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INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

DIGITAL AGRICULTURE IN ACTION
SELECTED CASE STUDIES FROM INDIA

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Abstract

Food systems around the world are suffering unprecedented challenges. These challenges are arising from the adverse effects of climate change, droughts, desertification, loss of arable land, unfavourable policies, lack of investment in rural infrastructure, as well as inefficiencies market linkages and access to finance for smallholders.

In order to address the challenges of agri-food systems and rural transformation, new development approaches are needed that combine innovative policies, technologies and organizational processes and practices, and use of digital and other types of innovation.

The growth of digital technology in the last decade has been phenomenal. This provides us a wonderful opportunity to identify digital solutions that are sustainable, and could help overcome agricultural challenges and accelerate achieving priorities. In order to make best of this technology revolution, it is important to understand these technologies and to identify how to sustain them, while taking into consideration factors such as infrastructure, policies and legislations, human skill and incentive mechanisms.

This publication is a limited stocktaking exercise on digital agriculture solution providers in India. The aim is to provide a knowledge product that would benefit future investments in the agriculture sector, specifically in food and nutrition security, rural development, and poverty alleviation in India and other countries.

This stocktaking exercise covered eight broad areas such as e-extension, food safety, Fintech, remote sensing, precision agriculture, e-commerce, artificial intelligence (AI), drones and satellite imagery (SI). The information collected includes an overview of the technology, methodology, benefits and impacts of the technology, context, drawbacks and barriers for the information and communication technologies (ICTs) adoption, government policies, some lessons learned and ideas for scaling-up.

This publication is an effort to provide insight into some of the digital agriculture solutions that exists in India and to share some of their experiences. Most of the data, case studies and success stories are verbatim from the respective companies. This should not be taken as an endorsement by FAO or ICRISAT of the companies or their solutions.

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A team led by Ram Dhulipala (ICRISAT) and Gerard Sylvester (FAO) and including Venugopal Mothkoor (Policy4Tomorrow) and Dharani Kanth Koganti (Policy4Tomorrow) compiled the synthesis report and the case studies.

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Abbreviations and acronyms

ACABC	Agriclinic and Agribusiness Centre
ADB	Asian Development Bank
AI	artificial intelligence
API	Application Programming Interface
APMC	Agriculture Produce Market Committee
AWS	automatic weather station
BIS	Behavioural Inhibition System
CCE	Crop Cutting Experiment
CSC	Common Service Centre
DER	Dvara E-Registry
DFI	Doubling Farmers' Income Committee
DFS	digital financial services
DIY	Do It Yourself testing kit
DLT	Distributed Ledger Technology
e-NAM	national agriculture market
EO	earth observation
FASL	Forecasting Agriculture Output Using Space, Agro-meteorology and Land-based observations
FBD	food-borne diseases
FCI	Food Corporation of India
FEWS	Famine Early Warning System
FI	financial institution
FLC	Fine Leaf Count
FPO	Farmer Producer Organizations
FSSAI	Food Safety and Standards Authority of India
GAPs	good agricultural practices
GDP	gross domestic product
GHG	greenhouse gas emissions
GIEWS	Global Information and Early Warning System
GSARS	Global Strategy on Agricultural and Rural Statistics
ICAR	Indian Council of Agricultural Research
ICRIER	Indian Council for Research on International Economic Relationships
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	information and communications technology
IDC	International Data Corporation
IoT	internet of things
ISRO	Indian Space Research Organisation

IRRI	International Rice Research Institute
JLG	Joint Liability Group
KCC	Kisan Call Centre
KYC	Know Your Customer
ML	machine learning
MSP	Minimum Support Price
NABARD	National Bank for Agriculture and Rural Development
NADMS	National Agricultural Drought Monitoring
NASS	National Agriculture Statistical Services
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NFC	near-field communication
NGO	non-governmental organization
NITI	National Institution for Transforming India
NLP	natural language processing
NLRMP	National Land Record Modernization Programme
NPCI	National Payment Corporation of India
NPNT	No Permission No Take-off
NSSO	National Sample Survey Organisation
OEM	original equipment manufacturers
PAD	Precision Agricultural Development
PMFBY	Pradhan Mantri Fasal Bima Yojana
PPP	public-private partnership
RCM	Rice Crop Manager
SASI	Shortwave Angle Slope Index
SAT	semi-arid tropics
SAU	state agricultural university
SMI	soil moisture index
SOFI	State of Food Security and Nutrition in the World
SHC	Soil Health Card
SI	satellite imagery
UAV	unmanned aerial vehicle
UIDAI	Unique Identification Authority of India
UPI	Unified Payments Interface
USGS	United States Geological Survey
VRT	variable rate technology


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Introduction

> "We are convinced that transforming our food systems to feed the world will be achieved with digital agriculture."
> Qu Dongyu, FAO Director-General

The agricultural sector, in the context of falling economic growth due to COVID-19, provides a unique opportunity to minimize economic losses and help alleviate some of the negative effects on poverty. Although contributions to the gross domestic product (GDP) decreased from 85 percent in 1951 to 16.5 percent in 2019–20, agriculture still plays a crucial role in providing livelihoods. Furthermore, as per the Periodic Labour Force Survey 2017–18, it employs 49.9 percent of the country's labour force. Despite targeted efforts of the government to mitigate COVID-19 induced shock on the agricultural sector, cases of farmers having trouble selling and harvesting were widely reported. Moreover, the likely persistence of a COVID-19 threat poses a significant risk to governments' flagship mission to double farmers' income. Hence, upscaling digital solution rollouts across the agricultural value chains can alleviate some of these challenges and increase overall welfare.

First, farm mechanization in India is around 40–45 percent compared to 57 percent in China, 75 percent in Brazil, and 95 percent in the United States of America. As regards the National Bank for Agriculture and Rural Development (NABARD) study, some reasons for low mechanization include small landholding size, poor access to power, high credit cost and complicated procedures, uninsured markets, and low awareness (NABARD, 2018). In order to address some of these issues, the government has instituted measures such as enhancing Kisan credit card limits, increasing insurance coverage through Pradhan Mantri Fasal Bima Yojana (PMFBY),[1] promoting the creation of Farmer Produce Organizations (FPOs) and formulating a model Agricultural Produce Market Committee (APMC) Act. Start-ups in India are also playing a decisive role in promoting farm mechanization, for example, drone-based solutions are being used in some clusters for the application of fertilizer and pesticides. In addition to reducing dependency on labour, such solutions reduce exposure to harmful chemicals. Drone and remote-sensing based products also facilitate crop health monitoring and reduce dependence on

1 Pradhan Mantri Fasal Bima Yojana (PMFBY). 2022. [online]. https://pmfby.gov.in

physical field inspections. The emergence of Uber-style digital platforms is helping to connect farmers to the suppliers of mechanical implements and to meet the demand in real-time. Such models may also create employment, especially for rural youth. However, many of these solutions are not scaled due to fragmented and highly intermediated supply chains. Government support for the creation of a connected ecosystem along with low-cost access to capital will give a major boost to farm mechanization.

Second, institutionalized advisory services in India are predominantly provided by extension officers. The increasing smartphone penetration and access to mobile internet has opened up opportunities for delivering extension services through digital routes. Few agri-tech start-ups have demonstrated impressive results through digital extension via audio and video content, in addition to SMS in local languages. Many companies are combining datasets such as remote sensing, drone, weather, and local conditions to generate local actionable intelligence, which is a huge improvement over generic advisories of the traditional extension. A few companies have set up call centres to facilitate two-way interaction and are co-opting farmers as co-producers of knowledge. In addition, several companies are innovating at the intersection of technology, social capital and business models to provide extension to underserved as well as unserved populations, thereby furthering the goals of inclusion. Partnerships with FPOs, progressive farmers, community-based organizations as well as publicly funded institutions are at the core of all of these innovations.

Third, the quality and cost of agricultural inputs are crucial for output and productivity. Farmers are largely dependent on input dealers/retailers for the choice of inputs and quantity to be applied. However, a non-aligned incentive system of retailers with that of farmers' interest leads to either excess application of inputs or selection of sub-standard input products, which in turn contributes to a decline in the soil fertility. The Economic Survey 2018–19 revealed that the fertilizer response ratio is declining due to an imbalance within the application, a lack of awareness, increasing multi-nutrient deficiency and poor crop management. On the other hand, input companies are experiencing significant transaction costs for the sale of their products owing to the highly intermediated supply chains. Digital technologies can reverse this trend by accurate identification and estimation of plant needs through the analysis of remote sensing, as well as local and drone data. Furthermore, digital technologies can facilitate the aggregation of input demand. This is mutually beneficial, as farmers can access quality inputs at a lower cost while companies save on supply and distribution costs, since aggregation facilitates economies of scale.

The Economic Survey 2018–19 indicated that the cropping pattern in India leans heavily towards water intensive crops. Some start-ups are promoting the use of internet of things (IoT) devices to monitor water requirements and promote efficient usage, while others are leveraging satellite-derived datasets to accurately estimate water requirements and remotely operate irrigation equipment. Delivering the latest technology breakthroughs to farmers through digital media and incentivize market players, especially start-up communities so that farmers receive quality inputs at a lower price would facilitate faster adoption of digital technologies by rural poor.

Fourth, farmers receive only a fraction of the price paid by the end-consumer because of poor infrastructure and inefficient market linkages. The APMC Act mandated the establishment of *Mandis*[2] for the protection of farmer interests – it however failed to fulfil its purpose. Despite the institutional infrastructure in the form of procurement centres guaranteeing Minimum Support Price (MSP), the situational assessment survey by the National Sample Survey Organisation (NSSO) in 2013 found that less than one-third of the farmers were aware of MSP. Even when farmers were aware, the absence of procurement centres in nearby villages, high transportation costs and the reluctance of mill owners to buy in small quantities proved to be a major obstacle to the realization of MSP. Some start-ups are now using digital interventions to facilitate higher prices for farmers. Besides enabling traceability, companies are also using technologies such as image recognition to grade the quality of produce and remove human subjectivity. Digital technologies are facilitating the aggregation of produce and providing direct linkages to sellers across the globe. Information on nearby market prices along with MSP is set up so that farmers can avoid distress sales.

Clearly, there is a need for digitalization, now more than ever. Digitalization will help Indian agriculture become globally competitive and self-sustainable. The digital literacy of farmers determines their capacity to adopt new technologies and practices; hence, start-ups must recognize the digital literacy gaps and provide solutions that address the requirements of illiterate farmers as well. Key considerations on the gender-digital divide and focusing on the local sensitivities will help sustain digital solutions. By encouraging public-private partnerships (PPP), promoting trunk infrastructure, and subsidizing access to small and marginal farmers, the government can play an enabling role in scaling such digital solutions.

This report aims to provide unique insights into how technology agents in India are shaping and transforming the agricultural sector. In addition to structured interviews with over 42 leading organizations in the domain of Indian agriculture, the report examines key trends under eight different themes, namely: artificial intelligence (AI), precision agriculture, e-extension, e-commerce, unmanned aerial vehicles (UAVs)/drones; food safety, Fintech, remote sensing.

2 Mandis are primary agricultural markets, intended as a safeguard for farmers from exploitation by large retailers as they are not allowed to procure directly from farmers.

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Chapter 1
E-extension

India is self-sufficient in food production and is the seventh largest agri-produce exporter in the world. It is one of the top producers of cereals, pulses, fruits, vegetables, milk, meat, and fish. Despite such achievements, Indian farmers are currently facing enormous challenges such as rising cultivation costs, declining soil fertility, climate change, labour shortages, and an uncompetitive market. The average monthly income of an average Indian farmer languishes at a minimum of INR 6426 against a monthly consumption of INR 6223, scarcely leaving any savings. Over 22.5 percent of the farmers in India are living below the poverty line; large tracts of land are unfertile and yields have stagnated due to unscientific agricultural practices (Committee on Doubling Farmers Income–Vol XI, 2017). In this context, agricultural extension services play an important role in enhancing farmers' income by providing timely updates on:

- appropriate technology options and use of such options;
- farm management techniques;
- information on quality and pricing of farm inputs;
- consumer and market demand for farm products;
- mechanisms for collective action;
- access to credit; and
- off-farm income generation options.

The role of extension services is not only a one-time delivery of information – it goes beyond. It is a continuous process of updating farmers with information on the latest scientific breakthroughs, good agricultural practices (GAPs), high yielding varieties, and market information across the crop cycle. Also, extension services play an important role in developing human and social capital, enhancing knowledge and skills for production and processing, facilitating access to market and trade, organizing farmer groups, and adopting sustainable natural resource management practices (Glendenning, Babu and Asenso-Okyere, 2010).

Up until the last decade, agricultural extension services in India were largely supply-driven through a special cadre of professionals, called extension officers. They were responsible for around 5–10 villages and had the onus to push the adoption of GAPs. However, evidence collected over the last decade indicates that over 59 percent of the households did not receive assistance from either government or private extension services. Of the 41 percent of households who received extension assistance, only 11 percent reported that

extension services came from public extension systems, *Krishi Vigyan Kendras,* and agricultural universities. There is one public extension agent per 1156 operational landholdings (Committee on Doubling Farmers Income–Vol XI, 2017). The supply-driven public extension services were largely unsustainable and had little impact on farmers' income. The public expenditure spending on education, extension, and training is a meagre 0.7 percent of the agricultural GDP in India.

Information and communication technology (ICT) has the potential to address information gaps and make up for the labour shortages in extension. The advent of ICT has transformed agriculture from a labour-intensive profession to a knowledge-intensive profession (FAO and ITU, 2016; FAO, 2017). ICT enables faster, wider, and real-time outreach. FAO maintains that the success of ICT initiatives is due to their ability to solve actual problems faced by farmers, while the Indian Council for Research on International Economic Relationships (ICRIER), 2018 stresses the dichotomy between knowledge and skills (Gulati *et al.,* 2018). The advent of ICT increased the availability of information, but the missing piece of the puzzle is the skill to convert this knowledge into tangible outputs. It is against this backdrop that this report provides a summary of the key trends in e-extension services, while describing how start-ups are playing a pivotal role in the creation of tangible outputs.

To realize the digital disruption in public EAS we need to create avenues for redesigning the extension processes (work on the frameworks not on the guidelines), stimulate new thinking (capturing innovations and start-ups within the system) and include crowd sourced extension innovations (allowing partnerships and local redesigning to certain extent) (Meera, 2018).

DRIVERS OF E-EXTENSION

Reduction in handset and data costs

Poor infrastructure makes it more difficult and costly to service farmers through traditional service channels, living in a remote location. The principle-agent problem coupled with a lack of accountability further erodes confidence in extension agent-driven agro-advisory system. ICT can enable a two-way flow and peer-to-peer flow of information, which thereby leads to the efficient delivery of advisory services (FAO, 2017). The greatest impact of ICT in agriculture is found in the reduction of price arbitrages as well as enhanced equity through democratization of information access (FAO, 2013a).

Access to information is becoming affordable as data and mobile handset prices continue to drop, thus driving adoption. Content delivery through audio or video messages tries to overcome the challenges with literacy. Farmers are also willing to pay for advisories that are relevant, actionable and adoptable to their situation.

A large presence of public institutional players

The Indian Council of Agricultural Research (ICAR), 112 research institutes, 64 state agriculture universities (SAU), four deemed-to-be universities, and three central agriculture universities have been at the forefront of driving the adoption of agricultural extension services. The extension services underwent several changes (Figure 1) over the years to fulfil the needs of changing times and to increase uptake and acceptability among farming communities (Committee on Doubling Farmers Income–Vol XI, 2017).

1970–1990: Training and visit programme driven by extension officers
1900s–2010: Agriculture Technology Management Agency (Covergence of different agencies on one platform)
2010–onwards: National Mission on Agriculture Extension and Technology

ICT initiatives driven by government

The Government of India has instituted measures over the last few years to educate farmers. The farmers' portal is a single umbrella platform providing information on various products such as crop insurance, storage, crop advisories, farm inputs, and market prices. Central and state governments use mKisan, an SMS platform, to send messages to farmers in their local language. Kisan Call Centre (KCC) and Kisan TV channel deliver extension content in regional languages (Committee on Doubling Farmers Income–Vol XI, 2017), and channel deliver extension content in regional languages (Committee on Doubling Farmers Income–Vol XI, 2017).

Emergence of agri-entrepreneurs

The Agriclinic and Agribusiness Centres (ACABC) scheme launched in 2002 aimed at providing agri-entrepreneurship among rural youth. Rural youth are trained in a wide range of services such as the sale of inputs, agricultural advice, marketing support, etc. (Committee on Doubling Farmers Income–Vol XI, 2017).

Farmer Produce Organizations (FPOs)

Small farmers are facing higher transaction costs to learn about consumers' choices, as regards deciding what and how to plant, and in selecting a partner for either purchase of inputs or selling the produce. The highly fragmented landholdings especially among the small farmers makes it costly for credit, insurance, and other financial institutions to provide their products and services. For example, the small ticket size of the loans for marginal farmers creates higher transaction costs for banks (FAO, 2017). In light of this, the emergence of FPOs is crucial to solving the critical challenges of achieving aggregation of produce in order to improve logistical efficiency, a cost-effective purchase of inputs, and easy access to credit. ICT can reduce transaction costs and transform agricultural practices (FAO, 2017) and also provide a mechanism for the easy management of FPO processes.

Disruption in extension services will be happen not only due to digital technologies but also through farmers' centric approaches that offer retail like extension services (advisory and supply chain coordination) specifically designed to meet and exceed expectations of farmers (Meera, 2018).

TRENDS IN E-EXTENSION

Emergence of public-private partnerships

Agricultural research institutes, SAUs and commodity boards have been instrumental in increasing the uptake of new agricultural management techniques and their varieties. First, their outreach is limited and caters to only 49 percent of the Indian population engaged in the agricultural sector. Second, resource-constrained state governments spend less on extension services given the competitive demand for state budgetary resources. Third, an extension agent's inability to influence farmers' behaviour and provide consistent and customized information at a granular scale is inhibiting the adoption of such an advisory. In view of these, new forms of PPPs have emerged to increase the uptake of extension services and reduce demands on the state exchequer. The ICRIER 2018 report revealed that although non-governmental organization (NGO)-led extension models demonstrate a certain amount of empathy towards local priorities, this is not scalable due to a lack of synergies with the public sector (Gulati *et al.,* 2018). However, the emergence of a vibrant start-up community is now changing the dynamics by actively networking with public sector agencies.

- Digital Green, Vassar Labs, ICRISAT, International Rice Research Institute (IRRI) and Precision Agriculture for Development (PAD) partner with extension officers to deliver customized advisory to farmers.
- Amnex and Niruthi collaborate with state governments in estimating potential yields using remote sensing data. Amnex and Niruthi also advise state governments to conduct Crop Cutting Experiments (CCE) more efficiently by advocating smart sampling.
- SkyMet collaborates with Government of Maharashtra to provide granular weather information to farmers.

Leveraging local networks

The NSSO seventhieth survey revealed that 20 percent of the farm households received extension advisory from progressive farmers. This inherent trust amongst local peer farmers is increasingly tapped into by start-ups who have established partnerships with such local progressive farmers and youth for increased uptake of extension services delivered by them. Face-to-face interaction is more credible and effective in an environment where literacy levels are low, and farmers still hold long-standing beliefs.

- Digital Green and Kuza work with local youth and train them as digital volunteers. These youths create videos of local best agricultural practices featuring progressive farmers and disseminate content created among peer farmers.

- eFresh partners with local farmers and works with them to adopt good agricultural practices.

Emergence of evidence-based delivery of agroadvisory services

The FAO report acknowledged the diversity in terms of ICT delivery services such as SMS, voice, video, and audio. It also cited that there is little evidence of which delivery services are optimal from the farmers point of view (FAO, 2017). Public extension delivery systems focused more on activities than outcomes (Gulati *et al.*, 2018). The start-ups have increasingly demonstrated an impact by identifying crop stress points and suggesting alleviating measures, thus reducing crop losses and protecting farmers' income.

- AgNext and Intello Labs use imagery analysis while cFog and Setallps use IoT sensors to analyse quality of produce. Quality assurance mechanisms help farmers get the right price for agricultural produce.

- Satsure, BharatAgri, Vasar Labs, Wadhwani AI, Marut Drone tech and SenseAcre use remote sensing products and apply machine learning (ML) algorithms to detect crop stress and suggest timely interventions.

- Kisan Raja and Eruvaka use IoT sensors to monitor water requirements during crop cycle and promote efficient use of water and energy.

- IRRI recommends application of fertilizer based on soil profile.

Push based services to pull-based services

The FAO study revealed that the ICT services implemented in the last few years are push-based rather than pull-based. Most of these services are unidirectional and no clarifications can be sought (FAO, 2013a). However, new evidence indicates the emergence of demand-based services and a bi-directional flow of information. Farmers are now co-producers in the creation of knowledge for extension services.

- Gram Vaani, a two-way interactional platform, has farmers and agri-experts exchanging messages as in a social media platform. Voice based Quora platform also helps farmers to know the solutions already available in the local database.

- Expert agronomists provide customized advisory to the farmers through the Agrostar call centre.

- KVKs, the field units, were set up by ICAR to test new seed varieties, agronomic practices, and machinery. There are 721 KVKs across the country to provide demand-driven services and information to farmers. KVKs conduct thousands of on-farm trials and lakhs of frontline demonstrations.

Bypassing local farm input players

Agricultural extension services by the private sector is largely driven by the 2.8-lakh dealers of seeds, pesticides, and fertilizers across the country. The major complaint about input dealers is that their incentives are driven by the commission they receive from input companies and furthermore, they practise product advisory and not technical advisory (Gulati *et al.,* 2018). Although public extension services deliver the correct information, farmers purchase the wrong products and as a result suffer productivity losses. However, this has slowly changed during the last few years. Start-ups through innovative partnerships with FPOs are consolidating the requirements of farm inputs and are now directly supplying quality inputs to farmers. This is mutually beneficial for both the farmers and input companies. Farmers receive product discounts and companies save on logistic costs.

- eFresh partners with FPOs to consolidate farm input requirements and makes such inputs available at a discount compared to market price. eFresh also ensures adoption of GAPs.
- Agrostar consolidates farm input requirements through the information received by call centres and makes quality farm inputs available to farmers.
- Kuza platform aggregates farm input requirements from agripreneurs and matches the aggregate demand with supply directly from manufacturers, thereby bringing better prices via economies of scale.

Emergence of extension services to support postharvest management

The current extension system is largely oriented towards crop production and cultivation activities. However, increasingly extension services are capacitating and training farmers on post-harvest management practices such as storage, packaging, grading, quality certification and market pricing.

- eFresh facilitates access to export certification requirements in regional languages and auditors certify the quality of produce. cFog and Stellapps use IoT sensors to monitor the quality, while Intello Labs uses image analytics.
- Kalgudi market linkage platform connects farmers directly to the market ensuring right price for farmer.

TraceX and SourceTrace use blockchain technology to track the inputs and management practices across the supply chain. All the stakeholders are on a distributed ledger platform ensuring transparency across the chain.

Group and individual-based extension services

The public sector-led extension services are mass-based, and start-ups implement extension services at the scale of a group (Self Help Groups [SHG], FPOs, forums, etc.) while the private sector extension is individual and contact-based. The advantage of this approach is that mass-based services are suitable for awareness building while the other two options are more relevant for implementation. Extension services by delivering real-time and location-specific updates improve the decision-making ability of farmers.

SkyMet provides location specific real time weather updates to farmers.

Kalgudi and the national agriculture market (eNAM) market-linkage platforms provide real time price information to farmers.

CHALLENGES FOR SCALING EXTENSION SERVICES

- Modern agriculture is capital and knowledge intensive. Investing in agriculture human and social capital, including bridging literacy and digital literacy gaps, are essential to sustaining digital services and improving adoption.
- Government needs to invest in trunk infrastructure, especially to improve connectivity speed and access.
- Availability of open data becomes critical, especially to drive adoption of extension services.
- There is a need for the simplification of current farm input licensing and quality grading system.
- With over 654 000 villages, 130 million farmers speaking around 800 languages under 127 agro-climatic zones, juxtaposing several datasets in an interoperable manner is a huge challenge (Committee on Doubling Farmers Income–Vol XI, 2017). Bigdata-based ML platforms using remote sensing data must be customized for each region due to language, culture, and behaviour variations across India. A significant cost is involved in adapting and operationalizing big data platforms for various regions and geographies.
- Lack of data standards impedes interoperability and slows down adoption of latest technologies (Committee on Doubling Farmers Income–Vol XI, 2017).

Chapter 2
E-commerce

The commerce of agricultural goods in India has changed tremendously over the years, as India has transitioned from subsistence farm economy to food surplus (Committee on Doubling Farmers Income–Vol IV, 2017). Today's India is the leading producer of cereals, pulses, vegetables, meat, milk, and fish. Periods of food insecurity led to the enactment of several interventions such as input subsidy, minimum support prices, public storage, procurement, and distribution of food grains, as well as measures to protect farmers' income and regulation of food supply to ensure food security. The marketing system envisaged for deficit production, however, is ill-equipped to handle the surplus economy (Committee on Doubling Farmers Income–Vol IV, 2017). Despite being the leading producer of many farm commodities, farmers have not been able to obtain access to exports due to the lack of export market intelligence. Exports are also hindered due to the near absence of post-harvest infrastructure such as collection centres, grading and packaging facilities, as well as poor logistic networks. Furthermore, the presence of multiple grading standards namely the Behavioural Inhibition System (BIS), Agmark, the Food Corporation of India (FCI), and Codex Alimentarius, difficulty in adherence, and limited grading infrastructure are also restricting the commerce of agricultural goods (FICCI, 2017). Moreover, the domination of small and marginal farmers with small unprofitable lots results in poor bargaining power, as compared to the organized traders and retailers. Small economic lots also increase the cost of grading, packaging, and transportation.

An effective marketing system is expected to communicate the demand signals from consumers to producers, so that the entire supply chain can gear up to meet the demands forecasted, and generated revenue is shared equitably among the various players of the value chain. The emergence of a new wave of digital technologies is enabling a much-needed shift in thinking from farm-to-fork to fork-to-farm. The ICT provides easy access to:

- a wider consumer base where distance becomes irrelevant;
- certification requirements at the farmers' fingertips at lower costs; and
- farmers' ways and means to consolidate and aggregate the produce to realise economies of scale.

ICT facilitates the integration of solutions across the value chain to benefit every stakeholder.

DRIVERS OF E-COMMERCE/E-MARKETING IN AGRICULTURE

Rising internet and smartphone penetration

Since June 2018, internet penetration in India has reached 39.3 percent, registering an impressive growth of over 24 percent between 2007 and 2017 (IBEF, 2018). The number of internet users (560 million) is the second highest in the world and data usage in India is on par with that of developed countries. India's active internet population is expected to reach 900 million 2025 (ICUBE 2020).

Favourable policies

Policies such as 100 percent FDI in B2B e-Commerce, Start-up India and Digital India are driving e-commerce in the Indian context. Pradhan Mantri Gramin Digital Saksharta Abhiyan has provided digital literacy to over 13.8 million Indians and aims to train 46 million more. India digital stack suite of applications such as Aadhaar UID,[5] e-Sign, e-KYC and DigiLocker have laid a strong foundation (Ministry of Electronics and Information Technology–MeITY, 2019). Most food products were brought under the lowest tax slab of 0 percent and 5 percent with the enactment of GST (Ministry of Electronics and Information Technology–MeITY, 2019).

E-commerce portals

Private players launched online platforms such as Big Basket, Grofers, Amazon Pantry, and Godrej's Nature basket to facilitate buying and selling over internet. eNAM is a pan-India electronic trading portal set up by the government to connect APMC mandis across the country. Over 585 mandis across the country are connected on eNAM (Ministry of Electronics and Information Technology–MeITY, 2019).

Large domestic consumer base

The Indian market size for food is expected to be around USD 544 billion by 2021. Over two-thirds of 1.3 billion people are young with a strong preference for convenience food, which pushed up the demand for packaged and labelled food. Organic packaged food witnessed double-digit growth in volume and sale in 2018 (Confederation of Indian Industry, 2019).

TRENDS IN E-COMMERCE

Creating alternate channels of delivery

The Doubling the Farmers' Income Report presented by the Government of India recognizes that one of the central tenets of an effective marketing system is the creation of alternate channels for delivery. The explosion of e-commerce platforms provided farmers an opportunity to engage in alternate delivery platforms compared to the former model where farmers only sell at market yards.

5 This is a verifiable unique 12 digit ID issued by the Indian government to its citizens, see UIDAI. 2022. [online]. New-Dehli. https://uidai.gov.in

- eNAM, an electronic trading platform, connects over 585 mandis; eNAM digitalizes entire operations from the arrival of stock at a mandi, quality grading of the farm produce, weighing of produce, participation in e-auction, generation of invoice and deposit of money into farmers' bank account. Produce is sent to the buyer using eNAM connected logistic chain.

- Kalgudi's own market linkage platform connects farmers to local and export markets. TraceX uses blockchain system to track the produce and assures quality to the end-user.

- Kalgudi, eFresh and AgroStar partner with FPOs and make available high-quality agricultural inputs at discounted prices compared to the former model where such inputs are bought at a higher price from local dealers and quality of such inputs is also unknown.

Cobweb marketing model to efficient marketing model

In a typical production cycle, farmers perceive price trends from the last season as a signal of market demand and produce crops that fetch a higher price. However, since farmers lack the means to comprehend the cropping choices and cultivation practices of other farmers, most often commodities that fetched higher prices in the past have a higher production than the market demand in the current season. This leads to excess supply and temporary dampening of the price. Farmers react to this price dampening by scaling back the production in the ensuing season which creates shortages leading to higher prices. This cycle of excess supply and shortages creates volatility in the entire marketing system with farmers having to endure the most of fluctuations. Also, such volatility is advantageous to traders who will have a higher capacity to stockpile goods compared to farmers who are the producers. Marketing will only be efficient if the price signal is ex-ante compared to the ex-post. Demand forecasting with volumetric information and ex-ante price information is a far better signal. This cobweb model is changing fast with the emergence of new technologies such as AI, and e-commerce platforms, which communicate the consumer demand to ex-ante and facilitate market linkages so that it benefits the farmer.

- Farmley combines various datasets such as trends, forecasts, and demand to deliver marketable intelligence to farmers by predicting commodity and grade-wise prices. The quality standards are also made available to farmers using a mobile app. Farmley platform also facilitates e-commerce by connecting FPOs to sellers across the country.

- SourceTrace platform combines predicted harvest date, yield estimates and crop calendar to estimate crop volumes, which in turn is used to predict price information.

Bringing production closer to consumer centres especially for perishable goods

Storing stock in a location near consumers will not only reduce inventory cost but will also reduce food waste, especially in the case of perishable goods.

- FoodPrint, a permissioned blockchain system built by TraceX, connects all stakeholders involved in an organic value chain including the end-consumer. By enabling QR code tracking, all the information across a value chain is captured and made visible to its stakeholders. FoodPrint connects fruit and vegetable growers to the nearest urban market.

Emergence of large e-commerce portals to minimize price dispersion

In the case of India, price dispersion that was measured at a ratio of highest to lowest crop price averages is very high due to factors such as poor connectivity, market power of intermediaries, local storage capacities, mandi infrastructure, storage life of crops and crop processing cost. Moreover, long intermediated supply chains, despite being closer to a market, increase price dispersion (Committee on Doubling Farmers Income–Vol IV, 2017). The national agriculture maeket (e-NAM) a nation-wide portal, is expected to correct such price dispersions. Many start-ups also connect farmers to wider markets to help farmers realize a higher price for the produce and minimize price dispersion. Many of these e-commerce platforms offer integrated services to shorten the supply chain.

- e-NAM is an electronic trading and marketing portal that connects about 585 APMC markets. Farmers have the freedom to participate in e-auction and sell produce to the highest bidder compared to the prevailing practice of selling at minimum support price. e-NAM also offers integrated services such as quality grading, packaging and transporting.

- Kalgudi and eFresh market linkage platform connects producers to wider market including exporters and ensures higher price for the agricultural produce. They also offer value added services in the form of certification of produce.

Reduction in losses in supply chain

The ICAR 2010 study estimates post-harvest losses in agriculture at a range of INR 4400 crore owing to poor market infrastructure, the long gestation period of infrastructure projects, and seasonality of produce (S.K.Nanda *et al.,* 2010). Given this scenario, some start-ups are digitizing the entire value chain to identify the source of bottlenecks. Also, by way of mapping and monitoring export certification standards, companies are helping farmers to realize higher value for the produce.

- Stellapps use IoT sensors to monitor quality of milk across a supply chain. In case of issues in quality, the problem can be traced back to the exact node. This prevents penalization of whole collection centre or rejecting the whole lot.

- Intello Labs uses ML-based image analytics tool to detect quality of produce. The quality information is made available to relevant stakeholders to enable evidence-based decision making.

- Eruvaka and cFog use IoT sensors to monitor oxygen requirements in shrimp ponds; use of IoT sensors helps in ensuring protection of shrimp health and in reducing energy cost.

Assuring farmers, a market price better than minimum support price

The Government of India has announced minimum prices for certain commodities based on the cost of production and other factors. The input costs in the market are considerably higher than those factored in MSP estimation (Committee on Doubling Farmers Income–Vol IV, 2017). However, with the emergence of dynamic start-ups we have seen a gradual shift towards a market price where farmers can receive more than the minimum price. By connecting markets that previously were not accessible to farmers, start-ups are ensuring higher price for farm produce.

- Kalgudi, SourceTrace and eFresh offer certification solutions to farmers; because of certification processes, farmers receive higher price for the produce.

- TraceX uses blockchain based solutions to ensure end-to-end transparency in the agricultural value chain; conscious consumers are willing to pay premium price for ethically produced and quality graded products.

Tapping into FPOs

FPOs overcome barriers of land fragmentation and bring benefits of economies of scale. Start-ups are increasingly connecting this newly emerging form of cooperative arrangements to local and export markets. They are also overcoming the three problems pointed out in the report on Doubling Farmers' Income (DFI), (Committee on Doubling Farmers Income–Vol IV, 2017) namely landed cost, quality concerns, and market linkages through these strategic linkages. Start-ups are increasingly identifying potential FPOs who have strong growth potential and linking them to the market.

- eFresh, Kagudi, Digital Green, SourceTrace and TraceX work with FPOs; such arrangements are mutually beneficial. Farmers can receive input products at a discounted price and connect to wider markets; companies can reduce the logistic cost.

CHALLENGES IN SCALING E-COMMERCE

- India currently processes less than 10 percent of its agri-output and most of the processing done is primary processing (Confederation of Indian Industry, 2019).
- There is a lack of cold chain infrastructure and limited presence of quality grading laboratories impeding the scalability of e-commerce products. Conscientious consumers shy away from buying a product without the quality rating.
- The standardization and harmonization of commodity grading and assaying standards are fundamental to avoiding high compliance costs for farmers.
- There is a need for a change in current certification mechanisms of agricultural produce, as they do not recognize new techniques such based on AI, ML and IoT for use in commodity grading and assaying activities.
- Necessary frameworks such as data governance that provides the necessary protection against data, traceability, payments and transactions are fundamental to scaling up agriculture/food-based e-commerce.

Chapter 3
Artificial intelligence

AI refers to a body of science wherein computer systems imitate tasks and behaviours, which otherwise are typically associated with humans, such as learning, reasoning, recognizing, and making decisions. AI enables computers to collect, analyse and process large amounts of data to recognize patterns, make decisions and more importantly provide feedback (World Bank, 2018). Although foundations for the field date back to 1956, it was not until 2010 that it gained prominence with the emergence of speech recognition, image classification and text translation (Stuart, 2019). Today, AI is already being used to speed up the process of vaccine development (Kent, 2020), fighting crime (Vajradhar, 2019) and improving education (Schroer, 2020) to name a few. The sub-areas under AI include: natural language processing (NLP), robotics, ML, automated reasoning, computer vision, speech recognition, virtual and augmented reality, deep learning, IoT, etc. AI encompasses the use of various such technologies to emulate cognitive tasks, formerly reserved for humans.

