

# Artificial Intelligence for Agriculture Innovation

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# Preface

Emerging technologies from drones to digitalization have the potential to transform farming productivity, reduce environmental impact and boost farmers' incomes.



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Agriculture plays a pivotal role in India's economy, with over 58% of rural households depending on it as their principal means of livelihood. The vision of the Artificial Intelligence for Agriculture Innovation (AI4AI) initiative is a commitment to improve the state of the farmers' world, with the operating principle to "think big, start small and scale fast". The initiative focuses on strengthening multi-stakeholder collaborations to analyse

and exploit the opportunities and challenges of applying upcoming technologies to transform the agricultural landscape, in a way that is profitable and sustainable for farmers.

Capitalizing on the value of emerging technologies such as artificial intelligence (AI), blockchain, drones and the internet of things (IoT) has the potential to impact productivity and efficiency at all stages

of the agricultural value chain. Only by integrating emerging technology into this domain can we hope to meet the aspirational goals of doubling farmers' incomes and increasing farm productivity, while reducing wastage and enhancing supply chain efficiency and transparency.

This report examines the potential of some exciting technological innovations. We can improve crop planning at micro and macro levels through AI-enabled models that link weather forecasts, dynamic soil data, warehousing and logistics infrastructure, and market conditions. We can introduce smart farming solutions, including IoT-enabled irrigation, dynamic soil health mapping at farm level, while leveraging AI in remote sensing and automatic weather station data. We can manage crop health more effectively through AI-powered pest control, agriculture input advisory platforms, and drone-enabled farm mapping and agriculture input applications. We can use IoT to enhance warehousing and logistics, and AI, spectroscopy and blockchain to enhance quality and traceability, and market linkage platforms. The report aims to identify emerging technology innovations that have

the potential to drive rapid progress in digitalization across the agriculture value chain.

This initiative is led by the World Economic Forum's Centre for the Fourth Industrial Revolution, India. It has been initiated as part of the Government of Telangana's Centre for Responsible Deployment of Emerging Technologies – a virtual interdisciplinary hub to collaborate on fourth industrial revolution technologies. AI4AI is conceived as a national initiative, in collaboration with the Ministry of Agriculture, the National Institution for Transforming India (NITI) Aayog and the Ministry of Electronics. It has established active partnerships with a range of stakeholders from agri-related industries, start-ups, academic and research institutions, and civil society, with the aim of developing an evidence-based, consensus-driven governance framework. We propose to scale up the initiative further to various collaborating states. There is huge interest in expanding to countries such as Columbia, Turkey, South Africa and Japan, that face similar challenges and opportunities in leveraging emerging technologies in their agriculture sectors.



**The present-day paradigm shift in agriculture is led by the vision of doubling farmers' incomes. We need to emphasize a new approach to science, technology, innovation, extension and education in the agricultural domain, which focuses on science for delivery in place of science for discovery.**

Praveen Rao, Vice-Chancellor,  
Professor Jayashankar Telangana State Agricultural University

# Executive summary

AI4AI's goal is to establish the frameworks through which emerging technology solutions can be scaled up across the agriculture ecosystem.

The Artificial Intelligence for Agriculture Innovation (AI4AI) initiative was launched in August 2020 by the World Economic Forum's Centre for the Fourth Industrial Revolution India, in active collaboration with the Government of Telangana and support from the Ministry of Agriculture, the National Institution for Transforming India (NITI) Aayog and the Ministry of Electronics and IT. The initiative now has 60-plus partners across the agriculture industry and emerging technology ecosystem, actively collaborating through weekly workshops from October 2020 to March 2021.

The initiative's multi-stakeholder community partners have completed a comprehensive review of emerging technology use cases, mapping them against a matrix of viability and impact, and classifying them as game changers, long-term interventions and easy wins. This community report is a summary of their findings. It paves the way for the next stage of the initiative, which is to launch pilot projects and to compile evidence-based frameworks through active learning from the field.

The report will also serve as a guideline document for agriculture leaders from other states in India and in other countries across the world dealing with similar challenges in assessing the opportunities for leveraging emerging technologies. The report helps address some unanswered questions around the application of artificial intelligence (AI), the internet of things (IoT), blockchain, drones and data governance in agriculture production systems.

In addition, this report provides a platform for agri-industries, start-ups, technology organizations, telecom and cloud service providers, academia and research institutions to understand the complete landscape and provides approaches to engage via collaborative frameworks.

Considering the expanse and complexity of agriculture production systems and the burgeoning landscape of emerging technology innovations, an intensive and focused effort is required to address the challenges and opportunities raised. This process needs multi-stakeholder groups of experts with specialized knowledge and experience in the areas relevant to AI4AI.



“ Each of the four groups has between 20 and 30 members across government, the start-up ecosystem, industry verticals, civil society, investor groups, and research and academia.

Keeping this in mind, the initiative convened four working groups with the responsibility of designing appropriate plans of action around the four broad themes of the AI4AI Initiative: intelligent crop planning, smart farming, “farmgate-to-fork” and data-driven agriculture.

The composition of the working groups is multi-disciplinary, embodying all the necessary competencies. Each of the four groups has between 20 and 30 members across government, the start-up ecosystem, industry verticals, civil society, investor groups, and research and academia. All working groups have conducted weekly meetings and subgroup consultations over a period of 16-18 weeks and have consolidated their learnings.

The initiative also convened a steering committee of leadership across government and private stakeholders to coordinate between the working groups, providing them overall guidance, support and direction, which has enabled them to function effectively and efficiently. The steering committee has also reviewed and validated the frameworks and action plans designed by the working groups.

Each of the four working groups analysed the landscape of opportunities of emerging technologies and shortlisted a group of themes and use cases to capitalize on these opportunities for agriculture innovation, as outlined below:

- **Intelligent Crop Planning:** This working group identified seven game-changer use cases across the themes of macro-crop planning and micro-crop planning. Providing advisories on sowing windows, analysing sowing areas, tracking sowing progress, providing advisories on crop varieties, and leveraging AI and remote sensing were considered most important for crop planning at macro level. The working group also identified a number of additional priorities: AI-based micro-crop planning models for agriculture input planning, irrigation resource mapping and the rollout of smart extension services for farmers and farmer-producer organizations.
- **Smart Farming:** This working group analysed opportunities for maximum leverage of emerging technologies across the themes of “farming-as-a-service”, advisories for agriculture inputs and crop health management. It identified eight game-changer use cases: IoT-enabled micro-irrigation, AI-enabled water resources planning, crop-health protection through the smart application of pesticides, AI-enabled agri-inputs advisories, smart crop insurance using remote sensing, blockchain-enabled fintech solutions, “uberization” of farm machinery and the creation of dynamic e-soil health cards.
- **Farmgate-to-Fork:** This working group focused on four different value chains: cereals

and pulses, vegetables, fruits, and plantations (cash crops). It identified five critical use cases leveraging emerging technologies. Measuring quality by using AI and spectroscopy, supported by blockchain-enabled traceability, was considered important for establishing trust in value chains. Platforms to promote buyer-seller linkages were the most favoured use case with the investor community. IoT- and AI-enabled warehousing and logistics systems, along with fintech solutions based on warehousing receipts, were considered the most innovative and disruptive use cases.

- **Data-driven Agriculture:** According to research by NASSCOM and McKinsey, there is a \$65 billion opportunity to be realized through enhancing 15 agriculture datasets, including soil health records, crop yields, weather, remote sensing, warehousing, land records, agriculture markets and pest images. The working group recommended taking measures to enable agriculture data marketplaces as a collaboration between government and the private sector, as well as forming public-private partnerships to enable AI and other emerging technology innovations in this important sector.

Emerging technologies, such as AI, IoT, blockchain and drones – further enabled by unlocking key datasets – offer an unprecedented and unparalleled opportunity to boost the efficiency and effectiveness of agriculture production systems. The key objectives of the AI4AI initiative are:

- to enhance digital and financial inclusivity among smallholder farmers;
- to build trust and transparency through quality and traceability;
- to protect the environment from unsustainable practices; and
- to establish sustainable farm incomes.

However, this needs a cadence-led approach of responsible governance to manage the negative impacts of technologies, while focusing on creating an enabling environment of coherent data management and capacity building across the value chain.

As next steps, the community partners will be working towards establishing frameworks through pilot projects across the identified themes and use cases. The World Economic Forum has a vision to evolve AI4AI as a multi-stakeholder platform of national and state governments, industries, start-ups and research institutions that fashions the frameworks through which emerging technology solutions can be scaled up and adopted across agriculture production systems.

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# Introduction: challenges and opportunities in agriculture



## 1.1 Challenges and opportunities in agriculture

Food and agriculture systems today are unsustainable for both people and planet. They operate at a high environmental cost, waste large amounts of product and leave many producers in emerging markets at or below the poverty level. Stakeholders from all sectors and regions have recognized the urgent need for a fundamental transformation of food and agriculture systems. Such a transformation would create sustained social value and deliver greater equity to the most disenfranchised.

