In collaboration with PwC India

WORLD ECONOMIC FORUM

Agritech: Shaping Agriculture in Emerging Economies, Today and Tomorrow

INSIGHT REPORT

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Images: Getty Images, Midjourney

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Foreword

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As the world grapples with the challenges of climate change, shifts in geopolitical dynamics, pressure on natural resources and rising pollution, ensuring food security for the ever-increasing global population becomes more and more important. Transforming agricultural production, using technology to enhance efficiency and promote sustainability, is an essential part of the solution to this problem.

While agritech technologies have existed for a decade, they have been seen as point solutions mainly focused on farm management rather than as a package of resources that can address critical interrelated inefficiencies in agriculture value chains from crop planning to consumption. It is imperative that agriculture is viewed from a systems perspective, as an interrelated chain of activities and actors. The use of artificial intelligence (AI), augmented reality (AR), internet of things (IoT) devices, robotics, blockchain and drones is providing tools for farmers, traders, logistics providers and food-processing plants to bring about this change in the agricultural sector and make it a more agile, better-informed and well-connected system.

However, such transformation should be made in line with principles of inclusivity, affordability, accessibility and collaboration. It is important that the smallholders and women who contribute significantly to global food production are not left behind. Excluding them would have a directly negative impact on global food production levels, especially in developing nations. It is also imperative to ensure that agritech services are affordable and easily accessible through both digital and "phygital" (combining human and digital channels) means to ensure effective outreach and adoption of tech at the last mile. Lastly, collaboration is the key to unlocking the other three principles. Given the complexities of the agriculture sector, working in isolation will not help the world community address the global challenge of food security.

In 2021, the World Economic Forum's Artificial Intelligence for Agriculture Innovation (AI4AI) initiative published a community paper documenting a range of agritech services from crop planning to harvesting, and shared a roadmap of how to work collaboratively with stakeholders in scaling these agritech services in Indian agriculture. We are pleased to present this report as a sequel to the 2021 community paper. It aims to provide a macro-level view of the integration of technologies needed to deliver systemic change in the agriculture sector and plot a way forward. We hope it will create interest among governments, the private sector – including start-ups – civil society organizations, farmers' groups and other stakeholders and help them find ways to collaborate, ensuring the greater vision of "inclusive tech for food security for all".

Executive summary

Public–private partnerships to scale Fourth Industrial Revolution technologies in agriculture can encourage farmers to invest in and adopt emerging technologies.

The agrifood sector sustains the livelihoods of more than 1.23 billion people globally.[1] The Food and Agriculture Organization of the United Nations (FAO) estimates that in order to feed the predicted 2050 global population of 9.1 billion, the sector will have to produce 70% more food than current levels – and to do so with similar resources. At the same time, the sector is grappling with the challenges of climate change, unequal distribution of food across the world's population, soil degradation and geopolitical disruptions to supply chains. Agritech services are positioned to be the catalysts of the next revolution in the agriculture sector and have the potential to help farmers produce more without requiring increased resources.

In 2021, the World Economic Forum published a community paper as part of the Artificial Intelligence for Agriculture Innovation (AI4AI) initiative that documented more than 20 agritech use cases in four categories: intelligent crop planning; smart farming; farmgate-to-fork; and data as an enabler.[2] This insight report, a sequel to the 2021 paper, takes an overview of the role of Fourth Industrial Revolution technology in shaping the agriculture ecosystem, including farming activities and supply chains in the same four categories as in the 2021 paper:

– **Intelligent crop planning:** gene editing and use of artificial intelligence (AI), soil testing-based and sowing-window advice

– **Smart farming:** AI and augmented reality (AR) for crop advice and field planning, hyperlocal weather predictions, robotics, yield prediction and distributed ledger-based index insurance

– **Farmgate-to-fork:** traceability, internet of things (IoT)-enabled warehousing, smart logistics and smart packaging

– **Data:** digital public infrastructure (DPI – platform, policy and protocols) and its implications for farmers

As advances in the agritech sector continue, adoption by smallholders and women farmers, two of the most vulnerable segments, remains a challenge. As outlined in a McKinsey Insight article,[3] globally only 39% of farmers have adopted at least one technology service. This average is weighted by a 62% adoption rate among European farmers, while in Asia adoption is only 9%. The lack of clarity on return on investment (RoI) for technology is one of the main reasons for such low adoption rates generally. Similarly, women farmers are at risk of being left out of the agritech revolution due to ingrained socioeconomic challenges such as limited land-holding rights, even though women make up 43% of the global agricultural workforce. As agritech scales, it is imperative that smallholders and women farmers are included, or the implications for food security and the livelihoods of millions of people in emerging economies will be affected.

Governments and the private sector should explore the kinds of public–private collaborations that have proved to be effective in creating sustainable public infrastructure and services. Agritech services have realized only a small part of the large, untapped opportunity to transform the agriculture sector in emerging economies. Governments will need to take on the role of enablers and offer incentives, both financial and non-financial, such as access to quality data through DPI or to on-the-ground channels in order to encourage the private sector to invest in scaling the adoption of agritech in the value chain.

It is important to appreciate that digital channels alone will not drive the adoption of agritech services. There is a need for shared resources – for instance, rural entrepreneurs, a network of mobile money operators or e-governance services – all of which could be vital to drive adoption locally. Since such services would be based in a given community, they would enjoy farmers' trust, and this in turn would help farmers to understand and appreciate the advantages of agritech and support them in their agritech-adoption journey. A local physical presence would also be important for the validation of agritech use, confirming the accuracy of satellite data on crops sown in a field, for example.

A collaborative effort by governments, the private sector – including start-ups and investors – academia and civil society is the need of the hour. Considering the complexity and interrelatedness of activities in the agriculture sector, scaling inclusive agritech can best be achieved by taking a multistakeholder approach.

Introduction

Digital technologies are steadily changing the global agriculture sector, and their role today is more crucial than ever.

The context

Farming is one of the most ancient of human activities, one that has weathered the changes throughout history but continues to face new challenges. Every past generation must have felt that the challenges of its era were unprecedented, and the same is true today. Climate change, global geopolitical problems and depletion of natural resources – especially soil quality – are the issues for the global agriculture sector now, raising questions about the collective ability to ensure food security and access to nutritious food for a global population predicted to reach 9.1 billion by 2050.

