AI4AI: Artificial Intelligence for Agriculture Innovation

Agri-tech Innovations in the Farmgate-to-Fork Ecosystem: Prospects for improved value creation and capture for farmers

Prepared in collaboration with TechnoServe India

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Project Set-up

The Artificial Intelligence for Agriculture Innovation (AI4AI) initiative was launched in August 2020 by the World Economic Forum and the Government of Telangana with the goal of leveraging emerging technologies to transform the agricultural landscape, making agriculture profitable and sustainable for farmers. The AI4AI initiative constituted four Working Groups to discuss technology-based solutions to a range of challenges in the agricultural ecosystem. This report was created by TechnoServe India, with the participation of the organisations from the 'Farmgate to Fork' Working Group.

Overview of the Indian Agriculture Sector

Agriculture is a critical pillar of the Indian economy, engaging 43% of the national workforce. However, smallholder farmers[1], who account for 86% of all farmers in India, are still some of the poorest people in the country, earning only 39% of what medium holders earn, and only 13% of what large holders earn. The COVID-19 crisis has exposed underlying structural weaknesses in agricultural value chains. Agricultural value is projected to decline by ~4.4 trillion INR in total between 2020 and 2022 (representing an annual decrease of 10-15%).

Key Challenges and Opportunities in the "Farmgate to Fork" (F2F) Space

Typically, smallholder farmers are unable to capture commensurate value for their produce due to low visibility of demand, exploitative intermediation, limited quality assurance, limited access to efficient and low-cost logistics, and low bargaining power. To improve farmer incomes, it is necessary to improve their value capture and to drive overall value creation.

Technology offers the potential to develop and iterate solutions rapidly, create cost efficiencies, introduce transparency in information flows, and strengthen connectivity between value chain actors. A variety of technologies in farmer-buyer matching, quality assessment, transportation and small-volume aggregation have emerged in India to drive the above value levers. India is also in a strong position to take these technologies to scale given rapidly growing internet and smartphone penetration in the country and the presence of a rapidly evolving agricultural technology landscape comprising of innovators, investors and adopters.

Mature State Projection of Integrated Technology Solutions

To develop technology-based solutions for F2F, we undertook a four-stage process of 1) developing model value chains, 2) identifying technology solutions with high potential, 3) identifying challenges across model value chains, developing integrated solutions to address these challenges, and gauging their capabilities at mature state, and 4) synthesizing solutions and quantifying their ecosystem impact.

We identified five types of technology solutions that can create value in F2F space: B2B Buyer-Supplier Matching Platforms, Farmer Aggregation solutions, Mandi Automation solutions, Hyperlocal Connect solutions, and Online Retail solutions. Among the five solutions, Business-to-Business (B2B) Buyer-Supplier Matching and Mandi Automation are expected to be the Game Changers, driving the majority of value creation.

- B2B Buyer-Supplier Matching platforms would facilitate linkages between aggregators and institutional buyers and processers. These platforms would service a wide range of crops and provide exhaustive information on the quality, quantity and price of produce to facilitate buyer-

supplier matching. While different B2B platforms already exist in the market (e.g., NCDEX, NeML, AgriBazaar, and Ninjacart), they still have significant gaps in the functionalities they offer. At a mature state, a fully functional B2B platform could create an extra annual value of $19-24 billion, allowing farmers to capture most of this value.

- The Mandi Automation solution would digitalise the traditional retail channel, i.e., the Agricultural Produce Market Committees (APMCs), and would connect smallholder farmers to intermediaries and institutional buyers. While eNAM is a government-led technology initiative in Mandi Automation, it is facing multiple challenges in effective scaling. It presently handles less than 1% of commodity trading volumes and accounts for less than 0.1% of the total trading value in the APMC channel. To scale up, eNAM would need to on-board more farmers and buyers by extending more incentives, and by optimising functionalities. At a mature state, eNAM could potentially create an extra annual value of $18-22 billion.
- The Farmer Aggregation solution would facilitate the aggregation of produce from smallholder farmers. It would connect farmers with aggregators and institutional buyers and would provide key value-added services such as shared-load aggregation, logistics services, and rapid quality assessments. Existing farmer produce aggregation solutions are still limited in scope and scale, and would need to improve their functionalities to reach a higher scale.
- The Hyperlocal Connect solution would help farmers to sell their fresh produce directly to consumers. Key functionalities of the solution would include a user-friendly sell and purchase interface, an efficient delivery network, and quality assurance. Existing hyperlocal technology solutions are still at a nascent stage of development and functionalities are underdeveloped.
- The Online Retail solution would connect retailers and consumers. To deliver useful e-grocery options, the solution would provide user-friendly buying experiences to consumers, make a large variety of perishable and non-perishable products available for purchase, have an efficient and low-cost logistics network, have a robust quality assessment approach, provide traceability tools from farmgate, and offer high payment flexibility. Existing online retail solutions such as BigBasket and Grofers have demonstrated high maturity of functionality offerings, though still at a limited scale, and are positioned to scale up to reach more consumers.

At a mature stage, we expect that the five technology solutions would add significant value to the ecosystem, estimated at $62-76 billion on an annual basis. Farmers would be able to capture $34–42 billion (50-60%) of this value. It is expected that 75–91 million farmers would benefit from the value creation associated with these solutions, accounting for 35-43% of the farmers in India. With the extra value capture, income in crop cultivation among the farmers impacted would increase by 70-80%.

Continuous commitment from different actors would be important to realise this 20-year vision. Key driving actors including technology companies, agri-businesses, ag-tech start-ups, the Central and State governments, development sector donors, and social organisations, would need to offer substantial and long-term resources and support to drive the transformation of F2F in the agricultural ecosystem.