Agriculture is a high-priority sector of the Indian economy, with 58% of all families dependent on it, directly or indirectly, for their livelihoods. The sector is at a critical juncture, with many challenges across the value chain. Though the adoption of digital technologies can contribute to addressing some of the challenges, success in this area has been isolated and has not scaled up adequately.

Challenges faced by the agriculture sector include the following:

- Small and marginal farmers (86% of farmers) own less than two hectares, causing unsustainable farm incomes and poverty;
- Unsustainable farming practices, resulting in soil degradation and water stress;

- Lack of datasets at farm, farmer and sector levels, leading to higher costs of services;
- Gaps in market linkages, challenges in price discovery for farmers and price volatility in the market;
- Lack of food processing, logistics and warehousing infrastructure close to farm gates, increasing wastage;
- Challenges in financial and digital inclusivity;
- Poor farm mechanization due to affordability challenges.

Emerging technologies driven by the fourth industrial revolution, such as the internet of things (IoT), artificial intelligence (AI), machine learning (ML), big data, drones and blockchain, are disrupting many industries, bringing rapid and large-scale change. Until now, the agriculture sector has been slow to harness the power of these technologies. Low adoption levels of emerging technologies in agriculture are due in large part to the complexity of the sector, which features small farm sizes, lack of telecoms infrastructure in rural areas, high regulatory burdens which raise costs, and revenues constrained by customers' limited ability and willingness to pay.

**86%**

of farmers own less than two hectares



## 1.2 Technology disruption

Agriculture systems in emerging economies are riddled with inefficiency and ineffectiveness. Fourth industrial revolution (4IR) technologies are making it easier to tackle some of these issues. Improvements in the performance and cost of computing power, storage and bandwidth have led to the growth of digital technologies. Taken together, these technologies can accelerate innovation, lower the cost to scale up solutions, increase transparency, enable consumers to make informed choices, and promote evidence-based policy-making. They are also transforming how innovations are being conceptualized, designed and commercialized, and radically changing the ways businesses operate.

Emerging technologies, such as AI, blockchain, drones, IoT and big data analytics, have the potential to enhance productivity and efficiency at all stages of the agricultural value chain, boosting farmers' incomes, increasing farm productivity while reducing waste, and enhancing supply-chain efficiency, transparency and sustainable resource use (see Figure 1).

Key objectives of emerging technology interventions in agriculture include the following:

- Sustainable farm incomes through better connected farm-to-market supply chains;
- Financial and digital inclusivity for smallholder farmers;
- Safety and trust in food systems;
- Real-time monitoring of environment impact;
- Improving productivity and efficiency through farm mechanization;
- Managing food wastage through digital enablement of storage and logistics infrastructure;
- Smart risk management of nature-related uncertainties.

Emerging technologies, however, are likely to introduce new challenges. They can create unintended consequences, including data breaches and lack of digital inclusivity, which must be considered and explored in advance. Their beneficial effects may be unevenly distributed, potentially deepening the divide between rich and poor. Harnessing the positive impacts of technological innovation and avoiding potential downfalls will require deliberate and coordinated efforts by investors, innovators and policy-makers.

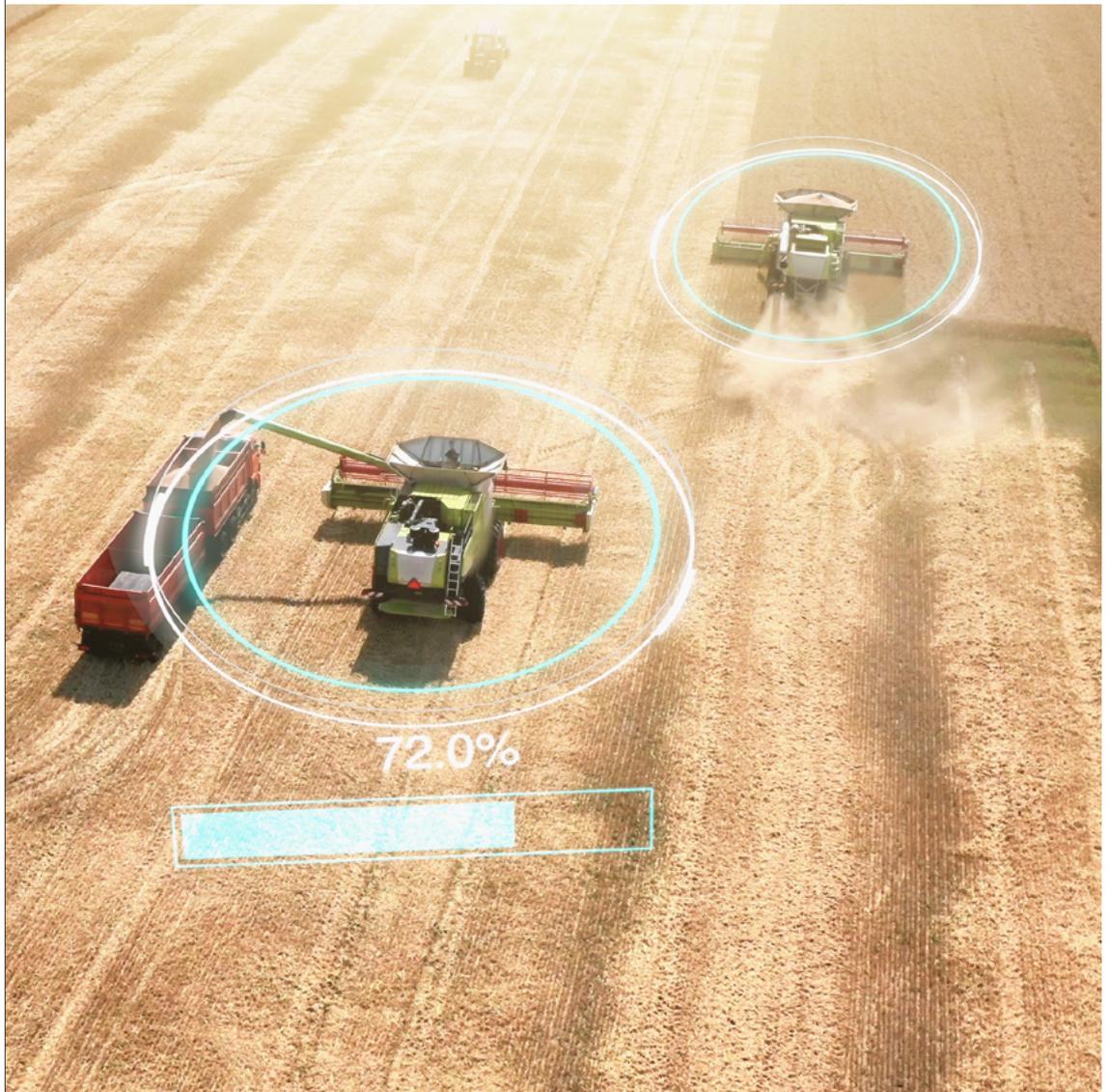
FIGURE 1 Emerging technologies in agriculture



Source: PwC

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## The Artificial Intelligence for Agriculture Innovation (AI4AI) initiative



## 2.1 Context and approach

Achieving a true transformation of agriculture systems requires a holistic approach, leveraging advancement in emerging technology innovations and engaging all stakeholders to accelerate the adoption.

Every stakeholder has an important role to play. Governments can deliver infrastructure and innovative policy, supported by the right financing mechanisms. Start-ups can enable innovative solutions, by leveraging fourth industrial revolution technology. Established companies can collaborate to open new markets through sharing data and intellectual property. Investors and donors can

provide growth capital and enable entrepreneurs. Civil society will bring the much-needed human touch to ensure the sustainability of these interventions.

An expansive sector such as agriculture requires a multi-dimensional approach to addressing issues and generating impactful, actionable recommendations. Against this backdrop, in August 2020 the Centre for the Fourth Industrial Revolution (C4IR) India launched AI4AI (Artificial Intelligence for Agriculture Innovation), an initiative to leverage AI and other emerging technologies to make a significant impact on the agriculture sector.

## 2.2 Vision and objectives

“The vision of AI4AI is “to transform the state of agriculture by deploying emerging technologies in an inclusive and sustainable way.”

AI4AI is conceived as an umbrella programme that seeks to create value across the entire agriculture ecosystem through the deployment of a wide range of emerging technologies, in a way that can scale up across India and provide insights and models for other emerging economies.

The vision of AI4AI is “to transform the state of agriculture by deploying emerging technologies in an inclusive and sustainable way.”

The AI4AI initiative aims to identify the role of emerging technologies with the potential for achieving global aspirations for agriculture systems. It seeks to evolve scalable frameworks for enabling the use of these technologies for constructive outcomes, while underlining the challenges and unintended consequences they may bring. While the programme focuses on technological

innovation, it recognizes that it is also essential to invest in low-tech interventions, create new and bold policies, improve resource efficiency, build trust and transparency, align towards common objectives and collaborate across independent working groups.