The following facts highlight the gravity of the situation:

– The Food and Agriculture Organization of the United Nations (FAO) estimates that, by 2030, 670 million people – or 8% of the world's population – will still be undernourished, which means there is no change from 2015 levels, when the UN's Sustainable Development Goals agenda was launched.[4]

– The Intergovernmental Panel on Climate Change's estimates, using a range of models, have concluded that climate change will negatively affect per capita calorie availability and nutrition to a substantial extent. It will also have an effect on child undernourishment and mortality through poor nutrition.[5]

– The availability of agricultural land is not a major challenge in itself; however, issues such as lack of infrastructure and physical inaccessibility to markets can make it difficult to access the land that is available. Furthermore, productive land is not equally distributed across all countries, making it more problematic for some to produce food locally to feed their own populations.[6]

– The economic impacts of natural disasters jumped almost eightfold from the 1970s to the 2010s, from $49 million to $383 million per day, and human activities have increased the probability of more frequent heatwaves.[7]

– The FAO has reported that 33% of the Earth's soil is already degraded and will continue to degrade, and soil erosion might result in a crop-yield loss of 50%. Human activity such as intensive agriculture, deforestation and overgrazing has increased soil erosion by a factor of 1,000.[8]

> “ Climate change, global geopolitical problems and depletion of natural resources – especially soil quality – are the issues for the global agriculture sector now.

Such a dynamic situation requires more informed decision-making at every level in the agriculture sector, from policy-makers and private-sector companies to farmers, especially those smallholder and women farmers who are typically more vulnerable. Digital technologies present a scalable and sustainable solution to these challenges. Traditionally, the agriculture sector – primarily in emerging economies in Asia, Africa and Latin America – has been slow to adopt digital technologies. The use of quantum computing, chips and other digital-technology solutions are restricted to the machines that farmers use. However, there have been some farmer-facing applications introduced – the adoption in many countries of smartphones to create an access channel to deliver efficient agriculture services being one example.

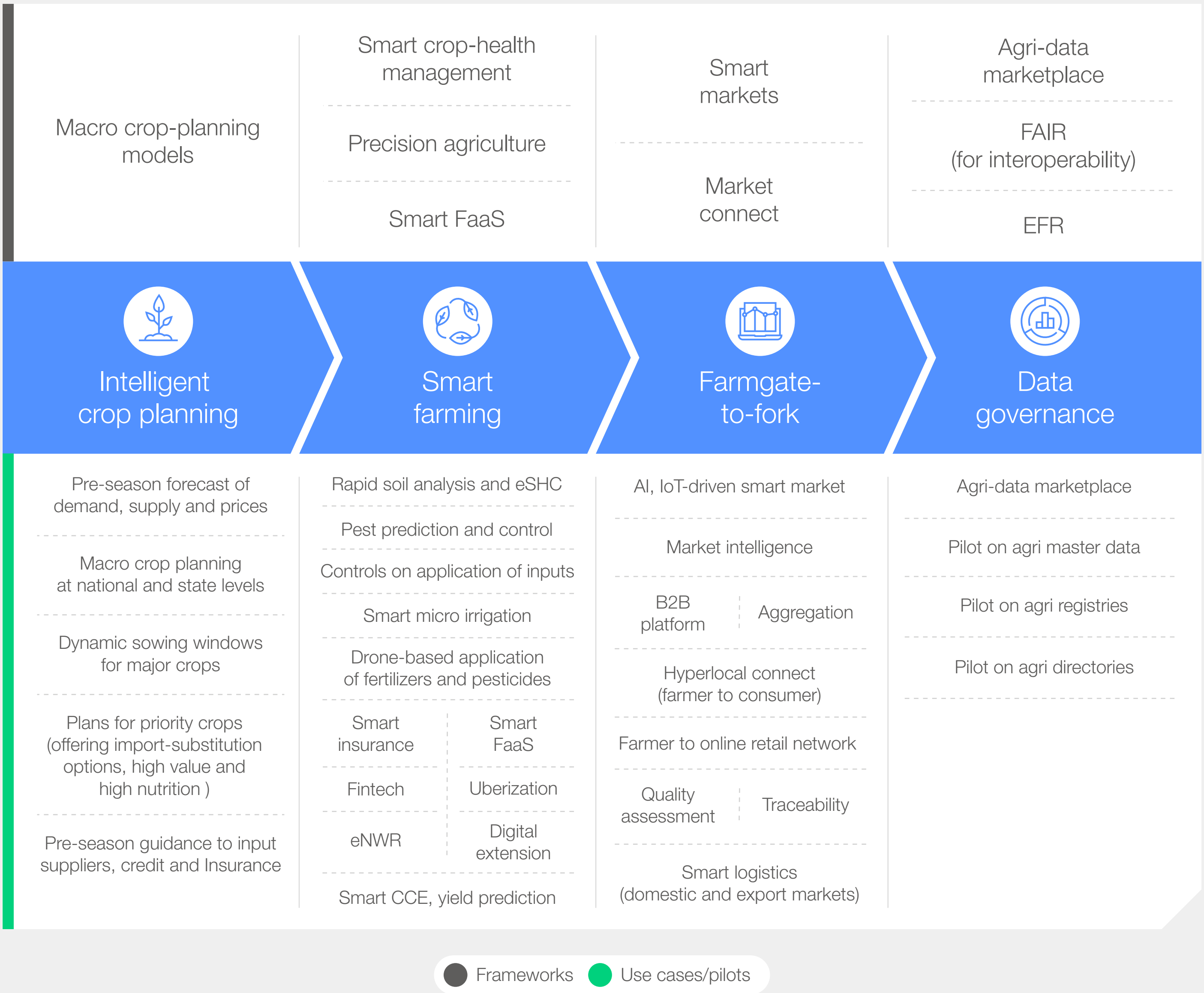
However, despite this past trend, the advent of AI and its employment in precision agriculture and the post-harvest supply chain has started to shake up the sector for the better. Coupling AI-based use cases with smartphone-based information delivery channels is a positive combination that can help farmers gain access to information and resources to tackle the challenges facing them. In this way, AI and phones are democratizing the use of technology, especially for the most vulnerable.

The approach

A number of agritech solutions have been available for almost a decade now, and have gone through a cycle of research, development, adoption and scale-up. However, to date these agritech services are yet to achieve scale when compared to the market potential that emerging economies offer. In this context, the World Economic Forum's Artificial Intelligence for Agriculture Innovation (AI4AI) initiative aims to scale such agritech services through public–private partnerships.

The Forum's 2021 community paper, published as part of its AI4AI initiative, documented more than 20 agritech use cases and technologies and presented a roadmap for these to be scaled in India in four broad categories: intelligent crop planning; smart farming; farmgate-to-fork; and data as an enabler.[9] Such categorizations help track the impacts of different technologies on the sector and, at a micro level, on farming at a specific location and/or on an individual farmer.

