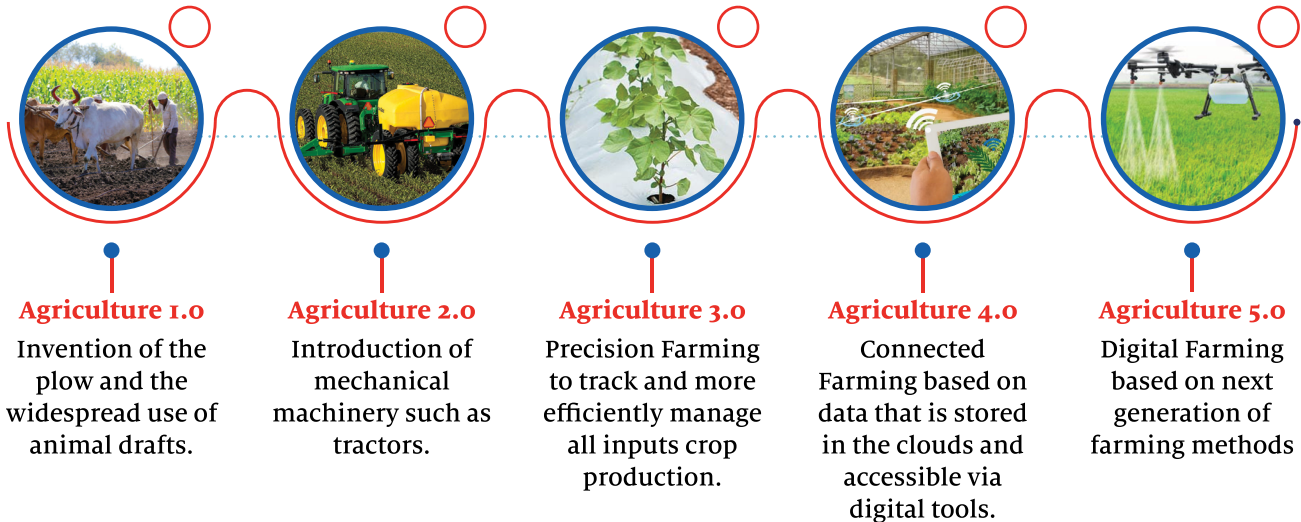
Agri-fintech companies: It includes digital payment systems, crop insurance platforms, and online lending platforms that offer farmers convenient and accessible financial solutions.

Other Technologies

- **Vertical farming:** The practice of growing produce in vertically stacked layers. It uses soil, hydroponic, or aeroponic growing methods to grow crops in a controlled environment.
- **Nanotechnology:** It is being used to develop nanopesticides and nanofertilizers to increase the productivity. E.g., Nano Urea developed by the Indian Farmers Fertilizer Cooperative Limited (IFFCO).

Box 1.1. Evolution of Agricultural technology

The technological model of agricultural production has undergone many transitions since the invention of tools like the plough. For example, the next generation of agricultural technologies, being termed as the 'Agriculture 5.0', envisions use of emerging tech like 5G for maximizing crop yields and other agricultural outcomes.



1.2. How are these technological interventions beneficial for the agriculture sector?

Technology has a major role in farming and agriculture practices and with the advent of digital technology, the scope has widened. Innovation in agriculture is leading an evolution in agricultural practices, thereby generating benefits like-

- **Enhanced yield and improved efficiency:** Technology has played a key role in increasing productivity and efficiency of agricultural operations. For example, the use of mechanization and high-yielding crop varieties that are resistant to pests and diseases has increased efficiency and output of agricultural activities.
- **Reduced Post-harvest losses:** Modern warehousing and inventory management systems, transparency in **price discovery and exchange process, cold chain packaging and transportation** etc. have helped in reducing waste in the food supply chain.
- **Women empowerment:** Agri-tech innovations are helping in bridging the gender gap in agriculture through promotion of **women-centric micro-financing models, upskilling** through e-learning modules etc.
 - Further, the gadgetry which results in drudgery reduction, saves time and labour for women farmers and helps them gain control over farming resources.
- **Economic Growth and Development of rural areas:** Technology in agriculture contributes to economic growth and rural development by increasing productivity and profitability, promoting **agri-entrepreneurship**, enhancing **value addition** and **agro-processing**, and creating employment opportunities.
- **Strengthens Agricultural governance:** Digitization of public agricultural infrastructure such as building **unified national market, performance dashboards**, etc. helps in identifying and building a database of farmers, linking identified farmers to their specific requirements and ensuring that service delivery systems are transparent and effective.
- **Enhanced sustainability of food systems:** Technological innovations such as climate smart farming and precision farming methods produce higher yields while reducing negative environmental effects like emissions due to overuse of nitrogenous fertilizers or pesticide runoff into rivers or groundwater sources.
- **Reduced costs and improved working conditions:** Automated farm equipment decreases the amount of physical labour needed for a farm's operation, while **increasing operational efficiency** for farmers.