The key objectives of AI4AI are:

- to enhance digital and financial inclusivity among smallholder farmers;
- to build trust and transparency through quality and traceability;
- to protect the environment from unsustainable practices; and
- to establish sustainable farm incomes.

## 2.3 Structure and process

In August 2020, C4IR India convened an AI4AI workshop that brought together a cross-section of stakeholders to identify priority issues in agriculture that could be addressed using emerging technologies.<sup>1</sup> Break-out groups highlighted several challenges and opportunities across the workshop’s four thematic areas, requiring focused effort to identify solutions based on technology governance and emerging technologies. Given the specialized knowledge and experience in agriculture innovation required, the Centre formed four working groups (WGs) to address these areas, as follows:

- **Intelligent Crop Planning:** working group A
- **Smart Farming:** working group B

- **Farmgate-to-Fork:** working group C
- **Data-driven Agriculture:** working group D

The WGs are multi-disciplinary, covering all necessary competencies without duplicating roles and based on a strong common purpose and shared accountability. Each group has between 20 and 30 members, selected from across government, industry (both Indian and multinational), start-ups, civil society, investor groups, research and academia.

In addition, WG members drawn from industry are representative of the wider value chain of sectors that impact the ecosystems of agricultural

innovation and emerging technology, including:

- Agri-trading, commodity exchange
- Agri-machinery
- Agri-inputs, irrigation, infrastructure, warehousing, logistics
- Telecoms, software, hardware

- Agriculture processing
- Banking, insurance
- Technology system integrators, cloud service providers

The responsibility of working groups is to design appropriate plans of action around their respective thematic areas. Figure 2 outlines their agenda and timeline.

FIGURE 2 Working groups – agenda and timeline



From November 2020 to February 2021, C4IR India helped bring all actors together to align on common objectives and enable innovation. Four months of continuous dialogue and collaboration revealed the potential impacts of specific technologies and ways to harness them for positive effect in India's agriculture system. Key findings from this phase of work are detailed in the next section of this report.

The AI4AI programme has also launched pilot projects in five districts of Telangana state, focused on priorities in the four defined thematic areas:

- Intelligent Crop Planning and sowing – “sow the right crop in the right soil at the right time”.
- Smart Farming – “maximize productivity, minimize input costs”.
- Farmgate-to-Fork – “sell produce at the right time to the right buyer at the right price”.
- Data-driven Agriculture – data governance and data regulation for smart decisions.

The Centre has created a steering committee to coordinate the working groups and their interactions with the wider programme. This multi-stakeholder advisory body has the following tasks:

1. Provide overall guidance, support and direction to the working groups to help them operate effectively towards achieving their aims.
2. Coordinate activities across WGs to encourage synergies and convergence between them and to avoid duplication of effort.
3. Validate and approve the frameworks and action plans designed by the WGs in their respective areas.
4. Explore synergies between the AI4AI programme and other national initiatives.
5. In partnership with C4IR India and the World Economic Forum, explore synergies and convergence with other projects addressing the UN Sustainable Development Goals (SDGs), to meet local challenges and opportunities, and to promote investments.

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# AI4AI key findings



The four multi-stakeholder working groups that convened weekly from November 2020 to February 2021 identified the major challenges and opportunities related to their respective themes. The groups conducted an extensive review of national priorities and the SDGs related to agriculture. They analysed emerging technologies at national and global levels, especially AI, ML, IoT,

blockchain, drones and data policy, to understand the challenges and opportunities these innovations present. They then analysed the benefits that would accrue to the farming sector and to society as a whole, through the application of these technologies to agriculture, led by government, industry, start-ups, banking, insurance and the wider farming community.

### 3.1 Analysing the agriculture start-up landscape for use cases

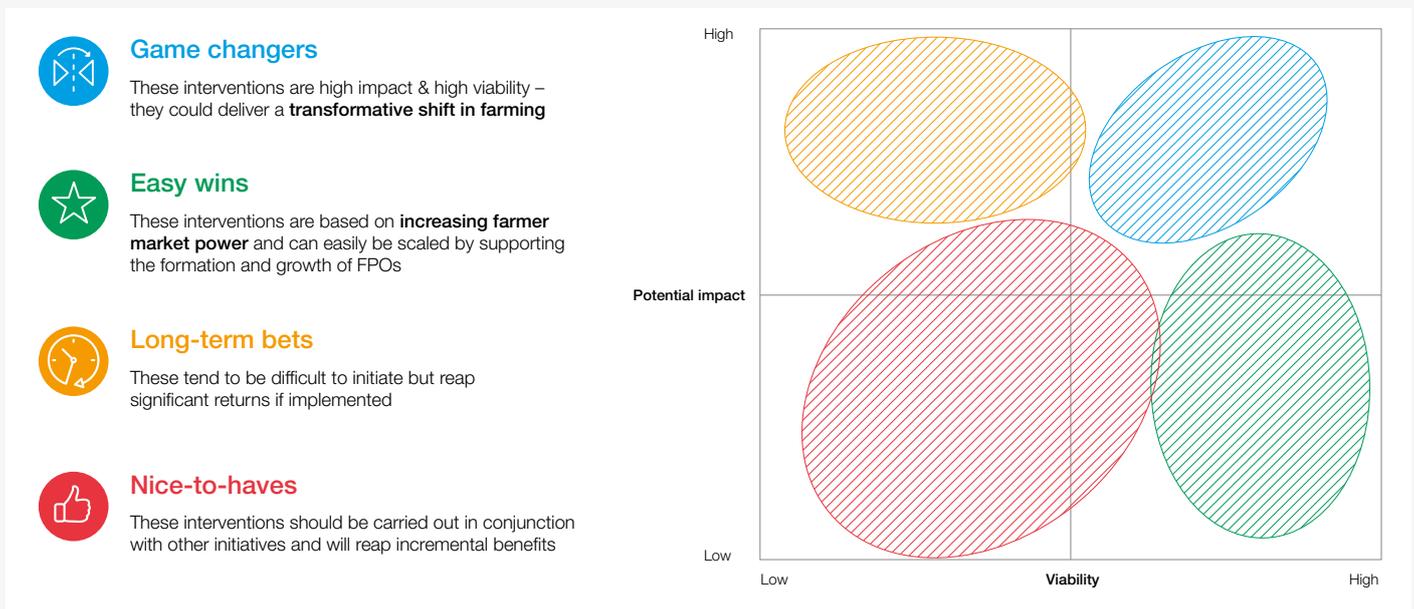
India is ranked second globally for the number of registered “agtech” start-ups. India has 3,116 registered start-ups in food and agriculture, and there has been 25-30% growth in this number year-on-year. Since 2014, \$500 million has been invested in this area and rapid uptake in the last 12 months highlights the impact of emerging technologies in a post-Covid world.

The four working groups analysed 70-plus start-up use cases<sup>2</sup> across more than 20 themes, crop segments

and value chains. They prioritized interventions based on two sets of criteria (see Figure 3):

- **Potential impact:** measurable and non-measurable benefits for the larger community, analysis of cost-benefit, affordability for user groups.
- **Viability:** technological viability, operational viability, timeframe of implementation, potential risks and output-action plan.

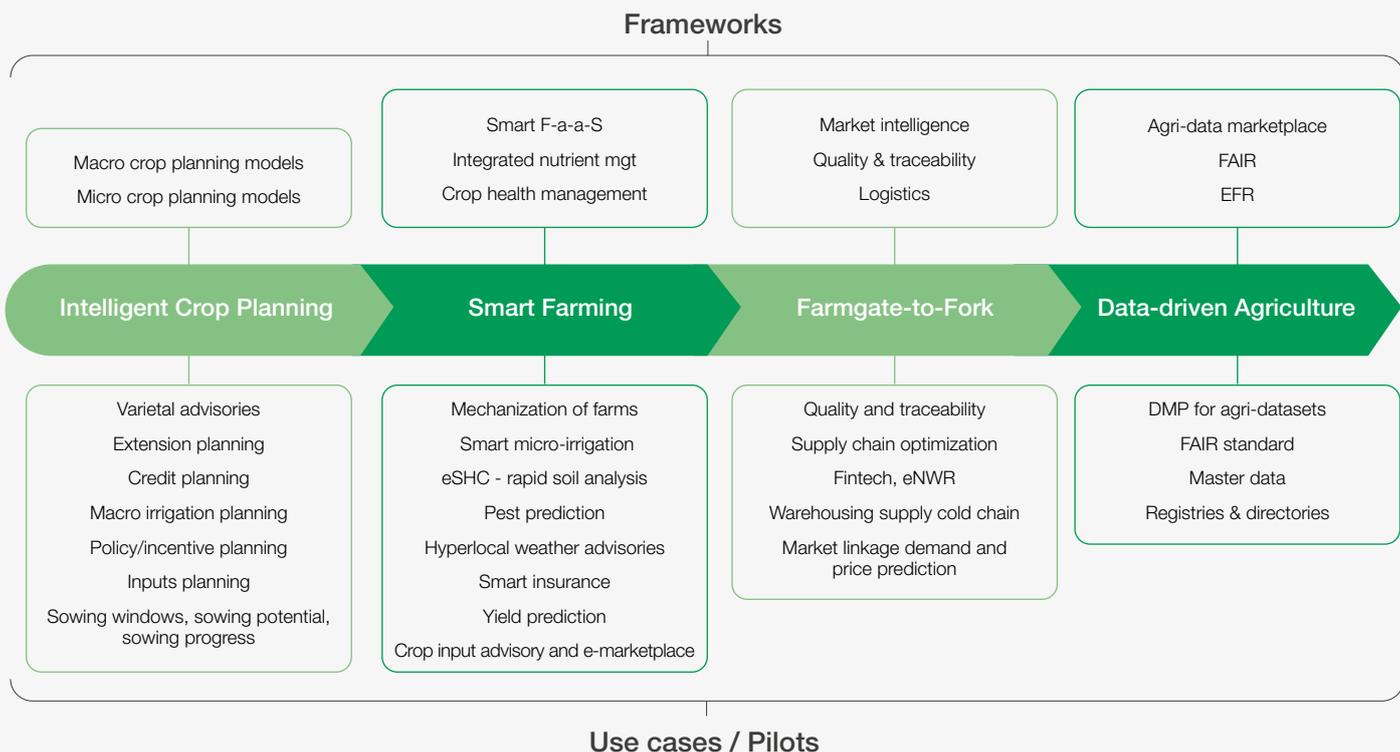
FIGURE 3 Impact-viability matrix to prioritize use cases