FIGURE 1 | **Unlocking value through frameworks and use cases**



Notes: FaaS = farming as a service; FAIR = Fast Agriculture Interoperability Resources; EFR = electronic farm record; eSHC = Electronic Soil Health Card; CCE = crop-cutting experiments; eNWR = Electronic Negotiable Warehouse Receipts.

Source: World Economic Forum

> The objective here is to provide an overview of promising technology in the agriculture ecosystem, the best ways forward and a call to action.

This insight report follows on from the earlier community paper and uses the same four-category framework, but it offers a broader global and agriculture-industry analysis compared with the farm-focused view of the community paper. To avoid repetition, the technologies that were included in detail in the 2021 paper have been excluded from this report.

The objective here is to provide an overview (and not an exhaustive list) of promising technology in the agriculture ecosystem, the best ways forward and a call to action to ensure that technology transformation is inclusive. Agritech innovations are highlighted on the basis of the impact they could have on managing risks from factors including climate change, soil degradation, post-harvest losses and demand-price volatility.

The report also aims to encourage policy-makers, multilateral organizations, civil society and the private sector – including start-ups and investors – by providing an overview of the role of agritech currently and where it might go in the coming years. It is expected that such information will help them strategize better and contribute to facilitating the ways in which agritech services can revolutionize the agriculture sector.

A team from the Centre for the Fourth Industrial Revolution India, the World Economic Forum and PwC India carried out consultations with 11 organizations and a desk review to map the game-changing technologies and services that are emerging and that could have long-term impacts on the agriculture sector and its ecosystem. The consultations provided insights on different agritech companies' strategic views of the sector and how they are responding to the needs of the market segment.

As mentioned above, the four categories of technology from the 2021 report have been used again here to ensure continuity of the analytical process. Taking a further step, however, these technologies are now also mapped to their possible impacts in driving financial inclusion, enhancing sustainability in farm activities and increasing efficiency in the post-harvest value chain (see Table 1).

TABLE 1 **Impact areas and mapping of use cases**

Impact areas	Definition	Use cases
Inclusivity	Increasing farmers' access to finance (credit, insurance and social security) to enhance resilience – especially women farmers and smallholders	– Distributed ledger-based index insurance
Sustainability	Increasing sustainability in agricultural production through optimal use of resources and developing resilience to climate change and other risks; focusing on advice (weather, sowing window, pest infestation, etc.), efficient use of inputs (fertilizers, water, etc.) and use of robotics	– Gene editing of seeds using predictive AI tools – AI-based soil testing – AI tools to predict optimum sowing period – AR in crop planning – AI and AR for crop management, crop advice, pest, plant diseases and nutrients – AI for weather prediction – Robotics
Efficiency	Improving post-harvest supply chains; focusing on reducing crop loss, demand-supply asymmetry and enhanced access to markets	– Yield prediction – Traceability using blockchain – IoT-enabled warehouses – Smart logistic solutions – Smart packaging

Source: World Economic Forum

It is important to highlight that this report is an attempt to map the technologies and not to endorse or promote one technology over another. The objective is to provide an overview and allow the reader to decide whether to follow up on any particular area of interest in greater detail.

1 Feeding the future: The role of agritech

Agritech services will improve sustainability and efficiency in the agriculture sector, which will ensure enhanced production from existing resources.

Food security in the face of climate change and other challenges requires new ways of thinking about agriculture and how it works. Information asymmetry and lack of access to agricultural inputs (such as fertilizers), finance and markets have been challenges for decades.

While there has been a strong focus on increasing production and productivity, the important element of reducing cultivation costs by optimizing resources has not received due attention.

However, adopting a new approach requires that agriculture be seen and further developed as an agile, informed and dynamic sector that, like any other business, concentrates on optimizing resources, reducing costs, focusing on long-term sustainability and responding to market needs.

The agritech sector is in the process of attempting to create this vision and offer services that respond to the needs of the hour and guarantee future food security.

1.1 Agritech: The situation today

Intelligent crop planning

Intelligent crop planning involves the use of AI-based models and other emerging technologies to create a detailed, market-oriented and sustainable macro- and micro-level crop plan that also responds to climate-change challenges and the nutritional needs of consumers. Taking into account advances in the sector, this focuses on:

- Identifying crops that can withstand the challenges of climate change-induced disasters or weather-pattern changes while maximizing production and yield and managing risks
- Using AI to predict gene-edited seed performance depending on different factors
- Using data to develop models that can predict cropping patterns, harvest periods and production to gauge demand and price fluctuations more accurately
- Targeting efficient nutrient management through soil testing
- Accessing digital financial services, including credit, savings and insurance, to procure quality inputs, deliver agritech services and manage the risks in terms of climate change-induced disasters

Use cases for intelligent crop planning are:

- **The gene editing of seeds using predictive AI tools:** Gene editing is where adjustments in existing genes in plants are made; it is different from gene modification, in which external genes are inserted into an existing genome. The objective of gene editing is to drive higher yields with fewer or similar levels of existing resources. These changes are not made by altering just one or two genes but are the result of multiple complex gene edits. AI plays an important role in this process. Agritech innovators are using AI and predictive analysis to analyse plant genes and help create a plan for multiple gene edits. The use of AI allows scientists to work on this complex process more efficiently and with higher success rates.
- **AI-based soil-testing solutions:** Soil testing at the early stages of crop planning is imperative to ensure better yields. Traditional soil-testing methods may take a few days or a few weeks, while a sensor and spectroscopy-based soil-testing kit might provide a report in near real time. However, the soil report itself is not the only outcome. Technology providers are also adding remedial actions based on the soil-test report in their modelling, allowing the farmer to take action based on the results.
- **AI tools to predict an optimal sowing period:** Changes in weather patterns occur naturally; however, current weather patterns are attributed to climate change driven by human activity.[10] Farmers have been adapting to these changes in their own environments – this is especially true for smallholders, given how many of them undertake subsistence agriculture. However, there is a need to provide farmers with standardized advice and information on ideal sowing windows that is based on predictions of weather patterns as well as the microclimatic conditions at a specific farm or cluster of farms. Solution providers may use a range of datasets, including previous weather data (temperature, precipitation), geospatial and hyperspectral datasets and microclimatic data through internet of things (IoT) sensors and microweather stations to generate advice for farmers. Studies have shown the benefits of choosing the right sowing window each season in order to maximize yield and minimize climate-related risks.
- **Augmented reality in crop planning:** Augmented reality (AR) allows farmers to get a visual feel for the crop plan and layouts of their fields by overlaying digital information onto the physical environment in which they operate.[11] AR-based crop modelling, although in an early phase of development and adoption, has the potential to scale if it can be developed as a service that can be used in an equitable way.