Project Setup

Overview of the AI4AI Initiative

The Artificial Intelligence for Agricultural Innovation (AI4AI) is a multi-stakeholder initiative jointly launched by the World Economic Forum's Centre for the Fourth Industrial Revolution India and the Government of Telangana, with the goal of transforming the agricultural landscape and making agriculture profitable and sustainable for farmers through technology innovation. Since its launch in August 2020, the initiative has convened more than 100 stakeholders representing the government, technology industry, food industry, and other key sectors to identify and pilot emerging technologies such as Artificial Intelligence (AI), blockchain, drones and Internet of Things (IoT) to solve pressing challenges in agriculture.

Background of the Report

The AI4AI initiative constituted four Working Groups to discuss technology-based solutions in agriculture: Intelligent Crop Planning, Smart Farming, Farm Gate to Fork, and Data-Driven Agriculture. TechnoServe led the discussions in the Farm Gate to Fork Working Group**,** and explored technology-based solutions to address challenges in harvesting and procurement, storage, marketing and trading, and processing and retail.

The following organisations participated in the F2F Working Group discussions:

- **Technology companies:** Amazon Web Services, IBM, Mastercard, Microsoft, SAP, Vodafone Idea
- **Ag-tech startups**: AgNext, Digital Green, Ecozen, MyCrop Technologies, Nurture.Farm, SourceTrace, Statwig
- **Food processing and retail companies**: Cargill, Indus Fresh, 3F Oil Palm, Reliance Retail
- **Government:** Department of Agriculture of the Government of Telangana; Department of Information Technology, Electronics and Communications
- **Academia:** Professor Jayashankar, Telangana State Agricultural University

This report was created by TechnoServe India, with contributions from participants in the Farmgate to Fork Working Group.

Structure of the Report

We used a three-phased approach to develop this report:

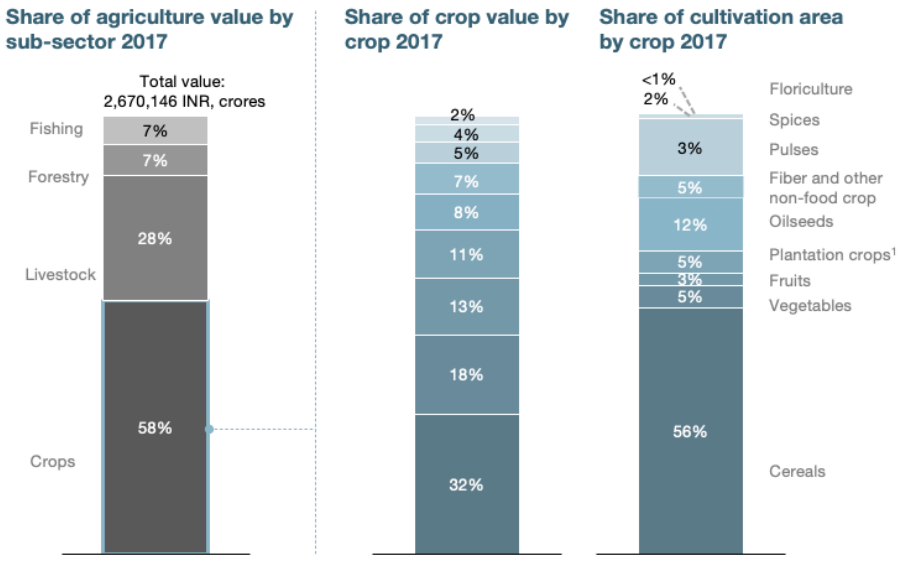
- **Identify pain points**: Based on inputs from industry experts, we identified the activities influencing the value of different crops at each point of the value chain. We then determined pain points for various actors participating in the value chain, and identified lost opportunities for value creation and farmer value capture.
- **Determine value drivers:** We then determined opportunities for value creation in agricultural value chains, with a focus on F2F-related solutions. We also explored high-potential technology interventions that could drive value creation, and assessed their techno-commercial viability and potential for impact.
- **Recommend interventions:** After identifying pain points and determining value drivers, we defined solutions catering to the unique needs of different types of value chains. Key capabilities, prospective partnerships, and important enablers for scale-up were identified. Individual solutions for value chains were synthesised, and integrated ecosystem solutions were developed as a result. Finally, we quantified the potential impact of these solutions over a 5-year, 10-year, 15-year, and 20-year horizon.

Overview of the Indian Agricultural Sector

Key highlights

Agriculture is a critical pillar of the Indian economy. Employing 43% of the country's workforce, it boasts globally-competitive production levels for various staple and commercial commodities. Within the agriculture sector, crops contribute 58% of the sector value, with cereals, vegetables, fruits and plantation crops accounting for 74% of crop value and 69% of cultivation area.

Figure 1: Share of Sub-Sectors in Agriculture Sector Value[2]



Despite forming the bulk of the country's workforce, farmers are one of the poorest sections of Indian society, and remain impoverished due to their inability to obtain commensurate returns from agriculture. Economic challenges are most acute for smallholder farmers, who form 86% of the Indian agrarian population, but earn only 39% of what medium holders earn, and only 13% of what large holders earn.[3]

Vulnerabilities due to COVID-19

The COVID-19 crisis has exposed several structural vulnerabilities in the agriculture sector. According to a forecasting analysis conducted by TechnoServe India in June 2020, the Indian agricultural sector is likely to see a decline in value of around INR 4.4 trillion, with the bulk of value decline in 2020 (INR 1.6 trillion) and 2021 (1.6 trillion), and a smaller yet substantial decline in 2022 (INR 1.3 trillion) as well. The decline in agricultural value is expected to be driven primarily by:

- a decrease in supply of marketable produce due to supply chain disruptions among crops that are perishable, have weaker supply chains, and are more vulnerable to negative supply shocks and to farm labour unavailability, and
- a decrease in farmgate prices for a subset of crops due to changing supply and demand dynamics.