This analysis against a matrix of potential impact and viability enabled working groups to identify specific value propositions for each stakeholder group’s set of proposed use cases. The analysis highlighted ways to leverage emerging technologies and established roadmaps to achieve results. The working groups analysed existing pilots undertaken by industry elsewhere in India as well as in Telangana state, leveraging the resources of the state’s agriculture university.

After 16 weeks of extensive discussions, the AI4AI multi-stakeholder groups identified a set of 11 frameworks and 24 use cases or pilots, to be explored further through evidence-based learning. Detailed findings in each of the four thematic areas are set out below, while Figure 4 provides a summary.

FIGURE 4 | AI4AI – the emerging big picture



11 Frameworks + 24 Pilots to be scoped by Q2 2021

## 3.2 Intelligent Crop Planning

The Intelligent Crop Planning working group was convened with the aim of increasing farmers' profitability and addressing the challenges of climate change, by deploying emerging technology-led crop planning models at the macro and micro levels. The key objective of this framework is to generate a macro-crop plan for agriculture and horticultural crops, considering biophysical resources, crop spread and crop productivity, market intelligence, consumer preferences, and infrastructure to make the crop plan comprehensive, inclusive, market-oriented, scalable and impactful.

The team is creating a robust methodology for developing, implementing and upscaling macro-crop plans in diverse geographies, with variable agro-climatic characteristics, and validating them for viability, robustness and economics. Intelligent crop planning must become an institutional mechanism for the synergistic interaction of multiple stakeholders (public and private sector) for the comprehensive development of the agriculture sector.

The crop plan strategy features an array of objectives as follows:

- Identify and promote technology-enabled cropping patterns that manage the impact of weather (normal and predicted), soil conditions, water availability and markets (domestic and

export), to maximize farm production and productivity.

- Develop models to predict demand, supply, prices and returns with better precision.
- Enable optimization of planning processes and logistics of upstream and downstream industries.
- Develop models to ensure timely availability of inputs, credit and insurance services to farmers.
- Promote collective and coordinated action by participants in the agri-value chain.
- Build preparedness and resilience to climate change and the emission of greenhouse gases, by increased use of technologies, thereby reducing risks and maximizing crop yields.
- Develop emerging technology-led macro and micro crop-planning models that become increasingly intelligent through continuous learning, and which could ultimately form the foundation of agriculture growth.
- Maximize income and profitability to farmers through validated, adoptable and scalable technology interventions.

## Approach to macro-planning

Macro-plans are prepared using the most representative, viable units of farmland – intelligent crop planning units (ICPUs). ICPUs are defined by four factors: soil characteristics and weather, rural infrastructure and farm credit, market intelligence and agriculture policy. These factors are considered the most logical in deciding a state-, national- or global-level technology-enabled crop plan.

The Intelligent Crop Planning working group's approach to macro-planning is based on the following steps and accompanying flow chart (see Figure 5).

1. Identification of a “workable planning unit” – the land management unit (LMU). This is a homogenous land unit having consistent soil parameters, landscape conditions, climate and length of growing period (LGP). The LMU is one of the four factors required to identify the ICPU.

2. Identification of intelligent crop planning units (ICPUs) – the most viable units of farmland.
3. Determining variables for ICPUs.
4. Determining data availability for designing ICPUs, for example:
  - a. public datasets in government & research
  - b. private datasets
5. Defining the pilot: four pilots are proposed across four ICPUs over two crop cycles, under both irrigated and rainfed conditions; two pilots will use only public sector data and technology, while two will use both public and private sector (industry and start-up) data and technology. The impacts achieved by leveraging the respective technologies will be measured and compared.

FIGURE 5 Approach to intelligent crop macro-planning



## 3.3 Smart Farming

The Smart Farming working group analysed 20-plus use cases across eight themes and prioritized them against the potential impact and viability matrix shown in Figure 3. The analysis led to the selection of the following three themes:

1. Farming-as-a-service (FaaS);
2. Crop health management: yield forecasting, pest management, smart insurance;

3. Integrated agri-input management: agri-nutrients, irrigation, fintech linkages.

The working group conducted a detailed study of the nine use cases found within these three themes and developed a framework for the piloting of emerging-technology innovations for evidence-based learning. The group's findings are presented in Figures 6-8 below.

FIGURE 6 Crop health management – pest management advisories

### Pesticide consumption in India



India is the **leading producer of pesticides** in Asia



Nearly **900,000 tonnes** of agrochemicals are produced annually: **over 50% of the total production is exported** every year

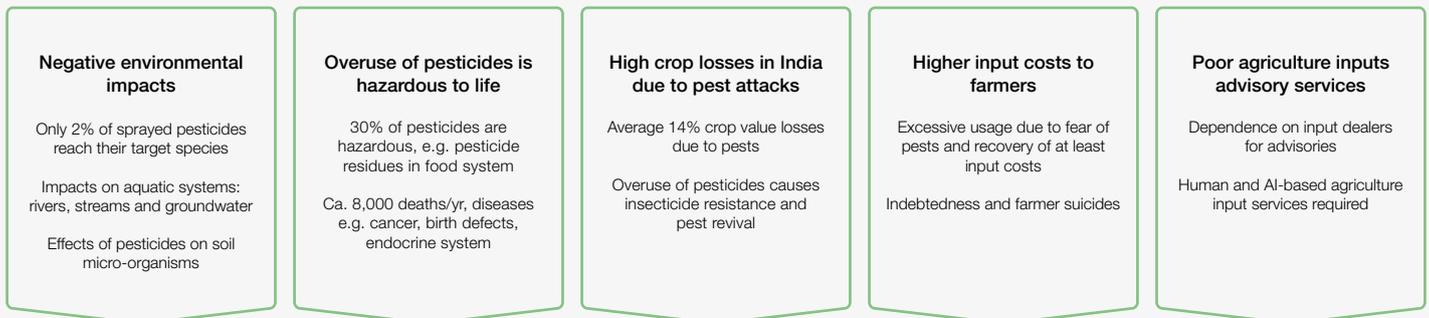


Top two crops for which pesticides are used: **Paddy (26%-28%) & Cotton (18%-20%)**



Top consumer of chemical pesticides is **Andhra Pradesh with 24%** of total consumption

**Eight states account for over 70% usage of agrochemicals in India**  
Andhra Pradesh, Maharashtra, Punjab, Madhya Pradesh, Chhattisgarh, Gujarat, Tamil Nadu and Haryana



### Solution

Artificial intelligence-based early warning system to provide smart farm-based advisories for pests



Calculate pest density from pest trap images



Economic threshold limit of pests



Recommended advisory on application: timing, type and quantity of pesticide

**25% higher income, 17% better yield**  
(Wadhvani AI: 17,000-farmer pilot for cotton)

Soil micronutrient, temperature, moisture data

Pest historical reports and crop images

Micro-weather historical data and forecast



FIGURE 7 | Integrated agri-input management – smart micro-irrigation



### Solutions



#### Remote sensing

Remote sensing data clubbed with deep-tech AI to monitor crop sown area and crop water stress



#### AI based weather forecasts

Assemble forecast with micro-level grids to ensure data granularity for true-to-ground data



#### IoT & crowd-sourcing

Soil moisture and piezometer sensors and mobile app data integrations with ML models



#### Drone watershed planning

Higher resolution of drone survey digital elevation models will yield accurate results