➤ **Improved decision making:** Digitization of agricultural processes can help farmers make smarter choices and **take evidence-based data-driven decisions** related to selection of crops and optimum use of inputs, identification and mitigation of risks like pests, climate variability and disasters, price management, etc.

➤ **Equity and accessibility of extension services:** Innovations like agri-fintech help in lowering barriers to accessing **agricultural insurance and financial services** as well as **market and technological data**.

Box 1.2 Digitalization of Agriculture: Building resilience in agricultural value chains

The pandemic and recent geopolitical crisis including the Russia- Ukraine war has highlighted the **fragile nature of global agricultural value-chains**. With the ongoing climate change, the demand and supply side bottlenecks in the agriculture supply chains are only going to worsen.

In this case, technology is going to play an important part in building resilience of food supply chains to ensure food security for the most vulnerable segments of the population.

Some examples of agriculture technology use-cases which can address some of the key stress points across the value-chain include-**IoT smart sensors and satellites** to mitigate the impact of weather conditions, and natural disasters like hurricanes, extreme droughts or floods; **use of blockchain** to optimize storage space and **farmer-centric mobile applications** to enable smallholder farmers participate in global markets; and **traceability software** to manage supply and demand.

Box 1.3. In conversation!

Application of artificial intelligence (AI) and machine learning in agriculture



Vinay



Hey Vini! Have you noticed how much technology is changing the agricultural landscape lately?



Really? That sounds fascinating. I knew AI had its applications in various fields, but how is it being used in agriculture?



That's impressive! So, with AI-powered tools, farmers can make data-driven decisions about their crops?



That's a great way to conserve water resources while increasing productivity. Are there any other ways AI is helping in agriculture?



That's incredible! It's like having an extra set of eyes watching over the fields 24/7.

Yes, I have heard that artificial intelligence (AI) is set to revolutionize the agriculture industry.

Well, AI is being used to improve different aspects of farming. AI algorithms can analyse data from various sources like satellites, weather stations, and sensors to provide farmers with valuable insights.

Exactly! For instance, AI can help farmers optimize irrigation schedules based on real-time weather data, soil moisture levels, and crop characteristics.

Another important use of AI is in crop monitoring and disease detection. With AI-powered image recognition, drones and cameras can capture images of fields and analyse them to identify signs of plant diseases or pests.



Vini

1.3. What are the major technological initiatives in India in the field of agriculture?

Government of India is currently putting in efforts for infusing modern technologies into the agriculture sector, through multiple initiatives like:

- ▶ **Digital Agriculture Mission (DAM):** It includes initiatives like- the India Digital Ecosystem of Agriculture (IDEA), Farmers Database, Unified Farmers Service Interface (UFSI), Funding to the States on the new Technology under **National e-Governance Plan in Agriculture** (NeGPA), Revamping Mahalanobis National Crop Forecast Centre (MNCFC), Soil Health, Fertility and profile mapping.
 - ▶ Under the **NeGPA programme** funding is given to State Governments for Digital Agriculture projects using emerging technologies like Artificial Intelligence and Machine Learning (AI/ML), Internet of Things (IoT), Block chain etc.
- ▶ **National e-Governance Plan (eKranti):** One of the major thrust areas of this initiative is promoting **technology for farmers** by facilitating farmers to get real-time price information, online ordering of inputs and online cash, loan, and relief payment with mobile banking.
- ▶ **AgriStack:** The Ministry of Agriculture and Farmers is in the process of finalizing 'India Digital Ecosystem of Agriculture (IDEA)' which will create the framework for Agristack in the country. It will serve as a foundation to **build innovative agri-focused solutions leveraging digital technologies.**
 - ▶ A **federated farmers' database** would serve as the core of the Agristack.
- ▶ **Promotion of agriculture startups:** The Government is actively promoting innovation and agri-entrepreneurship through measures like-
 - ▶ Setting up of '**Agriculture Accelerator Fund**' to encourage agri-startups by young entrepreneurs in rural areas.
 - ▶ **Innovation and Agri-Entrepreneurship Development programme** under Rashtriya Krishi Vikas Yojana (RKVY).
 - ▶ **Agri Business Incubators** have been established in different ICAR Institutes and Agricultural Universities.
- ▶ **Technology Innovation Hubs (TIHs):** They have been set up in premier institutes of national importance across the country with the objective of carrying out research, translation and technology development for various technologies including IoT and AI, in Agriculture.
- ▶ **Upskilling:** Krishi Vigyan Kendras (KVKs) and Agricultural Technological Management Agency (ATMA) at district level undertake training, demonstrations, exhibitions and skill development programs etc. provide information to the farmers, farm women, and rural youth.
- ▶ **Promotion of Mechanisation:** Schemes like **Sub Mission on Agriculture Mechanization (SMAM) and Promotion of Agriculture Mechanisation for in-situ Management of Crop Residue** aim to increase the reach of farm mechanization to small and marginal farmers.
 - ▶ Under SMAM activities like establishment of **Custom Hiring Centres, Farm Machinery Bank, High-tech Hubs and distribution of various agricultural machinery etc.** are undertaken.
- ▶ **International collaboration:** India has been actively cooperating with other countries in the field of agricultural technology. E.g., Agriculture is one of the priority areas under the India-Israel Industrial R&D and Technological Innovation Fund (I4F).
- ▶ **Mobile applications:** Indian Council of Agricultural Research (ICAR) has developed around 187 mobile apps on different farm and farmer related services during 2014-21, which are now integrated on one common platform called **KISAAN**.
- ▶ **National Agriculture Market (e-NAM) Scheme:** It created an online transparent competitive bidding system to facilitate farmers with remunerative prices for their produce.

Box 1.4. Geo-Intelligence for Agriculture in India: Leveraging satellite technology for Benefit of Farmers

- ▶ Indian Space Research Organisation (ISRO) collaborates with Ministry of Agriculture and Farmers Welfare on various applications using satellite data and geospatial technology in agriculture sector.
- ▶ Examples of national level programmes, where Satellite data and GIS and Image Processing Technologies are being used in various domains of Agriculture, are given below (Table 1.2.):

Table 1.2. National level programmes, where Satellite Technologies are being used in Agriculture

Programme	Activity
FASAL (Forecasting Agricultural output using Space, Agro-Meteorology & Land based observations)	Multiple pre-harvest production forecasts of major crops at district/state/national level.
NADAMS (National Agricultural Drought Assessment & Monitoring System)	Periodic district/sub-district level agricultural drought assessment
CHAMAN (Coordinated Horticulture Assessment and Management using geoiNformatics)	Area & production estimation of horticultural crops and horticultural developmental plan using geospatial technology
KISAN (C[K]rop Insurance using Space technology And geo-iNformatics)	To explore the use of remote sensing for more accurate assessment of crop yield.

2. What challenges does India face in its efforts to enhance adoption and utilization of technology in agriculture?

Over the past few years, India has witnessed widespread changes and advancements in farming approaches and techniques. However, the adoption of technology in agriculture is still low due to the following reasons-

- ▶ **Financial constraints:** Sophisticated agri-tech systems like precision technology generally have high costs of setting up which can be prohibitive, especially for small and marginal farmers in India.
 - ▶ Further, the need for **regular maintenance and updates** can add extra costs to running an agri-tech system.
- ▶ **Difficulties in scalability:** India's agriculture sector is characterized by **small and fragmented landholdings**, which pose challenges for most of the technological interventions, which are require economies of scale to be profitable. E.g., Irrigation systems are often not optimized for small-sized plots, making it difficult to maximize efficiency.
- ▶ **Limited know-how and technical expertise:** Farmers in India lack the technical expertise and hands-on experience needed to operate machinery and software effectively, rendering them unable to take advantage of today's advanced agricultural technology.
- ▶ **Challenges faced by agri-tech startups:** While agri-tech startups are being proactively being promoted by the government, they still face issues like **limited funding for early-stage, lack of structured agricultural data** and access to it, **regulatory uncertainties, and limited demand** from farmers due to a fragmented customer base.
- ▶ **Concerns around automation:** With farming being a major source of employment across the country, automation in agriculture sector could have a significant impact on the local economy leading to large-scale job loss.
- ▶ **Limited inclusivity:** There is a mismatch between what the organised Indian industrial sector in the field of agricultural technology is producing and what is accessible and affordable for the medium, small and marginal, and women farmers.