DRIVERS OF AI

- **Rise of big data:** As per the International Data Corporation (IDC), the global datasphere will grow to 175 Zettabytes (ZB) by 2025, almost six times the size in 2018. Over 75 percent of the world population interacts with data every day and IDC report expects that by 2025 each connected person will have one data interaction every 18 seconds (Reinsel, Gantz and Rydning, 2018). Such exponential growth in data is in turn aiding the growth of AI. Barry Smyth, Professor of Computer Science at University College Dublin, aptly stated: "Data is to AI what food is to humans."
- **Falling cost of storing data:** Today we have entered an era where the marginal cost of data storage is approaching near zero i.e. from USD 500 000 per GB in 1980 to 2 cents per GB in 2017 (NITI Aayog, 2018).
- **Advancements in computing technology:** Advancements in computing technology helped to drive down data and computing costs.

The National Institution for Transforming India (NITI) Aayog's strategy paper on AI released in 2018 identifies agriculture as a sector with one of the greatest scopes for improvement for the application of AI. The market size for AI in Indian agriculture is expected to grow from USD 240 million in 2017 to USD 1.1

billion by 2025 (Dua, 2019). Accenture recently reported that AI has the potential to add USD 9 billion to farmers' income (NITI Aayog, 2018).

India has over 500 million smart phone users. The growth in the number of smartphone users and internet users in India is providing volumes to the innovative AI companies to experiment and launch innovative solutions (PTI, 2020). Globally, digital entrepreneurship is growing, and the agricultural sector has not been left out. Digital entrepreneurship involves applying (novel) digital technologies to improve business operations, generate new business models and engage with customers and stakeholders. Agri-tech start-ups fuelled by funds from venture capital, increasingly take on AI-powered, data-based value propositions (Gurumurthy and Bharthur, 2019). FAO (2019a) identified the following broad functional domains for AI in agriculture:

- **advisory services:** use of mobile apps and chatbots to deliver advisories on weather conditions, crop demands and emerging threats;
- **precision agriculture:** use of data from IoT, drones, remote sensing channels to deliver crop- and farmer-specific advisories;
- **automation:** adoption of IoT devices, drones, and self-autonomous vehicles to boost farm mechanisation and reduce the dependence on labour.

TRENDS IN AI FOR AGRICULTURE

The agricultural sector is also seeing a rapid adoption of AI, both in terms of agricultural products and management techniques. AI can help farmers with information on quality of soil, what to sow, when to sow, when to apply fertilizer and water and the quantity as well, when to spray herbicide/weedicide/pesticide, when to harvest, where to sell and at what price to sell. AI is set to transform the sector by making agriculture more profitable, more productive, more sustainable and more accurate, and make farming easier (Dua, 2019). Latest estimates project a compound annual growth rate (CAGR) of 25.5 percent from 2020 to 2026 for the application of AI in agricultural sector (GlobeNewswire, 2020). The key trends observed in the sector include:

- **Use of AI to enable precision agriculture:** Companies are increasingly combining datasets such as IoT, remote sensing and on-ground information to provide farmers crop specific information.

- cFog and Eruvaka use IoT devices that monitor dissolved oxygen, pH and temperature conditions in shrimp farming and in agricultural fields to detect crop stress conditions. Stellapps uses IoT devices to detect and monitor milk quality across dairy value chains. Use of such data reduced input cost to farmers and ensured higher income.

- Intech harness Pvt Ltd, solution combines IoT and micro-controller devices to maximize water-use efficiency and thus helps farmers reduce both energy cost and protect groundwater table, which is fast depleting.

- Marut Dronetech, Thanos and Senseacre use drones for identifying pest-prone areas and targeted spraying, thus reducing pesticide usage and harmful exposure to chemicals.

- **Use of AI to enable crop health monitoring:** An increased shift to use remote sensing-based products to facilitate crop health monitoring rather than depending on field inspections.

- Wadhwani AI solution consists of use of ML based algorithms for the identification of pests, intensity of pest attack and recommendations to deal with pests. Kalgudi and Vassar Labs' Agricultural Information Management System use ML algorithms to identify the probability of pest attack and provide solutions to deal with such problems.

- PEAT Gmbh's Plantix app uses deep neural networks to identify plant pests and diseases from the picture uploaded by the user on the Plantix mobile app.

- **Use of AI to enable credit risk monitoring:** AI is used for structuring credit and risk assessments and following up on loan monitoring in financial technology (Fintech) solutions, targeting lending and insurance schemes to the vast and underbanked smallholder farmer population in India.

- SatSure's SPARTA platform combines satellite imagery (SI) with weather, IoT, social and economic datasets, among many others to generate insights on sowing window, harvest window, crop stress and crop yield. SPARTA helps financial Institutions in early risk identification, remote loan monitoring, product diversification.

- Skymet and Dvara E-Registry (DER) use ML products to quantify the risks associated with a parcel of land. Financial companies now leverage such information to monitor crop risks and reduce their own NPAs in the process.

- Niruthi uses remote sensing data and on-ground data collected by field agents to produce various value-added datasets. Bankers use such information to know if the loan has been utilized to sow the declared crop and alert farmers in case of any risks. Insurance companies use Niruthi's product to estimate average yields and reduce basis risk.

- **Use of AI to enable macro planning:** AI is increasingly being used by central and state governments to create macro plans in terms of estimation of crop yields; communicating sowing- and harvesting-window, weather updates; and minimizing gap between supply and demand through aggregation platforms. This can be met through collaborative partnerships with start-up companies.

- Skymet partnered with the Government of Maharashtra to deploy over 2100 automatic weather stations (AWS) across the state and provide real-time observed weather, historic and forecasted weather data to farmers. Skymet has also deployed about 600 agricultural sensors primarily to measure soil moisture, soil temperature, leaf wetness and solar radiation, which assist in crop health monitoring.

- The IRRI partnered with the Government of Odisha to implement Rice Crop Manager (RCM), which will provide site specific nutrient recommendations.

- Vassar Labs Agricultural Information Management System ingests various datasets (SI, historical weather datasets, etc.) to understand historical cropping patterns, climatic conditions, frequency of dry spells, and couples these with the latest information on irrigation sources and seasonal water availability to advise on agro-climatic zones planning.

- **Use of AI for quality grading/assaying:** Image recognition and deep learning algorithms are facilitating quality assessment using simple images clicked through a smartphone compared to the former logistic heavy model of quality determination through a testing in laboratory.

- AgNext and IntelloLabs use advanced image analytics to monitor quality of farm produce.

- Stellapps uses IoT devices to monitor quality of the produce.

Challenges to AI-based technology adoption and implementation are symptomatic of a highly fragmented agricultural market with high costs for onboarding farmers.

- Low adoption could reflect, in part, solution development that is insufficiently driven by demand i.e. end-user farmers (Gurumurthy and Bharthur, 2019).
- Common challenges include overcoming trust and disbelief by farmers, social and cultural barriers, lack of digital literacy and localisation requirements (e.g. language).

Need for boots on the ground

Start-ups and organizations are integrating more sustained local engagement and training as a part of the solutions to overcome these challenges.

Marut created brand ambassadors in pilot regions who used drone application and benefitted from it. Farmers' trust in local peers helps with a better uptake of such novel technologies. Marut also identified the influential actors in different districts. The engagement with SAUs and social activists helped Marut Dronetech increase the uptake of products as these influencers play a vital role in the on-ground dissemination and sustained use of the product.

These challenges also mean that scaling solutions across the country will require more time and resources – with substantial boots on the ground – than many of the start-ups may have originally expected for digital solutions. Many agri-tech efforts are focusing more on B2B or B2G business models, as the willingness of farmers to pay for such products remains low.

- Stagnant farmer incomes are responsible for a lack of the willingness to pay for technology solutions.
- ML models without proven and established accuracies affect adoption among the farmers who largely rely on the on-ground evidence.

Developing partnerships

It is not uncommon for homegrown agri-tech companies to gain initial traction through collaborating with local or state governments to implement their pilot projects and leverage B2G traction to scale into B2B models.

Intello Labs applies image recognition technology and deep learning algorithms to provide commodity testing and grading of wheat, corn, tomato, soybean, potato, and onion. Intello Labs started with a pilot project with the Government of Rajasthan on wheat and grain testing.

CHALLENGES IN SCALING AI FOR AGRICULTURE

Digital literacy and infrastructure

Basic building blocks such as digital literacy and an interoperable infrastructure are essential to sustain AI-based interventions. Although the government is making significant progress in the creation of digital infrastructure, the efforts to boost the digital literacy are still at the nascent stage, especially in rural areas.

The digital literacy gap is also used as an opportunity by many start-ups to upskill rural populations through training and job creation associated with AI in agricultural solutions.

The drone ecosystem in India is still young. There is space for private players or the government to provide training across the country for drone operation and data analysis, to bring about comprehensive remote sensing on agricultural land. Operating a drone requires three people – two pilots and one data analyst – and if each of the 250 000 villages across the country needs a drone per village, we are looking at the potential creation of '750 000 jobs across the country.

Lack of open datasets and data framework

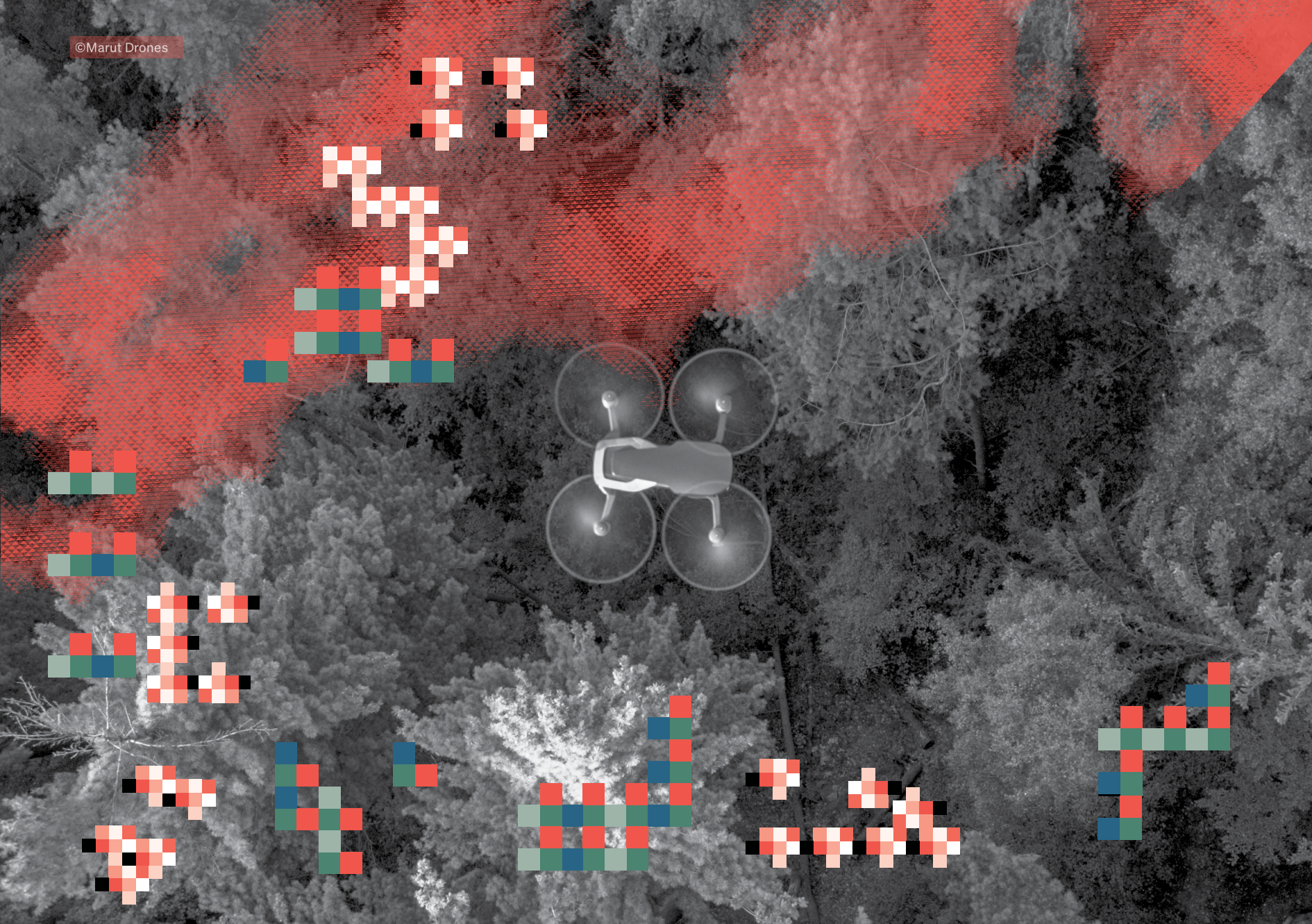
Data is paramount to building AI solutions. For agriculture, ML models require a range of data sets, including topography, climate, soil, seed varieties, crop diseases, pest management, etc. and of good quality. ICRISAT and the McKinsey Global Institute identified the scarcity of publicly available disaggregated data as a major bottleneck to developing AI solutions for agriculture in India. Furthermore, governments (state as well as central) collect huge volumes of quality disaggregated data from their field personnel. Governments however have no clear policy or a coordination mechanism to make this data available in a responsible way to support AI/ML based innovation through private sector. Checks and balances for data access and its use are not currently in place, thus hampering public interest as well as social values as regards AI in agriculture.

That said, there are increasing efforts being made for localized data generation and collection across India through the deployment of drones/unmanned aerial vehicles (UAVs) and remote sensing hardware. For example, drones equipped with a multispectral camera can capture crop spectral data, which can be used to monitor crop health. India is one of the fastest-growing markets for UAVs in the world; according to 6Wresearch, the UAV market in India is projected to grow at a CAGR of 18 percent during 2017–23 (6Wresearch, 2017).

However, hardware devices for drones and remote sensing are imported for the most part, and the high import duty on these devices poses a challenge for AI-based agri-tech start-ups. India's domestic drone manufacturing and servicing are in the early nascent stage. In India, drone usage has not yet reached its true potential due to high costs and low domestic availability of devices. Moreover, remote sensing data alone is not enough; collecting ground truth data is important for validation.

Start-ups and other emerging value-based players do not have access to public datasets especially with government institutions. Rich open data could spur innovation especially as regards the use of AI and ML in agriculture.

> “Without private sector accountability, we may be left in a situation where private companies are designing their own AI-based modelling solutions, which push their own products.”
>
> An official from the India Department of Biotechnology, which leads FarmerZone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Chapter 4
Drones

Drones from the mechatronic world – unlike the male honeybee in the biotic world – are rapidly evolving to serve the needs of a new technological revolution triggered by Industry 4.0. Like many other technological innovations born out of war scenarios, modern-day drones have evolved by carrying destructive payloads (Crilly, 2011) that cause damage across enemy lines to carrying payloads that save lives (UNICEF, 2020). Furthermore, they help industries, governments, healthcare workers and farmers to perform their day-to-day operations and services with speed and accuracy.

A use-case demonstration by Amazon of delivering a lightweight package to the customer's doorstep by drone triggered worldwide interest. Many commercial entities, governments and non-profits are now considering integrating drone services into their daily operations to improve efficiency.

Although drones are typically used to deliver payloads, their true strength is found in their ability to capture remote sensing data and use it to deliver actionable intelligence. For example, drones equipped with a multispectral camera can capture crop spectral data, which can be used to monitor crop health. A connected ecosystem that integrates drone data with other datasets and then delivers customized intelligence is actively sought after across several industries such as infrastructure, agriculture, insurance, transport, mining, telecommunications, media, and entertainment. Among all of the industries, agriculture is emerging as the second-largest consumer of drone services (Faraz, 2019). According to PwC, global trends indicate that the agriculture drone industry has a potential market size of USD 32.4 billion (PWC, 2016).

India is one of the fastest-growing markets for UAVs in the world. Despite the fact that in the past the focus was predominantly on UAVs for defence, commercial uptake is expected to dramatically increase by 2021 (PTI, 2018). The UAV market in India is projected to grow at a compound annual growth rate of 18 percent during 2017–2023 (6Wresearch, 2017).

DRIVERS TO ADOPTION OF DRONES IN AGRICULTURE

In the agricultural sector, drones are used for the broad functional cases (i) geographical analysis; (ii) crop protection and input management; (iv) crop monitoring; and (v) risk assessment.

- **Geographical analysis:** The drone dataset combined with on-ground information can facilitate quick identification of soil nutrient profile, while the traditional method where soil sample testing involves a huge logistic chain of activities. A drone can also facilitate a more accurate assessment that pertains to soil nutrient needs of each farmer. Digital elevation model data and payload data from drones can help accurately delineate land and facilitate infrastructure planning.

- **Crop protection and input management:** The multi-fold application include:

  Seeds, fertilizers, and pesticides application: Drones armed with precise knowledge about the location are currently used to apply inputs in optimal quantity. This facilitates farm mechanization and reduces human exposure to harmful chemicals.

  Irrigation: Water stressed indices such as a moisture stress index, tasseled wetness indicators, for example, constructed from drone data help monitor water stress in a crop. Modern-day drone data is also combined with IoT sensors to remotely operate irrigation equipment and improve efficiency in input management.

- **Crop monitoring and management:** Multi-spectral data captured from drones is combined with other datasets and used as input in ML algorithms. ML algorithms are implemented to provide rich insights on soil health, crop health, and crop yield. ML is now also combined with IoT devices to remotely operate farm machinery and provide for end-to-end automation of farm operations.

- **Risk assessment:** Drones have now become an on-demand alternative to satellite-based remote sensing products (Wade, 2015). Drones equipped with Normalized Difference Vegetation Index (NDVI) cameras give farmers and financial institutions insights on plant health and productivity.

- **Damage assessment:** Drone services are being used to provide a credible assessment of crop damage caused by natural calamities, pests, or animal attacks. Drones provide an independent and automated assessment of crop damage, allowing for more transparency and accountability in crop damage claims (FAO, 2018a).

TRENDS IN USE OF DRONES FOR AGRICULTURE

Primary and secondary research for this report indicated that agri-tech companies and start-ups are either integrating drone services to enable their core business or specifically providing drones as an on-demand service. A deeper analysis of these services showed that three broad trends are emerging when it comes to the usage of drones in agriculture:

- **Farmer targeted services:** Most drone-based agri-tech companies are start-ups that prefer to work with FPOs since the consolidation of smallholding farms reduces the cost per farmer. However, there is an interesting change as individual farmers are reaching out to these companies for pesticide spraying services. The strength of drone-based services lies in its data analysis and insights, but a typical smallholding farmer is willing to pay only for tangible services like pesticide spraying.

Marut DroneTech uses drone for targeted aerial spraying of fertilizers and pesticides. Marut was able to reduce input cost from INR 15 000 per acre to INR 11 380 per acre.

SenseAcre uses drones to first capture data to identify exact location of weeds/pests, then drones are also used for targeted aerial spraying of pesticides/weedicides. SenseAcre could also reduce input application by 72 percent.

- **Drones for enabling Fintech:** The Steering Committee 2019 report on Fintech related issues, held by the Department of Economic Affairs of the Government of India, recommends the adoption of drones and remote sensing services by financial institutions (Department of Economic Affairs, 2019). It furthermore recommends incorporating these technologies either directly or through Fintech service providers who specialize in such services. These technologies help with delivering efficient credit and insurance services through the objective assessment of any discrepancies in self-reported cropping patterns and CCEs.

In 2016, when the Beed district of Maharashtra was affected by floods, HDFC ERGO General Insurance (M Saraswathy, 2017) took to an unusual approach to assessing crop damage. It deployed drones to assess the crop damage caused by the floods instead of sending a field inspection team. After this pilot assessment, it developed an app (Shobha Roy, 2018) to upload geotagged images from the field to get updates on the crop situation.

Fintech firms are using a combination of satellite imaging, weather, and yield datasets, as well as crop monitoring data from drones to accurately assess and settle insurance claims fairly made by farmers. The combination of these data sets is also helping them to create a farmer's credibility index for banks and lending institutions to disburse loans and take pre-emptive action when risks are perceived.

- **Drones in agricultural research:** There is an active collaboration between agricultural research institutes and engineering universities to complement each other's research areas. They are co-creating data libraries that can train ML algorithms powering drones to operate in a range of standardized conditions.

ICRISAT's GEMS (Genotype by Environment by Management by Society) team, along with local and international experts, is developing an open platform to provide quality phenotyping services underan internationally unified and standardized set of protocols, which can enable a rigorous comparison of results across partner networks. "Once the platform is intensively tested and fully established, we foresee UAV-technology enabling the transparent and cross-comparable phenotyping for environmental adaptation to accelerate crop improvement in complex semi-arid tropics (SAT) agri-systems (Priyanka Gattu and Sunita Choudhary, 2019)."

Dr Jana Kholova, Senior Scientist, Crops Physiology and Modelling, ICRISAT

CHALLENGES FOR SCALING DRONES IN AGRICULTURE

A newfound interest and enthusiasm for drone services on both the demand and supply sides was observed, but some barriers appear to be slowing down the upscaling.

- **Challenges for operators:** With the increasing demand for drone services in agriculture, a large number of drone operators are needed. However, there is a shortage of skill development centres because there are only a few authorized centres and trainers across the country. As of 30 January 2019, there are only 34 DGCA approved trainers on RPAS (DGCA, 2019). In addition, the high licensing fee and educational requirements could become barriers for rural youth to acquiring the necessary skills for jobs as drone operators in the future.

  The government gave a one-time opportunity (Harshil Agarwal, Prashant Prakhar and Huzefa Tavawalla, 2020) for non-No Permission — No Take-off (NPNT) compliant drones to register their devices on the Digital Sky platform, and 19 533 applicants registered their machines to obtain a Drone Acknowledgement Number DAN (Forum Gandhi, 2020). However, it is not entirely clear whether these drones will be allowed to fly and how NPNT will be implemented to permit take-off.

- **Challenges for domestic manufacturing and servicing:** Currently, there are only five domestic NPNT–compliant drone manufacturers in India. Most drone service providers and operators are accustomed to flying internationally popular drone brands and have not yet made their devices NPNT compliant. When compared to the domestic brands these drone companies, given their international presence, can quickly customize and cater to the niche requirements of various industries. In India, however, drone usage has not fully developed its true potential because of high costs and low availability of devices.

  Domestic drone manufacturing and servicing are in the early nascent stage, as compared to that of Chinese original equipment manufacturers (OEM) like DJI, which has scaled up in a very short time because of the strong ecosystem supported by the government. The current policy needs to strike a balance by tapping into the expertise of foreign-manufacturers and allowing for joint ventures between local and international companies. Also, a drone service value chain should gradually be established that extends from manufacturing to servicing such as that of the automotive industry.

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Chapter 5
Food safety

"Food systems begin with crop planting. Traceability technologies are essential for smallholder farmers in developing countries, where it will help deliver the missing personalized farm advisory services based on farm input purchase and use. Tracing farm inputs from the factory floor to the farm will help reduce the chemical footprint in food production and antibiotic use in livestock. It will be a win-win for farmers, food companies and consumers."

Ajay Vir Jakhar Chairman, Bharat Krishak Samaj (Farmers' Forum India)

To make food safe, all the hazards that make food unsafe for human health must be taken into consideration. Hazards can be due to poor agricultural practices, poor hygiene, and poor maintenance along the value chain. Unsafe food creates a vicious cycle of disease and malnutrition (FAO and WHO, 2019), in fact, contaminated food sources cause more than 200 acute and chronic diseases. Large contamination and visible food-borne outbreaks form only a small fraction of the true burden of food-borne diseases (FBDs). The WHO estimates that 33 million years of healthy lives are lost due to FBDs (FAO and WHO, 2019).

The State of Food Security and Nutrition in the World Report (SOFI, 2019) points to an increasing trend of both undernourished and obese people across the world. Nearly 1.3 billion people did not have regular access to safe and nutritious food in 2018 and therefore experienced some form of food insecurity. Global estimates revealed that malnutrition costs up to USD 3.5 trillion per year to the whole society. Current production and consumption patterns are unsustainable to provide safe, adequate, and nutrient-rich food to 9 billion people by 2050. Existing food systems contribute anywhere from 20 to 35 percent share to the global greenhouse gas emissions (GHG) and cause significant deforestation and biodiversity loss besides land conversion. Agriculture alone accounts for almost 70 percent of freshwater withdrawals and is a major cause of water pollution.

In the Indian context, about 100 million people fall ill every year because of FDBs. With 1 in every 12 persons affected the economic costs to the country range from USD 12–55 billion. If no proper policy interventions take place, it is estimated that the number of affected people could go up to 170 million by 2030. The Food Safety and Standards Authority of India (FSSAI) report in 2019 stated that ten states in India are ill-equipped in terms of the number of laboratories and capacity of staff to enforce compliance with food safety regulations of FSSAI for all their residents.

DRIVERS OF FOOD SAFETY IN INDIA

Change in dietary patterns

Rapid urbanization, globalization of agricultural markets, rising incomes, increased supermarket penetration and mass food marketing are encouraging changes in dietary patterns across India. Nowadays there is greater demand for packaged food, especially from the working-age population (Shankar *et al.,* 2017). Dietary changes in India are typical of the changes occurring in many other countries. With the rise in income people have shifted away from a low-cost source of calories such as cereals, to higher-value foods and expensive energy sources such as milk, meat, fruits, and edible oils. (Shankar *et al.,* 2017). The FAO (2004) report identified two distinct shifts in dietary patterns: (i) income changes causing diet diversification – consumers move from inferior sources to superior ones and also substitute some traditional staple food with non-staples; (ii) effects of economic globalization leading to diet globalization with increased consumption of protein, sugar and fats in the second stage (Pingali and Khwaja, 2004; FAO, a (2016a). There is clear evidence that India has now entered the second stage of transition with nutrition security being a prime issue compared to 1980s where self-sufficiency in food production was the issue (Pingali *et al.,* 2019). Indian diets are now becoming more westernized owing to rising income, demographic transition, urbanization and spread of retail chains (Pingali *et al.,* 2019). Evidence indicates a link between consumption of energy-dense foods and rising obesity cases and non-communicable diseases (Gavaravarapu and Nair, 2015; FAO, 2018b). Furthermore, consumers' preferences change with the evolving dietary patterns.

Consumer awareness and expectations

Awareness and importance of healthy diets have deeply penetrated Indian consumers' conscience. Indeed, modern lifestyles with reduced physical activity coupled with a rise in non-communicable diseases have put pressure on consumers to adopt safer and healthier dietary options.

Food retail industry

The rising demand for higher-value goods and processed foods has also coincided with the growth of modern supermarkets or mega-markets. The number of supermarkets in India increased from 500 in 2006 to 8500 in 2016, and India's retail industry is ranked as the sixth largest in the world. The increased proliferation of retail chains is affecting how India eats (Pingali *et al.*, 2019). The notable success of retail can also be linked to the emergence of a 600 million strong middle class, half of India's population. India's new middle class composed of nuclear families, working youth, and working couples increased the demand for quality food products.

Role of government

The National Food Security Act 2013 stresses the importance of quality as opposed to quantity, access, and affordability. Indian food safety regulatory body, The FSSAI is also playing a pivotal role in spreading awareness amongst consumers on food safety (Verma, 2017). FSSAI's Eat Right movement delves into three aspects of food safety: (i) safety, focusing on hygiene, unadulterated food products, reducing contaminants and food hazards; (ii) health, focusing on diversified healthy dietary patterns, fortification, reduced consumption of salt, sugar and saturated fats and eating regularly, limiting the quantity; and (iii) sustainability, focusing on the promotion of local and seasonal foods, preventing waste, and conservation of resources during production processes (Agarwal, 2020). In a typical Indian household context where semi-processed food is purchased in small quantities from a local vendor in a non-packaged form, the adulteration of food becomes a major challenge to deal with (Gavaravarapu, 2019). About 11 percent of all foods sold in India are estimated to be adulterated (Gavaravarapu, Smith and Rimal, 2013).

Rise of social media

The increased incidences of adulteration and contamination reported on social media has put tremendous pressure on food and beverage manufacturers. In fact, the increased use of social media also saw a concomitant increase in the public demand for transparent food safety risk information (FAO and WHO, 2015). There has been a significant impact of social media on the brand value whereby it is encouraging retail companies to adopt higher standards. However, social media is a double-edged sword. The recent trend also points to the higher circulation of fake content on social media, which needs to be curbed. Pawan Agarwal, CEO, FSSAI stated: "such news creates fear amongst the public at large and erodes their confidence in the food control system of the country."

TRENDS IN FOOD SAFETY

The current production system needs to change in order to meet the requirements of two-stage diet diversification (Pingali and Khwaja, 2004). First, there is greater demand for the supply of domestic products. As a large portion of the food sourced and sold in India comes from millions of small and marginal farmers, it is difficult and costly to check the quality of agricultural produce.

With no standard cost-effective mechanism to objectively check the food quality, there is no incentive for either farmers or traders to adhere to food quality standards. This, however, changes with the advent of technology as it can facilitate consolidation and realize the benefits of economies of scale. Farmers also need to respond to satisfy the demand for new diets representative of global dietary patterns, as the country enters the second stage of diet diversification.

Second, integration across the supply chain becomes very pivotal between farmers, processors, distributors, retailers and consumers especially because it must efficiently cater to the changing demands of society (Pingali and Khwaja, 2004). Technology enabled start-ups to have played a very essential role in enabling this integration and creating value for the stakeholders in the agri-chain.

Third, with rapidly changing climatic conditions as well as dietary choices and demographics, there is immense pressure on the food production systems to produce more efficiently with a limited number of resources. Technology can play a vital role in bridging the asymmetry information gap in the current food production system and promote the more efficient utilization of resources. Broad trends observed in the food safety sector in India include:

- **Supply vs demand interventions on food safety:** On the supply side, issues with transparency and efficiency in agricultural value chain put farmers and consumers at a great disadvantage (Tripoli and Schmidhuber, 2018). Furthermore, the fragmented and unorganized nature of India's farm production system makes it difficult for a conscientious consumer to know the origin of the food on their plate and how is it produced. Although GAPs have been established, the enforcement and inspection mechanism of GAPs has largely been a paper-based process. Consumer awareness and the demand for certified products have pushed the actors in the supply chain to invest in traceability and facilitate food safety. Technology is enabling the adoption of GAPs, certification processes and ensuring traceability. Moreover, the emergence of technologies like the blockchain has a positive impact on food safety, quality and sustainability (Tripoli and Schmidhuber, 2018). There are also a few start-ups in India that have embraced blockchain to maintain a single source of truth for all the stakeholders involved in a value chain (Yes Bank and FICCI, 2018).

Blockchain can facilitate tracking the provenance of products, carry detailed attributes of product production and management processes across the agri-value chain, and ensure authenticity.

On the supply side, interventions on food safety are taking place, while on the demand side; start-ups are emerging with Do It Yourself (DIY) testing kits.

INTERVENTIONS BY INDIAN COMPANIES IN FOOD SAFETY ASPECTS

- eFresh uses digital tools to communicate information on global standards to local FPO. eFresh facilitates digitalization of transactions across the Agri-chain right from sowing seed to sale to the end-consumer.

- TraceX's blockchain platform connects all stakeholders – farmers, FPOs, food processors, financial institutions, logistics providers, and others, involved in a value chain. TraceX promotes efficient money management as the entire chain of interactions across a value chain are digitalized.

- Through Intello Labs' smartphone application, a player in the ecosystem uploads the image of the agricultural produce, which is analysed by a proprietary deep learning algorithm to grade the quality of a produce.

- DATAGREEN, a product by SOURCE TRACE, digitalizes the entire transactions and provides access to such information to certification authorities. Ready-to-use certification templates are made available to FPOs/farmer groups on the digital platform.

- cFog uses IoT sensors to ensure that shrimp farmers get a high yield. On other Stellapps applies IoT sensors to monitor milk quality.

As regards the central question of how technology companies are enabling adoption, there is evidence that among small and marginal farmers aggregating through FPOs are being promoted. This type of approach towards promoting cooperatives and other farmer organizations is a strategy also advocated by FAO (FAO, b (2016b). Targeting FPOs will help achieve the benefits of economies of scale and reduce the cost of technology for each farmer. eFresh, TraceX, Maruti Dronetech, SourceTrace and other players are partnering with FPOs to deliver digital solutions. FPO farmers are participating in an integrated value chain, which previously was not possible due to lack of access to finance, market and cost of compliance (Tripoli and Schmidhuber, 2018).

- **Food safety lens from production vs consumption side:** Food safety is largely seen through the lens of the supply-side – reliant on producers, processors, handlers and retailers – and there is complete lack of knowledge of how the consumption side factors influence food safety such as the cooking process, cross contamination and safe storage (Gavaravarapu, Smith and Rimal, 2013). Studies by the National Institute of Nutrition in the Indian context showed that although 90 percent of household food preparers wash their hands before cooking, over 75 percent do not use soap. Therefore, handwashing is more symbolic than an actual process of eliminating contaminants (Gavaravarapu, 2019).

- **From government responsibility to shared responsibility:** The FSSAI has only 131 certified laboratories for a population of over 1352 million, which is much lower than the number of laboratories per million in China, United States of America, etc. In a traditional regime, it is the unique mandate of government to ensure food safety.

However, the changing global norms and consumer expectations have led to practices where even ecosystem players such as farmers, processors and FPOs participate in sharing responsibility for food safety. Digital technology provided a platform where multiple stakeholders can interact seamlessly, which previously was not possible. Furthermore, the emergence of technology like blockchain provided an opportunity for the industry to explore new ways to address food safety issues. By enabling transparency and recording of data on quality, safety and sustainability aspects across the agri-chain, digitalization will help businesses and government to track compliance with domestic and global standards, and also improve the ability to trace the source of plant and animal diseases as well as control it. The certification process becomes simple, automatic and faster with the use of technology (Tripoli and Schmidhuber, 2018).

- Intello Labs smartphone application uses proprietary deep learning algorithms to grade the quality of an agricultural produce. Use of the product across a value chain also helps in identifying the stages of high risk and take corrective measures.

- **From resource intensive practices to resources conserving practices:** This aspect of the food safety dimension, often neglected, is an on-going conservation about resources in production processes. Globally, over one-third of the world's farmland is degraded, and agriculture alone consumes 70 percent of the world's freshwater. Agricultural sector contributes 20–35 percent of the world's GHGs (FAO, 2018b). The emergence of technologies, however, has provided an opportunity for the stakeholders in the agri-value chain to engage in sustainable practices. Start-ups in India are increasingly focused on reducing the cost of cultivation for farmers and to conserve limited natural resources.

- Marut Dronetech uses drones for input spraying at precision locations where deficits are observed.
- The IRRI's Rice Crop Manager tool adopts soil based nutrient principles for input application.
- cFog uses IoT sensors to monitor oxygen requirements and helps in energy conservation.
- AgNext and GramWorkX use IoT sensors to monitor soil moisture and estimate water requirements.

- **From public sector to private sector:** Success stories in the food safety sector in India have also emerged in the public sector. A case in point is the rise in the popularity of Amul. Today, however, niche companies are emerging from the private sector area to carve out their position in the market. There are over 4200 start-ups from the private sector in India today (Yes Bank and FICCI, 2018). Many of these dynamic start-ups are helping in early disease/pest surveillance. Global evidence of pest and disease epidemics negatively impacting quantity and safety of food sources is available, therefore, the role of early detection becomes very critical (FAO, 2019b).

- Amul is a popular dairy cooperative formed in 1947 and owned by over three million farmers in the state of Gujarat. It is a popular food product marketing organization that sells milk-based products across the country and is a market leader in many areas where it operates. Amul's cooperative dairy model is replicated across many Indian states.

- SkyMet uses IoT sensors to monitor soil moisture, soil temperature, leaf wetness and solar radiation. Kalgudi deploys ML algorithms to maximize the value for stakeholders involved in agri-chain e.g. if a particular farmer is interested in knowing the solution for thrips (pest), the platform maps out other farmers in the geographical proximity who might also benefit from the solution and make it available for them also.