Smart farming

Smart farming – which can also be referred to as precision farming – is the use of AI and other technologies to improve efficiency in farm operations. The level of efficiency can be measured based on the optimal use of resources while reducing soil stress, the timely application of inputs and early risk detection and mitigation.

Use cases of agritech for smart farming are:

– **AI and AR for crop management, advice on crops, pests, plant diseases and nutrients:** As with crop planning, AI and AR can provide advice to farmers based on images and videos captured on the ground. Most smartphones today are designed with built-in light detection and ranging (LIDAR) sensors that use lasers to build AR and projected reality AR. Farmers can therefore capture images and share them through start-up machine learning (ML) apps to be further analysed and provide agronomic advice. The ML app can use the images to diagnose plant health, pest infestations and yield predictions based on such elements as fruit size.

– **AI for weather prediction:** Traditional weather predictions are based on satellite imagery, weather stations and buoys out at sea that collect data alongside a battery of supercomputers carrying out complex calculations to predict the weather. It is a costly and lengthy process, and generally weather agencies release data at six-hour intervals. Predictive and AI model-based advice services do not challenge the traditional model, but by using historical data independently or by using a mix of historical data coupled with data sourced from hyperspectral imaging,[12] they enable local weather stations, in the space of as little as one minute, to predict weather up to 10 days in advance.[13]

– **Robotics:** The use of robotics in agriculture is advancing and becoming increasingly precise. Robotics largely focuses on weeding and the application of inputs (for instance, spraying of fertilizers and pesticides) as well as the harvesting of ripe fruits in orchards and plantations. The technology includes: a) machine-vision technology to locate, identify and assess a crop's readiness for harvest; b) mechanical tools used to apply inputs or to harvest produce; and c) in some advanced robotics, use of the Global Positioning System (GPS) to achieve the precise position of the robot on a large farm to plan the robot's movements and avoid collisions.[14,15]

– **Yield prediction:** Most of the yield-prediction models are generated by a neural-network-based algorithm that is inspired by the functioning of the human brain or by linear-regression models. The datasets used in yield prediction include soil data, temperature, humidity, nutrients, field management and crop information, among others.[16]

– **Distributed ledger-based index insurance:** When it comes to insurance, crop-loss estimation is a costly exercise in which crop loss is estimated through physical surveys and includes factors relating to farm practices. In contrast, index insurance is a simpler system in which a pay-out is triggered according to measurements of a metric or index such as rainfall or crop yield. With such a contract, the data source of a given index is linked to a smart contact on a blockchain platform.[17] In the case of an accident or natural disaster, or deviation from the index beyond or below agreed parameters, a pay-out is triggered without any human intervention and transferred to the beneficiary through a digital channel.

KSA faces arid conditions and water scarcity, challenging traditional farming. Therefore, there is a strong need to embrace emerging technologies like vertical farming, controlled environment agriculture (CEA) and precision agriculture with IoT, and use biotechnology for resilient crops. C4IR KSA is collaborating with C4IR India through AI4AI for agricultural innovation programmes to bolster food security and enhance sustainability. We look forward to contributing towards collaborating with global agritech entities to foster knowledge exchange and implement advanced solutions to enable a more prosperous and sustainable future.

Basma AlBuhairan, Managing Director, Centre for the Fourth Industrial Revolution, The Kingdom of Saudi Arabia (KSA)

CASE STUDY 1

Agerpoint

Since its inception, Agerpoint has made use of very expensive LIDAR sensors, employing thousands of laser beams to create a 3D representation and a digital twin of the plant, environment or object of focus. The firm then uses data engineering and models to extract information from the sensors. However, recent technology developments allow sensor stacks in Android and Apple products to operate on a par with earlier-generation LIDAR sensors costing $100,000, with the LIDAR sensors in today's smartphones able to be used to build AR and projected reality AR. Banking on this technology breakthrough, Agerpoint launched a mobile app named Capture, which farmers can use to capture field data as an image. The app then runs ML algorithms on the images, offering farmers readily accessible and accurate agronomic insights and information they would not have had even two years ago. These images are also analysed to detect the presence of disease, identify species and provide morphological indicators that diagnose the health of crops and pinpoint fruit types to predict yield. The app algorithms count the fruit clusters and model how much volume each cluster will give.

The key steps in the analysis of this cloud ecosystem are:

1. Create a digital twin of a plant in 3D
2. Extract accurate physical and spectral plant measurements
3. Collate data from multiple sources, such as drones, field observations, etc.
4. Create and deploy automated scalable models with end-to-end ML platforms
5. Organize, manage and share insights and visualizations for sectors such as supply-chain management, research-and-development regulators, sustainability/net zero organizations, marketers and farm growers

Data analytics, 2D/3D modelling and ML primarily use the following metrics:

Plant height	Plant health
Canopy diameter	Disease presence
Canopy density	Fruit count
Canopy volume	Fruit size/volume
Canopy outline	Yield estimate
Trunk diameter	Carbon score
Biomass	Geolocation

Source: Stakeholder interaction: https://www.agerpoint.com/

Farmgate-to-fork

The period following a harvest is a stressful one for farmers in emerging economies. The need for quick returns and the risks of crop loss lead many farmers to sell their produce at suboptimal prices. This is a systemic issue, and simply taking action to connect farmers to markets does not address it completely. The technologies now emerging are intended to address underlying issues such as a lack of quality standards, crop loss between farm and market, access to storage facilities and financing the use of such facilities.