Farmer income is also expected to take a hit as demand for agricultural crops is projected to decline by ~580 million MT, with a decline of ~12% in 2020, ~11% in 2021, and ~8% in 2022. The general economic slowdown, as a result of the pandemic, is expected to place additional stress on farmer economics and potentially reduce farmer household incomes by an average of ~33%, with a 31% decrease of income in crop cultivation (the main income source for farmers) and a 35% decrease in daily wages and allied sector wages (which are other important sources of income for farmers).[4]

Common Challenges Faced by Farmers

Farmers in India face multiple challenges in realising remunerative returns from agriculture:

- **Low visibility of demand:** Farmers have poor visibility of demand dynamics, and therefore often produce in excess or in deficit of market demand. During supply gluts, they end up having to sell produce at sub-optimal prices, and during demand surges, they find themselves unable to capitalise on price gains.
- **Exploitative intermediation:** Supply chains are often heavily dependent on intermediaries, who may enjoy disproportionately high value capture at the cost of farmers. Intermediation also results in the loss of critical information on quality desired, pricing, time of demand, etc., which, if made available, would critically help farmers plan production, harvesting and selling decisions.
- **Limited quality assurance:** Farmers know little about the quality requirements of buyers, and often supply produce of the wrong quality to them. Without assurance of appropriate quality, and without mechanisms to remunerate farmers based on quality, buyers often pay farmers less than their produce is worth.
- **Limited access to efficient and low-cost logistics:** Farmers do not have access to a robust logistics service for transporting produce. Logistical services catering to transportation of small volumes of produce are unavailable in rural areas. Even where available, such services are prohibitively expensive. As a result, farmers are unable to directly service the demands of buyers.
- **Low bargaining power:** An overwhelming majority of farmers in India are smallholders and produce in small quantities. They are unable to attract institutional buyers, and have few opportunities to negotiate with local intermediaries for better pricing and terms of trade.

To earn higher incomes from agriculture, farmers need two types of support:

- **Driving value creation** means creating value for all players in the value chain, including farmers. Value creation necessitates market system-wide interventions. When markets are designed to transmit information on supply and demand, farmers can align their production directly with buyer demands and access the best trade terms for their produce. Such transparent markets create value by shortening supply chains and minimising wastage of produce.
- **Improving value capture** means increasing absolute value realisation and "return on investment". When supported to participate in transparent markets, when connected with other smallholder farmers to increase bargain power, and when connected with buyers that have confidence in their quality of goods, farmers can realise higher value for their produce.

The Role of Technology in F2F

Technology offers the potential to develop and iterate solutions rapidly, create cost efficiencies, introduce transparency in information flows, and strengthen connectivity between value chain actors. In the recent years, India has seen the emergence of technology-based solutions to address challenges in the F2F space, some even demonstrating proof of concept. India is also strongly positioned to take these technologies to scale due to the following factors:[5]

- **High internet penetration:** With over 560 million internet users, half of whom are from rural areas, India is the second largest online market in the world. India also has a high possession ratio of smartphones, with as much as 40% of the user base from rural India.
- **High adoption of advanced technological applications:** The Indian AI market was valued at $6.4Bn in 2019, which is close to 16% of the global AI market.
- **Increasing participation of organised players:** Organised players in the country are also increasingly active in large-scale technology implementation programs to improve F2F operations

in agriculture. Multi-National Companies (MNCs) such as Reliance Industries are foraying into the growing agriculture technology business by deploying technology tools for marketplace coordination, traceability, etc., as part of their move to strengthen their market operations.

Recognising this opportunity, the Government of India has taken early steps towards developing these technologies for the agricultural ecosystem. Recent efforts have included the eNAM portal supported by National Government, Artificial Intelligence (AI) and Machine Learning (ML)-based agricultural price forecasting applications backed by the Government of Karnataka, and the 'Agri-tech Data Hub' being developed by the Government of Telangana. Recent policies and regulations in the country, such as the Farmers Produce Trade and Commerce (Promotion & Facilitation) Act, 2020 and the Farmers (Empowerment & Protection) Agreement on Price Assurance and Farm Services Act, 2020 are also supportive of high-potential technologies and can make an important impact in transforming Farmgate-to-Fork (F2F) ecosystem.

Mature State Projection of Integrated Technology Solutions

Overview of Approach

TechnoServe India adopted a four-step approach to develop recommendations for technological transformation of the F2F ecosystem in agriculture:

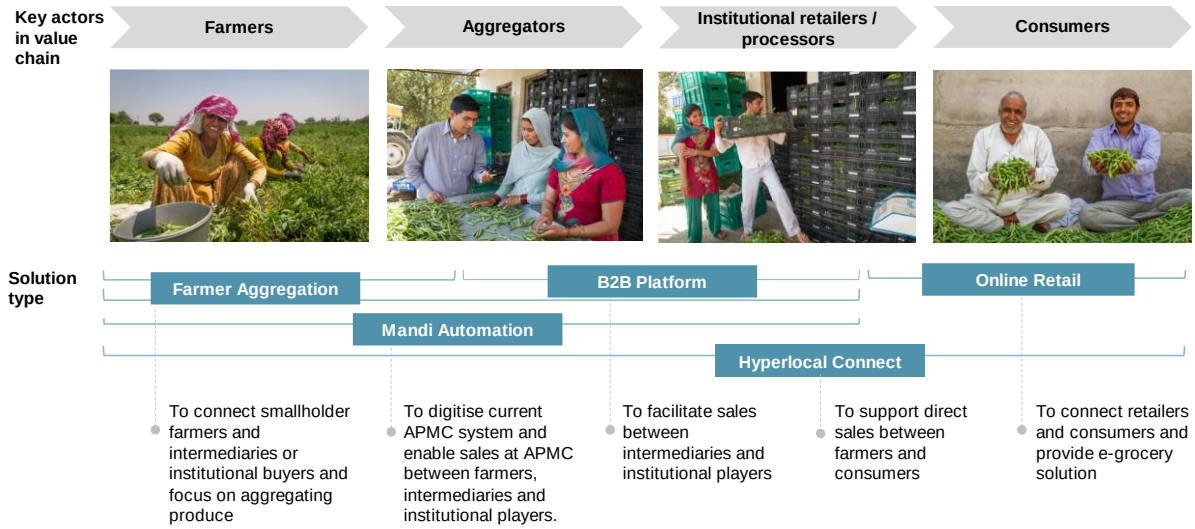
1. **Developing model value chains:** We developed "model value chains" for four distinct crop segments: cereals & pulses; fruits; vegetables; and plantations & spices. Model value chains were designed to abstractly represent the value-add activities characteristic to different demand centres for each crop segment, and provide an illustrative concept of how crops move through different nodes in the value chain before reaching the final demand centre.
2. **Identifying high-impact examples of technology solutions in F2F:** To explore feasible and impactful technology solutions existing in the F2F space, we collected 20 examples of technology solutions that have been deployed in agricultural value chains so far and facilitated the Working Group to discuss their potential impact and viability. Each solution was assessed for its potential in impact and techno-commercial viability. Potential impact was evaluated by the number of farmers who stand to benefit from the solution and the potential increase in farmer incomes, while viability was assessed based on scalability, financial viability, regulatory viability, and technological complexity. Based on this assessment, solutions were classified as Game changers, Easy wins, Long-term bets and Nice-to-haves.
3. **Developing "mature state" integrated ecosystem solutions to address challenges:** To understand the challenges in each value chain in depth and develop tailored solutions, the pain points of farmers and buyers as well as the needs of each party were identified in each model value chain. For each model value chain, we developed technology-based solutions uniquely responding to the pain points of value chain players, taking reference from the long-list of technology solutions we had assessed in Step 2. Following this, we assessed how solutions for each model value chain would evolve after reaching maturity, i.e., over the 10 to 20-year horizon. Finally, for each model value chain, we arrived at "integrated ecosystem solutions" that converged multiple individual solutions in their mature-state forms.
4. **Synthesising solutions and quantifying potential impact:** By looking at common characteristics of individual solutions among value chains, and potential for evolution to a state of maturity, the solutions developed for model value chains were synthesised into a larger ecosystem solution that reflected their capabilities at mature state. In addition, existing ecosystem solutions were assessed to understand their state of maturity and recommend an action plan. Finally, potential value creation through each ecosystem solution was quantified to specify impact for entire ecosystem and value capture by farmers.

Integrated ecosystem solutions

Through this exercise, we identified five types of technology solutions that we expect would meet the needs of the Farmgate to Fork ecosystem: the B2B platform, the Mandi Automation solution, the Farmer Aggregation solution, the Online Retail solution, and the Hyperlocal Connect solution.

Among the 5 integrated ecosystem solutions, B2B platforms and the Mandi Automation solution are expected to be the Game Changers in the F2F ecosystem, with the potential to drive highest value for all market players.

Figure 2: Five technology solutions along the value chain



B2B platform

The B2B platform would connect intermediaries to institutional players and processors, and facilitate sales and relevant value-added services for all parties. Some existing offers of B2B platforms include NCDEX, NeML, AgriBazaar and Ninjacart.

The B2B platform would serve a wide range of perishable and non-perishable crops and provide exhaustive information about products on the platform, including crop variety, volume, time of harvest, quality, source of origin, etc. To support the presence of key information, quality assessment and traceability would be integrated as important value-add services. Quality assessment would set up standardised parameters and offer tech solutions to determine physical and chemical quality of produce at the source location, while traceability solutions would make the movement of produce from farmgate through supply chain transparent, providing easier access to the source information. In addition, logistics and warehousing would be offered to improve transportation efficiency, and tech solutions would be deployed in storage space to control quality. Last, but not the least, various payment and financing options would be provided for business players to support smoother transactions.

Mandi Automation solution

The Mandi Automation would be a digital portal of the current agricultural market system, connecting smallholder farmers to intermediaries or institutional buyers/processors/unorganised retailers and traders to institutional buyers/processors/unorganised retailers.

In addition to being a pan-India trading portal for a wide range of crops, the Mandi Automation solution would offer logistics and warehousing solutions to support storage and transportation between sellers and buyers, quality assessment of the physical and chemical characteristics of the produce, source tracing of the produce, and financial services for fast payment and financing.

The National Agriculture Market, also called eNAM, is a solution developed by the government for Mandi Automation. It is a pan-India electronic trading portal which networks the existing APMC mandis to create a unified national market for agricultural commodities. Farmers can opt to trade directly on their own through a mobile app or through registered commission agents. Similarly, traders and exporters can procure quality products in bulk, at a single place, and can sell them further. eNAM presently faces multiple challenges in evolving to the next stage, especially in trading volumes and

value. To scale up to the next level, eNAM would need to get more farmers and buyers on board by improving its functionalities and by providing commercial incentives to users.

Farmer Aggregation solutions

Farmer Aggregation solutions would contribute to efficient aggregation of produce from smallholder farmers and transportation to intermediaries or larger buyers including institutional buyers, processors and unorganised retailers. Existing Farmer Aggregation solutions in India e.g. Mastercard Farmer Network and Loop, have seen limited adoption so far.

To ensure fair value captured by farmers, Farmer Aggregation solutions would need to provide complete functionality to address pain points of farmers, intermediaries and institutional buyers. Apart from creating linkages among smallholder farmers, intermediaries and institutional buyers, a user-friendly front-end for farmers would be important to allow easier access for farmers and high usage frequency. Its logistics would especially focus on shared load aggregation service in order to collect small volumes of produce from diverse locations at low cost and in a time-efficient manner. In addition, quick and standardised quality assessment would play an important role to remunerate farmers fairly. Also, traceability solutions and financial services would add value to both sellers and buyers.