➤ **Issues in Research and development ecosystem:**

- **Low funding:** In India, the share of agricultural research spending as a share of agriculture GDP is less than 0.35%.
- **Academic isolation:** India lacks an efficient and collaborative system for transfer of new designs/technology developed by research institutes to manufacturers/fabricators.
- **Poor Extension services and lack of handholding:** Scientific information is presented in a format unfamiliar to Indian farmers and ICT is being widely used to disseminate information with little consideration to digital literacy levels in rural areas.
- **Quality issues in Agricultural education:** India's agricultural institutes are unable to keep pace with advancement of modern agriculture technologies and still face major

issues like inadequate funding, outdated curriculum, reduced faculty strength, inadequate faculty development programmes, lack of modern infrastructure, etc.

- **Infrastructural issues:** Limited availability of basic infrastructure, such as stable electricity and internet connectivity, can hamper the adoption and effectiveness of agri-tech solutions.
- **Lack of knowledge about government support:** Financial credit to farmers can help to stimulate agriculture technology adoption, however its communication to target framers is low.
- **Potential negative impacts on the environment:** While technological transformation is being pegged as solution for enhancing sustainability of agricultural practices, there is limited knowledge about potential negative impacts of several technologies.

Box. 2.1 Environmental uncertainties of Agricultural technologies

The impact of current agricultural practices on the environment is enormous, which is evident by the fact that around **31% of global emissions originate from the world's agri-food systems**. Technological solutions have great potential to overcome and mitigate negative environmental outcomes such as overexploitation of resources like water and GHG emissions. However, some technological interventions can lead to potential negative outcomes as well-

- **Genetically modified crops:** They can pose risks like reduced genetic diversity and adverse impact on health of humans and pollinators.
- **Mechanisation of farms:** It is associated with issues like increased fossil fuel combustion and greenhouse gas emissions, soil degradation, land compaction, etc.
- **Promotion of monoculture systems:** Agri-tech systems often enable intensive monoculture practices which lead to reduced diversity, overuse of water resources etc.
- **Modern trawlers:** Bottom trawling enabled by new fishing gear can cause damage to seafloor habitats, such as corals, re-suspend sediment and disrupts bio-geochemical cycles that support ecosystem function.

Hence, it is crucial to conduct thorough analysis of technological applications and their impact on the environment before mainstreaming their use.

3. How can India excel in the field of agricultural technology?

- **Adopting innovative financing mechanisms:** Financial and institutional innovations like micro-financing, subsidized equipment and promotion of rental markets can help enhance adoption among small and marginal farmers.
- **Building awareness among farmers:** Concerted grassroots level efforts, both by government and the civil society, is needed to train Indian farmers in usage of digital and frontier technologies.
- **Focus on demand-driven innovation:** R&D programmes should focus on the development of appropriate technologies tailored for medium, small and marginal, and women farmers.
- **Public partnership with the private sector and agri-entrepreneurs:** Government needs to partner with private sector to provide sustainable funding, enhance data-sharing and establish regulatory guidelines to deliver sustainable and scalable solutions.
- **Improving R&D ecosystem:**
 - **Higher public allocations:** Concerted efforts should be made to raise expenditure on agricultural research up to 1 per cent of Agri-GDP.

- ▶ **Focus on extension service:** Reforms like ground level institutional framework for dissemination of research outcomes to the farmers, cloud-enabled databases and dashboards etc. are needed to enhance scientific capabilities of Indian farmers.
- ▶ **Developing links between research institutes and industry:** A consortium of research organizations, government ministries, public and private sector organizations, and non-governmental organizations needs to work in a coordinated and accountable manner.
- ▶ **Revamp agriculture institutes:** To create professionals and extension workers/consultants, capable of using modern technologies, educational institutions need to **modify their curricula, teaching and training methods** and incorporate application of modern technologies in field and
- ▶ **Policy support by the government:** Clear guidelines, standards, and incentives that support the integration of technology in agriculture, including infrastructure development, financial support, and intellectual property rights, need to be established.