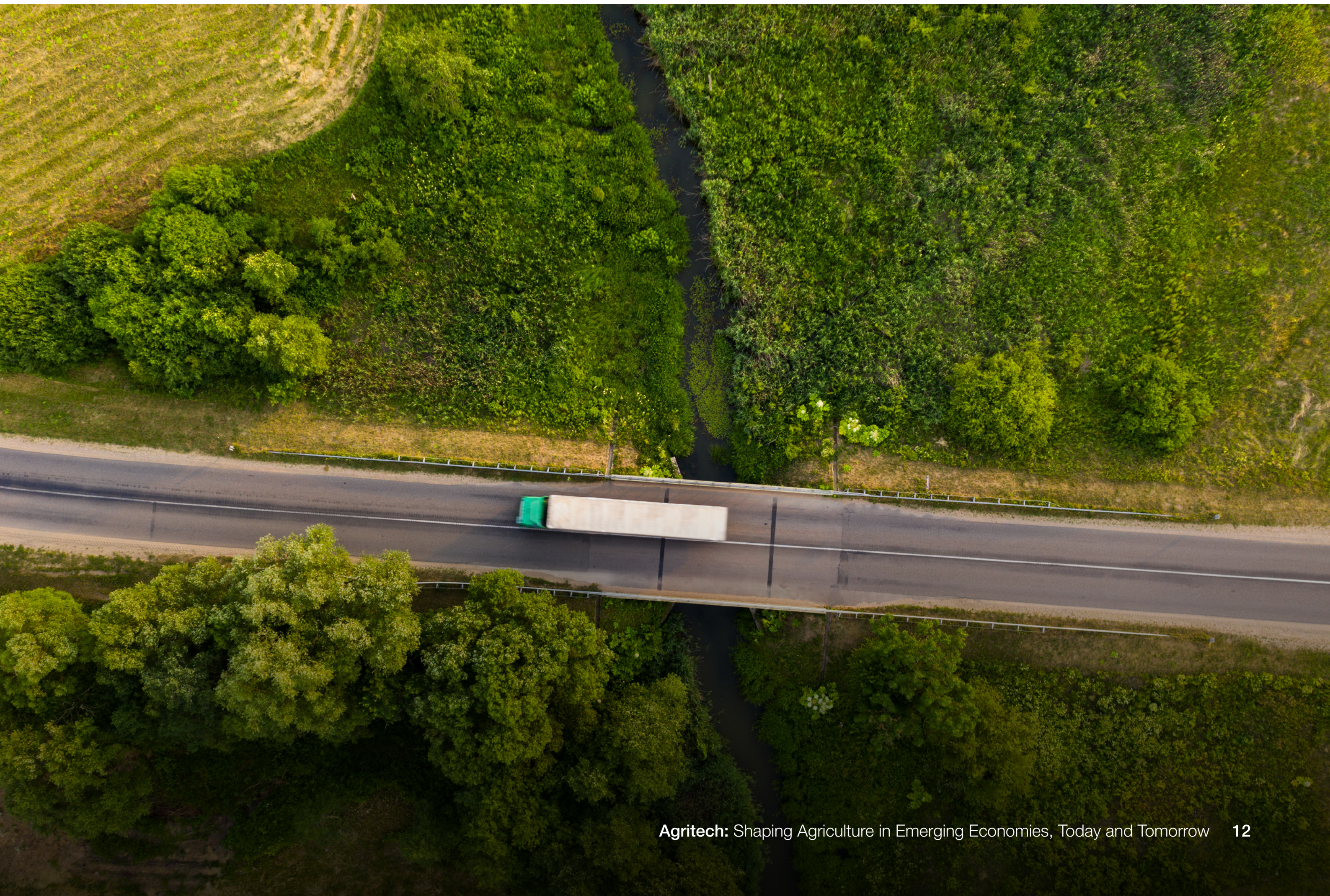
Use cases in the post-harvest supply chain are:

– **Traceability using blockchain:** Traceability is gaining traction as a critical tool in ensuring that customers can follow the progress of their food from the farm to their plates. It is also proving useful for farmers by allowing them to gain a premium on their products based on cropping practices and product quality. Traceability platforms use blockchain-based shared ledgers to record a product's journey at every step and provide three types of information: the state of a product/service; the transfer of ownership; and the transfer of funds.[18]

– **IoT-enabled warehouses:** Such warehouses have an edge over the traditional variety, as they provide real-time information on inventory and its location and condition, through sensors, radio-frequency identification (RFID) tags and GPS-enabled location tracking. IoT also allows efficient inventory management and analysis of a machine's performance and its condition, which offers the opportunity for maintenance to be undertaken before any error occurs.[19, 20]

– **Smart logistics solutions:** Crop loss due to poor handling and storage, lag times in transport and waiting time at the market is common in the agriculture sector in emerging economies. AI-based tools can help the post-harvest supply chain become more efficient by using data collected at different ends of the chain and analysing it to offer information on route optimization, commodity information and reduction of market waiting times.[21] Smart logistics can also include IoT-enabled cold-chain vehicles for transporting perishables.

– **Smart packaging:** Food loss or reduced food quality while in transit from the farmer to the processor to the end customer is an area of concern. At a micro or household level it could lead to food-borne diseases, while at a macro level it leads to economic loss. Smart-packaging solutions track food's quality and its environment through chemical or bio sensors, which monitor such parameters as temperature, pathogens, freshness and leaks.[22] In tandem with this, RFID is also used to monitor package movement.



Data – the driving factor

Digital public infrastructure (DPI) in agriculture is poised to become the critical enabler of agritech services in emerging economies. From an agritech provider's perspective, developing innovative and customized services requires a range of current and historical datasets, including those for soil quality and temperature. Ease of access to high-quality, usable data can generate social-economic value for both farmers and industry alike.

DPI for agriculture can include three components:[23]

- **Platform:** A technology platform allows the exchange of data with the consent of the owner of that data. In many cases the data owner and the data provider can be different entities. One example would be if an individual farmer's data held by a government body is shared with the private sector once the farmer has given consent. The platform may include components such as identity and access management, a data explorer, application programming interface (API) gateways, consent management and a transaction engine. Data exchange platforms (DXP) open the door to the transformation of agricultural services through real-time access to multiple datasets.
- **Policy:** There are three critical prerequisites for data sharing: to protect the individual; to prevent harm; and to promote innovation.[24] These three requirements can form the basis of a data-management policy that can be introduced alongside data-management platforms. Such a policy should focus on creating value for all stakeholders with the aim of accelerating innovation in the agricultural sector while safeguarding data, both personal and otherwise. Any policy should ideally be designed under the data protection legislation of a given country – India's Digital Personal Data Protection Act 2023 being one example.
- **Protocols and standards:** As a traditional sector that has been around for millennia, agriculture is rooted in the cultural and socioeconomic circumstances of a given locale, as well as its climate, and this has led to varied local names for crops and crop diseases. As DPIs are scaled, there is a need to focus also on the interoperability of platforms and to standardize terminology and schemas. A well-known example of such standardization is the standard botanical Latin names of plant species, while the FAO has come up with a multilingual vocabulary named AGROVOC. More work is needed in the area of developing data standards, however, and the AgriJSON initiative being pursued by the Indian Institute of Science in association with the World Economic Forum is an example of efforts being made to do just that.[25]