- **From non-inclusive to inclusive platforms:** Traditional technology platforms benefitted only the large farms while excluding the small and marginal farms. However, new waves of technologies are inclusive. The increasing penetration of smartphones coupled with falling data prices are providing an enormous opportunity to deliver agro-advisories through mobile platforms. Start-up companies are engaging in innovative ways to include small and marginal farmers in a value chain.

- IRRI uses existing extension officers to deliver soil advisories generated from Rice Crop Manager. IRRI has partnered with PAD to disseminate this information through SMS and voice calls.

- cFog uses IoT sensors to monitor crop health and send advisories through SMS and smartphone alerts.

- Kuza uses village youth to deliver agro-advisories through video messages developed in a local language.

- Use of ML to monitor quality of a produce: Several start-ups are using imagery recognition techniques to assess the quality of produce thereby ensuring better price realization for farmers. Instead of rejecting an entire lot, imagery analytics accurately distinguishes the good lot from the bad. The algorithms can also be used to grade the quality of produce compared to the traditional model, where farm produce is tested in a laboratory setting requiring both staff and infrastructure. The use of ML, therefore, is minimizing human intervention and is leading to precise quality estimation.

- Intello Labs uses advanced deep-learning techniques to monitor the quality of farm produce based on the imagery collected through a smartphone.
- AgNext scanner can grade quality of farm produce (tea, coffee, and spices (turmeric and ginger).

CHALLENGES IN SCALING DIGITAL TECHNOLOGIES FOR FOOD SAFETY

- Newer ways of grading agricultural produce need to be accepted. Although the effectiveness of image and sensor-based quality assessments has been proven, farmers continue to rely on traditional laboratory testing for grading services owing to non-accreditation to these new age methods.
- Prevalence of multiple regulatory authorities without harmonization of standards increases the cost of adherence for producers.
- The major challenge is the need to digitalize the entire farm-to-fork supply chain through use of digital technologies and platforms coupled with capacity development of various stakeholders, and this will require significant investments.


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Chapter 6
Fintech

The world of Fintech covers a wide range of financial services such as mobile payments, peer-to-peer lending, cryptocurrency, insurance, and credit aggregators that traditionally used human capital and now uses technology (Department of Economic Affairs, 2019). Fintech companies are also positioning themselves as an aggregator of financial products. They are expanding the agenda of financial inclusion by helping customers choose the right financial product (RBI, 2019). The expansion of access to finance continues to be one of the most popular options for reducing poverty (Wang and He, 2020). Evidence from across the globe indicates that financial inclusion has a multiplier effect in boosting income, reducing poverty and inequality (RBI, 2019). The Asian Development Bank (ADB) report, of 2017, finds that Fintech could meet 40 percent of the unmet need for payment services and 20 percent of the need for credit in Asia. The report has also found that an increased uptake of Fintech can also increase the GDP of a country (McIntosh and Mansini, 2018). In the Indian context, Fintech is still at a nascent stage; 64 percent of the Fintech organizations have been setup during the last 3 years and only 7 percent of them have turned profitable. The positive news, however, is that India has the second-highest global Fintech adoption rate and is behind only China (Yes Bank, 2018).

The agricultural sector is one of the priority areas where Fintech companies are playing a critical role in driving agricultural finance, given the huge gaps in institutional finance (McIntosh and Mansini, 2018). The NSSO (2013) survey revealed that almost 40 percent of loans are secured through informal sources and 26 percent through money lenders in India. Non-institutionalized finance leads to a higher cost of credit and continued indebtedness. Over 52 percent of farm households are indebted to the Government of India. Despite priority sector lending and large budgetary allocation to agriculture, only 15 percent of farm households receive a loan from institutional sources (Department of Economic Affairs, 2019). However, this myopic way of viewing Fintech's contribution to agriculture in the form of institutional finance limits the understanding of how Fintech is improving productivity across the agri-value chain. A Government of India report on Fintech identifies three key areas where Fintech is driving changes in agricultural sector, namely credit, insurance, and land records (Department of Economic Affairs, 2019).

- **Credit:** Fintech companies are partnering with FPOs, cooperatives, and other organizations in rural areas to identify credit needs of farmers. AI helps serve those outside the institutionalized financial system by using alternate information to build the risk profile of such customers. Few companies use social media data, psychometric tests, and web browser history while few others use transaction records, SI, weather data, agronomic surveys, and demographic features, to build risk profiles. Fintech companies are also using digital data trials to assess the credit-worthiness of customers, who otherwise do not have any documentary proof of income (RBI, 2019).

- **Insurance:** In the insurance domain, Fintech companies are working with input companies and other ecosystem players including the government to increase uptake of insurance products. Fintech companies are also increasingly using weather, yield, and remote sensing datasets for claim processing and correcting discrepancies in self-reported cropping patterns and crop-cutting experiment process. Using geolocation and telemetry data, insurers can conduct a risk analysis. This reduces the problem of adverse selection and lowers overall risk.

- **Land record modernization:** Bank credit for the agricultural sector is based on land ownership. The National Land Record Modernization Program (NLRMP) aims to digitalize land records and lay the foundation for conclusive titling. Fintech companies are also digitalizing the land record data.

Apart from these three areas, evidence indicates that Fintech companies promote the concept of micro-savings enabling a rise in savings, agricultural profits, and consumption (McIntosh and Mansini, 2018). Fintech companies are also playing an active role in promoting financial literacy, which keeps customers informed and allows them to browse available products, select the appropriate product for themselves and register a grievance in case of an issue (RBI, 2019). In India, some Fintech companies like PayTM, Mobikwik, Citrus, and PayU are leading from the front.

DRIVERS OF FINTECH

Unified Payment Interface (UPI)

With UPI, a payment service launched by the National Payment Corporation of India (NPCI) in 2016, parties transfer money using a virtual address like an Aadhaar number or mobile number or virtual payment address linked to a bank account. Before UPI, payments had to pass through multiple channels before reaching an intended beneficiary (RBI, 2019).

Joint Liability Groups (JLGs)

JLGs, an important innovation in the last decade, seem to have overcome information asymmetry problems, which is a characteristic of the agricultural credit market. Joint responsibility for a loan prevents adverse selection while peer-pressure to payback prevents moral hazard problems (McIntosh and Mansini, 2018).

Increased smartphone coverage and enhanced fraud detection capacities

Over 25+ crore people own smartphones in India (Yes Bank, 2018) and this strong presence of smartphones has boosted the Fintech industry. Now payments are made using near-field communication (NFC) without the click of a button. Payment apps are also doing away with the need to type in passwords by increasingly relying on biometric-based authentication. Moreover, banks and card companies are triangulating data from mobile and card transactions to detect fraudulent transactions i.e. whether mobile and card are being used from the same location or not (RBI, 2019).

Unique identification number

The Unique Identification Authority of India (UIDAI) was setup to issue an Aadhaar number, a tamper-proof identity number for each resident, to all residents of India. Over 1.2 billion Aadhaar numbers have been issued to date. The Government of India is also at the forefront for using Aadhaar as a financial address to transfer benefits of government schemes (RBI, 2019).

Government policies

The Reserve Bank of India's small finance banks and payment banks policy furthered expanded the agenda of financial inclusion (RBI, 2019). Under Prime Minister Jan Dhan Yojana, 34.01 crore (3401 million) accounts were opened with deposits of INR 89 257 crore (INR 8925.7 million) up to Jan 2019 in just five years. The Jan Dhan Yojana, Aadhaar, and Mobile number (JAM) trinity has created building blocks for driving financial inclusion in India. Jan Dhan accounts (34+ crore) coupled with Aadhaar authentication enables electronic Know your customer – KYC (Yes Bank, 2018).

Apart from growth in the use of smartphones and reduced data cost, the launch of UPI and Aadhaar has proved to be key to enabling the growth of Fintech in India. The ADB Report 2018 stated that without a credible identity system, credit and insurance coverage runs into several challenges (McIntosh and Mansini, 2018).

Open data policies

The Application Programming Interface (API) allows two different IT systems to communicate with each other that are platform agnostic and highly scalable. API 4015 was created under the open data portal initiative of the Government of India (Department of Economic Affairs, 2019).

Emergence of distributed ledger technology (DLT) platform

The identification problem in warehouse development receipts or asset registries, wherein the lender is not sure whether the same asset has been promised as security to anyone else (McIntosh and Mansini, 2018), has been solved by the emergence of DLT. It acts as a single source of truth for all stakeholders in a value chain and prevents malfeasance (McIntosh and Mansini, 2018). DLT, by using trusted validation mechanisms, enables members of a community to record transactions in a transparent and decentralized manner. The transactions recorded in DLT are visible to all members of a network and are immutable. DLT eliminates the need for a third-party intermediary and reduces the risk of the manipulation of a record (RBI, 2019); it also enables fully traceable supply chains. Traceability in turn enables value creation for various stakeholders in the agri-value chain and the farmers benefit from higher prices and manufacturers and retailers enjoy high consumer confidence (USAID, 2019).

Access to capital

The Government of India established a start-up India fund and similar such funds at the state level, which exponentially improved access to capital for Fintech firms. Fintech funds rose to INR 2.7 billion in 2017 from INR 300 million in 2016 (Yes Bank, 2018).

FASAL

The emergence of the Forecasting Agriculture output using Space, Agro-meteorology, and Land-based observations project (Fasal) in India created a trickledown system for remote sensing datasets use on a local scale. Fasal is a comprehensive programme with pre-production forecasts generated at national, state, and district levels in India.

FINTECH TRENDS IN AGRICULTURE

Collateral based lending to lending based on cash flow and business

Information asymmetry is an acute problem in the agricultural sector because banks and insurance companies are unable to assess the credit risk of farmers. This information challenge for banks and insurance companies translates into cumbersome paperwork and processes posing significant barriers for farmers to access institutional credit. A large gap between investments in the agricultural sector and the realisation of profits, coupled with co-variate risks due to weather changes imposes a significant financial burden on farmers (ADB, 2017).

Banks and other financial institutions lending to agriculture experience high transaction costs. The size of the typical loan of smallholders is small, and the fixed costs associated with operating banks that can be accessed by smallholders do not make economic sense. Furthermore, banks are bound by strict KYC norms, which in the case of smallholder farmers could be difficult for them to follow. Also, owing to the absence of institutions such as credit rating agencies that track credit history and behaviour of farmers, banks are finding the process of risk assessment of crop loans to be increasingly precarious. The collection of granular data of the plot of each farmer and tracking the progress of the crops are prohibitively expensive. However, without such monitoring, banks run the risk of farmers diverting loans towards other non-income generating activities, thus increasing the default risk of the loan.

Fintech companies are using alternative datasets such as transaction records, SI, weather forecasts, and records and agronomic surveys to determine the credit worthiness of farmers. This has enabled a shift from collateral-based lending to lending based on cash flows, sale of produce, and business history. Fintech companies are also helping banks to monitor the status of crops efficiently using remote sensing and other novel datasets.

- DATAGREEN platform of Source Trace digitalizes transactions across the agri-value chain. The data from the platform can also be used for assessment of the creditworthiness of an individual farmer.

- The transactional data captured by FARMMORE platform is used by FPOs to avail credit. The bank used this data to project FPO income and accordingly structured a repayment schedule in line with the FPO's debt servicing capability.

Credit services by non-banks and use of big data for credit profiling

In the past few decades, private input suppliers and buyers have increasingly offered credit services. Nevertheless, efficiency in credit services is vital for their own sustainability and ICT helps in credit profiling of farmers by reducing the fixed cost for institutions such as banks and facilitate higher staff productivity (FAO, 2013a). Furthermore, it can automate credit profiling and enable institution staff to focus on other value generational activities such as due diligence checks. The use of ICT will reduce administrative and human resource costs to track and process numerous small payments among small and marginal players (FAO, 2013a).

- Dvara E-Registry (DER) on its digital platform has farmer land details and along with remote sensing data is used to determine the credit profile and to assess crop health.

- Trace X partners with financial institutions and input suppliers and provides farm input products directly to farmers rather than credit; this prevents use of credit for non-agricultural purpose.

Farm mechanization shifting agriculture from being labour-intensive to capital-intensive

Fintech companies are the front leaders for driving farm mechanization and enabling movement from labour-intensive to capital-intensive agriculture. The shift, however, puts small and marginal farmers at a disadvantage due to huge capital requirements. At the same time, Fintech companies are achieving a fair balance in terms of allowing credit and insurance for small and marginal farmers, thereby creating a win-win proposition for the sector as well.

In fact, Fintech reduces the cost of providing financial services (McIntosh and Mansini, 2018).

- Dvara E-Registry platform enables banks and lending institutions to remotely undertake risk assessments as well as monitor crop risks on a real-time basis. The need for physical inspections has been eliminated by the adoption of remote sensing data.

- Niruthi's product combines multiple streams of information like remote sensing, ground truth data, weather data (including nowcast) along with yield data to generate rich farmer level insights. Niruthi's platform is now used by insurance companies enrolled in implementing Prime Minister Fasal Bima Yojana (PMFBY). Instead of relying purely on manual CCEs, companies are relying on Niruthi to enable faster and accurate claim processing.

Piecemeal and fragmented solutions to integrated/bundled solutions

Fintech companies have quickly realized that instead of offering fragmented solutions such as credit whose value addition is debatable, they should promote integrated/bundled solutions whereby farmers can benefit from receiving all services under a single platform.

- TraceX aims to connect stakeholders across the supply chain and enable transparency, traceability and provenance using its blockchain platform. TraceX also promotes efficient money management as the entire chain of interactions across a value chain are digitalized. Using TraceX platform, financial institutions offer demand credit to input suppliers who in turn transfer product to FPOs, rather than giving as cash directly to the farmers. This ensures the credit is used for the right purpose.

- Stellapps use IoT devices to monitor milk quality; by digitalizing the information across value chain, Stellapps enables identification of inefficiencies in a value chain. Transactional information of a farmer minimizes the problem of information asymmetry and especially helps the banks to overcome the problem of adverse selection.

However, Fintech companies should realize that there are externalities as well due to bundling. There is some evidence indicating that bundling of microcredit with insurance will decrease the demand for loans, as customers in this case, farmers are disincentivized due to extra premium (Miller, 2019).

Enhanced risk profiling

Risks in agriculture are aggravated by weather variability, frequent natural disasters, uncertainty in crop production and prices, lack of infrastructure and market linkages; in addition, its coupling with cropping changes, landholding size, remoteness of clients, and lack of access to institutional finance only multiplies risks in agricultural sector.

Traditionally, insurance companies relied on manual surveys and CCEs to construct the risk profile of farmers; however, such practices are expensive and not scalable. Both yield and weather-based index products proved to be

unsuccessful in the Indian context. Yield products failed as they relied upon CCEs, which depended on small samples, and such survey results being largely unrepresentative. Weather-based products are not reliable and suffer from poor accuracies. The lack of automated weather stations also amplifies the risks in weather index products, as finer resolution data are not captured in those models.

Today, remote sensing data are used to redefine a sampling frame for undertaking crop cutting experiment surveys. Satellite datasets – temporal, multispectral, synoptic, and multi-resolution images – are vital to improving monitoring systems. ICT innovations facilitate remote monitoring of parameters such as rainfall received and crop health over large areas.

Insurance companies can use such remote sensing data to underwrite and correctly price insurance policies. The use of technology helps the insurance companies to collect farmers' data efficiently and pool similar such farmers to reduce the overall risk profile along with transaction and human resource cost (FAO, 2013b). Reduction in cost to insurance companies help price such products at an affordable rate.

- SatSure's SPARTA platform combines SI with weather, IoT, social and economic datasets, among many others to generate insights on sowing window, harvest window, crop stress and crop yield. SPARTA helps financial institutions in early risk identification, remote loan monitoring, product diversification.
- Skysense's Agriculture Risk Monitoring System (ARMS) helps to quantify risks associated with a parcel of land for financial institutions.
- Stellapps and cFog use IoT devices to monitor health of milk and shrimp, respectively.

Emergence of public-private partnership (PPP) models

The governments, both at national and state levels, are promoting PPP models as technology implementation involves huge upfront cost. The Karnataka Government partnered with IBM for tomato price forecasting using ML. This government has also setup an Agri-tech fund of USD 2.5 million to promote start-ups. The Government of Maharashtra in partnership with Skymet has established automatic weather stations to improve yield prediction, which thereby strengthen insurance claim processing.

Agristack platform

A GoI Committee on Fintech has called for the creation of the India Agristack platform. Agristack may include landowner data, borrowing history, cropping pattern, and income data among other information (Department of Economic Affairs, 2019).

Emergence of chatbot solutions

Chatbots are increasingly relied upon by companies to service customers efficiently at no additional cost. NLP is being used by chatbots to increase the quality of engagement with customers (RBI, 2019).

CHALLENGES TO SCALING FINTECH IN AGRICULTURE

Uncertainty in farmers' income

A USAID study found microinsurance products need to recognize the seasonality of farmers' income to be successful. Studies revealed that there is a greater uptake of credit when the loan repayment is scheduled after harvest. Similarly, such a surge is also seen in the uptake of insurance products when insurance premium payment terms are deferred (Miller, 2019).

The financial products designed for farmers therefore could take a livelihood approach rather than purely crop loans. This is especially critical since agriculture linked incomes/profits are realized only towards the end of a crop cycle, whereas the investment is staggered all through the crop-growing cycle.

Human interface

The USAID study found that remoteness of availability of credit products translates into the use of credit for a purpose not originally intended. It was also reported that technology players should understand the importance of human touch-points especially when the trust in technology is low (Miller, 2019). In the Indian context, the uptake of agro-advisories is greater when delivered through peer farmer groups than through a digital platform.

Heterogeneity in farmer profiles

Technology enables easy scaling among farmers with similar needs. However, in rural areas farm households are generally characterized by heterogeneous needs and poor connectivity, making scalability a huge challenge. This is also the reason for the slow scale of digital financial services (DFS) solutions in agriculture despite showing promise (Miller, 2019).

The USAID study also found that several DFS solutions fail to deliver primarily due to lack of concern for the value-added services required by farmers. A farmer is unlikely to borrow if they are not confident about access to high-quality inputs or a strong market for selling their produce. In rural areas, where traditional financial services have been informal and group-based, the impact of DFS can be negative as well (Miller, 2019).

Limited funds

Although access to equity funding/risk capital showed exponential growth, there are limited funds available for firms in proof of concept and the early stage. (Yes Bank, 2018). The benefits of implementing DLT type solutions are dependent upon the network effect and can entail a high upfront cost (USAID, 2019).

Fragmented and informal markets

A highly fragmented supply chain increases distribution costs (USAID, 2019). Traceability solutions are largely confined to exported goods rather than in domestic markets where there is less demand because of lower standards, low enforcement, low consumer demand, and prohibitive costs for implementation owing to fragmented and informal markets (USAID, 2019). The challenges of scaling blockchain applications include: (i) requirement of sophisticated supply chain systems in the form of origin labelling; (ii) RFID tags; (iii) secure packaging; and (iv) intermediary networks (McIntosh and Mansini, 2018).

Regulatory complexity

Fintech companies in India recognize that meeting the regulatory standard is a major challenge (Bank, 2018).

Price sensitivity

The adoption of most solutions is problematical, as it is difficult to know how much to charge farmers owing to price sensitivity and the farmers' inability to pay. The USAID study also reported that subsidy continues to be a critical success factor as regards driving adoption among small and marginal farmers because of the economics of smallholder farmers (Miller, 2019). Consequently, Fintech companies resort to grants or outside funding to compensate for the lack of a viable revenue model (USAID, 2019). In addition, evidence collected in India indicates that indexing products like rainfall-insurance will enable farmers to shift from subsistence crops to cash crops; however, in order to generate enough demand, insurance products must be heavily subsidized (Miller, 2019). Moreover, to increase the uptake one needs to understand whether constraints are supply-driven (poor design of products) or demand-driven, or if they are caused by the lack of financial literacy or poverty of the farmers. (Miller, 2019).

Fintech needs to achieve an acceptable balance between promoting Fintech for consumer benefit and ensuring protection against new and emerging risks, while at the same time embrace technology. Most financial products are structured to hide risks e.g. the internal rate of return for many insurance products is a mere 3–4 percent, far less than advertised returns of insurance products. Closing regulatory gaps and arbitrage opportunities are essential for protecting the interests of the end consumer (RBI, 2019).

Chapter 7
Precision agriculture

Millions of small-holder farmers with poor access to education and information continue to be challenged when confronted by questions such as how to use their land, what to grow, how to grow, and in which market it is profitable to buy inputs or sell products (FAO and ITU, 2016). Farmers' reliance on rule of thumb, experience, local rumours, and instinct to make decisions leads to high risk and low returns. Timely access to relevant information is very important.

ICT currently has the potential to address the information gaps for small and marginal farmers. The advent of ICT has transformed agriculture from a labour-intensive profession to a knowledge-intensive one (FAO and ITU, 2016; FAO, 2017). FAO measures the success of ICT initiatives by their ability to solve an actual problem being faced by farmers (FAO and ITU, 2016). Precision farming is the application of data-based technologies such as satellite-based positioning systems, remote sensing, and IoT to:

i. optimize the use of farm inputs;
ii. protect the larger farm ecosystem; and
iii. improve the overall productivity.

With the identification of specific areas in a field the application of inputs can be well targeted, as opposed to the traditional model where inputs like fertilizers, fungicides, pesticides, herbicides, and irrigation are uniformly applied, ignoring any intra-field variability (EurActiv, 2015).

DRIVERS OF PRECISION FARMING

Emergence of geo-equipped farm machinery

Farm machinery, such as tractors, harvesters, sprayers, and planters are geo-equipped for the precise application of farm inputs, thereby reducing the need for human intervention as well as allowing for improved productivity and to overcome labour shortages.

Variable rate technology (VRT) systems

VRT is a site-specific application of inputs based on data collected from drones, satellites, and other devices. Farmers often do not use VRT due to the high cost of such systems. The irrational application of farm inputs caused a decline in output in India, in addition to an increase in the cost of cultivation. In view of this, the Government of India launched the Soil Health Card (SHC) scheme in 2015, where every farmer in the country was to be provided with an SHC every two years (Amarender, 2017). The availability of SHC encouraged farmers to adopt site-specific nutrient application practices.

Emergence of IoT sensors and satellite datasets

The availability of high-resolution datasets, the fall in internet access costs and high performing cloud-based processing power of AWS, as well as Google Earth led savvy tech users to remotely monitor the crop and generate site-specific recommendations (FAO, 2013b). IoT sensors deployed in the field to monitor soil acidity, soil temperatures, water requirements and data have been made available on farmers' smartphones for remote monitoring. Data from IoT sensors are also fed directly into farm machinery to completely automate farm processes and eliminate the need for human intervention.

Emergence of ML algorithms

The emergence of ML enables customized advisories specific to each farmer's needs. There is tremendous diversity in the use of ML algorithms in the agricultural sector with applications ranging from crop health monitoring, yield estimation, credit risk monitoring, and even quality grading to macro planning.

Labour shortage

Acute labour shortages due to urbanization and migration are pushing farmers to explore automation solutions. Nowadays, farmers are exploring the use of drones and IoTs to automate different farm processes such as irrigation management and chemical spraying. Such automation not only brings efficiency, cost saving and convenience to farmers, but it also has important environmental outcomes. Data-driven decision-making optimizes the use of input resources thus preventing environmental degradation and promoting natural resource conservation.

TRENDS IN PRECISION FARMING

Use of drones to facilitate targeted application of inputs

Companies and farmers are increasingly using drones for the application of fertilizer and pesticides. First, drones equipped with multispectral cameras can diagnose crop conditions. Second, drones equipped with sprayers supply a targeted application. This helps to reduce the cost of production and saves labour costs for farmers.

Trithi, Marut Dronetech, Senseacre, Piatrika Biosystems and Thanos are few start-ups that are using drone data to monitor crop health and for targeted spraying. Given the high capital cost, most start-ups are offering drones as a service and partnering with FPOs to aggregate demand and reduce cost per farmer through economies of scale.

Use of ICT tools for individual crop and farmer-based advisories

Many start-ups are seeing greater value in providing customized services to an individual farmer rather than sending generic messages. These companies are adopting a mix of ICT tools and traditional mechanisms such as partnering with local institutions/actors to disseminate intelligence generated from analysing large datasets. An impact study conducted by the IRRI also found that human-mediated recommendation communication is more effective than SMS or video channel-based communication.

- The Rice Crop Manager tool developed by IRRI generates site-specific fertilizer recommendations after analysing field data on irrigation, soil health and yield. This information is communicated to farmers through several channels such as SMS and voice calls. IRRI also partnered with local Common Service Centre (CSC) operators and input dealers to convey information back to farmers.
- PAD uses two-way voice-based mobile phone extension system wherein farmers receive a customized and voice-based advisory, weekly. PAD also partners with local actors to increase the uptake of advisory.

Use of IoT sensors for automating crop monitoring

Start-ups are developing innovative solutions wherein IoT sensors deployed in a field monitor crop conditions, soil moisture, soil acidity, soil temperature, and pH, and communicate this information to the farmers' smartphone to enable remote monitoring. Companies are also automating processes such as powering water pump/oxygen pump to meet the needs of crops. Such approaches appear to be taking off in aquaculture, especially shrimp cultivation. Shrimp cultivation is a high risk-high reward business, as shrimp health is very sensitive to dissolved oxygen and feed management in ponds. Farmers must be constantly involved to generate profits. IoT based monitoring and automation systems, however, significantly lower the risk in shrimp cultivation.

- Eruvaka and cFog use IoT sensors to monitor oxygen requirements of shrimp. The process of operating aeration pump is also automated.
- KisanRaja and HiHillTech use IoT sensors to monitor water requirements of crop. Farmers can operate their water pumps remotely and are also alerted when there is an erratic power supply, motor malfunction, dry run, or theft attempt. Amnex uses IoT sensors to monitor crop health.

Use of ML to monitor crop health

Start-ups are using data collected from the smartphones to detect pest infestation in crops. This helps to provide an accurate assessment of the type of pest and, as a result, choose appropriate pesticide/remedy in a specifically localized area.

Plantix and Wadwani AI are using imagery data collected from smartphones to detect the pest infestation. The diagnosis information is combined with recommendations to eradicate pests.

CHALLENGES IN SCALING PRECISION FARMING

- Despite the phenomenal increase in smartphone users in India, its growth occurs mainly in urban areas rather than in rural areas. Internet penetration in rural areas remains at a mere 20.26 percent compared to 64.84 percent in urban areas. Poor infrastructure and lack of digital literacy impede the adoption of precision farming.
- More than 58 percent of the operational landholdings are less than 1 hectare in India. The high capital cost requirements to implement precision farming techniques make it difficult for small and marginal farmers to adapt.
- In order to reduce the cost to farmers, first, supportive government policies could promote the use of IoT sensors and drones in India to reduce the overall cost of adoption, as an alternative to the current practice where many of them are imported; second, policies could include the exemption of GST for the purchase of machinery for agricultural use.
- The government should promote the democratization of information so that rich datasets can be exploited by start-ups to provide value-based advisory services to farmers.


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Chapter 8
Remote sensing

Remote sensing is defined as the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand, Kiefer and Chipman, 2015). Remote sensing in simple terms is the observation of the earth's surface through SI and/or aerial photography (FAO, 2013c), which is generally used to create large ortho-images with a high level of detail as compared to SI. Easy configuration and on-demand deployment are some of the advantages of air-borne sensors, which is clear in the increased use of UAVs or drones. Restricted safety regulations and limited battery capacities, however, limit the application of drones to large areas where space-borne sensors i.e. satellites, usage is visible (GSARS, 2017).

The principle behind remote sensing is to capture and measure electromagnetic energy emitted from the earth. Electromagnetic energy is captured using sensors loaded on satellites or aircrafts or drones. The source of electromagnetic energy can be the sun (passive sensors) or a radar system with its own light-active sensors (FAO, 2013b). The energy data are pre-processed and handed back to users for their application (FAO, 2013c). Remote sensing cannot reveal all of the wavelengths due to their inability to penetrate the earth's atmosphere (FAO, 2013c). Multispectral sensors have the ability to capture data of more than one spectral band (FAO, 2013b).

The answer to the central question concerning how electromagnetic data is useful lies in the fact that objects, an area, or phenomenon emit in a spectral signature in a predictable and repeatable way. A spectral signature varies with time as plants grow or ocean productivity changes due to the change in the angle of sun's incident energy. It is pertinent therefore to consider both time and topography of a surface for monitoring. The ability to capture regular and repeated observations of specific locations on different scales gives satellite-based remote sensing a distinctive edge, as compared to other remote techniques (FAO, 2013b).

The characteristics of remote sensing data include: (i) accuracy of measurement; (ii) spatial extent or coverage; (iii) spatial resolution or granularity; (iv) revisit frequency; (v) time series; and (vi) timeliness. Although remote sensing data of high resolution is desirable, the high cost of storage and processing limits the usage by multiple parties. Steps in imagery processing are: (i) geographical and radiometric corrections of image data; (ii) ground-truthing; and (iii) image analysis (FAO, 2013b). The manifold advantages of remote sensing data include: (i) low cost of data collection at a large scale for

wide-range of hard-to-measure characteristics e.g. night light, precipitation, wind speed, flooding, topography, forest cover; (ii) higher degree of resolution than other data; (iii) wider geographic coverage (Donaldson and Storeygard, 2016).

DRIVERS OF REMOTE SENSING FOR AGRICULTURE

Nowadays, satellite datasets are a source of vast land information for a variety of users at varying granularity (GSARS, 2017). A quiet revolution is taking place to improve access to remote sensing datasets and the usage of such datasets across different sectors. The drivers for remote sensing adoption are discussed below.

USGS data policy change

The change in data policy by the United States Geological Survey (USGS) in 2008 to open up the Landsat archive to the public free of charge revolutionized the adoption of remote sensing data across many sectors. Although, the National Agriculture Statistical Services (NASS), an agency of the US Department of Agriculture, used remote sensing data for acreage estimation in the 1970s, the rapid adoption of remote sensing data did not take place until after the USGS data policy change (Bailey and Boryan, 2010). The availability in this day and age of high-resolution datasets and decrease in cost has in turn increased its adoption among users (FAO, 2013b), whereas initially, remote sensing was primarily used by the military. Several public data sources are currently available for earth observation such as Sentinel, ASTER MODIS (GSARS, 2017).

Climate change

As countries around the world are grappling with issues on how to deal with climate change, remote sensing data are helping to monitor the use of natural resources and proving to be a powerful asset. This application is furthermore a useful tool in the agricultural sector where profound effects of climate change are visible. The risks in agriculture cannot be eliminated by merely following GAPs or adopting good quality inputs. Risks due to change in climate in the form of rising extreme weather events, pest attacks, and price fluctuations, continue to have an impact on farmers' income and yields. Sound insurance policies can help overcome such risks and protect farmers' losses. Traditionally, insurance penetration is low due to a lack of credible historical data, low customer understanding on insurance adoption and renewal processes, fraudulent claims and the high cost of delivery in remote locations (FAO, 2013b). The emergence of remote sensing, however, provides an opportunity for financial institutions to access and monitor farmers' data at a low cost and provide a more efficient delivery of insurance services.

Reduction in handset and data costs

The critical component of remote sensing usage is the solid ground truth information (Bailey and Boryan, 2010). Over the decades, access to information costs less as data and mobile handset costs continue to fall (FAO, 2013a); the emergence of mobile phones has provided an opportunity to collect ground truth data at a low cost (Ray, Mamatha and Gupta, 2014). Furthermore, only very high resolution (VHR) imagery of lower than 5 m needs to be purchased while many other datasets of varying resolution (high, medium and low) are available free of charge (GSARS, 2017).

Adoption of sustainable development goals

Remote data collected from SI and drones help farmers to optimally manage farm resources. In addition, remote sensing data helps farmers to reduce the cost of fertilizers, pesticide, and water. With access to reliable, timely and quality information, farmers have improved their potential to achieve higher agricultural yields more than before. Information on soil stress, water stress and crop health indicators coupled with market access information datasets provide decisive inputs to various stakeholders in the agri-chain to maximize value (FAO, 2017).

Google and Amazon cloud computing platforms

Google Earth Engine and Amazon web services provide an interface to access and analyse remote sensing datasets without investing in huge computing infrastructure (GSARS, 2017). Cloud computing has therefore become a very powerful tool for developing countries who would otherwise be constrained by internet bandwidth limitations (GSARS, 2017).

Role of ISRO (Indian Space Research Organisation)

In India, crop forecasting using remote sensing data emerged in the 1980s; however, it was not until 2012 that the crop-forecasting programme Fasal emerged, as the comprehensive programme with pre-production forecasts at national, state and district levels. Launch of Indian satellites RISAT-1, INSAT and Resources at-2 also boosted the availability of remote datasets for India (Ray, Mamatha and Gupta, 2014).

ISRO developed Bhuvan,[6] India's first geo-portal, on the lines of Google Maps to provide a seamless integration of multi-temporal, multi-spectral and multi-platform images (ISRO, 2012). Bhuvan provides earth observation data and visualization services to the public as well. Since its launch in 2009 when Bhuvan provided satellite images and basic GIS functionality, the functions being offered today are quite diverse – over 6000 map services are offered under Bhuvan (SCC India Staff, 2016).

National Agricultural Drought Monitoring System (NADMS)

NADMS, developed by the National Remote Sensing Centre, enables real-time monitoring of prevalence, severity, and persistence of droughts at the district/block level. Remote sensing derived indices such as NDVI, Normalized Difference Water Index (NDWI), Shortwave Angle Slope Index (SASI) and soil moisture index (SMI) are used to assess drought.

TRENDS IN REMOTE SENSING

From research to practical application

Low accuracy levels, lack of skilled personnel and prohibitively high investment costs blocked the use of remote sensing datasets for practical world problems. However, with an improved ability to access and process remote sensing datasets, higher accuracy levels and low investment cost, as well as the uptake of remote sensing products have increased. FAO states that advances in imagery and IT capabilities have enabled remote sensing to transition from a research effort to a production process. Today users also combine a variety of remote sensing datasets to generate unique insights e.g. optical sensors are used for differentiating crop types while active sensor SAR data are more often used for plant structure analysis. The integration of both datasets will increase accuracy (GSARS, 2017).

6 Bhuvan, Indian Geo-Platform of ISRO [online].

From macro to micro

The success of remote sensing datasets depends on their adaptation to local systems and conditions (GSARS, 2017). Diversity in cropping systems, management practices and environmental factors means that remote sensing data needs to be geographically specific to enable precision farming (GSARS, 2017). The core aim of precision farming is to maximize profitability, but it can also tackle safety, health and sustainability issues in farming (FAO, 2017). The increased availability of high resolution (over 1 m and larger than 5 m) and very high-resolution (greater than 5 m) datasets, with large swathe and high frequency, are driving the adoption even in developing countries. High costs, investment in skills, resources and equipment, which deterred adoption of precision farming is now changing with the fall in costs (Tiwari and Jaga, 2012).

- Marut Drones uses combination of Drones, IoT and AI to deliver targeted services to farmers in the form of early pest detection, crop stress monitoring and input spraying through drones.
- SenseAcre uses drone to enable precision farming. SenseAcre offered suite of services having land planning, areal image capturing, weed and pest detection, aerial spraying, and crop analysis.
- Dvara E Registry provides accurate and verified granular data about a precise land parcel owned by a farmer under assessment.

From global to local

Agriculture is a location-specific activity. The information can create an impact only when it is locally relevant and addresses the needs of farmers. The need for customization of content to local context is greater than ever (FAO, 2017). The USAID Famine Early Warning System (FEWS-NET), Global Information and Early Warning System (GIEWS) and such similar systems on the global scale use a coarse resolution that lacks attention to detail in crop classes and validation (GSARS, 2017). The Fasal programme in India pointed out a trickledown in the use of remote sensing datasets at a local scale. Fasal emerged as a comprehensive programme with pre-production forecasts generated at national, state and district levels in India.

- Skysense, a product of SkyMet, blends data generated from various sources such as IoT sensors (including AWS), remote sensing, drones, crowd sourced ground truth data and governments to provide historical, current and forecasted weather information products to the agri-value chain users across India.