Hyperlocal Connect solution

The Hyperlocal Connect solution focuses on facilitating direct fresh produce sales in local markets between farmers and consumers. Existing Hyperlocal Connect solutions e.g. Kalgudi and Farmerprice are still at a nascent stage of deployment.

Hyperlocal Connect would provide a user-friendly fresh produce sales and purchasing experience to both farmers and consumers via desktop and mobile. Key product information including prices, volume, produce sources, quality, etc. would be provided via platform. In addition, a fast and low-cost delivery solution would be enabled to transport the products from farmers to consumers. Easy-to-use and fast tech solutions in quality assessment as well as traceability would be offered via platform. Moreover, the platform would support various forms of payment. To facilitate usage for local farmers and consumers, selection of multiple local languages would be available on the platform.

Online Retail solution

The Online Retail solution would connect retailers and consumers in order to provide a purchase channel for both perishable and non-perishable food. There are a number of existing players of Online Retail solutions in India, including several fast-growing examples such as BigBasket, Grofers, JioMart and Zopnow. Although they are still operating at a limited scale, they have demonstrated high maturity in their functionality offerings.

A highly functional Online Retail solution would provide consumers with a user-friendly way to get their groceries online. It would cover a wide range of products and provide exhaustive information about them. At the same time, it would manage a smart logistics network to offer quick, smooth, accurate product delivery with low fees, while simultaneously ensuring product quality. Moreover, it would offer quality assessment and traceability solutions to ensure transparency of supply chain and product information. Flexible payment methods including cash and digital payment would be supported on the platform.

Impact created by the five ecosystem solutions

In a mature state, the technology solutions are expected to generate significant impact and nearly double farmer income from crop cultivation.

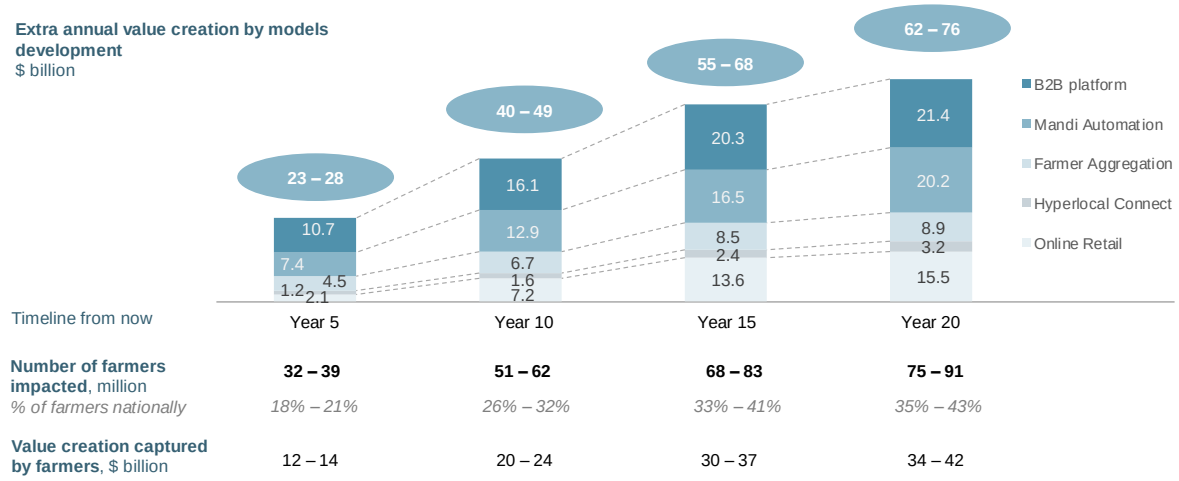
Assuming that these solutions reach maturity, 20 years from now, their combined value creation per year is projected to be $62 to 76 billion. 50-60% of the marketable volume in the sector is expected to be traded via online platforms, which will translate to a crop value of about $200 billion per year. Online platforms are expected to create 35% additional value in the sector through quality transparency, disintermediation, and improved market coordination.

Farmers are expected to retain around 50-60% of the additional value created, i.e. $34 to 42 billion. According to industry expert inputs and market report, around 75 to 91 million farmers are expected to benefit from the technology solutions in their mature state. This would account for 35-43% of farmers in India in year 20. Over the 20-year term, we expect farmers to see increased crop cultivation incomes of INR 31k – 38k due to additional value capture, which is 70-80% of the current farmer incomes from crop cultivation (estimated at INR 45k – 50k). This would mean an almost doubling of farmer incomes from crop cultivation over a 20-year term.[6]

Among the 5 technology solutions, B2B platform and Mandi Automation solution would be the main value drivers, contributing to more than half of the total extra value created. As estimated from market research and agriculture experts, the traditional retail channel, i.e., the APMC channel, presently markets 70-80% of the total marketable crop volumes produced by farmers[7]. Aggregators, traders and institutional buyers, processors, and unorganised retailers form the biggest demand centre for agriculture produce, and procure 55-60% of the total crop volumes produced by farmers. The B2B Platform and Mandi Automation solutions are expected to enable transparent buyer-supplier discovery between aggregators, traders, institutional buyers, processors and unorganised retailers, and facilitate improved market coordination across the traditional retail channel. Therefore, we expect that, together, the two solutions will handle the bulk of the agricultural trade in the country and will create the highest value in the agricultural ecosystem.

Online Retail is expected to grow rapidly (est. CAGR of 13% to 15% from year 5 to year 20) and is likely to be the third largest value contributor (20-25% of total value creation), partly due to the widespread consumer adoption of e-commerce, and partly due to the increasing number of online retail players in the Indian market. Farmer Aggregation and Hyperlocal Connect solutions are expected to see stable growth with a CAGR of 5% to 7% from year 5 to year 20. They would bring a smaller portion of value due to their limited market size and given lower market readiness.