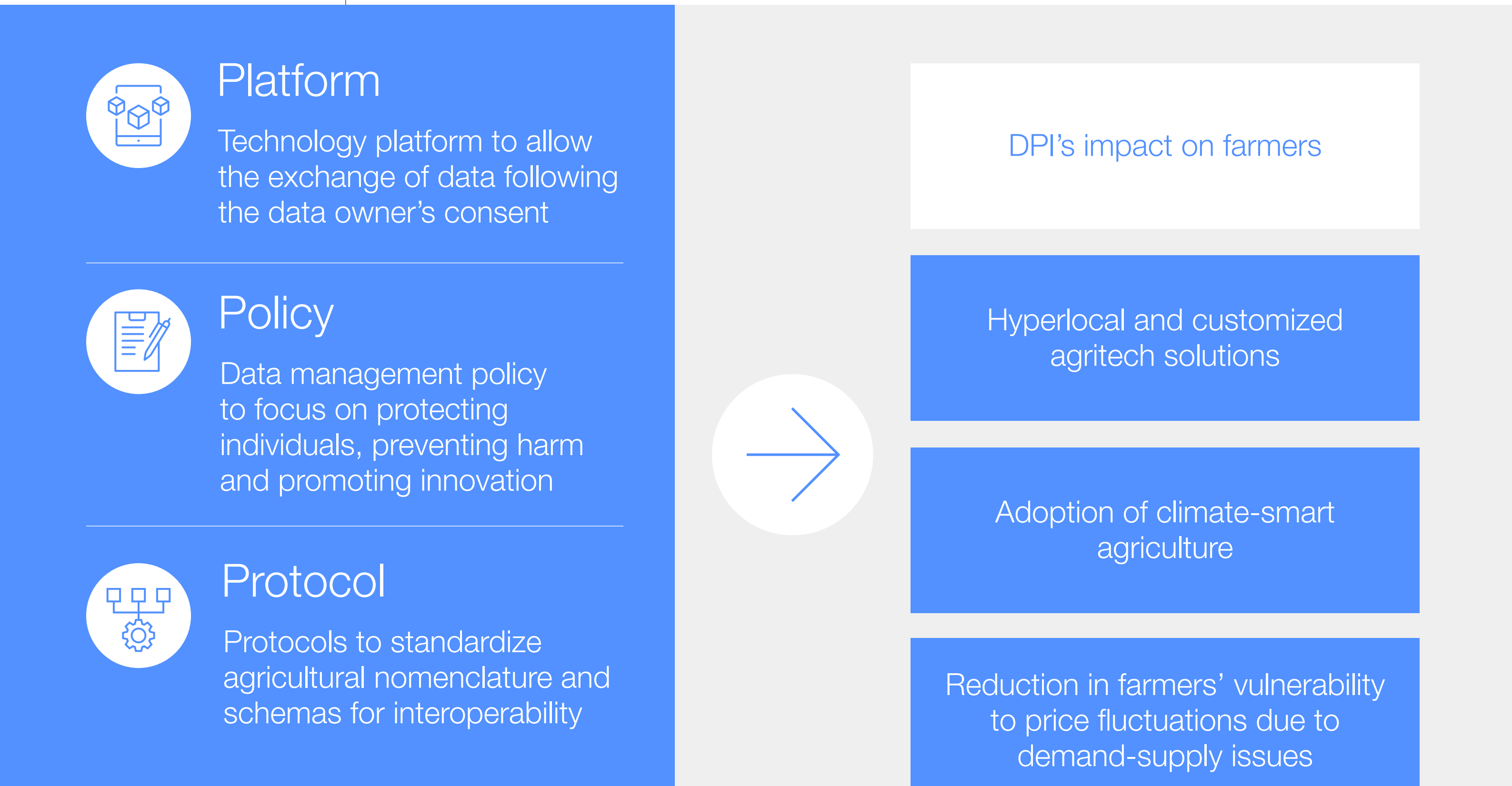
> **Rwanda faces agricultural challenges, including limited arable land, water scarcity, a predominant smallholder farming system and susceptibility to climate change. The integration of emerging technologies like precision farming, drones, IoT and blockchain in food-supply systems has transformative potential, enhancing efficiency and transparency. Keen to collaborate with the C4IR Network, we look forward to adopting digital agriculture best practices, learning from impactful smallholder farmer case studies and fostering public-private partnerships for sustainable agricultural development.**
>
> Joris Cyizere, Strategy Lead, Centre for the Fourth Industrial Revolution, Rwanda

As DPIs continue to become more sophisticated, questions should be asked about what they might mean for individual farmers and how they might help farmers adapt to or mitigate risks such as those arising from climate change. The propositions for farmers, as well as the wider sector, with respect to emerging challenges, are as follows:

- **Hyperlocal customized solutions at farm level:** DPIs could potentially offer farmers the ability to create a unique identity, providing an understanding of "who I am" (identity), "where I am" (georeferenced farm location) and "what I am growing" (crops sown and the area under cultivation). These three datasets help to establish an individual farmer as a distinct enterprise who can be offered a range of customized solutions at farm level, leading to efficient farm operations and enhanced revenues.
- **Adaptation of climate-smart agriculture:** Climate change is negatively affecting yield, production and the quality of food and causing post-harvest crop losses. Climate-smart agriculture (CSA) can help farmers adapt to changes for the long term while preserving or improving yield and quality. For CSA to scale, it is important that service providers and farmers have access to historical as well as current data in order to generate information on weather patterns and their effects on production in a particular location, to identify vulnerabilities and define adaptation measures.

– **Reduce vulnerability due to price-demand fluctuations:** Farmers and consumers alike are vulnerable to fluctuations in demand and price based on the flow of produce in a particular market or geography. Information asymmetry on three key datasets – the area under cultivation; sowing time and possible harvest time; and quantity of produce harvested – causes an imbalance in price-demand equilibrium and leads either to very high prices or a slump in the price of a particular product. Timely and accurate information and predictions to farmers, policy-makers, processors and consumers on these three parameters can reduce vulnerability for all stakeholders.

FIGURE 2 **Data – the driving factor**



Source: World Economic Forum

CASE STUDY 2

Agriculture DPIs in India

India has 15 agro-climatic zones, which makes it a very diverse agriculture ecosystem.[26] The country's federal government and several state governments are developing agriculture data stacks with the goal of transforming public services and providing a range of datasets to the private sector to foster digital tech in the country. Two case studies are Agri Stack, developed by the Indian Ministry of Agriculture and Farmer Welfare, and ADeX, developed by the state government of Telangana in collaboration with the World Economic Forum and the Indian Institute of Science.

Agri Stack: Designed to facilitate the delivery of agritech and other digital services to farmers by the government, agritech start-ups, the private sector or other institutions, Agri Stack holds three primary datasets: farmer identity; geotagged farm location; and crops-sown data. Agri Stack provides a database and registries, data standards, policies for data sharing and APIs. Data will be shared through a service layer/API, the Unified Farmer Service Interface (UFSI).