Non-optimal to optimal sampling

Nowadays, remote sensing data is also used to redefine the sampling frame for undertaking surveys e.g. the elimination of non-crop land extent from agricultural survey and reallocation of samples to remaining strata will improve stratification efficiency at no cost in most of the sampling designs (GSARS, 2017).

Current CCEs do not take into account crop conditions and this could lead to sampling errors. Remote sensing driven CCE aims to correct for such sampling issues and improve the accuracy of CCE in yield prediction.

Satsure's platform is used by insurance companies to efficiently select plots for conducting CCEs to ensure high accuracy and representativeness of results.

Rise of Fintech with the embrace of remote sensing

The ability to meet the food needs for all is critically dependent on our ability to understand the production trends, which in turn are influenced by coverage and yield. Conventionally, crop area and yield estimation are time-consuming, costly, tedious and suffer from human bias. The need for reliable, rapid, accurate and detailed mapping of production and yield data made the application of remote sensing necessary (GSARS, 2017). In this context, satellite remote datasets offer temporal, multispectral, synoptic and multi-resolution images that can improve monitoring significantly (GSARS, 2017).

ICT innovations facilitating remote monitoring of parameters such as rainfall received and crop health over large areas, brought down the cost of monitoring for insurance companies and increased uptake. Traditionally, the major reasons for low insurance penetration include: (i) frequent severe weather-related events; (ii) lack of reliable historical data; (iii) low customer understanding, adoption and renewal; (iv) fraudulent claims; and (v) high cost of delivery in remote locations (FAO, 2013a).

In this respect, ICT can help insurance companies collect reliable data and monitor risk events. ICT facilitates the reduction of basis risk for instance, risks based on indexed outcomes to calculate pay-out events and not linked to actual field outcomes. The use of average rainfall data for example may result in a pay-out to farmers who do not incur losses; this represents a cost for insurance companies and furthermore, farmers who have suffered are not paid. This is a deterrent to the future uptake of such policies, but the use of remote sensing data can reduce such basis risk. Insurance companies launched innovative financial products where losses are based on an index that correlates with parameters such as wind speed, and the amount of rainfall and yield loss. The information on such parameters is captured by using remote tools at a fraction of the cost and swiftly, as opposed to the traditional insurance models where loss is based on measurements on the field (FAO, 2017).

Insurance companies can use remote sensing data to underwrite and accurately price insurance policies. The use of technology helps the insurance companies collect farmers' data efficiently and also pool such similar farmers to reduce the overall risk profile along with transaction and human resource cost (FAO, 2013a). Reduction in cost to the insurance companies can help price such products at an affordable rate.

- SatSure's SPARTA platform combines SI with weather, IoT, social and economic datasets among many others, to generate insights on sowing window, harvest window, crop stress and crop yield. SPARTA helps financial institutions in early risk identification, remote loan monitoring, and product diversification.

- Skysense's Agriculture Risk Monitoring System (ARMS) helps to quantify risks associated with a parcel of land for financial institutions. SkyMet also uses drones to provide crop loss estimates.

- DATA GREEN, a SourceTrace product, digitalizes transactions across the agri-value chain and enables determination of creditworthiness of an individual farmer. Using harvest date, yield estimates and crop calendar, it can also estimate crop volume. The estimation is done on an aggregated dataset of satellite, on-ground, and survey data.

- Nairuti's product uses remote sensing data to monitor crop performance and estimate yield. This data helps bankers to know whether the credit is used for intended purpose and for insurance companies to protect losses.

Strengthened early warning systems

Confidence in the early warning system will increase as more data become available and processed, however, this will shorten the window for taking mitigating measures. The fundamental tension between timeliness and confidence can be resolved with the use of remote sensing datasets, which brings both richness and prompt availability to the front (GSARS, 2017). Provision of timely updates on local weather conditions can make the difference between a failed or successful harvest (FAO, 2017).

The support to a million smallholder farmers for the fight against pest/disease is fundamental from a global food security point of view, as support is provided for over one-third of the world population. The estimated reduction of a mere 1 percent in the 30 to 40 percent losses every year due to pest can supply adequate food for many. At the global scale, the FAO Locust Watch is one of most used applications for monitoring and forecasting locust development (GSARS, 2017). Indian start-up communities have developed similar applications, highlighted in the box.

- SatSure's SPARTA platform combines SI with weather, IoT, social and economic datasets among many others to generate insights on sowing window, harvest window, crop stress and crop yield. SPARTA helps financial institutions in early risk identification, remote loan monitoring, and product diversification.

- Skysense's Agriculture Risk Monitoring System (ARMS) helps to quantify risks associated with a parcel of land for financial institutions. SenseAcre's product uses drone data as input in proprietary ML algorithms to detect weeds and pests in the crop, and uses drones for targeted spraying.

- SourceTrace generates advisories on weather forecasts, crop calendars, pest and disease prevention/control, and market alerts, and communicates through audio/text messages after analysing data from satellite, on-ground and survey data.

- Nairuti's product uses remote sensing data to detect crop stress. Input companies are also provided such data so that they can mobilize resources to deal with crop stress.

CHALLENGES IN SCALING THE USE OF REMOTE SENSING IN AGRICULTURE

- Remote sensing data policy, 2011 envisages a critical role for intermediaries such as NRSC in aggregating and distributing the earth observation (EO) data rather than encouraging open data publication and distribution.
- There is a definite need to upgrade current data analytics platforms in the country, which requires weeks to process data compared to global platforms, that analyse and distribute the data within 5–6 hours of data acquisition.
- India needs to strengthen its position especially to ensure access to high resolution datasets (resolution of below 1 meter) wherein significant competition from private players already exists wherein 0.3-meter resolution datasets are provided.

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AGNEXT

WEB
https://agnext.com

PROBLEM

In any trade, for two parties to be able to agree on a fair price it is imperative that they agree objectively on parameters deciding the price. In less fragmented agricultural markets this requirement has resulted in high-end expensive equipment, used at the aggregation points to measure the pre-decided quality parameters that become key inputs for pricing a commodity.

However, for developing countries with highly fragmented markets, the value chain still depends on a manual quality assessment process, owing to the lack of cost-effective technologies customized for field conditions. Consequently, the process tends to be archaic, human intensive and often biased, which leads to high friction resulting losses in almost every step of trade cycle (Figure 1).

SOLUTION

AgNext provides the most advanced solution, Qualix, for development in modern-day agriculture, a sector in desperate need of change. Qualix is an award-winning integrated platform for agribusinesses that instantly assesses quality by using modern technologies and data sciences. Qualix helps organizations to leverage the decision-making capabilities by compiling data pertaining to quality for specific commodities across the value chain for example, collection centres, processing factories, procurement, storage, and laboratory testing.

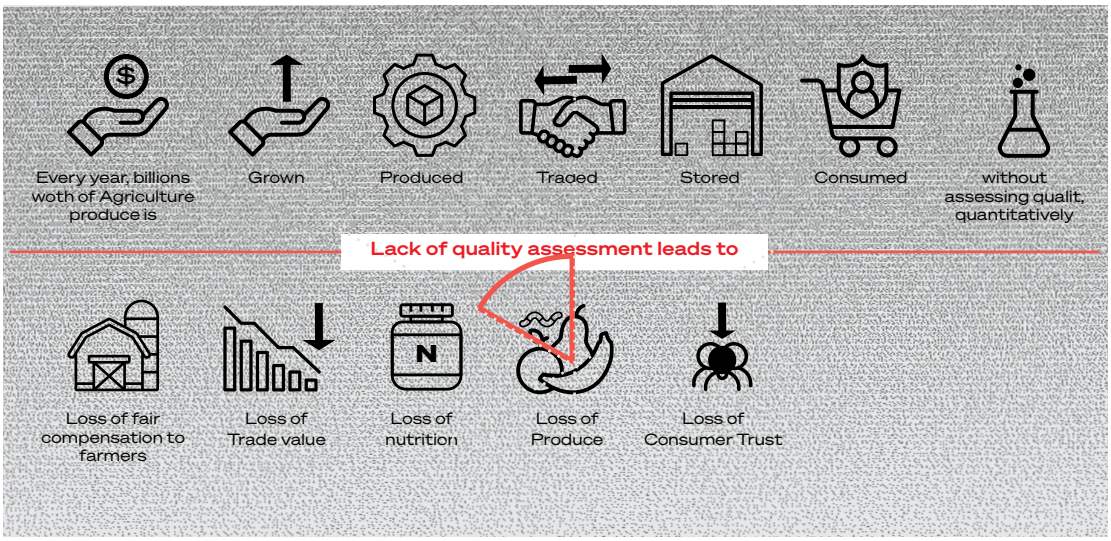

Figure A1
Effect of the lack of quality assessment

SOURCE: AgNext.

QUALIX - QUALITY AS A SERVICE

Qualix is a one-stop solution for quality control of most agricultural commodities such as grains and oil seeds (rice, wheat, maize), beverages (tea, milk), spices (turmeric, chilli) and animal feed.

- it provides guaranteed traceability through digitization of an entire supply chain;
- analyses supply chains, identifies critical control points;
- keeps track of supply chain;
- leverages the accountability through advanced analytics and reporting tools (Figure 2).

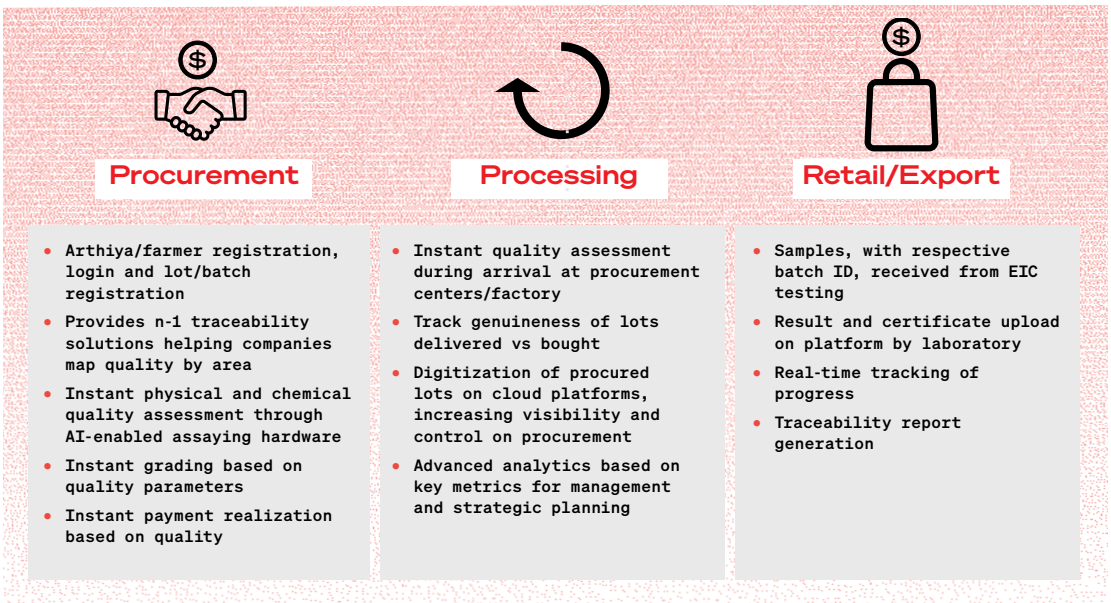

Figure A2
Supply chain of agri-commodity

SOURCE: AgNext.

Use-case: TRAgnext (for the tea industry)

For the plantation, AgNext proposes Fine Leaf Count (FLC) technology, the first of its kind in the industry. TRAgnext provides an instant quality grading capability through artificial intelligence (AI) based image processing to classify leaves, buds, shoots and other parts of the daily harvest coming to the factory. This cuts down on processing time and also ensures traceability by linking every transaction to the Qualix platform.

In addition, TRAgnext QTP has introduced transparency into the industry, ensuring that farmers are adequately paid and processors obtain the right quality.

Dairy Solution

AgNext technologies can analyse the chemical composition of milk (fat, SNF and protein) and, with a single scan of the milk sample, instantly provide results on whether the milk is mixed with adulterants such as palm oil, detergent, soda, or urea.

To date, there is no one technology available that can complete the full process for under 30 seconds. Because of the lack of technology, milk companies are unable to detect when value chain participants have adulterated milk, leading to wastage and most importantly, consumers totally lose trust.

Instant portable analysis ensures food safety, quality and traceability for the milk value chain, whilst the Qualix Platform ensures that the data integrates easily with all existing IT solutions. It has the flexibility to access farmer level data for any kind of business decisions (Figure 6).

Grain quality assessment

The AgNext portable grain quality assessment solution provides an instant and accurate chemical quality analysis of grains during procurement in the field or mandis. This effectively decreases the TAT (turn-around time) for farmers to have the lots tested and sold accordingly.

CHALLENGES

Convincing farmers and traders to rely on tech-based quality assessment was a challenge during the initial days, however this issue was overcome by providing continuous education.

AGROSTAR

STATES OPERATING IN INDIA
Maharashtra, Gujarat, Rajasthan, Madhya Pradesh and Uttar Pradesh

TARGET BENEFICIARY
Farmers, senior and middle management front-line staff of Agribusinesses

BUSINESS MODEL
B2F, B2B

PROBLEM

Farmers, mainly smallholders, lack easy access to good quality inputs and spend most of their time and money traveling anywhere from 5 to 50 km to buy them. Furthermore, farmers rely a great deal on inherited knowledge and peer-to-peer networks for important cropping decisions. Advancement in scientific knowledge on crops, soil, water and weather still need to be translated into personalized advisories, in order to guide farmers on their selection of ideal varieties and other inputs *vis-à-vis* their soil and agro-climatic conditions. Changing farmers' behaviour and enhancing the uptake of science-based interventions have been a significant challenge for a long time.

EXISTING SOLUTIONS

Farmers are dependent on local retailers for agricultural inputs like seeds, crop protection, crop nutrition, and farm implements. They also rely on local retailers for crop health diagnostics. Generally, farmers pluck infected plants, stems, or leaves and take them to the nearest retail store to seek the retailer's advice on chemical control measures.

Smallholder farmers' decision-making occurs in a highly complex social and environmental setting. Typically, their choices are based on their inherited knowledge and traditions when deciding about the crop, crop management and agronomy. In these changing times, the indigenous knowledge of farmers is not enough to cope with emerging threats such as climate change and new types of pests and diseases. Modern science-based decision support tools partly address some of these challenges, but their acceptance remains weak because of trust issues. Moreover, advisories tend to be generic due to the non-availability of plot-level granular data about soils and hyper-local weather. The government extension system continues to be scanty, and more often is not equipped with the latest technologies.

SOLUTION

AgroStar is a platform built to solve ground-level problems dealing with information gaps and accessibility of good quality agri inputs. AgroStar focuses on three consumer-centric pillars, that is, customized agri advisory solutions designed to help farmers increase the farm yields, availability of high-quality and original agri inputs, and home delivery of inputs to farmers. The platform is different from conventional players through its extensive utilization of technology and data to build scalable systems and processes to deliver its value propositions to farmers. AgroStar enables quick and easy access to good quality branded seeds, crop health and nutrition products to

farmers, even in the remotest parts of states where it operates. Typically, it is difficult for major brands to distribute their products in smaller and more remote villages, leaving no other option for local farmers but to rely on local substandard products. With AgroStar, farmers even in formerly inaccessible areas can access available products, advanced and latest knowledge and solutions for better crop management. AgroStar, through its toll-free call centre and the mobile app, deals directly with farmers and offers them a platform to buy any agri input of their choice listed on the platform. Its call centre enables farmers with feature phones to benefit from AgroStar's services. A trained pool of agricultural graduates works at the call centre under the supervision of a senior team of agronomists who solve the farmers' problems in real time. A distinctive feature of AgroStar is the importance placed on the participation of the team of agronomists in all crucial decisions. The platform integrates agronomy and scientific knowledge about crops and soils and includes the crop calendars while generating personalized advisories.

UNIQUE VALUE PROPOSITIONS OF AGROSTAR FOR THE FARMERS

- timely and instantly accessible scientific advisory for farmers to prevent and cure crop issues. This service is available through a smartphone app and a toll-free call, available in vernacular languages;
- wide variety, good quality, and original agri-inputs made available to farmers;
- doorstep delivery of farm inputs through an extensive last-mile delivery network;
- a unique mobile app platform for farmers to – connect and interact with each other, share farm stories, issues related to pests and diseases, and get real-time solutions through AgroStar's agri doctors and the community of experienced farmers;
- the platform offers agri inputs from over 200+ well known agri input manufacturers associated with AgroStar.

SOLUTIONS

AgroStar currently operates in the Indian states of Madhya Pradesh, Maharashtra, Rajasthan, Gujarat and Uttar Pradesh. The company has partnerships with over 200 input companies and lists over 3000 SKUs for these companies on its platform. In all of these states, AgroStar demonstrated a new channel for delivering farm inputs directly at the farmers' doorstep avoiding intermediaries. AgroStar uses its last-mile delivery network for the fulfilment of its order. Furthermore, AgroStar invests in creating fulfilment centres to facilitate pick, pack, ship, and timely delivery of inputs by storing inventory in every state where it operates. Before initiating any operations in new geographical areas, AgroStar generally organizes field meetings between its agronomists, field officers and farmers. These meetings are necessary for trust building and bringing about awareness of the numerous products and brands. The trust is further strengthened through order fulfilment by the last-mile delivery network and the constant advisories that keep farmers informed throughout the cropping season.

AgroStar initiates direct interactions with farmers when a transaction request is made through the app or through a missed call on a toll-free number. An agronomist returns the call to get more details about the nature of the queries. Recommendations are offered based on the information about soil

type, water availability, geographic conditions, and crop stage in order to grow a healthy crop and get better yields. The agri inputs, as per each order, are delivered to the farmers' doorstep by AgroStar's tech-enabled last-mile delivery network. Farmers can pay via cash on delivery or through various digital payment modes.

The system for farmers receiving orders at their doorsteps creates a very positive experience and reinforces the trust of farmers. Follow-up calls are also made to farmers offering guidance on how to use the products. Apart from instructions on how to place orders and receive extension support, the app also provides a social network platform for farmers to interact and post data. In the event of an adverse climatic event, farmers receive push advisories on crop protection and loss-mitigation strategies. Farmers who benefit from AgroStar spread the word to ensure that fellow farmers benefit from its services. This word-of-mouth promotion has played an essential role in rapid growth of AgroStar's customer base.

CHALLENGES OVERCOME

The initial ice-breaking stage to gain farmers' trust is slow. Through outreach programmes and constant communication through the apps, call centres, and interfacing with farmers during agricultural fairs, AgroStar receives feedback continuously from farmers so that it can improve its services. These efforts have helped to gain stakeholders' trust. "The biggest initial challenge was to gain the trust of farmers. As we gradually gained the trust, the positive spinoffs have been higher for us. New farmers get associated with us, thanks to the word of mouth" stated Shardul Sheth, CEO and Co-Founder of AgroStar.

HIGHLIGHTS

- use of original and quality agri inputs, complemented with scientific advisory from the agri experts of AgroStar, results in healthier crops, better yield, and reduced expenses;
- more than 3 million farmers across India onboarded to the AgroStar platform to seek scientific advisory and guidance and connect with fellow farmers through the social network on the app;
- toll-free number operational in five states in India – Maharashtra, Gujarat, Rajasthan, Madhya Pradesh and Uttar Pradesh;
- farmers are getting instant access to advisory and agri inputs through the toll-free number and the app.

ENABLING ECOSYSTEM ENTAILS

- support from government authorities;
- create an ecosystem for pushing digital transactions.

AMNEX

STATES OPERATING IN INDIA
Gujarat, Andhra Pradesh, Odisha, Maharashtra

TARGET BENEFICIARY
Farmers, Farmer Producer Organizations (FPO), governments and agri-businesses

BUSINESS MODEL
B2B, B2G, B2F

WEB
www.amnex.com

PROBLEM

Agriculture and dairy are the largest sources of livelihood in rural economy. Farmers engaged in these activities mostly derive their knowledge and skills from family, progressive farmers, and local extension officers. Over time, certain practices become intuitive or are taken from traditional methods, as they are based on the cumulative experiences of the community and ancestral farmers. However, traditional and indigenous knowledge are not able to help farmers cope with the new and emerging risks from climate change and weather variability, novel pest and disease infestations, and market volatility. Access to high quality and granular data on farms, soils, crops, and crop health on a real-time basis may help policymakers and governments to respond to evolving risks dynamically through targeted interventions. Moreover, historic and in-season granular data are essential to designing financial instruments such as crop insurance that protects farmers and rural livelihoods. Agriculture data are, however, largely collected manually by extension officers and often based on estimation. Information collected in this way is aggregated at the block, district, and state levels where key decisions are made based on this data. Manual data collection and aggregation are cumbersome, expensive and prone to discrepancies, which pose challenges to important activities such as policymaking, subsidies, crop insurance rollouts and claim settlements.

EXISTING SOLUTIONS

Decision making in agriculture-related activities is largely subjective and driven by human interventions. High-quality granular data enable a data-driven decision support system for farmers and support policymakers while designing interventions to mitigate risks involved in agriculture and allied activities. However, data infrastructure to support these types of cases is either non-existent, fragmented in silos, or inaccurate. Data collection and aggregation activities are most often ad-hoc and not systematic and prone to very serious errors.

SOLUTION

Amnex, an enterprise solutions company, works across high impact sectors providing solutions for various industries to transition into an era of digital transformation. Two of its focus industries are agriculture and dairy where it uses artificial intelligence (AI), machine learning (ML), internet of things (IoT), big data, and predictive modelling to manage these value chains.

In agriculture, Amnex's solution makes use of satellite imagery (SI) and data science techniques to support governments, insurance companies, and other value chain players with information on crop acreage, sowing, crop health, and crop loss assessment. The platform can also decipher and aggregate historic cropping information, weather data, soil data, irrigation information, market data, and other information from other databases. The platform can also fill gaps in data with SI and ML, which are rooted in agricultural domain knowledge. The solution has a farmer interface that combines farmers' traditional knowledge with technology, thus helping them make informed decisions to improve farm productivity and mitigate risk. The solution contains six wide-range core agricultural set of services:

i. Crop surveillance: This service enables farmers, insurers, banks, and agri companies to monitor crop growth, health, water stress, harvest readiness, and assess crop loss.
ii. Crop production estimation: This service provides farmers, insurers, governments, and other value chain players with estimates of crop yields based on satellite-derived vegetative indices data. This module also incorporates capabilities to support the Government of India's flagship crop insurance programme called Pradhan Mantri Fasal Bhima Yojana (PMFBY). This module also helps to optimize Crop Cutting Experiments (CCE) activity of PMFBY through satellite data-indices based smart sampling.
iii. Predictive analysis: Analysis using historical and current data provides farmers with intelligence on ideal sowing time, the most suitable crops to sow, real-time commodity market information, optimum fertilizer usage, and forecasts on early-season acreage.
iv. Agri IoT: Using field-based IoT sensors, it helps farmers quantify soil moisture and manage irrigation on the farm based on *in situ* soil moisture.
v. Climate-smart agriculture: This module supports climate-smart agriculture through plot level recommendations on crop compatibility, adoptive management practices and irrigation management. This module uses historical weather trends and data corresponding to a precise land parcel to enable this service.
vi. Agri-market analysis: This service analyses market trends in the agri commodity space to provide insights to agro input companies on estimating demand and supply.

All six-core services are packaged into the following three products:

i. Farmlive: precision farming solution, powered by IoT devices and high-resolution satellite and unmanned aerial vehicles (UAV) data to help farmers better understand their crop, soil, and farming practices. It ensures optimum usage of inputs through intelligent planning that would help farmers get better yields.
ii. CropTrack: farm advisory platform, aims to provide customized-technology driven agriculture advisory services to farmers and FPOs. It creates insights by leveraging satellite remote sensing, ML and advanced crop models, which can help farmers in crop planning, crop protection, best agriculture practices and farm input applications. This easy-to-use mobile application aims to increase farm income by improving farm productivity and reduce farm input costs.

iii. Agrogate: a web GIS-based application developed to provide agriculture advisory services for various stakeholders involved in agriculture-related decision-making process. It offers a holistic view of agricultural ecosystem. The ML driven insights offer greater visibility to decision makers in government to formulate optimal strategies for planning, distribution, marketing, procurement, transportation and storage of essential agricultural products.

Regarding dairy, Amnex's solution uses a combination of IoT, AI, and ML to digitalize dairy operations from grass to glass. The five core services in this solution are as follows:

i. an animal husbandry management system that identifies cattle, records medical history, insurance, and provides real-time alerts to farmers;
ii. a Bulk Milk Cooling Unit (BMCU) monitoring system that helps to monitor quality and quantify the milk collected, as well as the health of assets in the BMCU;
iii. a supply chain management system that helps with managing the logistics operations from milk collection activities to packaged product dispatch;
iv. a dairy plant operation monitoring system that aggregates plant-level data to assist in decision making;
v. an integrated command and control center that provides executives a comprehensive platform to remotely monitor activities at various nodes of a value chain.

All five of these core dairy services are packaged into a product called Dairynex. Amnex's end-to-end dairy management platform that monitors animal health, milk quality, transportation, and resource allocation. Through a single interface, all aspects of dairy operations ranging from planning to process optimization can be controlled.

UNIQUE FEATURES

- a unified enterprise solution for agriculture for governments, policy-makers and financial institutions providing high-quality information on acreage, sowing, crop health and estimated yields at very granular levels;
- use of data science techniques to manage and process huge volumes of SI and RS datasets;
- analytics for irrigation planning at the state level;
- fertilizer and pesticide recommendation with distributor information;
- integrated command and control centre (ICCC) for dairy operation;
- dairy logistic management system and plant operation management system;
- digital record system for animal husbandry.

SOLUTION IN PRACTICE

In agriculture, custom modules of the Farmlive, Croptrack, and Agrogate products can be rolled out for different use cases in an agri value chain. The products could also be configured for various users as well and sold only on a B2B basis.

The Farmlive app allows farmers to add and update their farm details and at the same time view details of their farms as per the registered survey numbers. Based on the input details, farmers get real-time advisories on the crop health status, market information, alternate crops, real-time weather information, etc. To enable intermediaries such as extension staff or field staff to collect such granular information, another app called Infolive is also available. This app is GPS enabled, and data from a farm is instantly uploaded to the webserver for further analysis and visualization.

The Agrogate web application provides a crop dashboard that shows the crop type and acreage of a selected state, district, block, and parcel of land. The visualizations permit viewing data at the plot level, block level, district level, and state-level as per seasons and timelines. Also, infographics can be generated to indicate the top five crops grown and the top five performing districts. Governments, banks, and insurance companies are the target customers for this product. Amnex has also offered solutions for insurance companies partnering with the PMFBY scheme. Amnex developed a custom mobile app to digitize the CCE data collection process for insurance companies. The CCE mobile application is a simple and precise application that requires minimal data entry fields. The GPS accuracy levels are kept at 20 m instead of 3 m and to avoid typing errors, drop-down lists are given for selecting field values. Furthermore, an autosave feature sends data to server at regular intervals. The CCE data received from the mobile app can be viewed on a web application from where photographs and data can be downloaded in PDF format. Finally, user activity can be tracked.

A grievance redressal app allows farmers to raise insurance claims for themselves or other farmers and monitor their progress in real-time. Once a claim is raised it is verified by a block officer as well as a district officer, after which it is sent to insurance companies. Insurance companies can view the requests in a web-based application and send their response of approval or rejection through the interface.In the dairy value chain practice, custom modules of the Dairynex product can be rolled out at various touchpoints in a dairy value chain.

The Digital Animal Husbandry System helps departmental users to provide efficient veterinary services. This digital record-keeping system maps livestock details with owner farmer, insurance, and lab reports to identify livestock and improve yields. By maintaining a digital repository of an animal's health history, the application can record, plan, and schedule visits by veterinary service providers.

The Smart BMCU Monitoring Platform enables executives to monitor BMCUs in real time. Through a single dashboard, BMCU health and performance of ground-level processes are monitored. At the BMCU level, data on milk quality, quantity, electricity consumption, and chilling unit temperature are captured by sensors and can be monitored remotely on a dashboard.

The Quality Supply Chain Management System is used to efficiently manage end-to-end logistics operations. The milk collection vehicles collect milk from village level entities at the appropriate time every day to ensure quality and upon collection a proof of collection message is generated. At the central plant, the milk tanker vehicle has secure access through an auto-

identification feature for a seamless entry and exit at the gates, weighbridge points, loading and unloading points, and laboratory.

The Dairy Plant Operation Monitoring System provides data-driven support to optimize operations. Operational data are captured from multiple sources and analytical insights are provided in the form of visualizations and detailed reports. Based on predefined KPIs, the system generates auto alerts if KPIs go above the threshold levels.

CHALLENGES OVERCOME

Farmers' inherit traditional farming knowledge from their ancestors and, over time, certain practices become an integral part of their culture. Although farmers tend to know their land, climate and soil well, the effects of climate change pose significant risks. Constant engagement and communication with farmers were undertaken to overcome some of these challenges. Similarly, co-opting front-line agricultural staff to use technology was a challenge. Constant engagement and trust-building proved to be the key to overcoming this barrier. Finally, although governments were enthusiastic about technology and data, they did not have the capacity or cultural preparation for data-driven decision making. Amnex found it necessary to train stakeholders on the use of data and, in phases, they were able to convince government departments to use data for decision making.

HIGHLIGHTS

- 196 024 km^2 area covered by capturing 2–3 TB of satellite data every day;
- 33 types of crops covered every season through analysis of more than 5 TB of satellite data for accurate results;
- more than 5 million Indian farmers impacted by Amnex tech-enabled agri solutions;
- 243 509 km^2 of cultivable area monitored from cultivation to harvest;
- executed digital dairy solutions for a large dairy client handling 7.5 million litre milk per day, and an association of 400 000 farmers owning 1.8 million cattle.

ENABLING ECOSYSTEM ENTAILS

Technology in agriculture is still at the very initial stages in India and more start-ups are needed to enter this space and change the narrative. However, unless there is an ecosystem of demand, it would not attract start-ups to enter this space. In PMFBY, the policy document explicitly mandated governments to use services for remote sensing technologies to estimate crop yield and damage while settling claims. Similarly, policy-based nudges for the deployment of digital solutions across a value chain are also important. Such policy interventions would create an ecosystem of demand for digital-based agri services and automatically create a pull factor for companies to create digital solutions in agriculture.

BHARATAGRI

STATES OPERATING IN INDIA
Maharashtra (95 percent business), Karnataka, Andhra Pradesh

TARGET BENEFICIARY
Farmers, extension staff, agri retailers

BUSINESS MODEL
B2F, B2G, B2B

WEB
https://bharatagri.com/home

PROBLEM

The last few decades have witnessed a great deal of experimentation as well as rollout at scale in digital extension services. Multiple organizations experimented with sending out farm-based advisories over radio, television, SMS, interactive voice response (IVR), and more recently through mobile apps, but these were mostly generic advisories and do not account for either the crop or soil variabilities of beneficiary farmers. Typically, farmers living in a geographic region or an administrative unit receive blanket advisories that are not specific to a crop or soil type. An obstacle to the preparation and dissemination of personalized and contextualized farm advisories is the absence of granular farm-level data on soil type, nutrient status, weather, and cropping systems. AgTech advisory companies must either purchase different data sets at high costs or crowdsource to start provisioning such services.

EXISTING SOLUTIONS

Many advisory-based apps that have appeared on the scene in India provide mostly generic advisories that are not personalized or contextualized to the situation of a farmer. Often such advisory apps attempt to present standard agronomy package of practices through various media such as text, audio, video, and animation. Besides, they do not prioritize a two-way communication between the advisory providers and farmers, hence, no real-time feedback based personalized advisory service. One possible reason for this is that for most apps, e-commerce is the mainstay and extension advisory is an ancillary feature. The strong belief amongst most agritech companies that small and marginal farmers are unwilling to pay for advisory services is also a deterrent for organizations to invest solely in digital extension.

SOLUTION

BarathAgri, a personalized farm advisory service, uses artificial intelligence (AI) and machine learning (ML) techniques to provide customized farm advisories to farmers. It is one of the few apps that uniquely provides advisory services and has farmer-customers paying for these services. In 2017, when it started, advisory services were disseminated through IVR and SMS channels, the primary focus being on developing a robust AI and ML algorithms for generating personalised advisories. An android-based app was launched to source data from farmers and offer personalized farm-specific advisories generated by using AI and ML algorithms. The android-based app provides dynamic weather-based advisory, crop management, soil nutrient

recommendations and farm mapping features. Farmers using the farm-mapping feature can geo-tag their farm boundaries. This helps AI and ML algorithm of BharatAgri to capture granular data on soil, water, and weather of farmers' land parcel from high-resolution global datasets.

Based on these data points of a farm, crop management and advisory services are provided on crop cycle–sowing till harvesting. A personalized crop calendar is generated and based on the weather and crop, BarathAgri sends out actionable insights and advisories to member farmers.

Based on the soil health information, nutrient profile of a farm plot is generated, and precise doses of fertilizer application are recommended to the farmer. Based on the underground water levels and water source profile, advisories on suitable crop profiles are generated. Finally, based on the presence of certain pathogens in the soil detected through the petiole/fungal and nematode testing, a crop nutrient advisory profile is generated. Additionally, a chat feature allows farmers to connect to experts and exchange communication on crop-related issues in real time.

UNIQUE FEATURES

- a free weather-based pest and disease advisory available to all farmers;
- a premium advisory services variant is available to farmers for INR 600 per acre per season;
- a rare app where advisory is the revenue generation services.

SOLUTION IN PRACTICE

BharatAgri brings farmers onboard to its platform either through direct channels, governments, or through local retailers. Farmers can download the app on their smartphones or with the help of a local channel partner and install the app. Once the app is installed, a farmer must input details of one of their crops, the location of their farm, irrigation sources, and the sowing date to access BharatAgri's predictive weather-based pest and disease advisory feature, free of cost. This feature gives farmers insights on the probability of disease and pests incidence in the ensuing five days. The app also has premium features to support weed management, soil nutrient management, and crop health management. In order for a farmer to unlock these premium features they need to enter details such as geolocation, crop variety, nutrient and chemical management, sources of water, farm mechanization, sources of labour, soil parameters, and also pay for these services. Additionally, if a farmer requires soil testing, BharatAgri arranges for a soil test through its logistics partners who can deliver these services through a private partner laboratory with a turnaround time of 48 hours. Alternatively, if a farmer already has a soil health card, they can simply upload it to the app.

CHALLENGES OVERCOME

The majority of farmers in rural areas tend to buy affordable smartphones whose processing capabilities are low. Also, they are not able to continually upgrade their smartphones to adapt to the changing app processing uploads. Consequently, a very primitive version of the app on that runs at a low-cost on the android phone was developed.

BharatAgri faced another challenge when forging partnerships with state government departments. The process to get associated with governments is cumbersome but the potential to upscale innovations and creating lasting impacts far outweighs these challenges. BharatAgri set up an

association with the Maharashtra government through the POCRA project of the World Bank where it was onboarded as a technical partner.

HIGHLIGHTS

- 175 000 unique farms serviced through advisory services;
- 35 000 paid users availing premium features;
- 20 000 soil samples collection facilitated in 18 months.

ENABLING ECOSYSTEM ENTAILS

Over the last few years, smartphones have become more affordable and rural internet penetration saw a dramatic rise, while costs of data dropped to affordable levels. This has enabled farmers to link to the digital world and interact with multiple digital channels to apps such as, WhatsApp, SMS, IVR, YouTube, and Facebook. Nowadays, farmers are in the initial stages of familiarizing themselves with digital channels. Digital proficiency is highly variable depending on the individual farmers; therefore, AgTech companies need to tailor their solutions based on the farmers' skills for using a digital mode of communication. For example, if farmers communicate better on WhatsApp, an automated messaging system can be built to help farmers interact with the company through WhatsApp. Similarly, if a farmer is at the beginner's stage of using mobile phones, tailoring the product navigation system through an IVR system will help. Since governments have the infrastructure at the last mile through grassroots institutions such as KVKs and cooperatives, it must allow start-ups to build upon this structure and get access to their marketing channels.