#### Crop acreage



#### Weather forecast data



#### Rainfall and weather

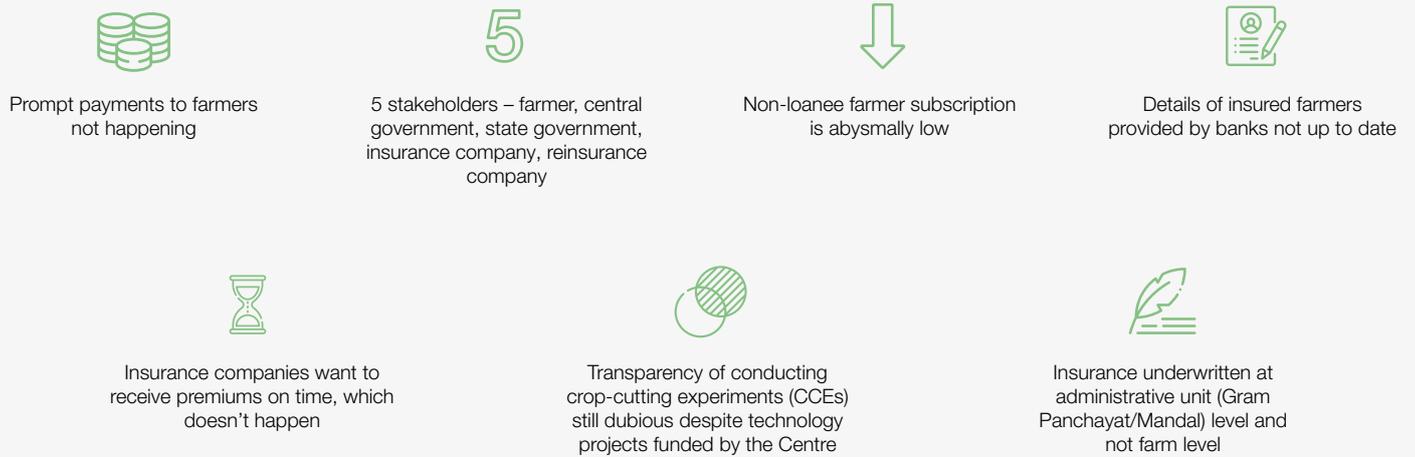


#### Satellite-based

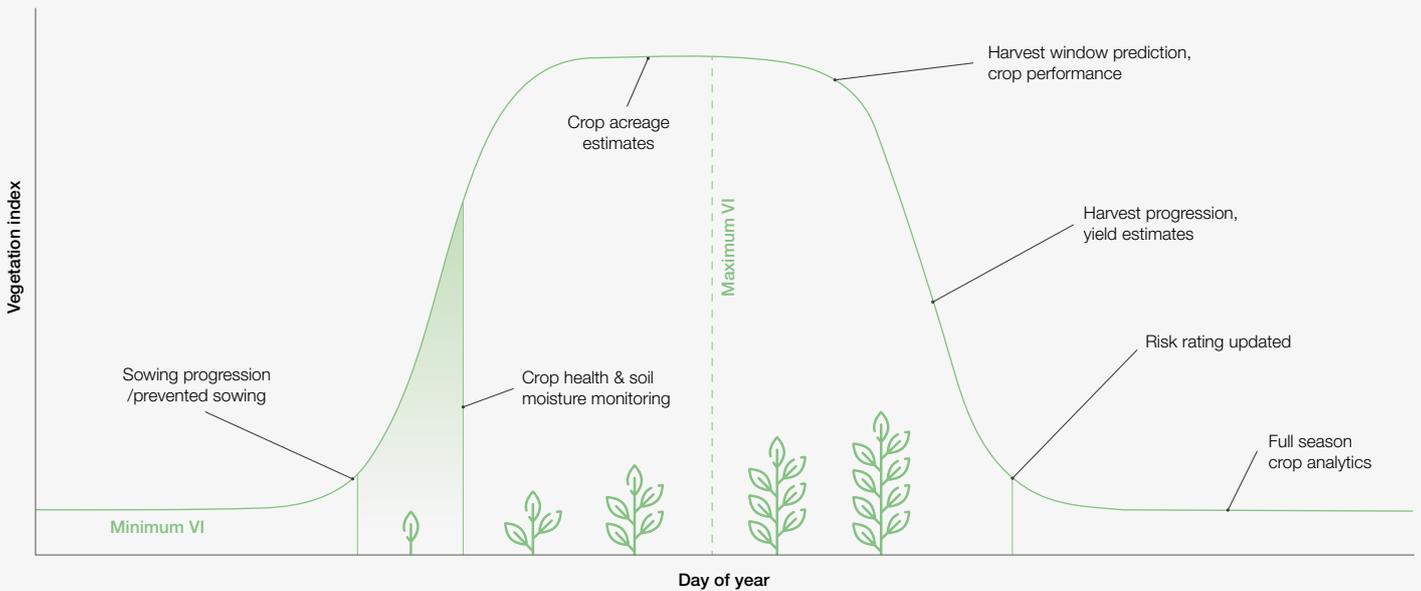
Crop water need – next 10 days → Identify areas with severe dry spell → Amount of water required for saving the farm

Timely advisories issued in 2018-19 led to the saving of 25,796 ha of groundnut crops in Andhra Pradesh

FIGURE 8 | Crop health management – smart insurance leveraging AI and remote sensing



### Digital twin of crops using satellite images & AI



## 3.4 Farmgate-to-Fork

The Farmgate-to-Fork working group was convened with the aim of addressing challenges in post-harvest value chain operations and recommending technological solutions to improve the income of farmers and improve returns for all supply chain players in the agriculture ecosystem.

The working group was divided into four crop segment subgroups – cereals and pulses, fruits, vegetables, and plantations, spices and oilseeds – with each crop segment having common producer and market characteristics. Subgroups were allocated participants from the working group who were known to have technical and commercial experience in that crop segment. Each subgroup assessed and developed case studies of 20-plus promising technological solutions. Some solutions were sourced from the agri-technology compendium developed by the Government of Telangana, and some solutions were provided by working group members.

Technology solutions were spread across six functional areas – quality assessment, logistics and warehousing, financial services, buyer-supplier matching, traceability and market risk management.

Subgroups collectively assessed the relevance of each technology solution to their crop segments, and prioritized them against the potential impact and viability matrix in Figure 3. Based on these prioritizations, subgroups assigned each technology solution one of the following four categories:

**Game changers:** High potential for farmers and overall value chain impact, with strong technical and commercial viability.

**Easy wins:** Medium potential for farmers and overall value chain impact, with strong technical and commercial viability.

**Long-term bets:** High potential for farmers and overall value chain impact, with medium technical and commercial viability in the immediate term.

**Nice-to-haves:** Low to medium potential for farmers and overall value chain impact, with low to medium technical and commercial viability.

Figure 9 below details the Farmgate-to-Fork technology solutions, organized by functional area and priority.

FIGURE 9 Farmgate-to-Fork technology solutions organized by functional area and priority

Functional area(s)	Innovation	 Cereals & pulses	 Vegetables	 Fruits	 Plantations, spices, oilseeds
Quality assessment	Cloud-based AI for grading and sorting	 Game changer	 Nice-to-have	 Game changer	 Deprioritize
	Spectral and machine vision-based quality assessments	 Easy win	 Nice-to-have	 Nice-to-have	 Game changer
	Image processing-based grading & sorting	 Easy win	 Long-term bet	 Long-term bet	 Nice-to-have
Logistics and warehousing	Solar-powered on-farm cold room w/ IoT	 Easy win	 Nice-to-have	 Easy win	—
	Warehouse management SaaS	 Nice-to-have	 Deprioritize	—	 Long-term bet
Financial services	Blockchain-based semi-automatic crop insurance platform	 Easy win	 Long-term bet	 Nice-to-have	 Nice-to-have
	Blockchain-powered warehouse receipt financing	 Easy win	 Nice-to-have	 Long-term bet	 Nice-to-have
Buyer-supplier matching	B2B electronic marketplace	 Game changer	 Game changer	 Game changer	 Game changer
	Farmer-level marketplace	 Long-term bet	 Long-term bet	 Long-term bet	 Long-term bet
	Hyperlocal transport services and market facilitation	—	—	 Easy win	—
Traceability	Blockchain and AI/ML farm-to-fork traceability	 Easy win	 Nice-to-have	 Long-term bet	 Easy win
Market risk management	Price predictor tool for farmers (agrowbook)	—	—	—	 Deprioritize

Next, the working group analysed 10 “model value chains” accounting for 62% of the crop production in the country, and developed technological solutions to improve value-chain efficiency. Model value chains represent the key demand centres and trade channels unique to each crop segment, and analysis of these helps to assess the unique constraints of supply and demand centres within specific value chains.

The model value chains that were analysed fell under the four crop segments as follows:

**Cereals and pulses:** Traditional retail, institutional trader/processor, government

**Fruits:** Traditional retail, organized retailer, value-added processor

**Vegetables:** Traditional retail, organized retailer, value-added processor

**Plantations, spices & oilseeds:** Traditional retail, institutional trader/processor

Subgroups identified the following primary challenges across value chains:

**Post-harvest losses in storage and transportation:** A significant portion of produce goes to waste due to long transit times, temperature fluctuations and contamination.