Figure 3 Key impact statistics from the technology solutions in the mature state



Timeline from now	Year 5	Year 10	Year 15	Year 20
Number of farmers impacted, million	**32 – 39**	**51 – 62**	**68 – 83**	**75 – 91**
% of farmers nationally	*18% – 21%*	*26% – 32%*	*33% – 41%*	*35% – 43%*
Value creation captured by farmers, $ billion	12 – 14	20 – 24	30 – 37	34 – 42

Next steps to scale up the integrated ecosystem solutions

To accelerate the timeline to reach scale and maturity of solutions, investments from different players are needed.

Solution	Current stage	Support needed	Key actors
B2B Platform	Pilot	• Extend services to additional crop segments • Improve functionalities • Integrate support services across key functions • Scale up geographically	Private sector players
Mandi Automation	Pilot	• Incentivise more farmers, traders and buyers to come on board • Extend solution functionality, including logistics and warehousing, quality assessment, traceability and so on	National government
Farmer Aggregation	Pilot	• Incentivise more farmers, traders and buyers to come on board • Invest in improvement of existing solutions and development of new solutions • Improve transportation solutions for farmers	National government
Hyperlocal Connect	Nascent	• Improve solutions for buyer-supplier matching and quality assurance • Explore efficient operating models, especially in logistics • Conduct pilots	State and local government
Online Retail	Emerging	No support needed	Private sector players

- **Technology companies** and **AgriTech players** would need to cooperate closely on developing technology solutions. Big Tech companies will have to commit on building best-in-class B2B buyer supplier matching platforms based on learnings from the e-Commerce industry. In addition, they would need to help emerging AgriTech players providing solutions in quality assurance, traceability etc., with enhancing their solutions through AI, machine learning, etc.
- **Agricultural business** would need to aggressively support emerging tech platforms by transacting on them at scale.
- **Government** would also play an important role to support development of solutions. The Ministry of Agriculture would need to invest in enhancing capabilities and adoption of eNAM in consultation with NGOs, agribusinesses, and technology companies. State government could take the lead to facilitate on -ground implementation of pilots to accelerate learning and improvement.
- **Donors** would provide sustained funding for pilot and scale-up of integrated platforms in different commodities and markets.
- **Agricultural social organisations** could help implement the solution in both pilot and scale-up phases, leveraging close relationships and collaboration with farmers and FPO, to accelerate testing and deployment of projects.

As next steps, stakeholders from different domains need to develop a shared vision and commit to long-term support to transform the Farmgate-to-Fork ecosystem with technology interventions. Key actors must invest in integrating best practices and best-in-class technologies into these solutions, in

rapid piloting and scale-up of ideas, in coordination among value chain actors, and in sustained funding support to ensure long-term success.

We encourage and invite more stakeholders to join us in building impactful and viable solutions for the Farmgate-to-Fork ecosystem, and we look forward to working together to create meaningful change by harnessing the power of technology.

Annex 1: Additional Mature State Projections of Integrated Ecosystem Solutions

Key functionalities of B2B platform

We expect that at mature state, the B2B platform would offer the following functionalities:

Functional area	Mature state functionalities
Buyer-Supplier matching	• Would service a wide range of produce, including fresh produce and non-perishable produce. • Would offer exhaustive information about produce, e.g., physical and chemical characteristics, source, etc. • Would connect intermediaries and institutional buyers at the national level, to serve nation-wide demand and supply centres. • Would provide quality and delivery assurance and hold all parties accountable. • Would have feedback mechanisms to gather data on highly-rated and poorly-rated farmers/aggregators and buyers, and closely moderate platform interactions.
Quality assessment	• Would be source location-based to allow information on the quality of produce to be available at the last mile. • Would be cost-efficient to deploy. • Would be easy to deploy at scale, and have high usability, even for low-literacy users. • Information on quality metrics and pricing would be transparent, both for farmers and buyers.
Traceability	• Would make information available on origin and movement of produce through low-cost technologies. • The data made available through the solution would be interoperable, for value chain players to improve sourcing model, and for financial institutions and other players to develop financing solutions on the back of this data, etc.
Logistics and ware-housing	• Would provide logistics and warehouse services with temperature and moisture regulation mechanisms for suppliers and buyers. • Would be powered by an AI-based logistics optimization model for improved shipment coordination and cost-effective transportation. • Would be an open platform that allows warehouse owners to list their warehouses, and enables buyers and intermediaries to book storage spaces via the platform.
Financial services	• Multiple business digital payment options would be provided by the platform, including credit card, online bank transfer, UPI, digital wallets, and so on. • Diverse financing options against receivables would be available based on the needs of different value chain players, e.g., advance payments for farmers, PO financing for aggregators, etc. • Options to purchase different financial products, such as forward contracts, futures, etc., would be provided.

Key functionalities of Mandi Automation solution

At mature state, eNAM would offer the following functionalities:

Functional area	Mature state functionalities

Buyer-Supplier matching	• AI solution would automatically aggregate small volume produce sales for big traders and institutional buyers on their demand to satisfy buyers' need and improve pricing for farmers. • Would list complete produce information on platform to facilitate purchase requests from buyers, e.g. farm origin, detailed quality assessment, etc. • Would provide AI-based demand and price forecasting.
Logistic & Ware-housing	• Would provide shared load aggregation service to connect various smallholder farmers and transport their produce to APMCs, including frontend app for farmer request, backend route calculation and truck coordination system etc. • Would have logistics and storage facilities to monitor temperature and moisture.
Quality assessment	• Would offer tech solutions of quality assessment for both physical and chemical characteristics, e.g. image-based AI solution, infrared spectroscopy combined with machine vision analytics, to increase assessment speed and make assessment more objective.
Traceability	• Would have a traceability solution with origin tracing from the farm gate.
Financial service	• Would offer farmers various options for digital payments, short-term financial credit, crop insurance, payment guarantee, payment on delivery, etc.