BIGHAAT

STATES OPERATING IN INDIA
pan-India

TARGET BENEFICIARY
Farmers, input companies

BUSINESS MODEL
B2C, B2B

WEB
www.bighaat.com

PROBLEM

Agricultural inputs make up a significant portion of the cost of cultivation for most farmers in India. Access to good quality inputs and awareness is one of the challenges faced by farmers. Quality and adulteration afflict the agri-input supply chains leading to poor germination rates, ineffective and environmentally damaging application of pesticides, as well as inadequate crop nutrients. Moreover, farmers receive crop management advisories from peers or the nearest input retailers who act out of self-interest rather than for farmers. Consequently, the advisory that farmers receive is either unscientific or inopportune.

EXISTING SOLUTIONS

Farmers purchase inputs mostly from a local retailer in the nearby village, town, or city. In addition, the local retailer acts as a moneylender and provides inputs to farmers on credit in anticipation of a post-harvest payment. This type of arrangement obligates the farmers to purchase input brands that would give the input retailers higher margins but in turn, poor outputs for the farmers.

THE SOLUTION

BigHaat operates an e-commerce platform for agriculture inputs such as seeds, agro chemicals, crop nutrients and machinery. The platform is accessible to both smartphone and non-smartphone users and also offers its services through a missed call option, where a farmer can dial a toll free number to place a request for call back from BigHaat. The BigHaat agronomy team would call back and provide assistance to the farmers. The agronomy team provides a crop advisory service and also assists with placing purchase orders on behalf of the farmers. Furthermore, BigHaat also operates a “Feet on Street” (FOS) model where a trained local team is sent to run content-based campaigns and provides knowledge-based services to build trust and awareness with farmers in a geographical cluster. With every farmer’s interaction, BigHaat collates unique data points to give farmers a customized crop advisory followed by an option to purchase quality inputs. Besides the mobile app, BigHaat also leverages Facebook, YouTube, WhatsApp channels to enable farmers to engage directly with the platform. With increased internet penetration in rural areas, 70 percent of the current transactions happen on BigHaat’s digital channels (website, app, WhatsApp, and Facebook) and 30 percent through assisted channels (FOS, Call Centre). BigHaat has on board major input brands that provide seeds, crop nutrition, crop protection, and farm machinery. All of these services are coupled with BigHaat’s knowledge platform that

disseminates agri tips, know-how, and videos to create awareness among farmers.

UNIQUE FEATURES

- product performance feedback mechanism for input companies;
- customer engagement through push notifications and social media platforms;
- tie-ups with 30–40 large input companies;
- data-driven advisory support in vernacular languages.

SODLUTION IN PRACTICE

BigHaat reaches out to farmers through multiple channels. When launching its product in a new geography and territory, it sends trained field teams to conduct knowledge campaigns in villages and also disseminates online content through videos, social media, and blogs to build awareness about BigHaat. A farmer can download the BigHaat App and have access to services ranging from the purchase of seeds, crop nutrients, crop protectors, and farm machinery. These services can also be accessed through their website, WhatsApp, and Facebook channels. Furthermore, farmers with feature phones can access advisory and purchase services simply through the missed call option. For input providers, BigHaat operates its e-commerce platform in two ways:

i. It has an inventory model where it purchases inputs in bulk from input providers and stocks it in a centralized warehouse where billing is processed; orders by the farmers are filled upon request. Based on the crop season and past demand trends, the warehouse inventory is stocked.
ii. It acts exclusively as a marketplace between sellers and farmers. BigHaat only provides order fulfilment services where the product goes directly from the manufacturer's warehouse to the farmer's doorstep. It is directly linked to the Indian Postal Services and a panel of e-commerce logistics service providers in order to ensure timely and accurate fulfilment of orders.

CHALLENGES OVERCOME

Building trust with both large input companies and even farmers proved initially to be difficult. Input companies were sceptical about whether farmers would ever make purchases on digital platforms. After taking farmers on board for its digital platform and creating a digital customer base of farmers, it was able to integrate major input brands. Through the FOS model they were able to convince the farmers that BigHaat was there, not merely to sell inputs, but also to provide knowledge and relevant advisories.

HIGHLIGHTS

- more than 70 percent of BigHaat customers are first time online users accessing high quality inputs;
- two million farmers have engaged on the platform since inception;
- 10 000 PIN Codes serviced across India;
- 5000 products listed for 120 crop varieties.

ENABLING ECOSYSTEM ENTAILS

With regulatory barriers in the form of multiple licenses to sell inputs in each state, the operational costs for service providers increase. If there were a unified pan India license, the logistics cost for e-commerce companies would come down and this same cost-benefit could be passed on to farmers.

SUCCESS STORIES

During the 2019–2020 crop season, potato farmers in the West Bengal state experienced major problems caused by the late blight disease. The fungicides needed to control this disease were in shortage in the local agri retail markets. Had they not come across the BigHaat platform, they would have risked losing the majority of the crop and would not have purchased the high-quality fungicide on time. BigHaat helped hundreds of potato farmers across West Bengal thanks to the availability and on-time delivery of fungicides to farmers, together with a crop advisory to help further contain the spread of the late blight disease.

CFOG SYSTEMS PVT LTD

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana, Kerala and Uttar Pradesh

TARGET BENEFICIARY
Big farmers

BUSINESS MODEL
B2G, B2B

WEB
https://cfog.business.site

PROBLEM

Aquaculture, especially shrimp culture, has become popular particularly in South Indian states. India is second only to China in terms of aquaculture exports. Shrimp farming, however, continues to be a very high-risk activity as shrimps are very sensitive to dissolved oxygen in ponds. If the dissolved oxygen is below the threshold even for about 15 minutes, shrimps become stressed. Apart from oxygen levels, pH levels and the temperature are also important parameters affecting the quality of shrimp.

Similarly, in agriculture any delay in a crop disease diagnosis can lead to potential losses to the farmer. Non-localized pesticide application increases the cost for farmers as they cannot assess the extent of the pest attack, nor can they define the exact location of the attack. Consequently, farmers apply pesticides on the entire farm. Furthermore, farmers tend to be reactive with crop management due to lack of data or tools that can alert them about impending pests or crop stress scenarios.

EXISTING SOLUTIONS

Shrimp farmers constantly keep aerators running to overcome the risk of oxygen levels falling to low levels, which leads to very high-energy costs. In agriculture, farmers rely on local and inherited knowledge to monitor crop health. Some best practices are followed in small pockets of the farming communities, but not on a large scale due to low usage of technology. Farmers use technologies such as sticky traps and pheromone traps to protect crops from pest attacks.

CFOG SOLUTION

cFog, a technology company, specializes in designing, deploying and operating IoT based solutions catering to specific and critical pain points in agriculture and aquaculture. Its comparative advantage is in the tactical use of solar powered gateway devices and patented sensor probe cleaning methods. These features enable their solutions to cope with some of the harsh environmental conditions at the deployment sites. cFog's approach to solution design is a blend of rigorous field testing along with localization to improve the usability and acceptability of technology amongst farmers. The thematic interventions of the cFog's solutions are:

i. AquaFog – aquaculture focused solution;
ii. AgriFog – precision agriculture solution;
iii. PestFog – early pest detection solution;
iv. WeatherFog – micro-weather monitoring solution.

AcuaFog comprises oxygen, pH and temperature sensors immersed in shrimp ponds. The patented sensor cleaning techniques ensure that the life of a sensor probe lasts beyond a shrimp growing season. The gateway device constantly transmits this data on a real-time basis to a cloud-based application. If the oxygen level falls below the critical threshold, the cloud based application alerts farmers through SMS and as an alert through the cFoG mobile app. Farmers can power accordingly on the aerators based on a real need and therefore optimize the incurred energy costs. Furthermore, data on pH and temperature can help farmers to intervene and address quality issues on a real-time basis.

In agriculture, AgriFog and PestFog help farmers with real-time data insights through IoTs so that they can make quick decisions to protect yields, reduce risks and optimize costs. IoT sensors are deployed on the field and farmers receive SMS/ smartphone alerts on the health of their farm. cFog has also partnered with other stakeholders in the ecosystem such as Satsure, the Government and Cisco India to create an enabling ecosystem solution for the farmer; for instance, to overcome the issue of placement of sensors within the farm cFog works with SatSure. The strategic placement of these sensors is representative of the entire farm. cFog's overarching objective is a tangible value creation rather than the "wow" factor of technology. In order to advocate and popularize the use of its interventions, there is a strong need to showcase the real impact of solutions on the ground by the few on-boarding farmers. Farmers' trust needs to be earned to enable them to shift from century old practices by adapting new technology. cFog therefore partners with governments and KVKs to set up demo pilots and earn the trust of local farmers. cFog's business model is a B2B and B2G. In B2G, the cost is borne by the government while the benefits accrue to farmers directly. In B2B, the focus is on corporate farmers who are into high value crops and therefore not constrained for capital.

UNIQUE FEATURES OF THE PRODUCT

- patented sensor cleaning kit which increases the lifetime of internet of things (IoT) sensor probes;
- IoT based early pest detection solution;
- soil, water and ambient health monitoring;
- strategic partnerships with ecosystem players to provide holistic solution.

SOLUTION IN PRACTICE

cFog started designing solutions for shrimp farmers given the proximity of the company to the coastal belt in Andhra Pradesh. Shrimp farmers are in general well off compared to an average farmer cultivating pulses and therefore can afford sophisticated solutions. cFog believes that reaching out to local experts and engaging actively with farmers is key to creating an impact: "more than often what happens is, being a technocrat, we endup getting so excited about the technology and the cool factor of technology and we end up doing a lot of sophisticated stuff but unfortunately the impact and usability is not such" says Robin Srivastava of cFog. cFog emphasizes the creation of tangible value, which will happen only when the product is customized to local needs. Shrimp yield is highly sensitive to oxygen availability i.e. shrimp are stressed if adequate oxygen is not available for 10–15 min. The necessity of aerators to supply oxygen to shrimp leads to heavy energy costs for shrimp farmers. However,

with the deployment of IoT sensors, real-time data insights enable farmers to save energy costs, which pays for almost all of the cost of the device. Besides oxygen, IoT sensors also collect pH and nitrate data, which are critical for shrimp yields. cFog IoT data provide value for every stakeholder in the shrimp value-chain directly from farmers, to pond care-takers, executives, and government departments.

Battle-tested IoT solutions for shrimp farmers provided cFog an opportunity to diversify and investigate other opportunities, including where an IoT based solution could address the pain-points of farmers. cFog IoT sensors deployed in agriculture can monitor soil moisture, soil pH, soil temperature, relative humidity and soil moisture. This real-time data is combined to calculate the probability of impending pest attacks and alert farmers. cFog partnered with Satsure to determine the best locations for IoT sensor deployment using satellite digital elevation models. Furthermore, sown areas, acreage, harvest readiness and harvest progression data from satellite is combined with IoT sensor data and weather forecast data to monitor crop health. To increase the acceptance of its products, cFog identifies local institutions that provide a physical touchpoint with the farmer. In Kerala for instance, cFog works through Village Knowledge Centres (VKCs), which are setup in each Panchayat by Government of Kerala.

cFog is currently piloting a solar battery-powered camera that captures the images of pests in a pheromone trap set up by farmers. This data is collected twice a day and sent to experts who determine the type of pest and suggest the intervention to be implemented.

CHALLENGES OVERCOME

Deposits of algae on the sensor-probes lead to inaccurate measurements, as a result, farmers could not rely on IoT data. cFog developed a patented sensor cleaning kit that slows down the algae deposition and increases the lifetime of the probes. IoT sensors communicate over GSM protocols, which limits its penetration to those areas with good network connectivity. Antennas can improve the signal gain but with an increase in the overall costs, therefore cFog selected other optimisations to improve the signal strength. “Neighbourhood mentality” was an additional problem that was solved through awareness building.

HIGHLIGHTS

- 40 aquaculture firms onboarded to the platform;
- four agriculture firms onboarded to the platform as a pilot in Kannur, Kerala.

ENABLING ECOSYSTEM ENTAILS

- The cost and quality of IoT sensors need to be upgraded especially if India wants to compete with China. Nowadays, there is greater confidence in the quality of Chinese IoT sensors.
- Government support in the form of higher budget and enabling policy for technology adaptation is needed to extend the solution to small and marginal farmers.
- The increased use of smartphone provides an opportunity for companies to go beyond the heuristic approach and adapt data-driven decision making to create business cases. Government needs to create an enabling environment where emerging technology can be adapted to local needs and aspirations.

CROPIN

OPERATING IN STATES OF INDIA
All states except the Northeastern states and Jammu and Kashmir.

TARGET BENEFICIARY
Financial institutions (banks, MFIs), insurance companies, seed companies, farming companies, agrochemical companies, government and development agencies, farm machineries and equipment manufacturers, livestock farming companies, aquaculture farming, greenhouse companies, plantation companies, and farmers

BUSINESS MODEL
B2B2C

WEB
www.cropin.com

PROBLEM

The absence of high-quality real-time farmer and plot-level data poses severe problems in the agricultural sector. Consequently, various stakeholders and consumers in the farm-to-fork agricultural value chains operate with limited or no data on the antecedents of agricultural products they work with. Agri-businesses lack data on agronomy, crop management, and post-harvest practices of products purchased and processed by farmers. Similarly, farmers have little knowledge of the markets, value addition, or the end-use of their agricultural produce. In many cases limited data collection undertaken by extension workers is more production centred and used for the purpose of aggregate statistics. Furthermore, data collection is in siloes and not in real time, and therefore offers very little value to businesses, financial institutions, and other organizations engaging with farmers. This lack of a wide perspective of farm activity makes it difficult for farmers to access capital, quality inputs, and advisories. For instance, input companies find it challenging to predict the demand for quality seeds, crop nutrition, and crop protection products, as there is no real-time data on localized weather, sowing cycles, and pest attacks. On the other hand, banks and insurance companies have financial obligations to the agricultural sector, and the absence of high quality historic and real-time data on crop yield, weather information, pest and disease attacks prevents them from creating customized farmer-centric financial products. Finally, there is an information gap on traceability of the produce at the customer's end, for example, information on the location where the produce was grown, pesticides or fertilizers used, harvest, storage, and processing practices.

EXISTING SOLUTIONS

Agri-businesses, financial institutions (FIs), seed companies, and processing companies need to engage with farmers. They generally deploy field extension officers as the single contact point for farmers. Although there is a government-

funded public extension system offering technical advice on agriculture to farmers, data and support for the system provided do not meet the needs of these players. Hence, agri-businesses create private extension systems, typically staffed with a ratio of 1:100 (one extension worker for every 100 farmers). The extension staff who collate farmer and field-level data cannot capture data in real time and provide insights for the various stakeholders engaged with the value chain. Most agri-tech companies who are trying to introduce digital innovation to farmers' engagement choose a specific pain point and tailor their solutions around that problem. Even though there are a few ERP-like solutions that digitize data collection and collect farmer data, they tend to capture data points that might not thoroughly help provide real-time solutions to farmers.

SOLUTION

CropIn is a leading 'Full Stack Agtech' organization that provides SaaS based services to agribusinesses globally. CropIn helps businesses to capture data through a suite of smart platforms that bring in end-to-end transparency in the agricultural value chain. Powered by artificial intelligence (AI) and machine learning (ML) models, CropIn's platform detects cropping patterns and predicts the future of the crop, thus highlighting the risk associated with it. Furthermore, the platform uses this data to provide contextualized advisory for farmers. A brief description of the suite of applications that Cropin provides for various use cases is found in Figures 1 and 2. Businesses have the option to choose a specific module based on their use case.

SmartFarm is a complete farm management solution that targets farming companies, seed production companies, agri input companies, financial lending institutions, crop insurance providers, and government bodies. It is a robust and flexible farm management system with a standardized package of practices that brings about accountability and efficiency in operations. Businesses also have the option to configure customized practices and advisory alerts based on their unique needs. Moreover, its end-to-end solution approach ensures traceability, accountability, and predictability through geotagging and adherence to compliances and certifications. Finally, using satellite and weather data, it provides input based advisory and real-time crop reports, insights, and alerts.

SmartRisk is a risk mitigation and forecasting intelligence solution that caters primarily to farming companies, seed production companies, agri input companies, financial lending institutions, crop insurance providers, and government bodies. It leverages agri-alternate data and provides risk mitigation and forecasting for effective credit risk assessment and loan recovery assistance. Proprietary machine learning algorithms built on satellite and weather data are used to provide insights at the plot and regional level.

SmartWare is a pack house solution for traceability and compliance, which caters to farming and seed production companies. It provides features for managing quality control, inventory management, SKU tagging and source traceability, order processing, and tagging. The solution is designed to ensure traceability from farm-to-fork and better marketability.

SmartSales is a comprehensive Customer Relationship Management (CRM) and input channel management solution that helps predict and improve sales and ensures end-to-end performance management of sales team.

AcreSquare is a unique farmer application that helps companies interact directly with their farmers, share content, educate them and provide consultation, thus enabling companies to extend the power of technology to their farmers and build farmers' loyalty. It provides periodic weather updates that are action-oriented, harvest projections, company broadcasts, instant solutions to crop concerns through farmer call centres.

UNIQUE FEATURES

- operates in a B2B2C model that gives it access to the network of farmers connected to these partner organizations;
- end-to-end suite of solutions across the agricultural value chain;
- products are crops and location agnostic value chain support including a package of practice for 9400 crop varieties.

SOLUTION IN PRACTICE

CropIn's solutions are targeted primarily at farming companies, seed production companies, agricultural input companies, financial lending institutions, crop insurance providers, and government agriculture departments. It operates on a B2B model where it provides services to farmers through organized business entities. CropIn's solutions help with the real-time management of complete value-chain operations so that partner organizations can reduce their costs and maximize revenue.

When a new customer is taken on board, the organizational hierarchy and the crops specific to the customer are configured on the platform. Unique login IDs are generated for executives, field functionaries and extension workers. Extension workers can interface with the CropIn platform through the CropIn mobile app. The extension workers can handle data collection activities such as farmer registration, capture seed requirements, field visits, supply of fertilizers, sowing date, crop health information, input application, and other field related activities. Captured data are aggregated on to web-based dashboards for managers and executives in the customer organization. Through these dashboards, executives can review real-time field visits, the activities of extension workers, the number of farmers they are engaging with, the inputs being supplied, and the status of crop growth on farms. On the platform, plot level granular data can be used to generate a customized production and harvesting plan for every individual farmer. While there is a standard package of practices available on the platform, customers also have the option to configure their unique packages on the platform as well. The interested crop data profiles are configured with the application so that CropIn can assist them with input plans, management plans, and harvest plans. Extension workers can disseminate advisories to farmers through their mobile app or text messages.

CropIn's AI and ML algorithms combine field data with satellite imagery (SI) and weather datasets to predict important information such as crop acreage, crop stage, crop health, and forecast yield. This data can be made available at various spatial scales ranging from an individual plot to regional and national scales.

CHALLENGES OVERCOME

The primary barrier that CropIn was confronted with was change management. Transforming a non-digital business into a data-driven organization requires systemic transformation. Although senior leadership understands the value of digital transformation, boarding front line staff and changing their attitude towards technology adoption is a challenge. CropIn undertook capacity building and advocacy to overcome these initial challenges.

HIGHLIGHTS

- CropIn has digitized over 6.1 million acres of farmland, enriched the lives of nearly 2.1 million farmers and currently manages data for 388 crops and 9400+ crop varieties. CropIn's global footprint spans across 52 countries in five continents (Figure 3).
- CropIn today employs close to 200 members and has so far received investments from India, the United States of America, and Japan amounting to USD 12 million. The current investment partners are Bill and Melinda Gates Foundation SIF, Chiratae Ventures, Ankur Capital, BEENEXT, Invested Development and Seeders.
- CropIn's superiority in providing world-class agtech solutions has been validated by domestic and international challenges that include:
    - automatic weather station (AWS) Digital Innovation Challenge;
    - Accenture Ventures Applied Intelligence Challenge;
    - Ag-Tech Developer Challenge conducted by RainForest Alliance;
    - Artificial Intelligence Innovation Challenge organized by the Government of Maharashtra and NITI Aayog (India);
    - HDFC Bank Digital Innovation Summit;
    - Artificial Intelligence Connect;
    - Agrow Awards 2018, London;
    - UNDP's Agorize Challenge for its Cultiv@te Program in the Philippines;
    - World Bank's Innovation Challenge for Agriculture and Food Security Risk Financing in Southern Africa, among several others.

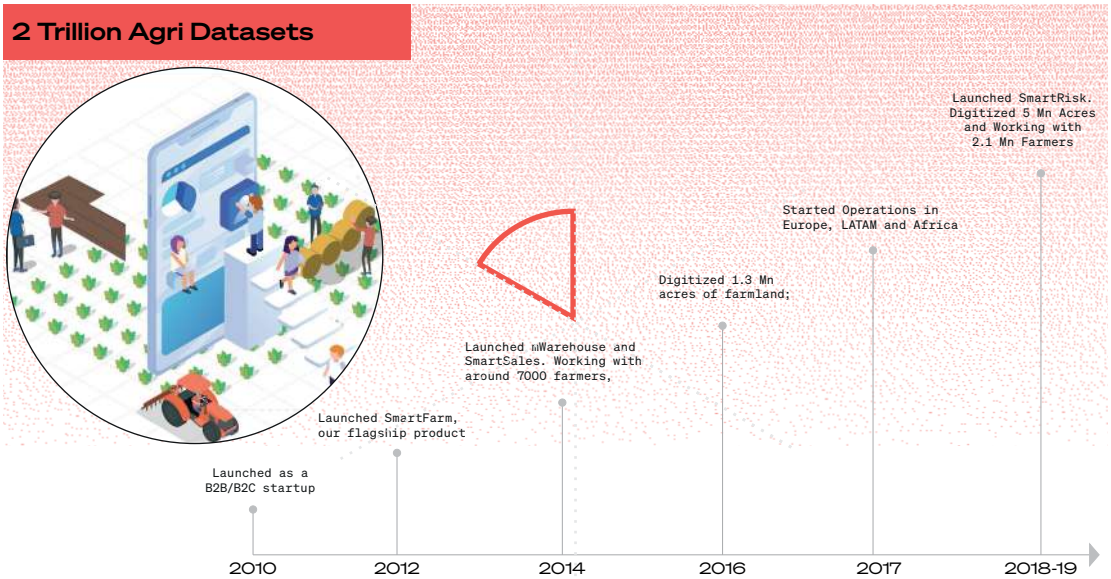

Figure A3
CropIn's evolution since inception

SOURCE: CropIn.

ENABLING ECOSYSTEM ENTAILS

There are close to 450 AgTech companies in India and approximately two-thirds of them work with different data sets that provide customized solutions to farmers, agribusinesses, and other stakeholders in the agricultural value chain. Most start-ups are trying to generate their own data sets or acquire them through secondary sources that tend to be costly. Governments are the custodians of large data sets and most of them are in silos and therefore difficult to access. On the one hand, digital initiatives such as the digitization of land records and water resource information management systems exist and are available. On the other hand, quick access that would help AgTech start-ups create innovative solutions for a positive impact on the agricultural sectors is not available.

DEHAAT™

STATES OPERATING IN INDIA
Bihar, Uttar Pradesh, Jharkhand, Odisha, and Delhi-NCR

TARGET BENEFICIARY
Farmers, agribusiness, micro-entrepreneurs

BUSINESS MODEL
B2B, B2F (Business to Farmers)

WEB
https://agrevolution.in

PROBLEM

In India, the farms are mostly small and the farmers marginal. Each one of them has a unique set of agricultural requirements ranging from the need to purchase quality agricultural inputs, advisory on crop nutrition and protection, technical support, financing, insurance, and market intelligence. The channels they rely on to meet these requirements include fellow farmers, local retailers, and extension workers. Agri-input and chemical companies, seed companies, financial institutions (FI), and other businesses that make products for farmers have no direct access to their customers; therefore, they rely on these channels to provide their products and services in the last mile. These channels however are not efficient nor are they synchronized with one another. Farmers, therefore, purchase seeds from one channel, access the advisory from another channel, and finance from yet another. This source of supply fragmentation is inefficient since each channel partner acts according to their incentives. Furthermore, the lack of efficiency results in low yields and lower incomes for farmers. More importantly, agri-businesses and FIs do not have good quality data allowing them to better understand farmers and thereby fine-tune or improve their products.

EXISTING SOLUTIONS

When DeHaat started its operations in 2012, the other large agricultural input companies, having realized the importance of direct access with farmers, started experimenting with technology and other physical channels to build direct relationships with farmers. However, these solutions were crop-specific and provided a single or a bundle of solutions for a single crop. There were some contract farming models where institutional buyers interfaced with farmers and provided end-to-end support for specific crops such as potatoes and tomatoes. There were also sweeping changes in agri-marketing with a push towards a more structured ecosystem for trading agricultural commodities. Although these entities had innovative solutions and products, they did not have direct access to farmers in the last mile.

SOLUTION

DeHaat, a full-stack agri marketplace, helps farmers access affordable agricultural services under one roof. Its digital platform interfaces with farmers,

micro-entrepreneurs, and institutional buyers. DeHaat operates its warehouses in the backend, which are key to the functioning of its supply chain.

Farmers are provided with the DeHaat Farmer app and a call centre that offers frequent crop-specific reminders through notifications and voice calls. These advisory calls are farmer- and crop-specific and disseminated in the farmer's local language. DeHaat's advisories are generated by a data-driven engine that uses machine learning (ML) and artificial intelligence (AI) methods. This engine prepares a customized advisory for a farmer based on the crop, variety, crop stage, local weather, market information, and other satellite-derived data Normalized Difference Vegetation Index (NDVI). Based on this type of real-time information, a farmer receives advisories in the form of notifications on the app or voice calls. The voice call feature enables feature-phone users to also receive personalized advisories every week. These advisories contain information about the appropriate proportion of input doses, crop care methods, and market information. The app also helps farmers with purchases of quality inputs and sale of the final crop outputs. Farmers operating a feature phone can call the DeHaat call centre toll free number. The calls are attended by qualified agronomists and professionals who help farmers with buying inputs, selling outputs, as well as provide other advisory services.

Micro-entrepreneurs can use the DeHaat microentrepreneur app (DeHaat for Business) and operate through a franchise model where each entrepreneur runs a DeHaat centre. The micro-entrepreneurs are generally young people from the local communities. The primary purpose of these entrepreneurs is to ensure the last-mile delivery of any inputs ordered by farmers. Even Farmer Producer Organizations (FPO)s can act as micro-entrepreneurs in some cases. Each centre is located near the farmers' base location and provides a one-stop solution for farmers to access inputs, advisory, and market linkages.

For institutional buyers, an online portal is provided through which corporate customers can place orders, track transactions, and monitor commodity procurement. In order to facilitate all of these functions it uses data science, ML, and AI technologies to predict yields and alert institutional buyers of any probable disruptions.

UNIQUE FEATURES

- 360-degree services from seed-to-market;
- operates a phy-gital model that supports farmers through digital channels as well as physical DeHaat Centres;
- solutions are farmer-centric and not crop centric, so it provides end-to-end solutions for any crop.

SOLUTION IN PRACTICE

DeHaat operates in a hub and spoke model where a DeHaat owned warehouse is modelled as a hub and the micro-entrepreneur franchises operating at the last mile are modelled as spokes. Before rolling out its services in a new location, the nearest DeHaat hub undertakes a series of farmer awareness, workshops and promotion programmes. From these programmes, the first few farmers who take interest in DeHaat either contact the call centre or download the app. A farmer is then onboarded through the call centre or registration on DeHaat Farmer app. Through the call centre, details of farmers and their crops are collected and customized advisory on soil health, input management, crop management, and market information for better price bargains are provisioned

immediately. Farmers using the DeHaat mobile app can also geotag their fields and receive advisories, which is specific to the location of the farm. The micro-entrepreneur franchises also onboard farmers in a catchment area of 3 to 5 km. Details of farmers are entered through the micro-entrepreneur DeHaat app and the entrepreneurs are then able to extend the same services of the call centres or the farmer app. On the institutional buyer's side, institutions are onboarded through an online portal that enables them to buy, sell, and transparently connect to farmers.

CHALLENGES OVERCOME

Although mobile phone penetration and usage has increased, there is still a need to understand the farmers' psychology and behaviour in order to build trust. DeHaat operates a physical model where micro-entrepreneurs from the local communities either introduce DeHaat or assist local farmers with making transactions and receiving advisories.

HIGHLIGHTS

- more than 3500 agri input products, from 100+ agri inputs companies, are listed on DeHaat portal;
- crop pest database for 29 major crops;
- works with more than 386 000 farmers;
- last-mile franchise networks of 1456 micro-entrepreneurs;
- more than 650 institutional bulk buyers on boarded and handling 700 MT volume per day;
- more than 35 percent increment in net revenue for the farmer through cost reduction, yield enhancement and better farm gate price.

ENABLING ECOSYSTEM ENTAILS

There is already a changing landscape when it comes to promoting innovative business in agriculture. Institutions such as the National Bank for Agriculture and Rural Development (NABARD), the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), the Indian Council of Agricultural Research (ICAR), and other nodal agencies set up incubation centres to promote start-ups. Indeed these institutions offer a head start, but more can be done in terms of easing the licensing regime when it comes to agri-inputs retailing. An inbuilt feature for FPOs or agricultural start-ups is strongly advisable, in order to have a unified licence to trade across the country, as opposed to getting a licence in each operating district.

DIGITAL GREEN

STATES OPERATING IN INDIA
Andhra Pradesh, Bihar, Odisha, Jharkhand, Chattisgarh, Uttar Pradesh, Uttarakhand

TARGET BENEFICIARY
farmers, extension workers, Farmer Producer Organizations (FPO)

BUSINESS MODEL
B2B2C

WEB
www.digitalgreen.org

PROBLEM

Extension officers in a traditional agricultural extension system are expected to visit farmers and disseminate information. The shortcomings of this system are predominantly because of an extension officers' inability to influence farmers' behaviour or provide consistent and customized information at scale. Furthermore, a scarcity of resources, lack of skills, capacity and the extreme localization of farming practices in the Indian context inhibit the effectiveness of the traditional extension systems.

EXISTING SOLUTIONS

Efforts made to address the knowledge gaps amongst farmers involving the usage of audio and text messages had a limited impact on the farmers' adoption of a new technology or intervention. In part, this could be attributed to the fact that in the agriculture environment, "seeing is believing." Indeed there is compelling evidence indicating the efficacy of experiential learning as a powerful learning tool for adults. Some experiments revealed that mediated video content had a better impact on farmers' learning than that of other digital means such as audio or text messages.

SOLUTION

Digital Green has a unique video-based peer-to-peer learning solution that emerged out of a Microsoft research project. Its uniqueness lies in the fact that farmers are onboarded as co-producers to create digital content. In order to put this into practice, Digital Green has created a cadre of community resource persons who are trained to create, edit, produce and finally disseminate videos using pico-projectors. These community resource persons scout for progressive farmers in local communities and feature them in videos that are categorized as best practice packages. Such videos are later used by these resource persons to educate farmers in other local communities. In these videos, the protagonists are now fellow farmers and the content is easy to understand; furthermore, the farmers watching these training videos consider them trustworthy. Indeed, Digital Green has broken social and cultural barriers of communication to bypass the seeing-is-believing concept. Moreover, it scaled these knowledge interventions by tapping into the information base of the close-knit agricultural communities. This approach addressed the issue of consistency and cost as compared to the traditional extension system, while complementing the

existing systems by bringing about efficiency and addressing issues of localization.

UNIQUE FEATURES

- unique peer-to-peer learning network facilitated by technology;
- farmer centric approach for content creation and dissemination;
- farmers are both content creators and consumers thus co-owning the entire process;
- blend of various technologies like interactive voice response (IVR), video, SMS.

SOLUTION IN PRACTICE

Digital Green primarily works with the governments and grassroots institutions in a programmatic manner. With a clear objective for embedding its digital interventions into the government extension ecosystem, it considers government extension workers to be the principal partners of Digital Green. However, it works with both extension agents and community resource persons who are from the local farming communities, and are trained on video production methods. They work with subject matter specialists to identify innovative and sustainable farm practices within their community. Furthermore, they capture essential video bytes of the selected farmers and put them together to produce best practice videos, which are subsequently used to train other farmers. The evidence from such mediated video lectures has been compelling. Feedback on the videos is sought from farmers for content improvement and to collate their interest areas corresponding to crop seasons. Analysis of this feedback data helps Digital Green to create targeted content for different stages of a crop season, while accounting for intra-regional variability in certain cases.

Early warning alerts, by combining data from the video platform with weather information, are delivered to farmers in real time using IVR. With an adoption rate of at least 50 percent in most cases, the video-based sessions prove to be more effective as compared to other traditional capacity-building practices. Digital Green continuously pilots and pivots around the use of emerging digital channels such as mobile applications, WhatsApp and Facebook. Since farmers are busy and their attention span while using social media platforms on their mobile phones is shorter, Digital Green has created content with a duration of less than 2–3 minutes. Additionally, to decentralize and localize extension it facilitates the creation of community-based mentor groups on WhatsApp to provide localized support. Digital Green does not charge farmers for the consumption of its services – revenue is largely raised through grants or donations from philanthropic institutions such as the Bill & Melinda Gates Foundation (BMGF) and USAID.

CHALLENGES OVERCOME

A major constraint encountered by Digital Green was a shortage of human resources, which was overcome by focusing on digitally skilled people. Senior bureaucratic levels have shown an openness to the adoption of digital technologies and extension but there are issues concerning motivation and skill deficiency at the level of community resource persons. This was however addressed by training them to take the lead in the initiative. The presence of too many apps can often be overwhelming for farmers and the affordability of mobile data is still an area of concern for a segment of farmers.

HIGHLIGHTS

- trained and created a cadre of over 6000 community-based resource persons capable of creating, editing and disseminating videos in local communities;
- cumulatively delivered mediated video content to over two million farmers across Andhra Pradesh and Bihar;
- created and indexed over 6000 videos on various crops, topics, and packages of practices;
- with 55 million YouTube views, Digital Green can analyse and deliver more customized and targeted content.

ENABLING ECOSYSTEM ENTAILS

- strong extension systems or grassroots institutions having digital literate human resources;
- a well-designed incentive structure for motivating frontline staff to take up digital advisories;
- investment by the government for the development of trunk infrastructure, especially for improving Internet access and speed;
- creation of a demand-driven system wherein digital services are demanded and paid for by farmers, rather than depending on subsidized services where they do not have an ownership.

DVARA E-REGISTRY

STATES OPERATING IN INDIA
Odisha, , Maharashtra, Rajasthan, Chhattisgarh, Tripura, Madhya Pradesh, Gujarat

TARGET BENEFICIARY
Banks, crop insurance companies, government and value chain players including Farmer Producer Organizations (FPO)

BUSINESS MODEL
B2B, B2C, B2G

WEB
https://dvaraeregistry.com

PROBLEM

Banks and financial institutions (FI) while financing agriculture are constrained due to the challenges they are facing with the availability of granular and reliable plot-level data. Banks require a mechanism to assess the creditworthiness of an individual farmer, which depends on the size of the farmer's plot, crops grown, historical yield data, availability of irrigation, and weather risks experienced in the past. Similarly, insurance companies, irrespective of whether they are providing weather or yield index-based insurance, require high-quality historical data to quantify the risks being underwritten. Both banks and insurance companies are heavily dependent on the field staff who visit farmers to collect local information and on strong statistical systems that can provide high-quality historic data. However, deploying field staff is expensive and un-scalable due to a huge number of smallholder farmers. As per the 2015–2016 agricultural census, 68 percent of the total holdings are below 1 hectare (roughly 2.5 acre) and 86 percent of the total holdings are between 0–2 hectares (0–5 acre). The problem is further exacerbated for tenant farmers when they try to avail financial services.