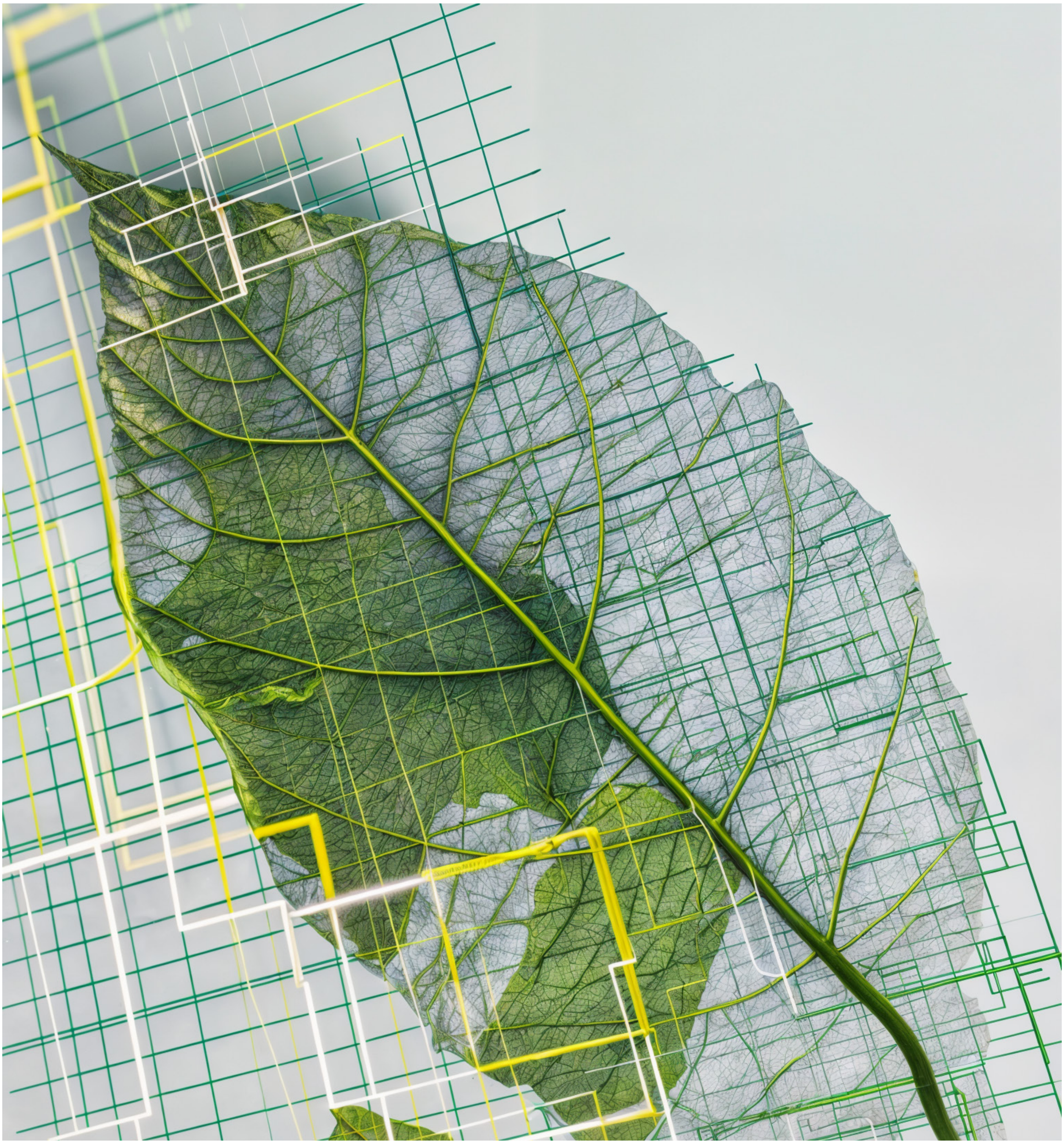
Agricultural Data Exchange (ADeX): ADeX is an open-source and open-standard public good that allows data sharing between data providers and data consumers, mainly the private sector, including start-ups, to build customized services for farmers. The ADeX platform is coupled with the Agriculture Data Management Framework, which lays out policy to enable the government to share data with the private sector once the farmer has given consent for it to do so.

In both Agri Stack and ADeX, providing access to finance, advice and markets are three important elements. In terms of interoperability, it is envisioned that a start-up or innovator might obtain a farmer's personal datasets from Agri Stack and also access ADeX for other datasets, such as weather, soil and pest-infestation data.

Source: https://agristack.gov.in/#/; https://dataexplorer.adex.org.in/

2 Inclusive digital agriculture: The need of the hour

Inclusivity will be key to any future scaling of agritech – the economics of adoption, gender parity and public–private collaboration will all help to drive this.



2.1 Solving the unit economics of tech adoption for smallholders

30%

of farmers cited unclear return on investment (RoI) as one of the top three reasons for not adopting agritech.

Trends such as consumers' preferences for healthier diets, increased smartphone ownership and high-speed and cheaper internet penetration, advances in AI capabilities, developments in genetic science and water- and soil-management technologies will all positively affect the scale-up of agritech services to between $46,000 and $60,000 million by 2030.[27,28,29,30] While adoption may continue to grow in larger farms, its adoption by smallholders in emerging economies may remain challenging.

Currently, only a quarter of US farmers use an internet-connected device to access data relating to farming, but the numbers are even lower in emerging economies.[31] As reported by McKinsey and Company, 39% of farmers globally are currently using or planning to use at least one technology in the next two years.[32] While 62% of European farmers have adopted technology, however, the figure for farmers in Asia is only 9%. One key reason for such low adoption is the high cost of technology, as cited by 47% of McKinsey's respondents.

A critical insight is farmers' perception of the value of agritech services. In the same McKinsey article, 30% of farmers cited unclear return on investment (RoI) as one of the top three reasons for not adopting agritech. They also shared that their minimum expected RoI is 3:1. Farmers were not able to attribute any change in yield or quality to agritech alone as production is also affected by external factors such as weather.

The key to scaling agritech will be to work out the unit economics for deploying and adopting agritech services for farmers and showcase empirical evidence about RoI at farm level.

2.2 Gender-inclusive digital agriculture: Acknowledging the critical role of women farmers

80%
of the food in developing countries is produced by women, mainly in predominantly agrarian or emerging economies.

The FAO reports that women form 43% of the agriculture workforce globally, while another estimate by the UN highlights the fact that women produce approximately 80% of the food in developing countries, mainly in predominantly agrarian or emerging economies transitioning to the industrial or service sectors.[33] However, women farmers' influence in the agriculture sector is minimal because of gender discrimination and because decision-making largely rests with male members of households. The low proportion of landholding among women is one critical reason behind women farmers' limited role in decision-making processes.