**Poor quality compliance:** Buyers often find that the produce supplied to them doesn’t meet their quality standards. Intermediaries in the value chain sell assorted produce, unsegregated by quality. Even where quality assessments and segregations are conducted, they are done in unscientific and non-standard ways.

**Poor traceability of origin:** As produce moves through the supply chain, information on its origin and transit is lost. Buyers may need to ascertain the veracity of specific “single origin” varieties of produce, or to trace back the origin of produce in the event of food-safety risk events, or to make assertions about following sustainable production and sourcing practices, but they are unable to do so due to the absence of traceability systems.

**Limited market transparency:** Farmers, intermediaries and buyers find it difficult to locate and connect with each other. Often, buyers resort to sub-standard and cost-ineffective supply centres to fulfil their demand, and farmers similarly settle for sub-optimal pricing for their produce. This limits farmer value-capture and creates value-chain inefficiencies.

In response to these identified pain points, subgroups developed an integrated solution for each value chain, comprising multiple technologies across the six functional areas. Solutions across model value chains have strong commonalities, with eight out of 10 integrated solutions having buyer-supplier matching as central functions (see Figure 10).

FIGURE 10 Emerging technology solutions for model value chains

Crop segment	Demand centre	Functional areas of integrated solution				
		Buyer-supplier matching	Quality assessment	Traceability	Logistics & warehousing	Financial service
Cereals & pulses	Institutional trader /processor	○	●	●	●	
	Traditional retailer		●		○	
	Government		●		○	
Vegetables	Traditional retailer	○	●		●	
	Organized retailer	○	●			●
	Value-added processor	○	●		●	
Fruits	Traditional retailer	○	●		●	
	Organized retailer	○	●			●
	Value-added processor	○	●		●	
Plantations, spices, oilseeds	Institutional trader / processor / traditional retailer	○	●	●	●	

Among the deep-dives into the challenges and solutions in crop segments and demand centres, **buyer-supplier matching** as a centric function is identified as a technology solution common to 8 out of 10 model value chains.

○ Centric function      ● Other value-added functions

“ The complete stack of buyer-supplier matching platforms is estimated to create an additional value of \$57-70 billion over a 20-year period.

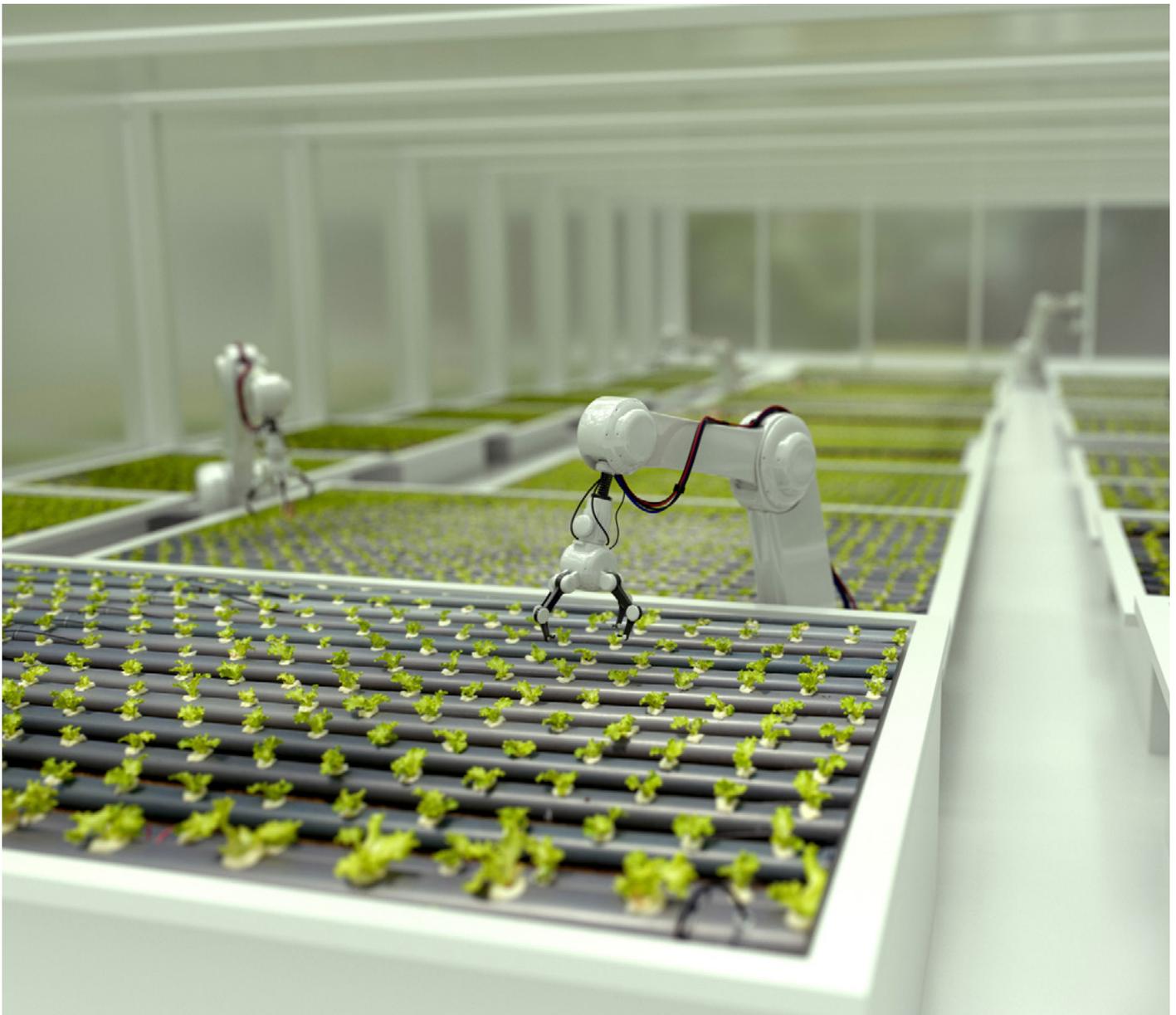
Following further discussions on individual solutions, the working group concluded that a B2B buyer-supplier matching platform model that facilitates trading between aggregators/intermediaries and buyers – with integrated services in logistics and warehousing, quality assessment, traceability and financial services – presents the highest potential to drive value capture and value creation in the ecosystem. Alternative buyer-supplier matching models are also being conceptualized, for example: farmgate aggregation platforms that link farmers and aggregators/intermediaries, online retail platforms that link retailers and consumers, and hyperlocal platforms that directly link farmers and consumers.

Other conclusions from the working group included the following:

- The farmer aggregation platform would be best led by the national government to ensure fair price capture for smallholder farmers. Existing practices in this area have shown low maturity of functionalities and require more investment in setting up last-mile operations.

- An online retail platform linking retailers and consumers would help promote e-grocery development in India. Some existing online retail platforms have already demonstrated high maturity of functionalities, even though they are still very limited in scale.
- Hyperlocal retail platforms facilitating direct sales between farmers and consumers would most directly improve value captured by farmers. Existing solutions in hyperlocal retail platforms are still at a nascent stage and need further functionality improvements and operational refinements.

The complete stack of buyer-supplier matching platforms is estimated to create an additional value of \$57-70 billion over a 20-year period. In this steady state, an annual additional value of \$15-18 billion would be generated for farmers. Within 20 years, between 61 and 75 million farmers (who would constitute 35-43% of the farming workforce) would stand to gain from these platforms.



## 3.5 Data-driven Agriculture

According to research conducted by McKinsey and the National Association of Software and Service Companies (NASSCOM), an Indian NGO, there is a

\$65 billion opportunity in India alone to be realized through unlocking 15 critical datasets in the domain of agriculture (see Figure 11).

FIGURE 11 15 critical datasets to unlock in Indian agriculture

Dataset	Description
1 Soil health	Agronomic details like soil-type and fertility, including nutrient availability (macro, micro, secondary), moisture content etc. for each farm
2 Satellite imagery	High resolution images to identify farm boundaries, crop distribution, yield etc.
3 Real time data on agriculture markets	Real time statistics on variety-wise market price and arrivals data from commodity trades
4 Crop yields	Data on actual yields for crop varieties per area harvest
5 Production & consumption data	Production and consumption volumes for crop varieties by month and location
6 Weather data	Climate details including rainfall, precipitation, humidity, sunlight, temperature, wind etc. at district level
7 Irrigation maps	High resolution irrigated area mapping to identify areas under irrigation, moisture levels in top soil, root zone etc.
8 Storage network details	Storage network details like crop varieties stored, maximum capacity, average utilization and safety buffer
9 Warehouse details	Warehouse details including locations, facilities like cold storage, capacity constraints, tariffs, operating and handling costs, fixed costs
10 Commodity profile data	Profile including standards for defects based on crop varieties & usage, shelf life, trade constraints, purchase limits, timing of production
11 Digital land records registry	Digital land records registry that establishes collateral and has legal validity with various departments (revenue, survey etc.)
12 Defect & pest images	Annotated dataset of images of different crop varieties for AI-based grading, diagnosis and defect identification
13 Agriculture market network	Agriculture market network by location, crop type
14 Import, export volume details	Import and export volumes for crop varieties by month and location
15 Historical purchase prices for crops	Historical daily purchase prices for crops by location, market type, level (e.g. farmer, middleman etc.)