For crop insurance, the absence of reliable granular data leads to significant basis risks and increases the probability of moral hazards. Currently, the Pradhan Mantri Fasal Bhima Yojana (PMFBY) uses Crop Cutting Experiments (CCE) to estimate yields but conducting and administering CCEs in its current form is fraught with challenges.

EXISTING SOLUTIONS

FIs rely on their existing workforce and in-house data to assess the creditworthiness of farmers. Deployment of field staff to collect data is expensive and un-scalable in the Indian context. Efforts in the form of the Kisan Credit Card and the Joint Liability Group (JLG) model were put into place to help farmers meet their credit needs. Nevertheless, most FIs are not equipped with the correct tools to carry out a thorough risk-assessment.

The PMFBY, the largest agricultural insurance scheme in India, relies on yield estimates from CCEs for claim settlements. Five CCEs are conducted for each Gram Panchayat (GP) or village and it is a highly labour-intensive process resulting in high operational costs. The basis risk is high as the actual yield of a farm might be different *vis-à-vis* the average of five randomly

conducted CCEs across a GP. In addition, there are cases of under-reporting yields as well as delays during the assessment of CCEs and data submission, thus increasing the risk for insurance companies.

DVARA E-REGISTRY (DER) SOLUTION

Dvara E-Registry (DER) provides a digital platform that enables different stakeholders in an agri-value chain, especially smallholder farmers, to access structured financial products and agricultural markets. DER's platform makes it possible for banks and lending institutions to remotely undertake risk assessments as well as monitor farm activity on a real-time basis. Using remote sensing, machine learning (ML), and geotagged images collected through DER's mobile app Doordrishti, DER provides granular data about each plot where the farmer cultivates. DER provides current and historical data pertaining to the cultivated area, crop, growth stage, health, yield and cultivation potential of land holding of farmers. These are valuable parameters for risk assessment while underwriting agricultural loans and monitoring a financial institution's crop loan portfolio. This helps banks to quantify risk at a farm plot level and make important decisions. The same streams of data could be processed to help crop insurance companies reduce their basis risk. Banks are increasingly using near real-time monitoring data to improve their lending products. For instance, DER's platform has helped farmers gain access to liquidity at the crucial stages of the crop's lifecycle at affordable interest rates, along with crop advisory services. By using DER's services, FIs are able to monitor the loan usages, make timely loan disbursements, and decrease risk at a minimal cost.

UNIQUE FEATURES

- triangulates data from three different sources i.e. ground images, remote sensing data, and weather data to ensure accuracy;
- DER's mobile app (Doordrishti) uses ML techniques to identify land plots (FarmNet). Images are taken from adjacent borders of the land plot to identify plot boundaries and localize the plot on a high-resolution satellite images;
- uses ML and transfers learning to engineer small customizations in the product to incorporate the needs of different regions and crops. This enables scalability;
- the data is disaggregated at land plot and farmer level, so it proves invaluable for purposes like credit, insurance, extension activities, input services, and procurement;
- the data platform can also be used by governments and regulators to enhance the delivery of financial services, prevent fraud and increase transparency in agricultural financial commitments.

SOLUTION IN PRACTICE

DER offers B2B, B2C, and B2G solutions aiming to address issues of financial inclusion and market access in agriculture. DER has also begun engaging with FPOs to scale its vision and reach every farmer in the country.

Tech-architecture of DER makes it possible to remotely monitor individual land plots and is of immense importance for all stakeholders in an agri value chain. DER's mobile app, Doordrishti, is used to collect two geotagged images for each plot, which are processed by their ML model (FarmNet) to identify a farm and its boundaries. This is one of DER's unique capabilities.

FPOs, value chain companies and non-governmental organizations (NGO) can digitally keep track of the needs and demands of farmers by using DER's platform. Targeted interventions using farmer level data are accelerating the mobilization process and achieving the desired change. DER's affordable data solutions can enable procurement companies, contract farming corporates, seed companies, equipment providers, commodity traders, commodity exporters and processors to revolutionize and scale their business models.

First, the Doordrishti app is installed on smartphones of field agents to facilitate field data collection (Figure 1). The agent uploads two high-resolution images of a plot using the app. Every image uploaded is geotagged with latitude, longitude and the compass direction. The field data are processed through ML algorithms, called FarmNet that identify a plot boundaries. This plot is first overlaid on a high-resolution satellite map to digitize the land plot on the DER platform. In the second stage, ML algorithms use remote sensing and other data streams to generate a historical profile of the plot, which can be used for credit risk assessment. Insights on the crops grown in the past, earlier peak yields, extreme weather events, and irrigation can also be drawn from the data. This information can be used to create risk profiles of the farm plot in question. The output is verified by DER and made available on a dashboard to banks or FIs. Once the loan is disbursed, DER's platform also provides a means for banks and FIs to remotely monitor the individual farm plot. DER's product suite is also uniquely enabling the Kisan Credit Card scheme. For instance, in some cases bankers are using information from remote sensing to make decisions during the review and renewal of Kisan Credit Card loans. While banks are interested in monitoring the crop status throughout a season, insurance companies are more interested in yields at the end of harvest. In addition to FIs, DER has designed other useful features for value chain players such as seed companies, fertilizers, buyers and processors.

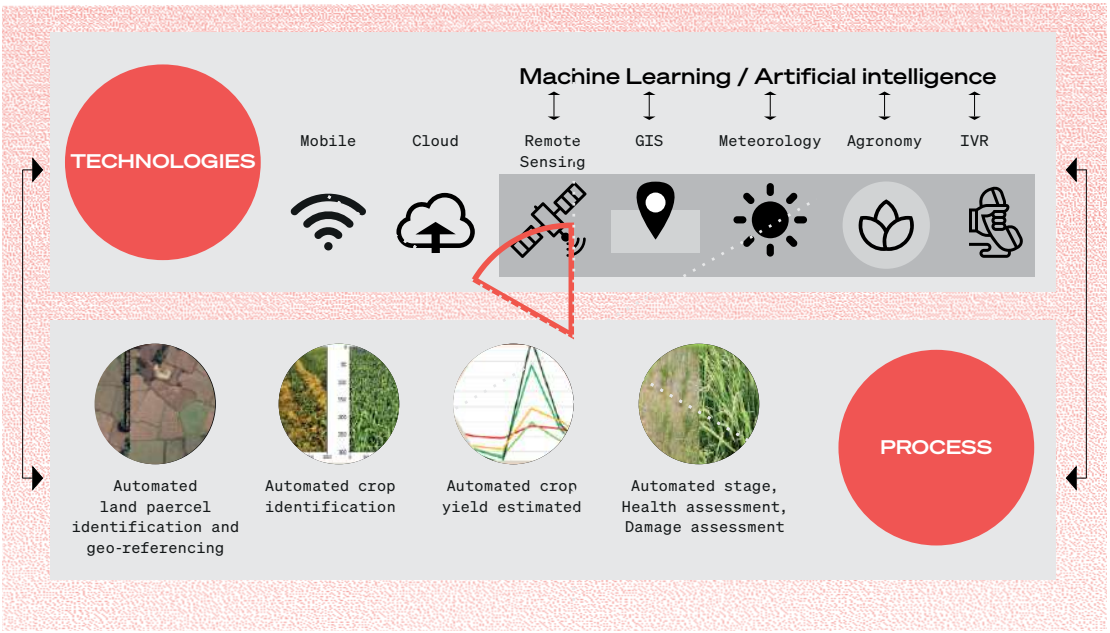

Figure A4
Doordrishti app help field agents to enable field data collection

SOURCE: Dvara E-Registry.

CHALLENGES OVERCOME

- In many states, since the land revenue systems are not integrated with the transfer of ownership of land, the land records are outdated. Furthermore, many states have not initiated geo-referencing of land records. Yield data are required to build robust ML models but this yield data that involves various government departments is not yet readily available. DER is partnering with state governments to get access to yield data and encourage digitization and geo-referencing of land records.
- Smartphone penetration in rural areas and particularly among farmers is low. DER is using the agent model right now as a snowballing technique to reach the maximum number of farmers. DER made provisions for multiple logins from the same phone based on unique ID passwords allotted to individual farmers. They are also exploring alternatives for feature phones.
- The model requires high-resolution satellite images and data in huge volumes to provide scalable solutions. Satellite data are expensive and not easily available for public access. Through MoUs with state governments, DER is expecting access to the same.
- Initially some sort of field presence is desirable to familiarize farmers with operating the app themselves. DER is working with local FPOs to gather the farmers together, ensure communication in local languages and run training programmes to make it easier for them to use the platform.

HIGHLIGHTS

- digitized about 50 000 land plots and collected data on 12 crops by analysing 18 000 crop images benefiting 37 000 farmers from over 160 villages across eight districts in three states;
- DER was recognized for its work on Leveraging Technology to Enhance Credit and Insurance Delivery to Small and Marginal Farmers in Odisha[1], at the Livelihoods India Summit organized by Access Development Services Limited;
- partnered with five FIs (MFIs and banks) within the first year of operation and started commercial operations with two of these partners;
- enabled institutional partners to make loans ranging from INR 30 000–40 000 and provided customized advisory services for nearly 2000 farmers;
- in spite of being in existence for just one year, DER, through its pathbreaking work is partnering with premier institutions in the agricultural sector such-as Mahalanobis National Crop Forecast Centre (MNCFC), International Food Policy Research Institute (IFPRI), and Precision Agriculture for Development (PAD). DER also has an active partnership with the Government of Odisha.

1 Livelihoods India Summit 2021. *Livelihoods in India* [online].

AN ENABLING ECOSYSTEM ENTAILS

Governments could set up a regulatory framework and allow markets to operate in such a way that private players are incentivized to introduce innovative products that are priced based on appropriate risks. However, any type of market interference in the form of farm loan waivers or relief measures, although well intentioned, is unable to bring in scalable and sustainable innovations. Quality research and design of efficient products for public good requires access to high-quality data, which is currently either inaccessible or too costly to acquire. The government should actively collaborate with the private sector to enable innovation resulting in impact.

EFRESH AGRIBUSINESS SOLUTIONS PVT LTD

STATES OPERATING IN INDIA
Telangana, Karnataka, Andhra Pradesh, Tamil Nadu

TARGET BENEFICIARY
Farmers, Farmer Producer Organizations (FPO)

BUSINESS MODEL
B2F, B2C

WEB
www.efreshglobal.com

PROBLEM

Governments are actively promoting FPOs[1] through the National Bank of Agriculture and Rural Development (NABARD), the Small Farmers Agribusiness Consortium (SFAC) and various other entities, but only about 5 to 10 percent of the total promoted FPOs sustained longer than three years. There are multiple reasons for this, one of which is the inability to adhere to multiple statutory regulations (GST, income tax, GST, Companies Act) and high penalties for non-compliance. Furthermore, registered companies need to maintain the financial data for the past eight years. FPOs that access bank credit must submit regular data on inventory, stock, sales, business trends on data and other financial transactions. Often such critical data are not maintained or in some cases are prepared by the FPOs, in the case where no trained labour in rural areas is possible. Banks are therefore put into a challenging position when dealing with having to distinguish between good FPOs and bad FPOs. Moreover, once the government support is terminated, FPOs need to be trained on how to undertake a commercial activity and find options for generating profit and sustainability.

Moreover, FPOs are not able to fully benefit from market linkages or to market and sell produce at a remunerative rate, owing to various operational challenges. There is also the problem of the lack of awareness among farmers about good agricultural practices (GAP) that pave the way for safe production of farm produce and exports. On the inputs side, over 30 percent of the agricultural inputs sold in rural areas are spurious.

EXISTING SOLUTIONS

FPOs hire an accountant and qualified labour handle the various compliance and information requirements. However, issues of attrition and labour churn can pose problems. Traditional ERP systems fail to work in the agricultural context due to their complexity and lack of user-friendly interfaces. Furthermore, many other existing digital solutions work on specific aspects of agriculture and lack an integrated approach to solving the critical problems faced by FPOs. As for the exports of agri-produce, most of the GAP accreditations are inspection-based and require farmers to maintain huge volumes of data and records.

1 FPOs are set up primarily to provide small and marginal farmers with a greater bargaining power with institutional buyers (retailers, exporters and processors) and enhance market linkages. With an average of 1000 farmers in each of the FPOs, these FPOs can exploit economies of scale.

SOLUTION

The e-Fresh suite of digital products adopts an integrated approach to solving the problems faced by FPOs. The highlights of eFresh solutions are as follows:

i. digitalization of agri-value chain including compliance to rules/ regulations, HR management, and day-to-day financial management;
ii. setting up Farmer Development Centres (FDCs), the physical entities under FPOs to provide access to quality farm inputs at competitive prices;
iii. disseminating GAPs through model farmers programmes;
iv. enhancing market linkages.

The FDC is a physical store that is set up by eFresh in important crop production centres, owned and operated by the FPO on a franchise basis. eFresh has partnerships with major agri input companies, service providers, therefore, can procure quality inputs at lower costs through volume aggregation. These inputs are stocked in FDCs operated by FPOs. The profit margin from the sale of input is split into a pre-agreed ratio between eFresh and an FPO. By adopting the eFresh franchise model, FPOs are relieved of paying security deposits and from the tedious process of entering agreements with different agri input suppliers.

FDCs are also provided with a POS tool that digitizes all of the financial transactions of the FPO including purchases, sales, expenses, stock, and inventory. They also prepare the P&L, expense statements, and data visualization using data analytical techniques. Banks and auditors working with FPOs get access to this data, thus facilitating greater transparency and eventually better credit access through remote monitoring. FPOs can also place bulk orders to eFresh for restocking through digital platforms. The FDCs also try to partner with financial institutions and upsell health insurance and other products.

eFresh also facilitates FPOs to undertake reverse market linkages from farmers. It uses its eProcure app to capture the traceability and quality specifications of the products being procured and maps these specs to the specs defined by EU ACP, BIS, NCEDX, eNAM. This helps FPO list inventory in a much more market aligned way.

eFresh aims to create one FDC for a cluster of 10 to 20 villages. To bring greater awareness about GAP and to facilitate the sale and distribution of agricultural inputs in every village, eFresh uses the concept of model farmers and village agents' programmes, respectively. While model farmers work closely with eFresh to demonstrate GAPs to fellow farmers, the village agent is provided with an eFresh mobile app to show all the eFresh products to farmers and place their orders. The orders are filled by eFresh for FDC and subsequently delivered to farmers by means of village agents. eFresh is now actively piloting the village agent model with the Village Level Entrepreneur (VLE) programme of the Government of India.

To ease the burden of various compliances, eFresh also has its eQMS and eCompliance tool, which handles the digitization of the FPO profile and statutory requirements with simple user interfaces for FPO. All of the various apps of eFresh are available in English, Kannada, Telugu and Tamil. The eCompliance app has FAQs and can also connect FPO staff with auditors to deal with credit and compliance-related issues.

UNIQUE FEATURES

- FPOs can access farm produce quality specifications database of different countries enabling them to connect to international markets and realize higher prices for their produce;
- identification and nurturing of FPOs with strong growth potential;
- qualified auditors available at the local level are mapped on the platform;
- agri-value chain stakeholders are provided digital access to FPO data e.g. inventory, purchase, sale, and compliance;
- FDC, a physical delivery point for delivering quality farm inputs, is set up within the FPOs;
- certification of farm produce;
- manage operations, compliance and profitability by accessing data real-time from the desk.

SOLUTION IN PRACTICE

First, eFresh identifies FPOs with a strong growth potential by examining their financial discipline and institutional linkages. Generally, it looks for FPOs with active CEOs and directors who are well linked with banks. It has well-defined, filtering criteria to identify potential FPOs that it partners with. The identified FPOs are provided with digital tools to digitize the entire value chain of activities including day-to-day operations so that data can be monetized. The access to digital data is provided to all stakeholders such as banks, thus bridging information gaps that existed previously to the eFresh solution. FDCs are set up to ensure the availability of quality farm inputs at a price lower than the local market. eFresh takes a survey to better understand crops and agricultural input products sold in the micro-market of FDC and is set up and stocked accordingly to supply inputs in demand. Farmers can buy inputs over the counter from FDC, and eFresh has a more decentralized channel for selling and delivering inputs. It identifies village sales agents and through its mobile app, sources orders, which are sent to FDC and then supplied directly to farmers through sales agents. The eFresh team selects two farmers from each FPO as model farmers, who have applied the prescribed best practices and produced high quality and high yield produce, as brand ambassadors for spreading awareness on GAPs. eFresh is also involved in reverse market linkages with the support of FPOs through its eProcureplatform. This platform offers more fine-grained market linkage opportunities with its information on export specification parameters embedded, as well as global importers such as the European Union, besides certifying the agricultural produce. eFresh is currently working with FPOs in Karnataka, Tamil Nadu, Telangana, and Andhra Pradesh. Through its partnerships with FPO promoting organizations like NABARD, GIZ, APMAS, Sammunati, it also plans to expand to Madhya Pradesh, Maharashtra and Bihar.

CHALLENGES OVERCOME

The biggest challenge that eFresh has faced has been to gain the farmers' trust, which was accomplished through its model farmer concept and supply of quality inputs. In the case where FPOs, the centre of the eFresh solution, sought only to benefit from a three-year subsidy provided by the government, and did not actively engage with farmers or represent their interest and enhance their bargaining power, it failed to reach its objective. Therefore, eFresh, identified the FPOs with a strong growth potential by assessing various parameters such as for example, institutional linkages, the commitment of CEOs and directors.

eFresh also works closely with FPO-promoting organizations. Furthermore, digital platforms are provided free of cost to FPOs and customized as per the needs of stakeholders. Digital tools are also multi-lingual due to the poor English language skills in many rural parts of the country.

HIGHLIGHTS

- operating in four states Karnataka, Telangana, Andhra Pradesh and Tamil Nadu;
- developed India-specific Good Agricultural Practice Manual;
- 12 FDCs are setup and over 100 000 farmers onboarded the platform;
- developed agricultural portal with exporters requirements for many crops;
- first Indian company in agriculture to assist farmers obtain NABCB accredited India GAP certification under the category of small and marginal farmers.

ENABLING ECOSYSTEMS ENTAILS

- simplification of the licensing system for agri inputs;
- privatization of marketing platform to ease market linkages.

ENAM

STATES OPERATING IN INDIA
70 percent of all districts in India

TARGET BENEFICIARY
Farmers, traders, commission agents, mandi staff, administrators, government bodies

BUSINESS MODEL
B2G

WEB
https://enam.gov.in/web

PROBLEM

The Agriculture Produce Marketing Committee (APMC) Act regulates the sale of agricultural produce by farmers and traders in India. The act was legislated and enforced by state governments. To comply with this regulation, state governments established an APMC market yard aka mandi for a contiguous cluster of 150–200 villages. Farmers in a cluster transport their agricultural produce to a designated mandi where commission agents aggregate produce from multiple smallholder farmers, after which licensed traders buy this produce through an open-cry auction. The commission agent charges a fixed percentage from farmers for facilitating trade and the mandi charges a fee for operating the market. However, over time unfair practices and a trader-agent nexus on the part of the mandis proved to be detrimental to farmers. Non-standard and unclear assaying and grading practices, limited means for storing commodities, and asymmetric information are some of the disadvantages for farmers. First, commission agents arbitrarily discount the weight of produce brought by farmers and furthermore attribute an inferior quality grade, even in the case where the produce is of a better quality. Second, commission agents and traders cartelize and do not pay a fair price for the produce to farmers; therefore, the trader-agent cartel extracts double arbitrage at the expense of farmers. The absence of credible information sources on regional, national, and international prices of commodities or in other nearby markets allow traders and agents to exploit a price arbitrage. Unless there is a system for regional and national supply and demand-based price signals to inform the price discovery at the local mandis, traders will continue to exploit information asymmetry to their advantage. There are about 2477 mandis in India and 4843 sub-market yards as of 2019, mostly reporting a very similar situation.

EXISTING SOLUTIONS

Modelled after the Russian markets of 1950s, the APMC act is historically restrictive and outdated. The inception of this idea was to create a marketplace for 150–200 villages where farmers would take agricultural produce and sell their commodities based on a transparent price discovery mechanism. However, the APMCs over time have become highly cartelized and influential because the traders operating in the mandis are not only informal moneylenders to farmers, but have also become a strong lobby that can influence the outcome of local elections. The quasi absence or difficulty with obtaining access to

institutional credit leaves farmers with no choice but to depend on traders for their liquidity needs. Traders use this dependency to take advantage of farmers at the time of harvest and sale of produce. The government has tried to improve returns for farmers through a multi-pronged strategy. Through the Warehousing Development and Regularity Authority (WDRA) accredited warehouses, farmers can store agricultural produce and pledge these stocks for immediate liquidity. This was established to ensure that farmers were not forced to undertake distress sales for their immediate cash needs. Governments have rolled out various specialized financial products to enhance farmers' access to institutional credit. One such financial product, Kisan Credit Card has been prevalent over the last few years. Governments have also been trying to use revenue from the mandi fees collected to improve grading, assaying, and processing infrastructure for the benefit of farmers. The trader-farmer nexus, however, resorts to practices such as under-booking of the quantity traded between a farmer and producer to lower the incidence of mandi fees.

SOLUTION

An electronic trading and marketing portal, the national agriculture market (eNAM), connects about 1000 APMC markets or mandis across India into one unified market network. The eNAM portal breaks information asymmetry to bring transparency to prevailing prices at the national level and in other mandis on eNAM. With information on the real-time prices for commodities at various mandis, it is expected that farmers will be able to make decisions that maximize their economic returns. The auction process in eNAM is also digitized to ensure that farmers receive fair payment for their commodities. Payment is made instantly based on the quality of a commodity whose grade is based on objective assaying methods. It blends APMC's physical market space with a digital platform to bring in transparency and make information for all the 1000 APMC markets available to any farmer, trader, and commission agent in real-time through web based and mobile applications.

iKisan, a division of Nagarjuna Fertilizers and Chemicals Limited, is the pioneer in agri tech in India commencing with the agri portal ikisan.com as early as 1999, when internet technologies were still at the nascent stage in India. The portal gained a reputation with a million footfalls per month for agricultural information search. Eventually iKisan developed ICT technologies in remote areas of the country through information kiosks. iKisan implemented turnkey projects in many states of India by automating agricultural markets and digitising trade for price discovery.

eNAM is an evolutionary and improvisational of iKisan's ERP solution that was purpose-developed for digitizing mandi operations. This ERP was first implemented in 52 markets in Punjab and 31 markets in Tamil Nadu. In Punjab, the product was rolled out to digitize the trading process in each mandi and bring some incremental efficiency by digitalization of transactions. The rollout in Tamil Nadu however piloted the idea of linking the digitized mandis into a unified platform and provisions to facilitate intra mandi transactions within the state. It was anticipated that such an integration could improve transparency, price discovery, and better price realization for farmers through better information linkages. Furthermore, in Tamil Nadu, a new feature of digitally capturing the weight of a commodity was also added to the application. The success of these initiatives seeded the vision for a unified national agricultural market in 2014. Eventually, through a transparent bidding process, iKisan was brought in as a strategic partner to implement eNAM across the 585 selected APMC markets across India from 2014 to 2019. Another 415

mandis were linked with eNAM and integrating eNAM with 1000 mandis. Moreover, eNAM will integrate more markets and also allow interoperability with private and other online agricultural markets to achieve a better price discovery, enable trade between different geographies and position eNAM as the platform of platforms.

The eNAM trading portal facilitates farmers, traders, and commission agents to trade across the country. Based on the quality, supply, and demand for commodities, real-time prices are visible. The entire auction process is online, and farmers can choose to participate in an auction process that is pan-Indian. If the farmer is satisfied with the bid made by a trader or commission agent, they can accept the bid and payments are made online. eNAM rollout was accompanied by key policy changes by the participating state governments. Across the implementing state, a single trading license is valid, besides the single point levy of market fee.

UNIQUE FEATURES

- 1000 digitally-enabled APMC markets for stakeholders to trade;
- unique dashboards for farmers, traders, and commission agents.

SOLUTION IN PRACTICE

eNAM is a full-stack solution for digitally streamlining the entire agricultural trade process from the time a farmer enters an APMC mandi until they make a sale and exit. As soon as a farmer arrives at an eNAM enabled APMC mandi, the number of the vehicle in which the produce arrives is registered and they are given a gate entry slip. The vehicle is directed to a lot-operations unit where a sample of the commodity is taken to a lab for sampling and assaying and evaluating. The lab technician captures the test results against the farmer's registration and simultaneously the lot is weighed and approved for trade. At the registration kiosk, a farmer is given a unique login and password where they can register their lot for the e-auction. Similarly, unique logins are provided to traders and commission agents who can select multiple commodity lots and place their bids against each lot. When the e-auction opens, bids can be placed for commodities listed in different mandis across the state. Based on the bids received, a farmer can choose to accept or reject a bid. Upon conclusion of this process, a bid manager publishes the results of the bid online where concerned parties can view auction results on their respective dashboards. A bid manager has the power to extend a bid in the case where the time has elapsed and no bids have been made. Also, they can reject bids if any unethical or unfair practice by a buyer or seller is brought to their attention. Once the sale is accepted, payment is made online and a sale invoice is generated for both parties. If the trader or commission agent who has made a successful bid is from the same mandi where the farmer has registered the commodity, a bill of sale is generated and the purchased lot is handed over to the buyer. If the buyer is from a different location, the commodity is handed over to the APMC and a logistics partner helps with delivering the sold commodity to the buyer's location. A vehicle with goods can only exit the APMC mandi with a proper bill of declaration. If a farmer chooses not to sell the commodity on a given trading day, they can deposit the commodity at a WDRA accredited warehouse and obtain a Negotiable Warehouse Receipts (NWRs), and post the verification of quality and quantity of the deposited produce. The NWRs can be encashed or pledged by farmers.

CHALLENGES OVERCOME

As APMC acts were legislated and enforced by state governments, the central government came up with a regulatory framework to carry out the market digitization process before the rollout of eNAM. A scheme was rolled out for mandis wishing to participate in eNAM in the first phase. Out of the over 950 applications received, 585 mandis were identified to participate in eNAM. Each participating mandi was given INR 75 lakh for setting up the basic digital infrastructure like computers, billboards and Wifi. There was initial scepticism on the part of many mandis because they were predominantly controlled by traders and commission agents. With the constant persuasion and deployment of over 784 people in these 585 mandis, digitization of trades on the eNAM platform was gradually achieved. A key challenge that continues however is the highly localized and non-standard grading and assaying practices, which are different in each state. For a seamless inter-mandi, trade to be facilitated there must be a standard process for quality determination across all mandis. eNAM is working on and exploring invasive and non-invasive technologies that can objectively assay and grade various commodities.

HIGHLIGHTS

- 20 million farmers registered on the portal;
- over 150 commodities are traded;
- 30 million MT of commodities traded on eNAM since its launch;
- 100 000 traders registered on the trading portal;
- 75 000 commission agents registered;
- 40 varieties of fruits and vegetables are being traded;
- more than 400 transactions done per minute.

AN ENABLING ECOSYSTEM ENTAILS

The participation of Farmer Producers Organizations (FPO) in eNAM can further improve overall functioning of eNAM. FPOs, with a suitable infrastructure, could replace mandis to provide the physical backend of eNAM. Although there is an active push for the creation of FPOs, the management and business development areas for sustaining FPOs must be improved. Farmer aggregation needs to happen in a structured and sustainable way so that the farmer's collective bargaining power increases. In addition, banks need to move beyond the low 45 percent priority sector-lending threshold and approve more loans for farmers rather than for other agricultural institutions. The high service cost for agricultural loans that lending institutions quote needs to be decreased through digitalization and employment of agricultural graduates from rural areas who can service remote areas. Traders and commission agents who have access to capital need to be encouraged to create storage infrastructure and digital assaying infrastructure where they can make fair profits.

ERUVAKA

STATES OPERATING IN INDIA
Andhra Pradesh

TARGET BENEFICIARY
Farmers, businesses

BUSINESS MODEL
B2B, B2F

WEB
https://eruvaka.com

PROBLEM

Shrimp farming is a high risk-high return aquacultural activity with only a small percentage of farmers who manage to make profits, while a vast majority experience losses with their investments. There is very little support available for the decision-making process for shrimp farmers to help minimize their risks. Farmers tend to resort to their intuition for daily shrimp cultivation. Similarly, there are no existing decision support tools that provide advice for farmers on timing their harvest in line with risk-reward preferences. Income from shrimp farming is very sensitive to the water quality of the ponds, feed management, and shrimp health. Water quality is linked to dissolved oxygen (DO) levels and the temperature of ponds, which in a very short period can change due to environmental factors. Farmers have to, therefore, pay attention to DO levels and temperature almost on a real-time basis.

In the case of shrimp farming, feed makes up about 60 to 70 percent of the total cost. Water quality is a critical parameter for the success of shrimp farming. The normal mortality rate of shrimps in clean water is 10 to 15 percent. Overfeeding, however, leads to the accumulation of waste feed at the floor of pond, thus reducing water quality, and can increase mortality rates to about 50 percent. Furthermore, manual feeding does not always lead to higher feed conversion ratios (FCR) if the shrimp are not hungry, and excess feed has an adverse impact on water quality. Disease outbreaks are another major threat to shrimp growth and health, and remedial measures often lead to the indiscriminate use of chemicals and antibiotics, which input company markets aggressively. Antibiotic residue beyond the permissible levels can disqualify farmers from benefiting from exports.

CURRENT PRACTICES

Traditional cultivation methods of aquaculture are based on the intuition that farmers have developed over the years. A standard mechanism has not been put into place to quantify DO levels and monitor shrimps' appetite or health in real-time. In order to maintain the dissolved oxygen levels, aerators – turbine-like structures that lift water into the air from time to time – are generally used during the crucial phases. However, an erratic electricity supply can create a huge risk if the aerators cannot be run during a crucial phase. If the farmer is not vigilant or is unaware, even a few hours of mismanagement could prove costly. Therefore, farmers deploy diesel generators to ensure continuous backup for electricity. To check for feed consumption patterns and disease, farmers have a small net (check tray) at the corner of pond where they physically

lift shrimps out of the water to check on their activity and health. However, the subjective nature of human judgment poses a colossal risk if the farmer does not accurately detect disease. After the first visible sign of floating dead shrimp, in a matter of hours the entire colony of shrimp is affected. Finally, getting the right feed conversion ratio (FCR) is problematic and most often based on intuition and guesswork. Farmers who manage this efficiently can save on costs and prevent excessive ammonia accumulation that affects the overall water quality.

SOLUTION

Eruvaka Technologies has a suite of on-farm diagnostic equipment that focuses primarily on the three pillars of shrimp pond management – water quality, feed management, and shrimp health. They have integrated solar-powered sensors, mobile connectivity, and decision-making tools to affordably monitor and automate aquaculture. One of the issues that Eruvaka is addressing is the inefficiency of feeding in the shrimp farming business. Feeding is done manually and farmers lack the technology to control the schedule, pace and quality of feed distribution.

The set of hardware and software tools enabling real-time monitoring and bringing efficiency to shrimp cultivation are as follows:

PondGuard is a cloud-based self-calibrating and self-cleaning pond management solution. It helps farmers monitor DO, pH, and temperature levels of ponds in real-time and subsequently take preventive action. Voice-based call alerts and notifications on Eruvaka's mobile app are sent to farmers if the DO and temperature levels are not within the optimum range. The automatic aerator control feature saves farmers 20 percent on their energy bills by powering the aerators based on the DO levels. Eruvaka's mobile app can also be used to remotely monitor aerators.

PondMother is an automated precision feeder that adjusts aquafeed based on shrimp activity, water quality, and weather data using intelligent artificial intelligence (AI) algorithms. The shrimp are fed optimally using pre-configured and adaptable feeding schedules, which can be controlled using Eruvaka's mobile app PondLogs. In-app settings allow farmers to control feeding frequency and volume for each pond at scheduled intervals. This precise feeding technology improves feed conversion ratio (FCR) by 30 percent resulting in an equivalent amount of savings on input costs. Moreover, improving FCR reduces feed wastage and thereby minimizes adverse impact on water quality.

ShrimpTalk is an appetite based intelligent feeding system that uses underwater acoustics to sense hunger and feed shrimp based on demand. Connected to the PondMother, this AI-driven device helps in delivering precision feed 24 x 7 and enables good shrimp growth and health.

PondLogs is a farm management software that logs all feed data and enables farmers to monitor and control the **PondGuard** and **PondMother** devices remotely. A farmer can analyse yield potential and make informed decisions on when to harvest the crop based on market prices.

Eruvaka is developing a prototype of an AI based image-processing tool called ShrimpSnap that can assess shrimp growth and also identify symptoms of the disease from images of shrimp.

UNIQUE FEATURES

- combines cloud computing with mobility to provide farmers real-time insights to control feeders and aerators remotely;
- patented floating sensor buoys that can be operated remotely;
- precision feeding of shrimp for better growth and savings on aquafeed;
- an affordable rental model that allows farmers to rent the devices on a seasonal basis.

SOLUTIONS IN PRACTICE

PondGuard is a floating buoy with sensors submerged into the pond to monitor DO and temperature levels in real-time. Based on the real-time changes, it triggers the PondRunner (aerators) to maintain the water quality of pond. DO levels and temperature play a critical role in feed consumption and metabolism of shrimp. The growth and feed intake of shrimps are highly impacted by the temperature of the pond. Furthermore, the ShrimpTalk module captures the intensity of the underwater sound triggered by hungry shrimp to decide on the hunger intensity. Shrimps tend to grow optimally when fed according to their hunger cycles. Moreover, the PondMother is a floating buoy with a 125 kg hopper capacity digital feed dispenser that uniformly dispenses feed in a 12 m radius. It is also solar-powered and has a 4-day battery backup that receives instructions from a backend AI system to precisely feed shrimp based on data inputs from PondGuard and ShrimpTalk.

Eruvaka's backend AI system adapts to the changing DO and temperature of the pond, hourly/weekly consumption, and growth patterns of the shrimp to dynamically adjust feed and run aerators to create favourable growth environments for the shrimp. The AI system also logs their growth rate in each pond and alerts farmers about harvest time of the shrimp.

Currently, Eruvaka operates without a sales team and gets new business through referrals. After a new sale lead, as a first step the team visits the farmers' shrimp ponds to study its status and historical performance data. A value proposition plan is offered to the farmer and if accepted, work starts initially in one-tenth or a small fraction of the total number of shrimp ponds. Once harvest cycle is successful and the farmers become familiar with the technology, it is scaled to the rest of the ponds.

CHALLENGES OVERCOME

In order to understand the science of shrimp cultivation and the general norms, the cultural practice was a major challenge that Eruvaka researched on. Fine-tuning of technology to suit the practices of farmers involved several iterations and pilots with feedback from early adopters. For example, developing ShrimpTalk did not take much time. Commercialization of the product, however, took four years because of the sensitivity of feeding operations to shrimp health and water quality. Eruvaka fine-tuned its products and process by working with farmers who were willing to experiment with initial prototypes. It was a co-learning and co-creating process where many views were shared, especially from smaller farmers who in general had a greater understanding of their ponds and shrimps. Eruvaka was able to win the farmers' trust by collaborating with them throughout the entire 90-day cycle, constantly updating them on the day-to-day changes.

HIGHLIGHTS

- 25 percent reduction in feed costs and a 30 percent increase in overall profits;
- 2500 installations across India and a total of 5000 across the world;
- monitoring 6000 hectares of shrimp ponds across eight countries.

AN ENABLING ECOSYSTEM ENTAILS

This technology is easily affordable for medium-sized farmers, and small farmers can also benefit when they are clustered and have been provided with these technological services. Considering that over 80 percent of shrimp farmers are small farmers, clustering can indeed have a greater impact. Together with this technology, farmers should be provisioned with holistic services such as water quality testing and shrimp pathology to detect health and diseases.