Key functionalities of Farmer Aggregation solutions

We expect that at mature state, farmer aggregation solutions would offer the following functionalities:

Functional area	Mature state functionalities
Buyer-Supplier matching	• Would link smallholder farmers to intermediaries or institutional buyers to facilitate direct sales from smallholder farmers. • Would provide information about production and facilitate purchase requests from buyers, e.g. crop, volume, region, time for purchase, etc. • User-friendly front-end would be provided to farmers to list sales information, select aggregators by regions and prices, and book transportation vehicles for produce.
Logistic & Ware-housing	• Would provide shared load aggregation service to connect various smallholder farmers and aggregate their produce. • Would offer logistics options near the farm which provide low-temperature and moisture-regulated space.
Quality assessment	• Standardised parameters would be used for quality assessment. The solution grades produce and remunerates farmers accordingly. • Option for image-based AI solution would be provided to assess produce quality quickly based on physical characteristics.
Traceability	• A traceability solution would be offered to summarise source information of produce, including date and place of origin, farmer profiling, etc.
Financial service	• Would offer farmers fast and various payment options, including digital payment and cash payment if needed.

Key functionalities of Hyperlocal Connect solution

We expect that at mature state, hyperlocal connect solutions would offer the following functionalities:

Functional area	Mature state functionalities

Buyer-Supplier matching	• Would provide a user-friendly experience to farmers for selling and to consumers for purchasing produce, available in desktop as well as mobile versions. • Would focus on various kinds of fresh produce from local farmers on the platform. • Would provide consumers with basic information on prices, sources, and physical characteristics of products. • Would provide farmers with suggestions about the market value of the products, which would help them in product pricing.
Logistics & Ware-housing	• Would build a smart logistics network to gather produce from farmers and find the quickest and lowest-cost route to deliver products to consumers. • Would have moisture- and temperature-regulated storage space in logistics facilities to ensure products do not get spoilt before reaching consumers. • Would offer a cold and dry warehousing solution to farmers if they have need to store their produce for longer time. • Would provide quick, smooth and accurate delivery of products with low delivery fees.
Quality assessment	• Would offer farmers easy-to-use and fast tech solutions to perform quality assessment of produce. • Would conduct simple product review of physical appearance when collecting products from farmers to ensure basic product quality. • Quality assessment results would be uploaded with product information to the platform.
Traceability	• Would offer farmers incentives and technological solutions to record the source of the produce, including details like farm activities, farmer profiling, etc., especially for organic produce.
Financial service	• Would provide various forms of payments like debit card, credit card, e-wallet, cash on delivery, etc.
Other services	• Would be available in multiple local languages to facilitate usage for local farmers and consumers.

Key functionalities of Online Retail solution

We expect that at mature state, online retail solutions would offer the following functionalities:

Functional area	Mature state functionalities
Buyer-Supplier matching	• Would provide a **user-friendly experience** to consumers to purchase **produce**, available in both **desktop** and **mobile** versions. • Would cover a **wide range of products** including perishable and non-perishable items. • Would provide **key information about products** on quality, price, source and nutrition. • Would **source** produce from the supplier **efficiently**, even in a multi-vendor sourcing model, to ensure sufficient stock and good quality of produce.
Logistics & Ware-housing	• Would have **moisture- and temperature-regulated storage space** in warehouses and logistics facilities to ensure products do not get spoilt. • Would manage a **smart logistics network** to gather produce from one or multiple suppliers and to find the quickest and lowest-cost route to transport the produce. • Would provide quick, smooth and accurate delivery of products with low delivery fees. In addition, it would offer options for time slot for delivery and self-pickup.

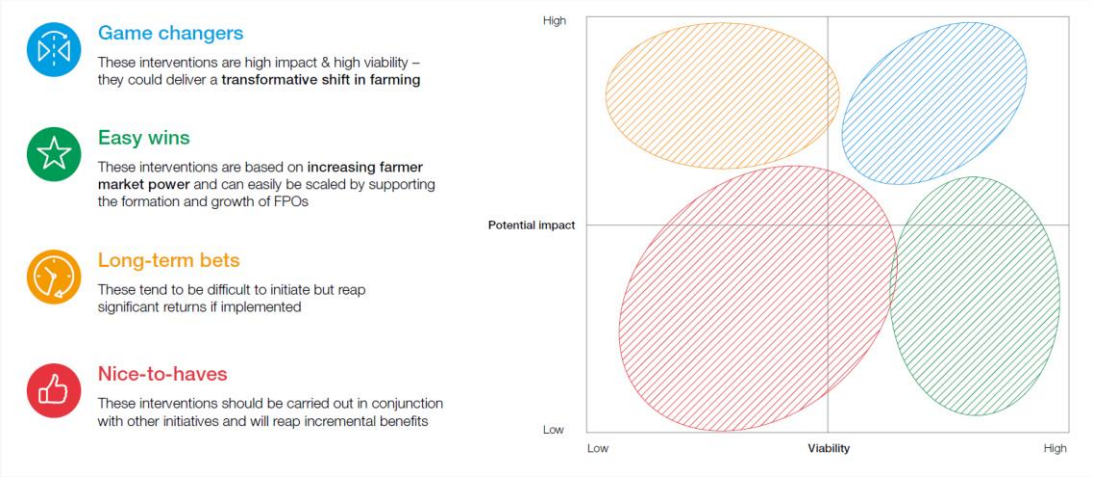
Quality assessment	• Would leverage technological solutions to perform **quality assessment** for both the **physica**l and **chemical characteristics** of the products. • Would list quality assessment results and provide product information for consumers.
Traceability	• Would use technological solutions to **trace the source of the produce from the farm-gate level**, especially for organic produce. • Would list sourcing information of all products.
Financial service	• Would provide **various forms of payments** like cash on delivery, debit card, credit card, e-wallet, etc.