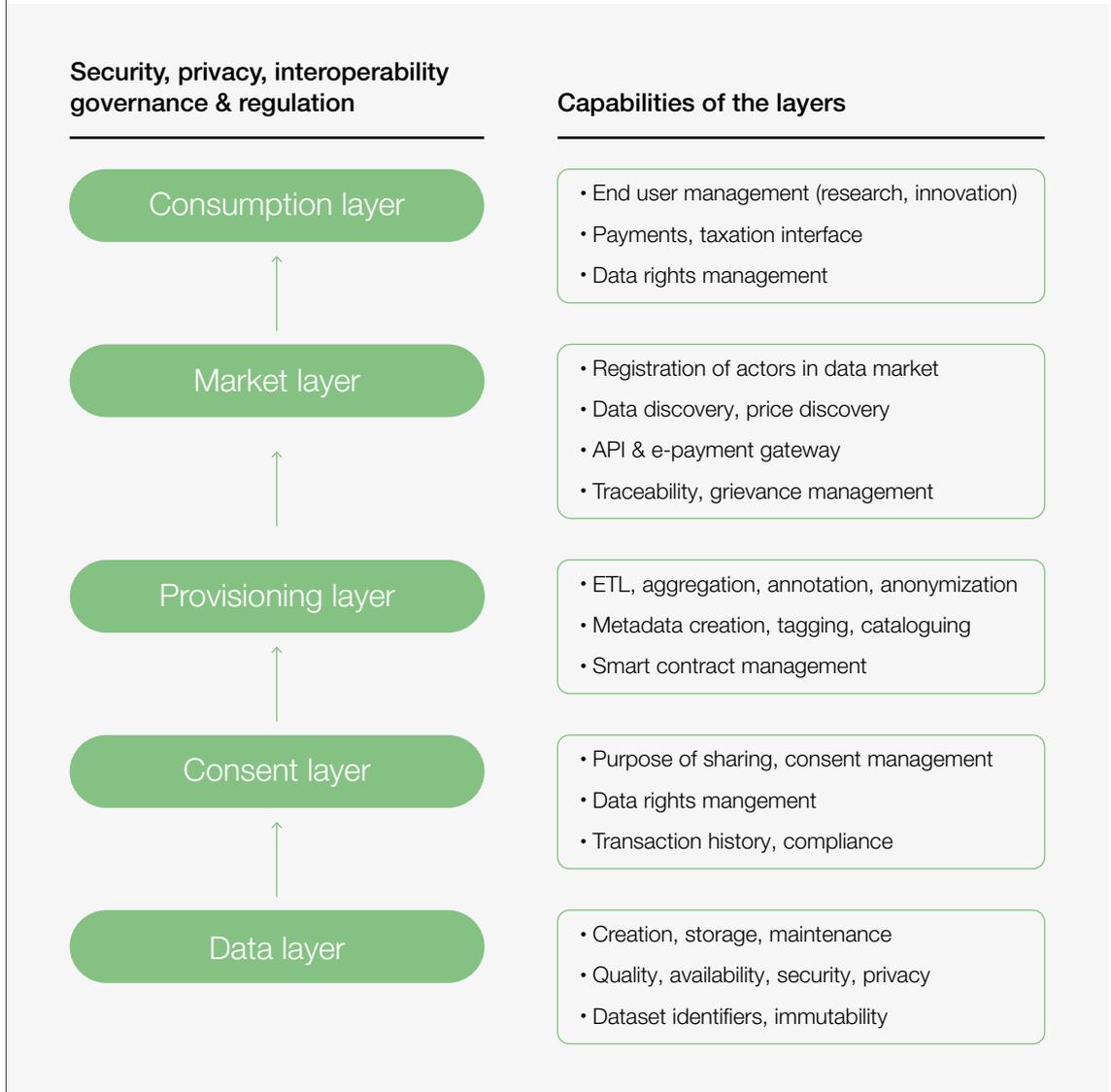
Source: NASSCOM and McKinsey

The data marketplace will play a pivotal role in the growth of the data economy. The architecture proposed for the data marketplace is founded on a set of universally accepted principles that include open standards, protocol-based interoperability, orthogonality of the core components, federated architecture, open APIs, security-by-design and privacy-by-design. Adherence to these principles

would ensure the foundational objectives of the data economy, such as equitable participation, autonomy, innovation and protection of stakeholder interests.

In line with the principle of orthogonality, a five-layered architecture is suggested. The five layers span the length and breadth of the data marketplace (see Figure 12).

FIGURE 12 Five-layer model of the data marketplace



## Accelerating the growth of the data marketplace

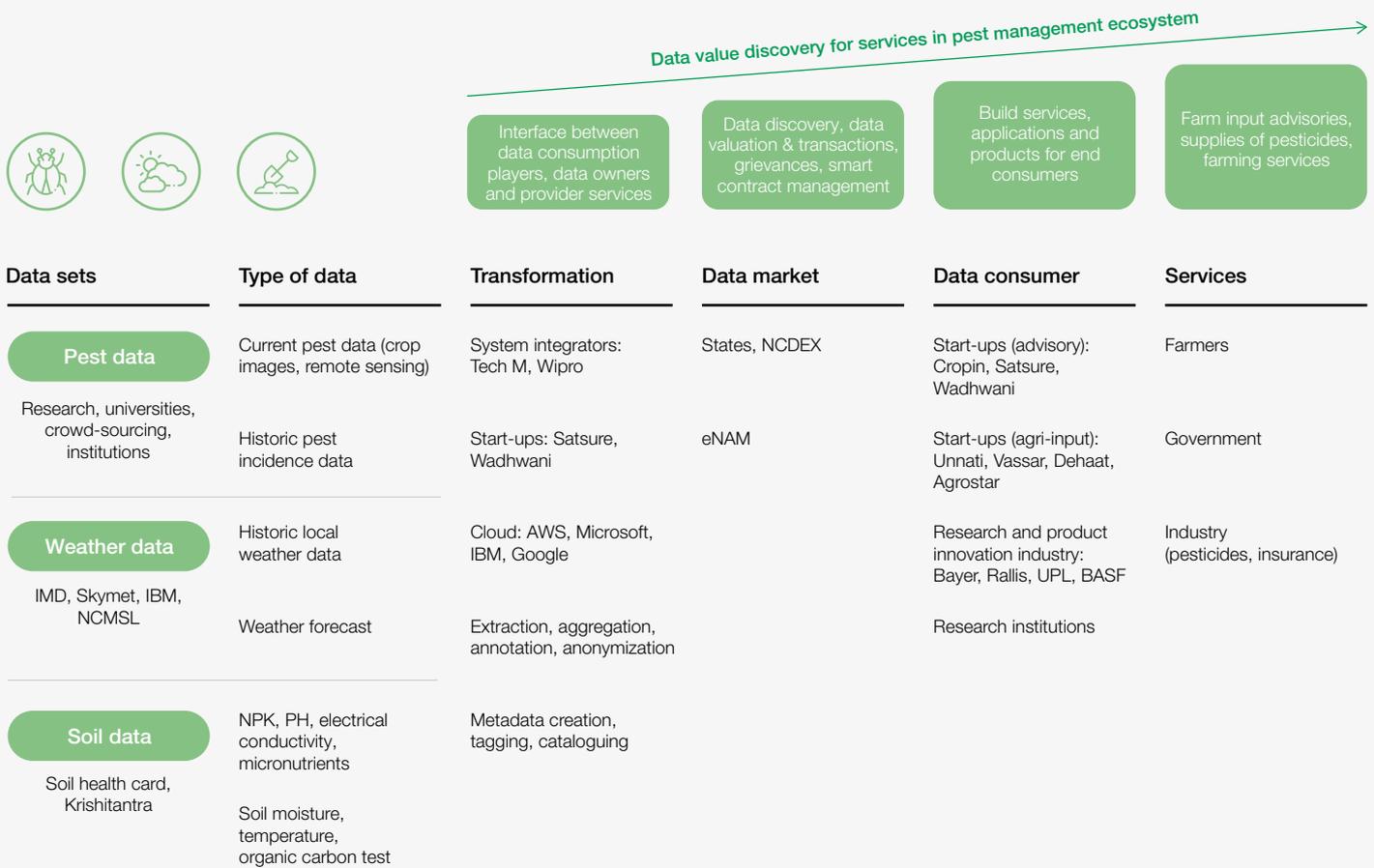
The working group recommended a set of measures to accelerate the growth of data marketplaces for agriculture, based on five enablers:

- **Availability** of datasets on the marketplace
- **Marketability** of the datasets
- An environment of **trust**

- Good **governance** of the marketplace
- Effective **regulation**

An illustrative list of use cases to emphasize the need for focused efforts to build large datasets to help drive value-creation in the Indian agriculture sector is presented in Figure 13 below.