FARMLEY

STATES OPERATING IN INDIA
Bihar, Haryana, Maharashtra, Karnataka, Jammu

TARGET BENEFICIARY
Farmers, senior management, middle management, front-line staff

BUSINESS MODEL
B2B

WEB
https://farmley.com

PROBLEM

Farmers sell their raw produce in mandis with little or no value addition. Experience however has demonstrated that with little value addition the prices obtained by farmers are varied. After harvest, farmers search for ways to generate liquid cash. This sense of urgency stems from the inadequate storage in their vicinity and no assurance or immediate forecast of escalation in prices. Farmers do not have enough information or decision-support tools to decide if they should immediately sell or store their produce, to time their sale for a later date. As for value addition, farmers have little or no training on value addition with minimal processing and grading. The vast intermediation in the farm to food chain not only leads to information asymmetry but also leads to information loss. The consequence of the farmers' inability to maintain their crop, undertake value addition, or grading is that farmers receive a small fraction of the consumer price for theirs crop.

EXISTING SOLUTIONS

Agricultural trade in India is largely facilitated by institutions called APMC market yards or mandis. At the mandis, local traders or intermediaries buy the raw produce from multiple farmers, aggregate the produce, and sell it to processors. Very often, the processors buying from these local traders are in the geographical proximity of the mandis. Processors have the infrastructure and knowledge to process a given product and can grade it according to its quality; moreover, they have a direct link with bulk buyers and industrial consumers and hence, first-hand knowledge of quality specifications and are therefore able to map these specifications into their grading and assaying activities. The grading standards and perceptions vary regionally and depend on different customers, and industries based on the end use. Traders and processors through their networks and direct market linkages are better informed about prices of various commodities and grades across different markets and industries. Furthermore, they use market intelligence to their advantage and maximise profits in the farm-to-food value chain. Also, they use their infrastructure and forecasting abilities to store the produce for sale at a more opportune time.

SOLUTION

Farmley uses a combination of e-commerce, machine learning (ML), and backend physical infrastructure (collection centres, supply chain, logistics,

packaging facility, quality assurance) to disintermediate the agricultural value chain. Farmley deals with non-perishable agricultural products and works mostly with Farmer Producer Organizations (FPO). It connects FPOs directly to customer-facing companies like BigBasket, Grofers, and other large retail chains that sell directly to customers.

Farmley's platform uses live commodity prices at various mandis, past trends, forecasts, demand cycles, and processes these data points through ML algorithms. The output of these algorithms is a commodity- and grade-wise price or a per SKU price. FPOs working with Farmley are provided a mobile application called FarmleyBiz where the listed prices can be viewed. The mobile app has well-defined commodity-wise quality standards and FPOs can also enter commodity specifications. Using the app, FPOs can list the quantity and grades of the produce available if the listed price is acceptable to them. Similarly, on the demand side consumers can see Farmley's listed price and place orders on the platform based on FPO listings. The platform keeps tracks of executed trades and also maintains a live inventory status of FPOs. After the conclusion of trade, the platform facilitates logistics and automates the documentation and paperwork required for transportation of the commodity to the end consumers. Farmley operates its own collection centres (CC) where FPOs bring their produce traded on the Farmley platform. It furthermore undertakes quality testing at these CCs to ensure that grade of a produce brought by the FPO is consistent with the grade as listed on the platform and purchased by the buyer. Upon completion of this quality assurance process, Farmley packages produce and manages the entire supply chain until it is delivered to consumers. FPOs and consumers can track it in the supply chain and also generate GST compliant invoices for facilitating transportation.

UNIQUE FEATURES

- an ML-based dynamic pricing model that allows farmers to realize profits based on the live market prices, past trends, and demand cycles;
- complete supply chain management along with documentation including integration with GST portal;
- logical separation of mandis as the customer side mandis and farmer side mandis to offer more nuanced prices for a commodity.

SOLUTION IN PRACTICE

Farmely works primarily with FPOs and different engagement approaches based on the availability of processing infrastructure. For FPOs having processing infrastructure, Farmely offers guidance and training on grading and provides market linkages with buyers on its platform. For FPOs without the requisite processing infrastructure, it connects farmers with processing and grading units where the raw produce is processed and graded as per predefined market standards. Farmley also provides market linkages to these FPOs. Farmley's field staff undertakes daily physical surveys of mandis for commodity prices. The data are input into Farmley's ML-based price engine that generates daily prices for every commodity and grade. For a few commodities, Farmley generates hourly prices as well. These prices are listed on Farmley's platform and visible to both FPOs and buyers.

Farmers or vendors willing to sell their commodity products at the listed price can enlist the available quantities into the system via the FarmleyBiz application. Interested buyers can buy the listed commodities. The application allows FPOs to generate dispatch plans and vendor invoices to monitor and manage the shipments. The platform engages the FPO farmers by sending

regular updates on market prices, news, and events to help them organize their production. Farmley manages the complete supply chain from FPO-to-consumer through its collection centres (CC), packaging, and logistics services. The CCs have quality-assaying infrastructures for quality assurance activities. Quality assaying and grading require a great deal of manual intervention and consequently a wide scope of subjectivity. Farmley is trying to automate quality-grading activity using internet of things (IoT) technology. At present, Farmley operates collection centres in Purnia (Bihar), Vashi (Maharashtra), Sonipat (Haryana) and Mangalore (Karnataka).

CHALLENGES OVERCOME

Reaching out to an appropriate group of farmers and FPOs and building trust were the initial challenges. Farmley set up collection centres where its team members interacted directly with farmers and farmer groups to convince them to process and grade their raw produce and sell it via the Farmley e-commerce platform. Also, Farmley's field staff undertook field demonstrations and training on quality grading, value addition, and offered immediate payment, unlike the mandis where local traders make payments after a time lag. Once the news spread about the incremental profits farmers were earning, farmers in the cluster started engaging with Farmley. Another challenge was the digital literacy and onboarding of farmers and farmer groups on the platform and convincing them to transact via a virtual medium. This was partially overcome by simplifying user interface and offering a multi-language interface. Regional variations of grading standards and the lack of harmonized grading standards also posed problems. Market research and stakeholder consultations helped bridge these gaps.

HIGHLIGHTS

- currently providing market linkages to about 12 FPOs and 40 000 farmers;
- enabled trade of agriculture commodities that have a cumulative value of INR 1500 million.

ENABLING ECOSYSTEM ENTAILS

More warehouses and peripheral processing units can enable farmers get their produce processed, graded, packed, and stored, and hold until the right price is obtained. Furthermore, financing of commodities stored in warehouses will help prevent farmers from accepting distress sales for immediate liquidity. Standardization and harmonisation of commodity grades are another critical enabler for a seamless trade of agriculture produce.

SUCCESS STORIES

Farmley's, Bihar cluster focuses mainly on the production of makhana (lotus seed) that is consumed globally. The market data from the customers on the Farmley platform revealed that the quality requirements of five suta (practical measurement unit) plus lotus seeds was too inferior for the majority of consumers, while 6 suta plus were too costly to be commercially viable for scale. Based on this information, Farmely created a new quality genre of 5.5 suta lotus seed, which reduces wastage for the producers and is economical for customers. This led to an increase of an INR 50 per kg margin, a 25 percent reduction in wastage, hence an overall 37.5 percent increase in overall revenue. This also resulted in a five percent lower cost for customers than procuring 6 suta plus lotus seed.

FASAL

STATES OPERATING IN INDIA
Chhattisgarh, Karnataka, Madhya Pradesh, Andhra Pradesh

TARGET BENEFICIARY
Farmers, extension workers, vineyards, seed companies, and tea and coffee growers

BUSINESS MODEL
B2F, B2B

WEB
https://fasal.co

PROBLEM

Food systems from farm-to-fork are a complex interplay of actors, environment, and knowledge systems, both formal and informal. Crop growth and yields are dependent on many environment variables beyond the control of farmers. However, with timely interventions farmers can control or minimize any potential income loss from yield losses or crop damages. Farmers can also improve their income by optimizing their input costs on fertilizers, chemicals, and irrigation. Most farmers in India inherit agricultural knowledge through family or rely on indigenous and local knowledge systems to make key tactical decisions about their farms. Therefore, their decision-making is not completely based on science or data and most times adversely, impacts cost of cultivation (and consequently their income). Emerging phenomena such as climate change, new pests, and diseases, erratic, and extreme climate events leave them completely exposed to risks. Data and science-based interventions can reduce the risks of farmers from the time of sowing until harvest, but translating complex science and data into actionable insight needs to be affordable, in real-time and easy to use applications for farmers. Monitoring and measuring key environmental variables and generating hyper-local weather forecasts are critical for provisioning farm-level crop-specific and crop stage based actionable intelligence system.

EXISTING SOLUTIONS

Most farmers draw on their inherited knowledge or the indigenous knowledge within the local communities for important tactical decisions on crop management. To facilitate better technology and transfer, most state governments have invested in traditional agriculture extensions. However, the public extension system is not only expensive but has left out a large portion of smallholder farmers who do not receive any extension service. Furthermore, the traditional extension is not designed to support farm-level decision making in real-time. There has been some progress in delivering weather forecasts and agromet advisories through mobile apps and text messages by the public and private sector. However, most of these efforts cannot offer the context-specific granularity and personalization that farmers require.

SOLUTION

Fasal is a farm level, crop-specific and crop stage based actionable intelligence platform that provides customized insights to farmers. These insights are generated through artificial intelligence (AI) models that use data captured from a farm by Fasal's internet of things (IoT) devices. The IoT devices capture localized environmental parameters through a robust set of sensors installed on the farm. This data encompasses other relevant data sets and is processed through Fasal's AI models to provide farmers with actionable insights on farm planning, irrigation, disease, and pest management. Fasal's solution also helps farmers maintain a financial profile of farms by digitizing the costs of cultivation and farm income. Fasal's solution, therefore, de-risks farmers and helps reduce costs, improve yields, and conserve water.

Fasal's solutions are crop centric and currently available for horticultural crops such as grapes, tomatoes, capsicum, chilli, and pomegranates (Figure 1). Hardware and sensors deployed on a farm and a decision support system provided for farmers vary accordingly to crops. For instance, Fasal's solution for grapes proactively helps farmers anticipate downy and powdery mildew through microclimatic forecasting and AI algorithms. Similarly, it helps farmers monitor water stress and the field level evapotranspiration to manage irrigation and berry size. Its irrigation planning alerts work best with drip irrigation systems on the farm. Fasal's platform can be integrated with irrigation pump controllers as well so that farmers can automate farm irrigation based on soil moisture. Similarly, Fasal's solution helps with crop-specific disease and pest alerts, and crop health management based on the farms' microclimate, crop, and soil conditions. Fasal's mobile app alerts farmers and also provides information about micro-climate for farms through intuitive visualizations. The AI-powered forecasts can provide farmers necessary information for spraying pesticides and irrigating crops in optimum quantities with accurate time intervals. Fasal has a team of agronomists, pathologists, physiologists, and other scientists to develop AI-based algorithms for generating these insights. Fasal also partners with various weather forecasting agencies to arrive at an ensemble forecast model supporting hyper-local weather forecasting for a specific farm.

Fasal's hardware and sensors are industrial grade. Although it designed the hardware it works with original equipment manufacturers (OEMs) who make hardware and sell it directly to farmers. Fasal charges a unit-based subscription to farmers varying in cost according to crop and also the insights offered.

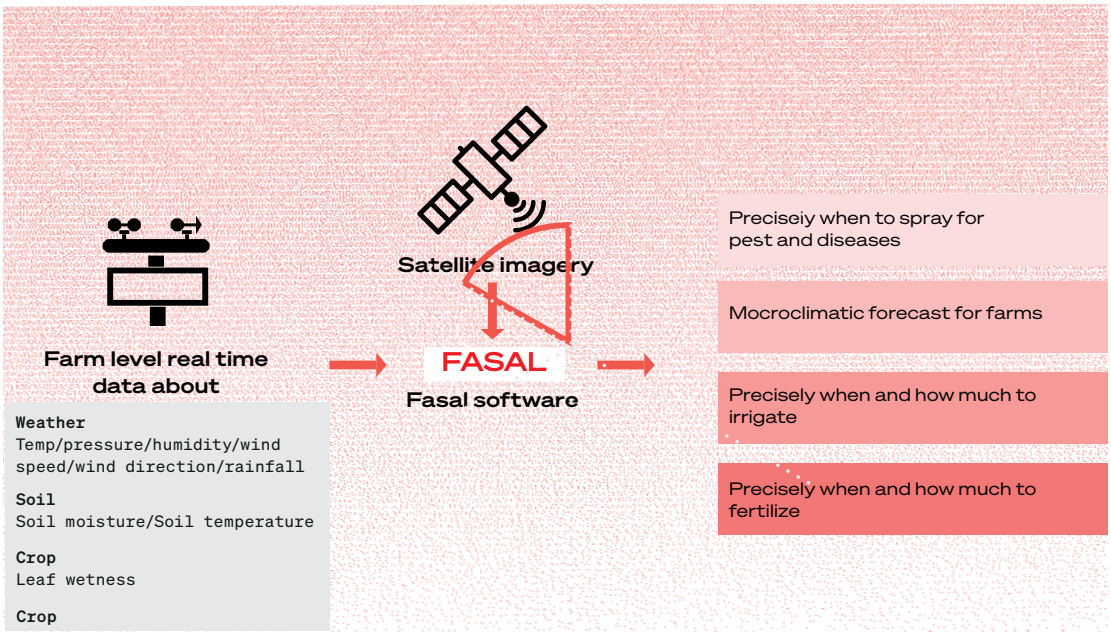

Figure A5
Fasal's solutions are crop centric

SOURCE: Fasal.

UNIQUE FEATURES

- focus on high value horticultural and plantation crops;
- crop specific and crop stage based insights;
- localised farm data from nearly ten industrial-grade sensors;
- works in low bandwidth environments by re-engineering data packets;
- adapts to periods of complete connection loss by storing data on device.

SOLUTION

Fasal's farm-based IoT sensors deployed on the farm continuously monitor critical farm-related parameters and upload data to Fasal's cloud platform using cellular connectivity. Currently, Fasal's hardware sensors can monitor weather (temperature, pressure, rainfall, humidity, wind speed, wind direction), soil (soil moisture, soil temperature), crop (leaf wetness) and solar parameters (LUX/solar intensity) and the frequency of data monitoring; transmissions can be configured. Hardware and sensors deployed on farms vary according to the crop and insights required. Fasal's hardware is placed strategically on a farm so that point data from sensors is representative of the data of the entire farm. The aggregated real-time farm data is processed by the Fasal's AI algorithms and insights are generated. These insights are disseminated to the farmer through Fasal's mobile app along with advisories. The three core features offered by the app for the crops are detailed as follows:

i. **Irrigation management:** It provides farmers with information on plot-specific water tension for efficient irrigation management.

ii. **Disease management:** When the climatic conditions are favorable for crop disease to manifest and spread, alerts are sent to farmers so that a farmer can pre-emptively take plant protection measures.
iii. **Pest management:** When the climatic conditions turn favourable for the pests' population growth, alerts are sent to farmers so that they can spray preventives at the right interval.

The Fasal mobile app also provides a 14-day hyper-local weather forecast, data trends, and analysis for daily, weekly, and monthly data that can be viewed as a report on the app. The pest, disease, and irrigation management modules depend on the hyper-local forecast. The app also provides a feature for managing the farm finances and can be viewed by farm managers on their mobile devices or desktops. Also, farmers receive alerts on changing commodity prices from nearby mandis and in addition, can generate bills for any commodity sale.

CHALLENGES OVERCOME

The development of hardware to withstand harsh climatic conditions was initially a challenge. Fasal improvised its hardware to overcome these problems. It uses an affordable industrial-grade package of sensors that can withstand most climatic conditions in the country. Fasal re-engineered the data packets and designed its solution to store data locally on the device to overcome network problems in low bandwidth regions. Another challenge that Fasal overcame was the complexity of huge volumes of data that they integrated with science, and translated into useful insights for farmers. Fasal invested in hiring internal teams of data scientists and agricultural scientists to overcome these challenges. Like most agritech start-ups, Fasal also faced the issue of convincing farmers to use its technology solution. However, testimonials from opinion leaders and word of mouth publicity helped it to convince farmers.

HIGHLIGHTS

- an average savings of 20–30 percent in water consumption with a range maximum of 70 percent;
- an average increase of 8–15 percent in crop yield with a range maximum of 20 percent;
- an average saving of 18–25 percent in spraying costs with a range maximum of 60 percent;
- INR 60 000 savings on a one-hectare grape farm per season through an increase in yield and a decrease in production costs;
- 7000 + acre of horticultural farmers are being served.

AN ENABLING ECOSYSTEM ENTAILS

Governments can support the start-up ecosystem, which entails:

i. creating a positive perception on the usage of technology;
ii. help start-ups with identifying the right target groups who will benefit the most from deploying these technologies; and
iii. make tech-tools more accessible.

GRAMWORKX AGROTECH PVT LTD

STATES OPERATING IN INDIA
Maharashtra, Karnataka, Tamil Nadu, Telangana, Andhra Pradesh

TARGET BENEFICIARY
Farmers, businesses

BUSINESS MODEL
B2F, B2G, B2B

WEB
www.gramworkx.com

PROBLEM

India accounts for 17 percent of the world's population but has only 4 percent of the world's freshwater sources – 60 percent of these resources are consumed for agriculture irrigation. Even though water is perhaps the most precious natural resource that needs to be managed judiciously, there are no real-time data-based decision support systems on irrigation management for farmers. Most farmers follow rudimentary methods and are guided by physical sensing and their intuition to manage irrigation in their farm plots. In areas with an abundance of freshwater, farmers often tend to over irrigate, leading to higher water wastage with no economic impact, as agricultural power is either subsidized or completely free in most states. Eventually, this could further push water abundant areas into water stress if the situation is not proactively managed. Labour shortage is also another impediment to a more judicious use of freshwater resources, since operating irrigation pumps and channels comes at a cost and represents a time overhead for the farmer. Due to changing market conditions, India's labour market is also undergoing a structural change with the decline of agricultural jobs by 25 million, while non-farm jobs have risen to 33 million in 2011–2015. On the other hand, farmers are giving up on agriculture due to the absence of an irrigation system. More than half of India is already facing water stress because of withdrawals at 40–80 percent of the available supply.

EXISTING SOLUTIONS

There is a greater reliance on rudimentary practices such as naked eye checks, touch, and feel to determine water/irrigation requirements. There are no reliable data-based decision support systems that provide real-time insights and indicators specific to a crop or its sowing time.

GramworkX solution: uses IoT sensors and real-time data analytics to provide rich insights on the quantum of water needed and the timing for a particular crop, in order to move farmers towards sustainable water management practices. Second-generation farmers who are tech-savvy and who understand the importance of a judicious use of water for the environment and sustainability are drawn to the GramworkX solution.

The solution is based on the principles of a closed-loop ecosystem and comprises hardware (IoT sensors) and software deployed on the cloud. The

hardware suite consists of the India Meteorological Department (IMD) approved sensors that measure temperature, humidity, pressure, rainfall, wind speed, wind direction and flow meter, as well as the telemetry systems to wirelessly transmit sensor data on a real-time basis to the cloud. The software stack (which comprises Gramworkx IP) encodes scientific methods such as the FAO Penman-Monteith method and Soil-Water Balance method to estimate the evapotranspiration (ET).

Apart from ET, Gramworkx also uses algorithms to compute crop factors and several other indices based on the sensor data. All these data points are processed to provide farmers a daily irrigation schedule, which is specific to the crop and based on the real-time data from the farm. Gramworkx's uniqueness is found in the fact that it computes ET not only from the plant but also from the soil surface and loss of water in the environment. Its solution therefore depends on data from various other sensors apart from the soil moisture sensors to compute ET. This solution quantifies water lost by a plant, which in turn helps to scientifically estimate the exact quantum of water that needs to be supplied back into it. The solution also has IoT based actuators that can automatically switch on/off electrical pumps and solenoid valves through an app thus eliminating the need for any manual interventions.

UNIQUE FEATURES

- easy product installation – do it yourself model;
- data analytics module – calculates daily water requirements based on crop, geography, and soil;
- real-time notifications and data accessibility via a mobile android app;
- end-to-end automation system minimizing labour requirements.

SOLUTION IN PRACTICE

GramworkX's vision is to revolutionize the way farmers use water by providing data-based decision support systems through IoT and data analytics. GramworkX's solution and platform was the outcome of the experiences of its founders who performed hobby farming before deciding to fuse technology to solve a critical issue in irrigation management.

Gramworkx operates in B2B and B2B2C models and targets mid-size and big farmers growing water-sensitive crops, for example, crops whose yields are adversely impacted or whose quality deteriorates if timely irrigation is not provided (Figure 1). In the first phase, GramworkX is targeting potato, since it is part of the POTO (potato, onion, tomato, others) family; three crops, potato, onion, and tomato make up 60 percent of the vegetable volumes consumed in India. Fruits and vegetables are cultivated in about 8.9 Mn ha in India and potato is grown in about 25 percent of this area. In addition, the average potato yield in India is about 50 percent of the average yield in advanced countries. The potato crop has several important stages that are critical to the yield and are sensitive to the availability of soil moisture. There are about 24 000 mid to large potato farmers in India and GramworkX estimates that timely irrigation based on its data support systems (DSS) can help its customers increase yield by 30 percent, which can translate to an enhanced income of INR 1 lakh per hectare. The GramworkX solution is crop agnostic and can easily be configured to other crops as well. In the second phase, GramworkX aims to target banana, tomato, and grapes. The yield of banana and tomato is water sensitive at the critical stage, as soil moisture levels influence the acidity of grapes. Higher acidity lowers sweetness of grapes leading to the rejection of grapes by wineries and other industry

processors. GramworkX is also targeting companies like ITC, Pepsico, HUL, Waycool and other leading contract farming companies for arrangements with farmers. Such companies would be interested in part funding GramworkX solutions for two reasons. Such solutions give these companies richer field-level data and help their decision-making. These companies are increasingly interested in the sustainability of their supply chains.

GramworkX is also developing a machine learning (ML) based model to predict ET based on weather data. This, in combination with spatial modelling, can help to predict ET for any region across the globe with great accuracy. This widens the capacity of the applications, as ET is one of the major components of the hydrologic cycle and its accurate estimation is essential for hydrologic water balance, irrigation system design and management, crop yield simulation, and water resources planning and management.

CHALLENGES AND MOVING FORWARD

- In India, the input subsidies and commodity price policies favour crops such as paddy that are water intensive. Most states offer free electricity to draw out groundwater for irrigation. Subsidy-based approach to irrigate farmlands led to negative environmental consequences in many parts of India. In Punjab (North India), over-exploitation of ground water due to subsidies on power has already led to an alarming situation. Studies indicated that groundwater is depleting at a rate of 0.3 to 1.00 m annually.
- Drip irrigation improved water use efficiency in a focused manner. This has, however, not been met with the quantification of water needs. Quantification using 'x litre/crop/day' could be a potential next step.

HIGHLIGHTS

- The initial testing and validation of algorithms with Indian agricultural scientists and subject matter experts has been promising.
- Gramworkx is in early stages of implementation with total deployment in less than 10 field locations with hardware testing and validation of algorithm on an on-going basis.

ECOSYSTEM ENTAILS

- government budgetary support to make the product available for small and marginal farmers;
- awareness campaigns through demonstrations and information penetration on the importance of such digital technologies needs to be adopted. Focused funds or channels towards enabling such could enable scaling.

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT)

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana, Karnataka, Odisha, Uttar Pradesh

TARGET BENEFICIARY
Agricultural research organizations, government departments, development organizations, funding/donor organizations, extension workers, farmers

BUSINESS MODEL
B2B, B2F

WEB
www.icrisat.org

PROBLEM

Agricultural research and development projects involve many field- and farmer-centric activities. Research and development organizations hire technical staff to interface with farmers and these interactions and field efforts generate a great deal of data. Organizations need good quality data to understand whether a particular intervention is creating the desired impact at the desired scale. Monitoring and evaluation (M&E) plays an essential role in understating the impact, outcome and focus of projects. First, failing to measure impact often leads to inefficient outcomes such as wastage of resources while scaling up the initiative when the initial results are questionable. Second, the lack of impact measurements also means stakeholders are unsure of whether the intervention works on the ground. Better data from the last mile where interventions are delivered can also help organizations engage in mid-course corrections within the project, and ensure that initiatives produce the intended outputs and outcomes.

EXISTING SOLUTIONS

Impact and output measurements and computations rely on manual and fragmented data collection efforts from the field. Field staff and enumerators survey use paper forms and fill in the forms as they collect data. There is some use of technology through tablet devices and mobile apps such as the Open Development Kit (ODK). However, this data collection process does not efficiently integrate data from the different formats and requires a certain amount of manual effort, which can furthermore lead to transcription errors. Consequently, precious time and skill of project managers, researchers and stakeholders is spent on data clean up and validation leaving little time for value added analytics. Data analysis in existing tools is not intuitive and is therefore dependent on skilled personnel hired to compile reports.

SOLUTION

Given the importance of quality data in real time in the field, along with actionable insights for agricultural research for development programmes, the ICRISAT designed, developed and implemented a modern information and technology (ICT) based M&E platform. The platform enables quality data collection for agricultural research for development programmes with real-time tracking and actionable insights for course correction and implementation. The full version of the platform is called MPro (Measure Pro). Its open version is called MOpen (Measure Open).

The platform (i) enables the collection of geo-tagged data of farmers, farmland, crops, demo plots, capacity building activities in real time from the source where data are generated; (ii) collection and aggregation of periodic reports, updates information from different implementing partners; (iii) keeps track of the KPIs (key performance indicators) and progress of project implementation; (iv) provides a web-based multi-layered dashboard to visualize the reported data both spatially and temporally; (v) provides spatial distribution of the project intervention sites and the adoption; and (v) schedules and manages field level activities carried out by partners and staff on the ground.

The platform modules are organized as: (i) the feld data collector, which facilitates data from front-line staff; (ii) the Beneficiary Management System (BMS), which uses QR codes to uniquely identify each beneficiary; (iii) thefield staff tracker, which helps keep track of activities of field staff; (iv) the activity tracker, which supports project management; and (v) the visualizing platform, which provides an analysis and visualization of the data as it is collected from the field.

MPro has both mobile and web interfaces so that data collection can be undertaken through a mobile phones or computers. Field operators can conduct surveys, share stories and visuals through the mobile interface of platform. Field staff can also upload pictures and post comments apart from the data on a survey. The platform can also be configured to create unique wiki page for every project and aggregate uploaded pictures and comments from the field. The data-analytics module generates instant analysis and graphs, tables and maps as activities progress on the ground. This data aggregated along these lines can be exported for the preparation of project reports, or can be imported into statistical packages such as SPSS and SAS for a more rigorous analysis.

UNIQUE FEATURES

- easily configurable and scalable;
- customizable and adaptable for different project use cases;
- offline/online data collection;
- real-time data analysis and integration with other statistical packages;
- secondary data ingestion and analysis;
- QR code-based beneficiary management and tracking system to collect beneficiary level panel data;
- multi-language support;
- ability to portray activities/outputs as contributions to Sustainable Development Goals (SDG)..

SOLUTION IN PRACTICE

The MPro platform was conceptualized and designed in response to the vision of ICRISAT to modernize M&E function across its projects. The tool is managed by the digital-agriculture-youth (DAY) theme at ICRISAT, Hyderabad. The use

of the platform commences with a consultation with project managers and preparation of the requirements. Based on this, MPro team configures various survey forms to be used on the MPro mobile app as well as web forms and dashboards. MPro's architecture enables role-based access that can be configured by the MPro team. Hence, field enumerators can log into a MPro mobile app and will only see those forms that have been mapped to their log in. Field operators collect data through surveys or share stories. MPro solution has since been extended to other organizations such as the International Livestock Research Institute (ILRI), the International Center for Tropical Agriculture (CIAT) and FAO.

CHALLENGES OVERCOME

The biggest challenge was to create a flexible tool that could be repurposed for different project arrangements with minimal effort and time. Instilling confidence in the utility of investing in digital tools and enabling seamless transitioning from paper-based methods to a digital platform also proved to be demanding. The team spent a long period creating confidence and comfort for the early adopters.

HIGHLIGHTS

- offering digital M&E solutions to over ten large initiatives in ICRISAT;
- offering solutions to centres such as ILRI, CIAT, FAO;
- aggregates data of over 500 000 records.

AN ENABLING ECOSYSTEM ENTAILS

Understanding the requirements of all of the actors in project management, catering individually to each user group, and creating value-addition has enabled the digital transition to run smoother. In addition, having a visionary leadership and executive support is critical to the success of any digital transformation effort.

SUCCESS STORIES

The Measure platform was originally designed and developed by ICRISAT in late 2017 for its internal M&En process. Several projects led by ICRISAT and implemented by various other CG centres and National Agricultural Research Systems (NARES) partners in sub-Saharan Africa and South Asia use the Measure platform extensively. Some of them include the Bill & Melinda Gates Foundation (BMGF) funded Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa (AVISA), Harnessing Opportunities for Productivity Enhancements of Sorghum and Millets (HOPE II); the USAID funded groundnut up-scaling project in West and Central Africa (WCA) and the Malawi Improved Seed Systems and Technologies (MISST) project in Malawi. The Avisa project is using the platform for planning, budgeting and reporting from over 110 individual researchers and managers from seven national research institutes, three CGIAR centres and the Syngenta Foundation for Sustainable Development spread across seven countries in the sub-Saharan Africa.

Although the platform was originally developed by ICRISAT for its internal consumption and use, its agility and flexibility made it adaptable to any agricultural research and uptake programme. In 2020, features of the Measure platform were significantly re-engineered and the new version of the platform was renamed MOpen and MPro.

One of the key projects using the Measure platform is the USAID Feed the Future funded Accelerated Value Chain Development (AVCD) programme in Kenya, which is led by the International Livestock Research Institute (ILRI) in partnership with the International Potato Center (CIP) and ICRISAT. AVCD is a USAID/Feed the Future (FTF) funded three-year project being implemented by the International Potato Centre (CIP), ILRI and ICRISAT to enhance resilience, agricultural productivity, food and nutrition security and overall economic welfare of actors along the value chains of livestock, dairy, root crops and drought tolerant crops in Kenya. The focus of the AVCD project is to increase the production of high-quality seed, and ensure that smallholder farmers, especially women and youth, have access to seeds from improved varieties. The Ministry of Agriculture, Livestock and Fisheries, Kenya, in partnership with ICRISAT is working in Busia, Keiyo Marakwet, Siaya, Kitui, Makueni, Tharaka Nithi and Mbeere counties in the country.

The AVCD programme adopted Measure at the end of its Phase 1 to visualize the M&E data. In Phase 2, Measure was mainstreamed from the start and the QR code-based BMS was introduced to effectively and efficiently track the programme beneficiaries in real time. Close to 34 000 farmer interventions were tracked in real time in the field using the BMS in the last ten months.

IFFCO KISAN SANCHAR LIMITED (IKSL)

STATES OPERATING IN INDIA
Pan India

TARGET BENEFICIARY
Farmers, food-processing companies

BUSINESS MODEL
B2C, B2B

WEB
https://iffcokisan.com

PROBLEM

Traditionally, advisory services in India are driven by extension officers who have the onus to incentivize good agricultural practices (GAP) as well as new technologies and developments in cultivation practices. However, the services offered overall by extension officers have given inadequate, inopportune, and unsustainable results, and seem to have had little impact on the farmers' income. The labour deficit in extension, climate change, and the generic nature of the advisories are not able to meet the farmers' needs for specific advisory services.

EXISTING SOLUTIONS

Advisory services delivered through extension officers and communication with farmers through radio and video platforms are the main solutions to this problem. There are some promising agricultural efforts being made by using physical kiosks and electronic touchscreens installed in villages. The radio and video platforms or the kiosk model, however, are part of the mass broadcasting of advisories and do not offer the convenience of accessing real time contextual advisories, which cater to the specific needs of farmers. The strong penetration of mobile phones coupled with a fall in data costs has led to the growth of text (SMS) based advisory services. The SMS-based advisories are an improvement over radio and other mass broadcast methods, as they offer benefits for the farmers and, with sufficient details about the subscribers, text advisories can be customized to fit the end-users' needs. Despite the emergence of the many text advisory platforms and their apparent convenience, the uptake of this type of advisory service continues to be low due to poor literacy and comprehension at the small and marginalized farmer level.

SOLUTION

IFFCO Kisan Sanchar Limited (IKSL) is a subsidiary of Indian Farmers Fertiliser Cooperative Limited (IFFCO), a multi-state farmer cooperative incorporated in 1967 to manufacture and market fertilizers for farmers in India through its federated 35 000 Primary Agriculture Co-operative Society (PACS) as members. IFFCO has since diversified into various adjacent domains to thus identify rural focussed solutions related to ICT/telecom, finance and general insurance. In 2001, IFFCO also initiated a wide area network-based Kiosk solution in regional languages; these Kiosks were placed at IFFCO Kisan Kendras in about 100 locations where farmers could go to procure agricultural inputs as well as packages of practices (POPs) printouts for their crops in

regional languages. Having foreseen the potential of mobile phone penetration in India and its potential use in e-extension, IFFCO started text based agriculture advisory services in 2004–2006. The independent evaluation of these advisories, however, found that the uptake of text based advisories was only about 2–3 percent. IFFCO realized that for a more effective uptake of these services, the translation of texts into voice-based services could be used. Due to the fact that in the early 2000s these services were costly, IFFCO incorporated IKSL as a joint venture between IFFCO and Bharti Airtel, India's largest mobile telecom company. IKSL provided the farmers with Green SIM cards, which are currently retailed through a network of over 22 000 retail agents. There are nearly three million Green SIM subscribers who receive three free voice-based agricultural advisory messages per day on topics such as cultivation practices, weather forecast, pest and disease management, market information, financial literacy, government schemes, livestock management, health and sanitation. IKSL's advisories are designed to engage farmers throughout the cropping season and are available as texts as well as through voice-based services. IKSL invested in creating technology platforms to support Green SIM-based advisories and furthermore progressively created very strong teams to create content for its advisories in the local languages. IKSL is headquartered in New Delhi with state offices in 14 states. Each state office has a team of agricultural experts, scientists and small and medium enterprises (SMEs) who work closely with local state agricultural universities (SAU), Indian Council of Agricultural Research (ICAR) institutes to create advisory content for various crops and commodities in the vernacular. The HQ team primarily works on coordination, programme management, software development and digital innovation. IKSL obtains regular feedback through surveys of farmers and subsequently performs analytics to understand the advisory uptake and improve its advisories. In addition, it uses data from its voice-based services to assess the usefulness and relevance of its advisories to farmer subscribers.

IKSL experiments with technologies including satellite and geo-spatial technologies and internet of things (IoT) to automate and improve the quality of advisories. IKSL has ongoing partnerships with IMD, IBM and other weather data companies for customizing advisories based on weather forecasts. IKSL also encourages and facilitates community-based organizations such as as Farmer Producer Organizations (FPO), non-governmental organizations (NGO), and Self Help Groups (SHGs), and installs automatic weather stations (AWS) and IoT-based weather sensors to improve spatial and temporal resolutions of farm-specific local data. For such farms, IKSL combines data collected from the field with that of the satellite, IoT, and socio-economic data to generate near real time granular, contextualized and more importantly, actionable advisories. To improve engagement with farmers with smartphones, IKSL deployed a mobile app for them. Farmers can create digital profiles through this app and access advisories, provide feedback or ask questions. The mobile app Krishi Dev Gyan with its reverse image recognition feature also provides instant pest and disease diagnostics through images uploaded by farmers. The digital profile can be combined with satellite datasets to create a risk profile for each farmer, which is further used to deliver targeted advisory services.

IKSL's end-to-end traceability-enabled extension platform can be offered to other agri ecosystem collaborators such as development agencies, research institutes, input players, financial institutions (FI), and food processors, to improve efficiency with data driven solutions at each stage of value chain.