Annex 2: Working Group Assessment of Existing F2F Solutions

To explore feasible and impactful technology solutions existing in the F2F space, we collected 20 examples of technology solutions that have been deployed in agricultural value chains so far and facilitated the Working Group to discuss their potential impact and viability. These examples of technology solutions in F2F were collected through rapid secondary research, and in some cases, were also provided by some participants in the Working Group. The technology solutions broadly fit into six categories: Quality Assessment, Logistics and Warehousing, Financial Services, Buyer-Supplier Matching, Traceability, and Market Risk mitigation.

Each solution was assessed for its potential in impact and techno-commercial viability. Potential impact was evaluated by the number of farmers who stand to benefit from the solution and the potential increase in farmer incomes, while viability was assessed based on scalability, financial viability, regulatory viability, and technological complexity. Based on this assessment, solutions were classified as Game changers, Easy wins, Long-term bets and Nice-to-haves.

Figure 4: Assessment matrix for impact and viability



We identified six game changing interventions. The shortlisted solutions were considered for larger scale deployment in integrated technology solutions.

Figure 5: Impact and viability analysis for emerging technological interventions[8]

Annex 3: Methodology notes

Impact of technology solutions for the Farmgate-to-Fork ecosystem

The exercise of sizing the potential impact of the five technology solutions is a directional analysis. Estimations of the technology solution impact on price, supply and farmer number in mature state depend on applicability of technology on different crops, maturity of the technology, as well as other factors such as value chain actor adoption, government regulation and efforts on behalf of the stakeholders to scale the technologies – all of which are difficult to predict accurately. Estimation was completed with available public information and industry expert inputs and assumptions were applied where proven figures were not available. Most of these technologies are still in a nascent or pilot phase, where there are very limited use cases with solid performance statistics. Therefore, assumptions were developed with closely comparable domestics and international cases as well as by Indian agriculture and technology experts with an optimistic mindset. Estimation could be potentially influenced by unpredictable future changes in macro- and micro-environment.

Key functions applied to calculate the impact of technology solution are:

Extra Value Impact at mature state = (Base Price * (1+Technology solution impact on Price[%])) * (Base Supply x (1+Technology solution impact on Supply[%])) – (Base Price * Base Supply)

Extra Value Impact in Year X = Extra Value Impact at mature state x Technology solution roll-out degree in Year X [%]

Key assumptions for the valuation include:

- Base price and base supply are the values of all crop in India in 2020, for which data from Agricultural & Processed Food Products Export Development Authority (APEDA), Area and Production Statistics from Ministry of Agriculture and Farmers Welfare (DAC), Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) was leveraged. Values were firstly calculated in different crop level and summed up to crop segment level.
- Technology solution impact on price, supply and farmer number at mature state was estimated based on available domestics and international use cases, challenges of related functional areas in value chain, and technology applicability by crop. Literature and case studies were utilised to generate the estimation, and expert opinion and closest comparable estimations were used where no literature was available. General impact from solution by crop segment, functional areas and demand centre was estimated to be 5-25%. Technology applicability was assumed to vary from 15-90% depending on degree of crop commercialisation and technology features.
- Roll-out degree of solution was assessed based on maturity of existing practices in the solution area and potential growth driven by market demand and different actors. Literature research and inputs from agriculture and technology experts were applied to deliver the estimation.

Endnotes

[1] Smallholder farmers are defined as farmers owning <2 hectares of land.

[2] Agricultural Statistics at a Glance 2019, Govt. of India, 2020; Indian Tea Association; All accessed 20 Jan 2021; TechnoServe India Analysis.

[3] Employment in agriculture (% of total employment), ILOSTAT database, International Labour Organisation; Report of the Committee on Doubling Farmers' Income, Volume II "Status of Farmers' Income: Strategies for Accelerated Growth", Ministry of Agriculture & Farmers Welfare, August 2017; All India Report on Agriculture Census 2015-16, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, 2020; All accessed on 20 Jan 2021; TechnoServe India Analysis.

[4] The results of the 2021 Economic Survey released by the government indicate the possibility of rapid recovery, and has presented that the Indian agricultural sector has shown more resilience than expected amid the adversities of COVID-19. However, it remains unclear whether agricultural sector growth will translate to improved farmer incomes. Studies released at the time of writing this report have, in fact, validated our hypothesis that farmer livelihoods have been adversely affected by supply chain and market disruptions due to COVID-19. According to the COVID-19 Livelihoods Survey, conducted by the Centre for Sustainable Employment at Azim Premji University, nearly 50% of the farmers surveyed for the study earned less than half of what they expected in 2020, and 89% of farmers reported that they were unable to sell their produce at full prices.

[5] Digital India Report, McKinsey Global Institute, 2019; Internet Trends report, Mary Meeker, 2019; National Strategy for Artificial Intelligence, NITI Aayog, June 2018; All accessed 20 Jan 2021; TechnoServe India analysis.

[6] Agri Exchange database, Agricultural & Processed Food Products Export Development Authority; Area and Production Statistics, Ministry of Agriculture and Farmers Welfare,; FAOSTAT, Food and Agriculture Organisation. All accessed 20 Jan 2021; eNAM website; "Market value of online grocery across India in 2018 and 2019 with a forecast until 2024", Statista, April 2020; "India's online grocery market may clock $3 billion sales in 2020", The Economic Times, May 2020. Accessed 5 March 2021; WEF Working Group input, TechnoServe India analysis.

[7] The volume includes volume traded within APMC and volume traded outside Mandis while recorded as APMC trading.

[8] Compendium on Emerging Technologies on Agriculture, Telangana State Agricultural University; Working Group inputs and TechnoServe India analysis. Some solutions are categorized under same number since their application of technology and impact are very similar