FIGURE 13 Data marketplace use cases – pest condition prediction & advisories



**Note:** names of organizations are representative only and not an exhaustive list

4

# Conclusion and next steps



“ In the next phase of the programme, it will be necessary to test the assumptions and hypotheses made in this report.

Over the past six months, a comprehensive picture has emerged of what is possible through a multi-stakeholder and consultative approach. This report provides a bird’s eye view of the potential themes and use cases that can be explored further, with possibly significant gains to stakeholders, especially farmers.

The process has been rigorous and thorough. The AI4AI initiative appointed four working groups to address four themes: Intelligent Crop Planning, Smart Farming, Farmgate-to-Fork and Data-driven Agriculture. The initiative’s findings have arisen as a result of the extensive, weekly meetings held and inputs provided by project members over the past 18 weeks.

The project has identified a set of 11 frameworks and 24 use cases across the four themes. The frameworks identify existing challenges and gaps in policy, governance and domain practices and make suitable recommendations to address these gaps through the deployment of emerging technologies. The use cases are intended as pilot projects to demonstrate the potential added value arising out of the deployment of new technologies.

A comprehensive report containing the frameworks and use cases – along with the scope, value proposition to various

stakeholders, and methodologies – is expected to be released in the coming months. This will be a guidance document for all stakeholders in the development and use of emerging technologies in the agriculture sector in India.

In the next phase of the programme, it will be necessary to test the assumptions and hypotheses made in this report. The best way to achieve this is to implement a well-designed, large-scale set of pilot projects to realize the value propounded in the major frameworks and use cases. The pilots will be conducted in Telangana in select ICPUs, starting this crop cycle in May. Discussions will be initiated with other states in India to join. The AI4AI programme is open for extending to other global pilots in emerging economies.

C4IR India will disseminate a comprehensive report on AI4AI, containing specific and actionable recommendations, among the stakeholder community – especially all the state governments and agricultural universities in India. We hope that such a step will catalyse action to implement the different frameworks and use cases across India through local initiatives. C4IR India and the World Economic Forum stand by to facilitate such initiatives appropriately. In line with the multi-stakeholder approach advocated by the Forum, we propose to implement AI4AI in a mission-mode.

## 4.1 AI4AI impact objectives

The AI4AI initiative is aimed at demonstrating value to the main stakeholder of the agriculture sector, namely the farmer, through a multi-stakeholder approach. The AI4AI impact objectives for phase 1 are defined as follows:

- One goal: the economic development of farmers through a multi-stakeholder approach
- 10 streams of new value (e.g. seven use cases across three different themes)
- 100 farmer-producer organizations
- 1,000 villages
- 100,000 farmers

It is proposed that states can select a minimum of 10 new value streams to measure impact and validate frameworks out of the themes and use cases identified as game changers in this report, as listed below:

1. Designing an AI-driven macro-crop planning model for 10 integrated crop-planning units;
2. Providing pre-season crop/variety advisories in project areas;

3. Smart FaaS (farming-as-a-service), an ET-based one-stop-shop for farmers’ needs throughout the agri-cycle;
4. Creating e-SHCs (e-soil health cards) and making them accessible online to the target group of farmers;
5. Implementing smart crop insurance in the entire project area;
6. Demonstrating traceability of agricultural produce in respect of high-value agri-produce;
7. Designing an AI-driven market intelligence system;
8. Establishing an AI- and IoT-based platform with farmer/value chain/buyer linkages, integrating quality and traceability;
9. Establishing a data marketplace platform for selected datasets, which could include data on weather, soil, inputs and crops grown;
10. Creating an EFR (electronic farm record) for each farmer in the target group.

The Government of Telangana, the Professor

Jayashankar Telangana State Agricultural University and relevant industry representatives are already exploring the scope, deliverables, responsibility matrix, success KRAs and terms for the pilots. The geographical scope extends to 10 districts of Telangana state, with approximately 100 villages to be selected in each district in contiguous mandals within the corresponding LMUs (50% of the LMUs are to be in rainfed areas and 50% in irrigated

areas). The domain scope extends to all the major crops grown in the selected districts.

This programme of pilot projects will be taken up nationally with the help of the Ministry of Agriculture, NITI Aayog, other state governments, industry partners, civil society partners and the start-up ecosystem.

## 4.2 Implementation framework for pilots

The programme is to be implemented in a mission-mode, given the seasonality of the agriculture sector. As such, the following multi-level implementation framework is proposed:

An **empowered committee** at the state level, led by the principal secretary (agriculture), is proposed to define the vision, give direction and take all the project-related policy decisions. It would consist of representatives of all major stakeholder groups. It may meet on a monthly basis.

A **steering committee** at the state level, led by a senior officer of the domain, should review and guide the project on a weekly basis, and take all the operational decisions.

District-level **project committees**, headed by the concerned district collector, should review the

progress of the project and ensure timelines are met and bottlenecks removed at the field level.

A significant effort will be made on **capacity building** at multiple levels, especially at the field level, including the functionaries of agriculture, revenue, development, irrigation and other departments. The methods should include workshops, newsletters, knowledge portals and webinars.

An effective **awareness campaign** should be launched in project areas, to ensure the increased uptake and utilization of project services and offerings by farmers, FPOs and market players of the agri-ecosystem.

**C4IR India** shall play a facilitatory role in the smooth implementation of the project and realization of the goals.

## 4.3 Milestones and timelines

The project is proposed to be implemented over four agricultural seasons spread over two

years (2021-2023). Figure 14 gives a high-level view of the major milestones and timelines.

FIGURE 14 AI4AI project timeline and milestones

Season	Milestones to be crossed
<b>Monsoon crop cycle 2021</b>	<ol style="list-style-type: none"> <li>1. Preparation of detailed project plan</li> <li>2. Collection of basic data and establishing sources of data</li> <li>3. Design of software and AI tools</li> <li>4. Establishing IT and non-IT infrastructure</li> <li>5. Conducting small pilots on five use cases</li> <li>6. Awareness and capacity building</li> </ol>
<b>Winter crop cycle 2021-22</b>	<ol style="list-style-type: none"> <li>1. Launch five use cases</li> <li>2. Touch 10,000 farmers</li> </ol>
<b>Monsoon crop cycle 2022</b>	<ol style="list-style-type: none"> <li>1. Launch all 10 frameworks / use cases</li> <li>2. Touch 50,000 farmers</li> </ol>
<b>Winter crop cycle 2022-23</b>	<ol style="list-style-type: none"> <li>1. Impact 100,000 farmers</li> </ol>

**Notes:** The monsoon crop cycle in India is from June to October and is known as the Kharif

The winter crop cycle in India is from November to April/May and is known as the Rabi

# Glossary

4IR	Fourth industrial revolution	IWMI	International Water Management Institute
AI	Artificial intelligence	KRA	Key result area
AI4AI	Artificial Intelligence for Agriculture Innovation	LGP	Length of growing period
AWS	Automated weather station	LMU	Land management unit
C4IR	Centre for the Fourth Industrial Revolution	LUP	Land use planning
CCE	Crop-cutting experiment	ML	Machine learning
DMP	Data marketplace	MNC	Multi-national corporation
EFR	Electronic farm record	NASSCOM	National Association of Software and Service Companies
eNAM	Electronic national agriculture market	NBSS	National Bureau of Soil Survey
eNWR	Electronic negotiable warehousing receipt	NCDEX	National Commodity & Derivatives Exchange Limited
eSHC	Electronic soil health card	NCML	National Collateral Management Services Limited
ETL	Extract, transform and load	NPA	Non-performing asset
FaaS	Farming-as-a-service	NPK	Nitrogen Phosphorus Potassium
FAIR	Fast access interoperability resources	NRSC	National Remote Sensing Centre
FPA	Food-processing automation	PJTSAU	Professor Jayashankar Telangana State Agricultural University
FPO	Farmer-producer organization	PPP	Public Private Partnership
ICAR	Indian Council of Agricultural Research	SaaS	Software-as-a-service
ICPU	Intelligent crop planning unit	SDGs	UN Sustainable Development Goals
IMD	Indian Meteorological Department	WG	Working group
IoT	Internet of things		

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# Endnotes

1. The workshop report can be viewed on the TopLink event page under the Sessions tab (in Programme).
2. In software and systems engineering, a use case is a list of actions or event steps typically defining the interactions between a role (known in the Unified Modeling Language (UML) as an actor) and a system to achieve a goal. The actor can be a human or other external system. Source: [https://en.wikipedia.org/wiki/Use\\_case](https://en.wikipedia.org/wiki/Use_case)



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