Limited access to smartphones for women in these circumstances is another critical challenge. Many agritech services – advisories, for example – are delivered through smartphones, and without them women are not able to access or implement advice effectively. Their lack of phone-operating skills when conducting more complex tasks such as making or receiving online payments or downloading or registering for apps is another big hurdle.

As the use of agritech expands, women farmers must not be left behind in the sector's transformation journey. Digital inclusion will remain difficult until gender roles are redefined in agriculture and women's rights of access to information and decision-making are mainstreamed.

However, as multiple stakeholders engage with the transition – which is likely to be a long-term intervention – in the shorter term, agritech can focus on driving this change through partnerships with women's collectives, such as women's cooperatives or self-help groups that are working on capacity-building for women farmers. Such organizations have been operating for decades, challenging discriminatory social norms, building women's capacity to become successful entrepreneurs and demonstrating the power of community-based organizations in driving change.

Agritech can build in women farmers' inclusion in digital agriculture in four ways:

- Enhancing access – identifying digital and physical or human channels to increase access to digital technologies and agritech
- Co-creating digital solutions specifically for women farmers, forging collaborations with the private sector, innovators, agricultural universities and women farmers' organizations
- Supporting agritech adoption through capacity-building and post-sales services via on-the-ground agents
- Identifying and highlighting risks and harms, and building capacity to mitigate these in the early stages of the adoption journey; issues such as data privacy must be included in capacity-building as well as product design

FIGURE 3 **Gender-inclusive digital architecture**

Source: World Economic Forum

The private sector is recognizing that, as in rural markets, women will play a major role in driving global economies, and that acknowledging this trend in its early stages will give women the edge by creating path-breaking innovations. The same goes for women's role in the agriculture sector: empowering women farmers and creating gender-focused digital solutions are the way forward.

2.3 Harnessing the power of public–private collaboration

Policy support and the facilitation of business by governments coupled with private-sector innovation and investment create long-lasting, self-sustaining ecosystems.

Collaboration between public and private organizations has been an effective tool in driving the scaling of infrastructure and services, affecting populations by initiating projects such as the building of roads and ports or development of financial systems. Policy support and the facilitation of business by governments coupled with private-sector innovation and investment create long-lasting, self-sustaining ecosystems.

There is a strong case for fostering public–private collaboration (PPC) to scale agritech. Although agritech services have been growing swiftly, scale-up is still limited in emerging economies, and smallholders are affected the most by sector challenges. Ecosystem impediments, such as the lack of availability of high-quality and usable data, lack of technical understanding or knowledge of agriculture in start-ups, the high cost of educating and onboarding individual farmers – especially smallholders – and the fact that agritech is usually delivered as a point solution rather than as a holistic package focused on the entire value chain have all slowed agritech's growth, hampering it from reaching its full potential.

In PPCs, governments can play a critical enabling role without acting as the procurer. Procuring agritech services and then delivering them to farmers alone will not help build a sustainable agritech market. The need here is for government incentives – financial and non-financial – that will encourage the private sector to invest in scaling agritech in value chains or geographical regions. Such incentives might include: improving the availability of data through a data exchange; initiating an agritech sandbox (held in agriculture universities) to co-create, test and validate agritech solutions; and the availability of on-the-ground channels, such as self-help groups, cooperatives, government agri extension workers and/or banking agents to onboard farmers. Each government can identify the incentives based on the agritech ecosystem within its individual jurisdiction.

2.4 Linking digital and physical channels

Leveraging physical channels – by, for instance, supporting rural entrepreneurs or using an existing channel of farmer collectives, cooperatives or organized channels, such as mobile money agents or e-governance agents – will be crucial in driving the adoption and active use of agritech services. This can be termed "phygital" – integrating physical channels to deliver tech solutions to last-mile customers.

The importance of this is down to the following factors:

- Digital capacity, trust and perceived RoI all play critical roles in the adoption and active use of agritech services in emerging economies. While the lack of any physical presence or interaction leads to lower trust in a new service by farmers, the presence of entrepreneurs/agents from the farmers' own communities helps to build farmers' capacity to appreciate the advantages of agritech services, supporting them on their journey from adoption to active use and, most importantly, continuing to do so once they are onboard. A good example is the Saagu Baagu project,[34] implemented by the government of Telangana, whose partner, Digital Green, appointed a cadre of local entrepreneurs who reach out to farmers about the project and bring them onboard.
- An on-the-ground presence is also required to validate digital data in order to bolster AI/ML models. For example, while government agencies and start-ups can provide geospatial data on crops sown in each farm, their accuracy can be measured only through validation that further strengthens the AI/ML models which analyse the geospatial data. In India, Agri Stacks is employing on-the-ground resources to capture data on the crops sown each season. The plan is to share this data with both the government and the private sector's geospatial data platforms for validation and to build ML accuracy.

Conclusion – and a call to action

Agritech services are not only affecting farm operations, they are transforming the agriculture industry and enhancing resilience, agility, efficiency and transparency in the entire ecosystem.

It is clear that agritech powered by Fourth Industrial Revolution technologies will drive the next wave of transformation in the agriculture sector. Challenges such as climate change, unstable geopolitical situations and disrupted supply chains will affect the entire agriculture industry, regardless of the size of an operation. The advent of agritech technologies must therefore be viewed from a macro-industry perspective in order to drive value along the entire supply chain, which will help build resilience, agility, efficiency and transparency for the agriculture sector.

It is essential that policy-makers view agritech integration from a systems perspective and develop digital public infrastructure, policies and programmes to increase the affordability of agritech. For the private sector – including investors and start-ups – and think tanks, efforts to map empirical evidence of the impact of emerging technologies on farming – yields, quality, revenue, cost of cultivation, logistics costs and post-harvest crop loss – will help to generate interest from farmers as well as from small and medium agricultural enterprises, encouraging them to adopt and actively use Fourth Industrial Revolution technologies.

The World Economic Forum's agritech initiative, Artificial Intelligence for Agriculture Innovation, is aimed at scaling Fourth Industrial Revolution technologies through public–private partnership. The Saagu Baagu pilot project conducted in collaboration with the government of Telangana focused on introducing four agritech services to 7,000 chilli farmers. This saw a remarkable 18% increase in farmers' absolute profits over their peers who were not part of the intervention and is now being scaled to 500,000 farmers planting five crops in 10 districts of the state.

This initiative highlights the importance of multistakeholder collaboration and of a multifaceted approach. The agriculture sector needs similar collaborative efforts to be targeted at the common goal of empowering farmers to adapt to climate change and other risks while developing the industry ecosystem.

Technology is simply an enabler, however. It is not a magic wand. It is those involved in agriculture who must empower themselves and take the right decisions by adopting rational methods and making use of the tools of technological innovation.

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