Box 3.1. Agri-tech start-ups and their role in transforming India's agriculture sector

With multiple initiatives, the Government of India has been actively prioritising the growth of Agri-tech startups. The Economic Survey of India 2022-23 highlighted that over the last six years with over 1000 agri-tech start-ups having emerged in the sector.

In the upcoming future, agritech start-up are expected to play a crucial role in the growth of India's agricultural economy, especially in the following segments-

- ▶ **Market Connectivity:** Building seamless digital platforms that can fully integrate value chains and support value chain actors to process the market linkage from the small and marginal farmers faster.
- ▶ **Crop Planning:** Advisories on extents, locations and varieties of crop to be grown in different agro-climatic zones and optimal sowing windows, with focus on import substitution, nutrition, and export revenues.
- ▶ **Smart F-aa-S (Smart Farming-as-a-Service):** Providing an entire range of digital services to the farmer in respect of crop management, including Integrated Nutrient Management, Uberized farm machinery services, Hyper-local weather advisories etc.
- ▶ **Post-harvest optimization:** Increasing automation in agricultural operations with tech solutions to reduce manual errors.

Conclusion

Accelerating technological advancements in farming are predicted to have a profound impact on the agriculture industry. With India's population expected to reach 1.5 billion by 2030, as per the United Nations report on World Population Prospects 2022, the emphasis on sustainable food and nutrition security is warranted. Agri-tech solutions will drive the next-gen evolution of the sector and help India transition towards sustainable and less resource-intensive food systems. Influential factors that will define the success of agriculture technology in India are technology affordability, ease of access and operations, easy maintenance of systems and supportive government policies.

TOPIC AT A GLANCE

Agriculture Technology

- ⊖ Agri-tech encompasses a broad range of disciplines and devices that improve agricultural output. That includes vehicles, robotics, computers, satellites, drones, mobile devices, and software.



Prevalent technological applications in the agriculture sector

- ⊖ Farm management and monitoring technologies.
- ⊖ Mechanisation of agricultural activities.
- ⊖ Biotechnology tools and techniques.
- ⊖ Digitalization of Agri Logistics and other extension services.
- ⊖ Vertical farming techniques like hydroponics, aquaponics etc.
- ⊖ Nanotechnology for creating nanopesticides and nanofertilizers.



Benefits of Agriculture Technology

- ⊖ Enhanced yield and improved efficiency.
- ⊖ Reduced Post-harvest losses.
- ⊖ Women empowerment and Economic Growth and Development of Rural areas.
- ⊖ Strengthened Agricultural governance
- ⊖ Enhanced sustainability of food systems. Reduced costs and improved working conditions.
- ⊖ Enable data-driven decision making. Improves equity and accessibility of extension services.



Government initiatives

- ⊖ Digital Agriculture Mission (DAM).
- ⊖ AgriStack and India Digital Ecosystem of Agriculture (IDEA).
- ⊖ Promotion of agriculture startups through measures like Agriculture Accelerator Fund, Innovation and Agri-Entrepreneurship Development programme etc.
- ⊖ Upskilling via Krishi Vigyan Kendras (KVKs) etc.
- ⊖ Sub Mission on Agriculture Mechanization (SMAM) and Promotion of Agriculture Mechanisation for in-situ Management of Crop Residue to promote mechanisation.
- ⊖ National Agriculture Market (e-NAM) Scheme.



Challenges

- ⊖ High costs of setting up and maintenance.
- ⊖ Difficulties in scalability due to small and fragmented landholdings.
- ⊖ Limited technical expertise among farmers.
- ⊖ Challenges faced by agri-tech startups like limited funding for early-stage, lack of structured agricultural data regulatory uncertainties etc.
- ⊖ Labour concerns around automation.
- ⊖ Limited inclusivity of technological solutions.
- ⊖ Issues in R&D ecosystem: Low funding; Academic isolation; Poor Extension services and lack of handholding etc.
- ⊖ Infrastructural issues, lack of knowledge about government support and environmental concerns.



Way Forward

- ⊖ Adopting innovative financing mechanisms like micro financing, rentals etc.
- ⊖ Building awareness among farmers.
- ⊖ Focus on demand-driven innovation.
- ⊖ Public partnership with the private sector and agri-entrepreneurs.
- ⊖ Improving R&D ecosystem through higher public allocations; focus on extension service; developing links between research institutes and industry etc.
- ⊖ Revamp agriculture institutes.
- ⊖ Policy support by the government for infrastructure development, financial support, and intellectual property rights.

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