IKSL caters to about 200 000 farmers through its institutional Samadhan services, devised as a telecom agnostic platform where farmers do not need to change their SIM cards as was the case with Green SIM-based services. Samadhan Services are flexible in terms of responding to the needs of research and development, and targeting specific areas of intervention for social development institutions and corporates. IKSL works with prominent institutions such as the National Bank for Agriculture (NABARD), the Borlaug Institute for South Asia (BISA), the BAIF Development Research Foundation (BAIF), and the International Rice Research Institute (IRRI) on climate smart agriculture across ten states as part of the Samadhan. Another important intervention of IKSL is the Kisan Call Centre (KCC) for the Ministry of Agriculture and Farmers' Welfare, Government of India. KCC employs about 700 agricultural graduates and IKSL manages recruitment, training and analytics for KCC. Farmers can access KCC services through a toll free number. Since inception, KCC has answered over 10 million calls in 28 different languages. IKSL constantly analyses call centre data to improve the quality of its advisories. Encouraged by the success in e-extension, IKSL began venturing into providing market linkages and an end-to-end traceability solution from farm-to-fork. Digitization of farmers and farms provides visibility for farmers and collaborating agencies such as NGOs, banks, insurance providers, government institutions, agro-processing agencies, food companies and corporates.

UNIQUE FEATURES

- voice-based contextualized and actionable advisories provided in the local language on a farmer's mobile phone;
- artificial intelligence (AI)-machine learning (ML)/IoT based data-driven digital ecosystem for, prescriptive and predictive interventions;
- digital profiling of farms, farmers, and continual record-keeping of the issues and their advised solutions;
- reverse image mapping for pest and disease diagnosis;
- near real-time personalized voice advisories;
- interactive mass communication model with measurability feature on the absorption of communication.

SOLUTION IN PRACTICE

IKSL services are available to farmers through Green SIM, SAMADHAN, Krishi Dev Gyan Platform and KCC.

KCC: IKSL partnered with the Government of India to establish the country's first KCC. A dedicated toll-free farmer helpline number is being run by IKSL on behalf of the Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers' Welfare, Government of India. About 30 000 farmer calls are handled every day through this helpline. Nearly 700 farm tele advisors who are agriculture experts, agricultural graduates, and postgraduates attend to farmers' queries and provide solutions.

Green SIM: IFFCO partnered with the telecom service provider Airtel to issue farmers Green SIM cards that provide free voice messages for rural subscribers. Farmers using these services receive three free voice-based messages that are location specific, relevant, timely and contain high-quality information in the local language. The same advisory services can be accessed through the IFFCO Kisan Agriculture Mobile App. The app also enables farmers to make use of the Samadhan Services where farmers can enter their farm and crop

details and receive personalized predictive and prescriptive advisories and voice clips. Farmers opting for Samadhan get personalized voice and text messages for the chosen crops as per their sowing dates.

Samadhan Services: SAMADHAN Service is a telco agnostic voice and text based advisory service that provides need based predictive, prescriptive and actionable advisories involving a community focussed approach, in association with some partner organizations. Farmers associated with any organization can subscribe to the Samadhan services. The advisories provided are curated and validated by the partner organization, considering the objectives and outcome of the association.

Krishi Dev Gyan: It is an AI/IoT-based ICT platform that leverages a mobile-based innovation delivering data driven decision-making capabilities to the farming community. Farmers can enroll for this service through partner agencies and benefit from hyperlocal weather based advisories, pest and disease forecasts. This platform uses satellite data analysis of the digitally profiled farms to generate farm specific customized and personalized solutions. IKSL is increasingly designing its interventions around FPOs, and taking advantage of its connections with farmers and farmer networks across the country. It is furthermore rolling out digital solutions to facilitate market linkages, commodity trading and value addition. IKSL is also launching its own brand called Swarnahar to offer retail processed products of the commodities procured from engaged farmers.

CHALLENGES OVERCOME

Onboarding farmers for a new platform in order to use and adopt the advisories initially proved to be a challenge. IKSL partnered with like-minded institutions and farmer associations to create community-specific modules for crops that were of interest to the community. As digital literacy was found to be limited in the rural areas, IKSL trained unemployed local youth to assist families and communities to navigate through the app. IKSL also had to overcome challenges around data availability while designing and developing some of its services. For instance, the pests and diseases diagnostic feature of the mobile app required a good repository of images in initial stages for ML. Moreover, rural areas often have a poor cellular network, especially for high-speed internet. Initially data recording activities in remote areas were hampered significantly. Therefore, IKSL developed a network agnostic app that does not require GPRS connectivity for data recording on the ground. All of the data recordings could also be done in offline mode. The GPRS requirement was limited only to transferring data to the server cloud.

THREE HIGHLIGHTS

- the Green SIM has a subscriber base of 3 million farmers each of whom receives three voice-based advisories per day;
- the KCC has cumulatively handled over 10 million farmer queries in 28 Indian languages in the last ten years. KCCs handle nearly 30 000 queries on a daily basis;
- delivering Krishi Dev Gyan based services in collaboration with NABARD to nearly 200 000 farmers in ten states of India.

ENABLING ECOSYSTEM ENTAILS

Approximately 800 agritech start-ups have been operating in India but most are working in silos. Furthermore, there is a significant overlap in the interventions of these agritechs, which can be categorized into four or five categories. Governments can play an enabling role by democratizing data and making it available to organizations based on an intended purpose. Most farmers are not tech-savvy yet, therefore there is a need to invest in capacity building and training. Finally, although mobile hardware device costs have fallen significantly, low cost and seamless data services in the rural areas are still needed.

Implementation case - A Success story from Nasik, Maharasthra India

Kagome Co. Ltd, a Japan-based company and the world's largest tomato processor entered into a Service Agreement with IKSL in 2019. Its major objectives were to develop, conduct and implement best practices and customized management to ensure the supply of suitable best quality varieties of tomato for processing, cultivation practices control, pest and disease management, recording and monitoring of farm activities in pilot locations.

Project activities commenced with 140 farmers in 24 villages of Nashik, Kopargaon and Shirpur districts in Maharashtra, with the digitally profiling of 257 acres of land along with the associated farmers' profiling. Four dedicated field staff were assigned to capture ground data using IFFCO Kisan's KDG app. IKSL calibrated KDG with Kagome's specific tomato cultivation package and practices (PoPs) that were suitable for obtaining required quality and quantity. The farmers taking part in this pilot were provisioned actionable voice and text advisories in the local (Marathi) language, including practice reminders, weather alerts, pest and disease management techniques. The pilot successfully put into place a scheduled implementation of POPs on all of the farms with optimal, timely and judicious use of the targeted inputs (fertilizer, pesticides and fungicides).

Consequently, in 2020 Kagome Co Ltd received an average 35 MT/day of desired quality tomatoes at its processing facility for the entire season as planned. Farmers witnessed an average yield of 25–28 MT per acre, which is optimal considering the varietal performance. In fact, over 7000 MT tomatoes were harvested cumulatively until May, of which 5000 MT was processed as planned by Kagome.

This intervention also led to a favourable economic outcome for farmers as well as for Kagome. When harvesting started in February, the average market price of tomato was between INR 8–9 per kg, and Kagome spent 30–40 percent less for procurement of the highest quality tomato from the farmers, while farmers registered a 10–20 percent higher rate than the prevailing market rate during the mid-harvesting season. This was possible due to the persistent efforts made to earn the trust of the farmers by continual physical as well as virtual engagement. Furthermore, the required support to farmers was provided through IKSL's platform and jointly by IKSL and Kagome field teams.

INTECH HARNESS PVT. LTD

STATES OPERATING IN INDIA
Gujarat, Rajasthan, Maharashtra

TARGET BENEFICIARY
Farmers

BUSINESS MODEL
B2B, B2C, B2G

WEB
http://intechharness.com

PROBLEM

Borewell irrigation through pumps connected to power grids encounters challenges due to an erratic and fluctuating power supply. Farmers have to visit their farms physically and operate their own pumps. Additionally, power is supplied at unusual hours (late in the night) by grid further accentuating the challenges faced by farmers. Since power is either supplied free of cost or at highly subsidized tariffs for agricultural purposes, most farmers deploy auto-starters and leave the pump powered-on for as long as there is electricity. These extended usage cycles with power fluctuations exhaust the water pumps, with the additional burden on farmers to provide frequent maintenance. Furthermore, these power fluctuations result in excess irrigation and depletion of water, a valuable resource; for example, a five horse power (HP) pump running for 15 minutes would pump out 12 000 litres of water. Unmonitored, such cycles would oversupply water causing crop damage and the depletion of water tables. Similarly, a 10 HP water-pump burns about 72 units of energy per month. Given that about 2.1 crore pumps are running across India, the energy consumed is equivalent to 1.51 billion units.

EXISTING SOLUTIONS

Agricultural pump operating mechanisms include manual control by farmers themselves or the hiring of a dedicated person to power on and off the motor. There are also some partial automation solutions, ranging from auto starters to GSM-based controllers. All these solutions, however, require human intervention.

SOLUTION

Intech's device addresses the Sustainable Development Goals (SDG) 12 (responsible consumption) by bringing about water sustainability in pump-based irrigation. Intech's patented product costs approximately INR 7500 and is a microcontroller-based add-on connect-and-forget device that adapts to the erratic power supply cycles and precisely irrigates the field as per the farmers' requirements. Through a simple interface (keypad), a farmer can issue instructions based on irrigation requirements and the device ensures that these requirements are fulfilled. Consequently, water is not pumped indiscriminately as in the case of an auto-starter or by flooding the crop. With Intech's solution, water supply is precise, with zero wastage of power or water thus reducing the carbon footprint on account of the power saved. The device also overcomes the need for manual intervention, a limitation of the GSM-based systems. Intech's devices can also be retrofitted to take advantage of

the advances of the internet of things (IoT) technologies. Intech is piloting the use of field sensors like soil moisture, ambient temperature, and soil pH. Through the use of mobile internet, these data points can be transmitted to cloud-based applications and a scientific and real-time data-based irrigation can be enabled through Intech's devices. Intech is in active collaboration with Mahathma Phule Krishi Vidyapeeth (MPKV), Rahuri, to pilot this offering. Intech is also collaborating with pump manufacturers to provide them with data from pumps, which can help manufacturers schedule their pump maintenance services based on the real-time usage data or engage more proactively with their customers.

UNIQUE FEATURES

- universal pump add-on device that has seen five-year commercial viability;
- artificial intelligence (AI) -enabled, time-based automated system with intelligence to respond to disruptions like temporary loss of power and/or water;
- auto-detection of water levels and patterns;
- programmable password protected operations schedules to operate a pump;
- modular features to connect to IoT and sensor-based technologies.

SOLUTION IN PRACTICE

Intech's device is a programmable microcontroller-based hardware that can easily be attached to any water pump. Initially, after installation the farmer needs to feed in the number of hours the pump has to run. Thereafter, there is no need for the farmer to physically operate the pump for their irrigation needs. If there is a variation in the power supply, Intech's device adapts to fluctuations in power and water levels and pumps the required volume of water precisely corresponding to the fed time function.

For example, if a farmer feeds a four-hour watering cycle but the power supply to the field location is only available for two hours in the afternoon and three hours in the evening, the device automatically adapts to these conditions and powers the motor when power is available; the motor runs its instructed cycle. Similarly, this farmer friendly device adapts to fluctuations in voltage and water levels to meet the farmer's demand.

CHALLENGES OVERCOME

The product was developed in house and therefore its cost was not too high. However, field testing of the device and sourcing farmer feedback was costly. Constant improvisation based on a series of trials and feedback was critical to build a reliable and durable device. The project was entirely bootstrapped by family funds. The agricultural background of the extended family of the promoter was helpful for Intech to overcome some of these challenges. Intech also received support from Tata Trusts during their field trials and product development phases.

Intech found it challenging to sell their devices and scale it up using the traditional retail model. Convincing farmers to spend INR 7500 (approximately USD 100) as an add-on device proved to be difficult. However, after having demonstrated the savings and convenience of operating the pumps, Intech focused on the B2B model by approaching non-governmental organizations (NGOs) and pump manufacturers as a conscious business development strategy. The NGOs were impressed by the impact of Intech's

devices and pump manufacturers on business, as it offers the possibility to use data to improve their engagement with customers. Intech received INR 2 million from the Government of India under the RKVY–RAFTAAR scheme enabling it to commercialize this IoT based solution. Intech was also selected by UNIDO for its First India Accelerator Program.

IMPACT

- currently 80 devices are in operation at farms across Gujarat, Rajasthan, and Maharashtra;
- for a 15 minute excess run of a 10 HP pump, the estimated savings are 576 kWh / Units of power and 0.472 tonnes p.a. reduction of carbon footprint;
- for a 15 minute excess run of a 5 HP pump, estimated savings of water is 12 000 litre per instance of excess run.

AN ENABLING ECOSYSTEM ENTAILS

Governments, investors, and CSR donors could engage with the start-up ecosystem and look at mainstreaming innovation in their projects. Ecosystem enablers such as incubators could focus on sustainability, impact, and proof of revenue generation. Governments could catalyse innovation by providing early-stage-start-ups, access to their networks to test and rapidly prototype innovations.

INTELLO LABS

STATES OPERATING IN INDIA
Pan India

TARGET BENEFICIARY
FPOs, marketing agencies, processors, wholesaler/retailer

BUSINESS MODEL
B2B

WEB
www.intellolabs.com

PROBLEM

Manual and highly subjective quality checking practices for agricultural produce result in income loss for farmers. Furthermore, there are no inherent incentives for farmers to grow better quality produce or maintain good agricultural practices. The trader who buys the produce from farmers in the spot markets (mandis) estimates the quality directly. Consequently, transactions at the mandi between a trader and farmer is not completely based on globally accepted quality standards for the commodity. There are cases where traders short change farmers because of information asymmetry and categorize high quality produce as inferior. However, this type of variability found in the manual assessment of quality is a problem for both the bulk buyers and retailers. A brief survey of procurement agents working for a large retailer in different warehouses suggests that there is very little automation or innovation to minimize human intervention during quality checking activities of agri produce. The quality rating of health, safety, nutrition, and the taste of food production today is largely non-existent or manual. Farmers have no understanding of the quality of their produce and often do not have information on nearby market prices. This situation creates a vicious cycle where farmers' low income leads to low investments, which in turn generates a low yield. Moreover, mistrust exists on the consumers' side as there is no certification proving that the produce is from a trusted party.

EXISTING SOLUTIONS

Quality checking, grading, and assaying activities in the agricultural value chain are usually manual and highly subjective. Traders in mandis rely on physical inspection and a subjective assessment to grade the agricultural produce brought by farmers. There is not much evidence to suggest that quality checking activities in organized retail or involving corporate buyers are radically different from these traditional methods. Positive developments addressing these issues have been made. The Government of India supports the establishment of quality assaying labs in mandis on a pilot basis. A few private grading laboratories approved by the state government grade agricultural produce. However, awareness of standards across many parts of the country is limited. Furthermore, testing facilities are often inadequate and unable to cope up with the huge quantities of produce during the harvest season. Moreover, the restrictive practices of tying farmers to the local mandi/

market also leave no choice for them but to explore other lucrative opportunities in the market, which may fetch a higher price than offered by Mandi. Restrictive regulations prohibit purchases by exporters or processors from farmers directly.

SOLUTION

Intello Labs is a data science company that is trying to automate the quality checking activities of agricultural produce. Intello Labs also pursues solutions that address issues regarding quality, safety, nutrition and taste as well, through computer vision and deep learning algorithms. Its mobile application and the cloud-based algorithms automate the quality checking process of agricultural produce. The product can be used across agri-value chain to build a holistic understanding of how different processes and actors influence food quality and safety. Application users have to either click on the picture of the produce or upload the image; Intello' Labs' algorithms analyse the image and instantly provide a quality score. Based on the defect, the application can also assign a grade to the produce.

UNIQUE FEATURES

- real-time assessment of the quality;
- solution is ready for 45 commodities/SKUs;
- a configurable platform that can be aligned to various grading standards;
- a streamlined process for the addition of new commodities.

SOLUTION IN PRACTICE

Intello mobile application can be used by a trader, aggregator, bulk buyer, or any other actor in a farm-to-fork value chain. Application users either simply click on the picture of the produce or upload the image. The image is immediately analysed by Intello's proprietary deep learning algorithm to check the quality of the produce and indicate a quality score. The algorithm can also be configured to immediately grade a produce. There are different indicators used by the algorithms to grade the quality of different crops for example, the shape and colour of tomatoes are used to ascertain its freshness. Intello also developed a Near-Infrared Red (NIR) based tool called DEEP to assess fruit sweetness. The safety aspects covered by Intello platform go beyond the regulatory compliance requirements and embrace other aspects that impact pricing of a product. The platform can also be configured to improve the procurement process of bulk buyers by defining commodity-wise desired quality range and tolerance ranges. The information from points of procurement is also made available to management in the form of a dashboard. Management can get better insights on the number of lots accepted or rejected after the lots are checked for quality through the mobile application. The vendor-wise information tagged with quality will help companies identify reliable vendors and pay a premium for products with higher quality. Warehousing companies that have traditionally invested in quality assaying labs are also exploring Intello Labs' solutions to reduce cost and bring efficiency, currently catering to about 45 crops/SKUs. Moreover, a comparative advantage is also found in its scalable image-tagging platform, which enables it to readily add new commodities.

CHALLENGES OVERCOME

The greatest challenge was to source sufficient data to train machine-learning (ML) algorithms to distinguish agricultural products based on their quality.

Furthermore, the huge variation and absence of any standardization in the quality checking process across commodities posed significant challenges. Apart from extensive consultations with partners, the Intello team also collected images from various markets to train its algorithms for quality grading. As the solution was rolled out on a pilot basis, Intello was faced with poor network connectivity and inadequate lighting conditions for images being uploaded. Intello adjusted its products to overcome these operational challenges and also trained staff on how to use the application.

HIGHLIGHTS

- Cardamom is typically sold in Kerala/Tamil Nadu at an auction. Traders decide the quality of the cardamom lots and make a bid accordingly, however, the system lacks transparency. After working with one of the planters/auctioneers, Intello Labs was able to publish data on the lots with details on its quality. This information was shared with all of the traders. With the improved transparency, farmers can generate extra income of INR 50–100 per kg.
- A large e-commerce company that used Intello's platform improved the quality of fresh produce delivered to its customers. This company offered concessions to its customers if they received poor quality produce. Since the rollout of Intello's solutions, the company's concessions decreased from 4.6 percent to two percent in six months.
- A large retailer benchmarked its procurement process of papaya against its competition using Intello's platform. This helped the company resolve critical supply chain issues.

AN ENABLING ECOSYSTEM ENTAILS

- Intello believes in the need to work closely with governments to achieve impact. However, the bureaucratic infrastructure of governments curtail the pace of product rollout. The government needs to find mechanisms to quickly evaluate insource innovation emerging from start-ups and embed them to address pressing problems.
- Quality checking companies and labs in India are certified by AGMARK. However, companies such as Intello do not necessarily meet the standards of AGMARK's certification process, as they are more aligned with the standards of wet chemistry labs. Legislation and policy that takes cognizance of these new technologies can also mainstream these innovations.

CASE STUDY

Papaya produced in North India in early 2020 was of very poor quality. Intello's client mentioned that, in general, the papaya produced in the region (even stocks with competitors) did not reach a good standard. However, by using Intello's product the client was able to identify that wastage in their input lot, which was as high as 70 percent as opposed to the 30 percent wastage for their competitor. In sum, the client could justify that the high defect rate was due to the acceptance (instead of rejection) of poor quality products at the farm gate itself.

INTERNATIONAL RICE RESEARCH INSTITUTE

STATES OPERATING IN INDIA
Odisha, Bihar, Uttar Pradesh

TARGET BENEFICIARY
Rice farmers, agricultural extension workers

BUSINESS MODEL
Youth and women as Agro-advisors, Common Service Centres (CSC)

WEB
www.irri.org

PROBLEM

Rice is a staple food for more than two-thirds of the world and is grown by 150 million poor, smallholder farmers who own less than 1 hectare of land. Any change in rice prices has direct and immediate ramifications for the food security of millions of people. Rice consumes approximately 40 percent of irrigated water and is the source of 10 percent of the world's methane emissions. Rice productivity continues to be low due to poor crop management practices such as the excess application of fertilizers, which increases cultivation costs and has a detrimental long-term impact on soils. Fertilizer is often applied without sufficient information on the soil fertility status or the crops' specific nutrient requirements, leading to either nutrient toxicity or deficiency due to overuse or inadequate use. The high resource requirements for rice and the increased frequency of extreme weather events due to climate change also affect productivity. The traditional extension system is time-consuming and its resources overstretched, and therefore is unable to offer customized farmer-specific recommendations on varietal selection, soil health and crop management based on an individual farmer's risk-reward calculus.

EXISTING SOLUTIONS

In the past, owing to the low penetration of technology, agricultural advisories were largely driven by government extension officers. Eventually the few information and communication technology (ICT) based advisory systems intended to supplement traditional extension systems offered only generalized advisories.

SOLUTION

The International Rice Research Institute (IRRI) developed a suite of ICT tools to address systemic knowledge gaps in rice based cropping systems. IRRI's strategic advantage lies in the use of its scientific expertise in developing solutions, which are simple and easily adaptable. The set of tools include:

- **Rice Crop Manager:** RCM is a web-based tool based on the scientific principles of site-specific nutrient management. Extension staff at block and village levels were prepared through a training of trainers (ToT) model on how to operate the tool, explain a broad concept of

site-specific nutrient management, interview farmers and transfer crop management advisories to them in a printed one-page format.

- **Rice Doctor:** Rice Doctor, a smartphone and web-based application, uses text descriptions and images to help users diagnose specific pest, disease, and nutrient deficiencies problems affecting their rice crop. Fact sheets on 88 pests and diseases affecting rice, including their management techniques, are made available in the application.
- **SeedCast:** SeedCast, a mobile application and web-based tool, is for seed demand aggregation. Dealers and extension officers indicate the demand for different seed varieties. An aggregate demand is made available to seed companies, which will produce and market varieties in specific locations. SeedCast thus bridges the supply and demand gap. Farmers can also use the app to access information on seed brands, including their availability with local dealers. This tool was developed based on the demand from the Odisha state government.
- **Rice Knowledge Bank:** Rice Knowledge Bank (RKB), an online platform, is providing extension staff, researchers, students, and farmers with practical know-how on key steps in rice cultivation and production in addition to recent innovations. RKB includes information across various stages of rice cultivation (i) pre planting – choosing the right variety, developing crop calendar and preparing field; (ii) growth – farm management; (iii) post-production–drying, storage, and milling information. RKB is available for general information on rice production through its global portal as well as specific website, which is in the Odia language.
- **Oryza:** Oryza (ORYZA), a crop modelling and systems analysis tool, simulates the development, growth and yield of different rice varieties in response to inherent soil, physical and chemical properties, microclimate and prevailing agronomic practices. ORYZA serves as an ideal tool for research that addresses the optimization of water and nitrogen management, identification of constraining factors on yield within site-specific conditions and the assessment of climate change effects on production.

RCM) the most widely scaled and utilized digital agricultural tool developed by IRRI, with more than two lakh recommendations generated to date. The case study focusing specifically on RCM has been presented.

UNIQUE FEATURES OF RICE CROP MANAGER

- localization of solution after extensive consultations with stakeholders;
- nutrient and crop management recommendations specific to each plot and farmer;
- engagement with local government and NGOs to reach farmers;
- advisories in local language;
- partnership with the common service centres for a wider range. Partnership with Precision Agriculture for Development (PAD) to enable voice-based advisories.

SOLUTION IN PRACTICE

RCM is localized for each country. The tool aims to address the local pain points and to create the maximum value possible for farmers. Furthermore, each country- and state-specific RCM tool is often designed based on the local

demand. To ensure that these deployments are successfully implemented, IRRI has developed partnerships and ensured a buy-in for the local bureaucracy. The products are also piloted among identified farmers for demonstration purposes. RCM was originally developed in the Philippines to provide inputs to farmers on fertilizer application. Based on its success and utility, IRRI adapted this tool to the rice-based cropping systems in Odisha and partnered with the Department of Agriculture, Government of Odisha. After extensive surveys and field trials, algorithms were developed for the computation of nutrient requirements. The extension staff delivered the benefits of this tool to farmers owing to the challenges of digital literacy and low penetration of smartphones. The extension staff collect information about a farmer through a set of questions on variety, expected yield and crop management practices. Based on the information submitted, a unique nutrient recommendation profile is provided to the user on the type of fertilizers, quantity, and timing. Farmers are given a printed copy to refer to this throughout the season and are advised to apply the nutrients accordingly. IRRI has partnered with Precision Agriculture for Development (PAD) to disseminate this information through voice calls.

The operationalization of RCM in Odisha involved training extension staff on using RCM laptops, tablets and smartphones. As a pilot study, IRRI trained input dealers as they are a key source of information for farmers who rely on them for advisories. IRRI also partnered with Common Service Centres (CSC) to interview farmers visiting the centres, and to provide them with a printed copy of RCM recommendations.

A survey conducted by the monitoring team revealed that farmers are willing to pay for such solutions. The survey also found that there is a greater acceptability of recommendations when RCM recommendations were human mediated.

CHALLENGES OVERCOME

The first major objective was to train local functionaries on how to interview the farmers using RCM on mobiles. The team conducted digital literacy training before the demonstration of mobile web-based applications, as many extension officers did not know how to use or interact with mobile web-based applications. The next step was to communicate the recommendations to farmers and evaluate their ability to comprehend and use the recommendation. The team organized and conducted extensive workshops throughout the villages to educate the farmers. The team undertook extensive field research to understand the reasons for non-adoption by farmers to improve the tools and maximize the acceptability of the recommendations.

HIGHLIGHTS

- The use of RCM increased average yields by 0.4 tonnes per hectare per season;
- 170 000 farm advisories on fertilizer application generated through RCM;
- more than 85 percent farmers, who benefitted from RCM in India, wish to reuse it the upcoming season.

AN ENABLING ECOSYSTEM ENTAILS

- improving internet connectivity. The government needs to invest in connectivity infrastructure;
- increasing awareness on the use and utility of digital platforms, especially among existing players, is a strong requirement;
- identification of local champions is necessary to drive greater acceptance;
- training and capacity building of existing ecosystem players;
- creation of collaborative platforms where both public and private players can participate and co-create.

Testimonials

Kartika Samal (Farmer, Bhadrak, Odisha, India):

> "I applied fertilizers as per Rice Crop Manager recommendations in half of my land and in the other half I applied fertilizers as per my usual practice. In the Rice Crop Manager plot, the yield was higher, by 1.2 tonnes and there was a cost saving of INR 1 200 per hectare as less fertilizers were applied."

Shrabani Moharana (Assistant Agriculture Officer, Gadamanitri, Government of Odisha, India):

> "Being an extension agent, it is helpful to me to use the tool for recommendation of fertilizer and for providing advisory services to farmers to increase their rice yield as well as improving their livelihoods in general."

KALGUDI

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana, Karnataka, Odisha, Sikkim

TARGET BENEFICIARY
Farmers, Farmer Producer Organizations (FPO), input and warehouse dealers, food processors, and consumers

BUSINESS MODEL
B2B and B2C

WEB
https://kalgudi.com

PROBLEM

Information asymmetry is a significant problem in the agricultural sector where not every stakeholder in the value chain has access to information about other stakeholders, which creates work duplication. Furthermore, the lack of commodity standards and taxonomy put the smallholder farmers at a great disadvantage. Consequently, most of the economic surplus in a value chain remains disproportionately in the hands of intermediaries, leaving little or negligible returns for the farmer or producer.

EXISTING SOLUTIONS

The existing digital solutions and interventions are piecemeal; hence, they fail to create an incentive for the continued engagement of stakeholders on digital platforms. Unless there is some immediate gratification for stakeholders at the transactional level, many of these digital interventions are unlikely to succeed in the long term. Furthermore, the existing solutions are unable to fuse innovative technologies such as Big Data, machine learning (ML) and guide decision-makers to identify problems at the systemic level and provide guidance for the policy-level levers.

SOLUTION

Kalgudi is a web and mobile-based one-stop solution for all actors in an agricultural ecosystem. It uses ML and combines it with field learning to deliver high-quality advisories. The main pillars of Kalgudi's solution include:

i. Core services: Kalgudi is leveraged by ecosystem partners to provide targeted services to farmers such as training programmes, farm activity reporting, farm advisories. FPOs management is also part of the suite of core services.
ii. Kalgudi has an ML demand prediction system for various products and services used by farmers. This ensures that the actors in a value chain consuming Kalgudi core services benefit from advanced technologies like ML.
iii. Market linkages for FPOs and rural Self Help Groups (SHGs).

UNIQUE FEATURES

- available on multiple platforms i.e. web, mobile, SMS and voice broadcast;
- digitalization of agricultural interactions;
- sends information only when there are a clear need and gratification to the stakeholder by consuming it;
- creates a traceability matrix from digitalizing transactions between ecosystem partners;
- captures feedback from the end-user.

SOLUTION IN PRACTICE

Kalgudi connects every stakeholder onto a single platform, for example the farmer, input dealer to processor, logistic provider, and consumer. Kalgudi digitalizes interactions between several players in an ecosystem. This digitalization later helps to build a traceability matrix that can position the farmer to capture higher value, that is, the end consumers who can see information about crop production are likely to pay a premium for the product. Kalgudi deploys ML algorithms to maximize the value for stakeholders involved in the agri-chain, for instance, if a farmer is interested in knowing the solution for thrips (pest), the platform maps out other farmers in the geographical proximity who might benefit from the solution and makes it available for them. At the core of Kalgudi's design is an embedded structure that creates incentives for participating actors to engage in and contribute to the digital ecosystem. In an environment where a farmer receives multiple messages from different service providers such as input companies and extension officers, Kalgudi aims to send messages only when deemed pertinent. This avoids overtaxing farmers with irrelevant information. Kalgudi aims to maximize the value and utility of each message, as compared to the conventional model where farmers are overwhelmed by the volume of messages and as a result, attach less importance. Kalgudi's platform also provides the end-consumer feedback to farmers and processors so that they can enhance the value of their products.

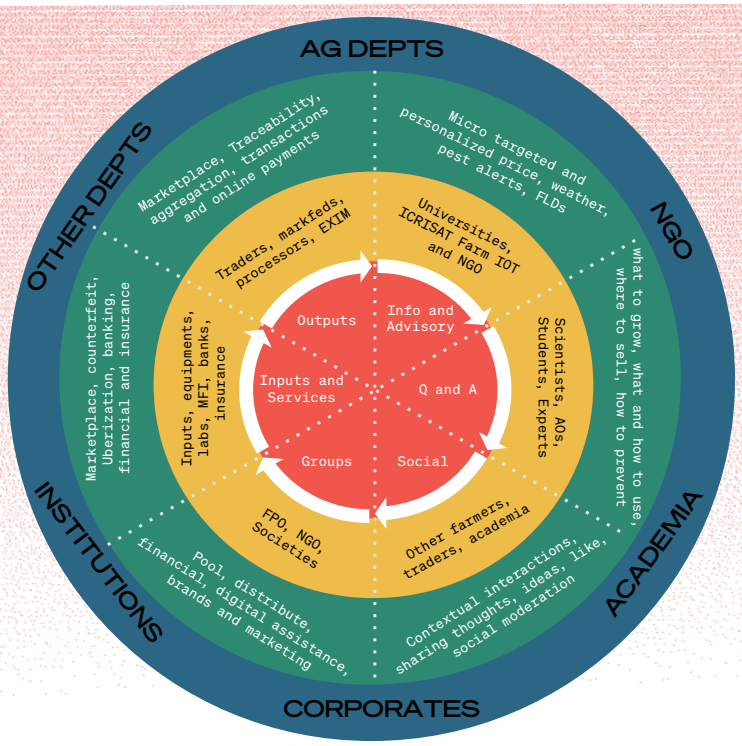

Figure A6

SOURCE: Kaldugi.

CHALLENGES OVERCOME

Kalgudi had to overcome social and cultural barriers during the initial stages because farmers and other stakeholders had little trust in the system. The initial days also saw several altercations between the farmers and Kalgudi employees due to the lack of trust and miscommunication between the parties. Kalgudi partnered with local institutions and used technology platforms to build trust by providing tailor-made advisories. Kalgudi has also overcome problems of poor digital illiteracy, diversity in farmer base, in addition to identifying the right actors for information dissemination and anticipation of when and which farmer will use the marketplace. Kalgudi used an ML system to reengineer the content and micro-target it to the right stakeholders.

HIGHLIGHTS

- 5 million profiles (farmers, traders, input dealers, food processors, warehouses, logistic providers, rural self-help group women, etc.) onboarded to the platform;
- reduced the cost of inputs to farmers by at least 30 percent by exploiting economies of scale;
- over 25 000 products made by rural SHGs are now sold through Kalgudi's market linkage platform;
- diverse customer base includes farmers, FPOs, input-dealers, banks, non-banking finance companies (NBFCs), governments, agricultural universities, rural SHGs, institutions such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and consumers.

ENABLING ECOSYSTEM ENTAILS

- creation of digital presence for every stakeholder;
- active engagement with farmers.

SUCCESS STORY

Tfresh.org

A digital intervention in collaboration with the state government to support horticultural farmers during the COVID-19 crisis.

The southern state of Telangana has nearly 307 000 acres of mango plantations, which produce about 1.38 m tonnes of popular mango varieties like Dashehari, Baneshan, and Himayat. The state is a front-runner in the mango trade with supply chains spreading across India and the world. Anticipating a favourable season, farmers, traders, exporters and processors initiated trade negotiations in February 2020. However, the COVID-19 pandemic disrupted the entire trade value chain and farmers started to make distress sales.

The horticulture department of the Government of Telangana took immediate action to devise a strategy to help farmers get a fair price for their produce. First, it launched a web and app-enabled e-commerce platform called www.tfresh.org powered by Kalgudi. Urban customers can directly place orders from farmers on this website. Second, the Indian Post Department engaged as the logistics partners to make door deliveries of the orders placed.

Third, a sustained digital campaign was launched to promote the consumption of Telangana mangoes in urban areas and extended bulk purchases to national and global buyers.

Although the government's requirement came with short-term notice, Kalgudi set up the entire backend process, whereby only Telangana grown mangoes were white boxed and provided with QR codes to ensure an end-to-end traceability. The mangoes were delivered to customers through the postal department. In just a few days, marketing, order tracking, support, fulfilments, traceability, and other third-party integrations were completed. Within a week of its launch, the site had over a million hits and generated more than 8000 orders, amounting to over 30 tonnes of mangoes with a 99 percent customer satisfaction feedback. The success of this mango sale nudged the horticulture department and Kalgudi to add different fruits and vegetables to its trading portal.

KISANRAJA

STATES OPERATING IN INDIA
Telangana, Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu, Haryana, Punjab, Rajasthan, Madhya Pradesh, and West Bengal

TARGET BENEFICIARY
Farmers

BUSINESS MODEL
B2C

WEB
www.kisanraja.com

PROBLEM

The power supply to agriculture in most Indian states is generally erratic, unreliable, and not well planned. For instance, nine hours of ensured power supply to farmers promised by a state government can be delivered randomly at any time of the day. Grid power may be supplied in the morning, mid-afternoon, or even late night. Farmers are put at serious inconvenience and risk due to the fluctuation of the power supply, which adversely affects the operation of their pumps. In fact, they invest a lot of time, energy, and fuel to travel to the farm to operate their irrigation motors. To overcome these challenges, farmers install auto-switches and leave their motors running as long as power is available. A prolonged running of a motor is damaging and leads to huge wastage and depletion of the groundwater table. Furthermore, when a motor continues to run after a well has gone dry it burns the pump out, incurring further losses for the farmers.

The quality of the power supply is another challenge. An inadequate power transmission infrastructure and oversubscription (excessive draw from the grid than the installed capacity) over a long period of time leads to voltage fluctuations. For example, while subscribing to a electricity connection, a farmer may make a request to run a 5 HP motor on the farm. Over time however, most farmers upgrade to a 10 to 20 HP pump to draw water from rapidly depleting water tables. With multiple changes of this nature to a demand unaccounted for, the installed power transmission infrastructure including the transformer capacity leads to fluctuations in voltage and therefore the transformer breaks down. Additionally, faulty three-phase connectivity frequently damages motors, and farmers must spent money for annual repairs and maintenance.

EXISTING SOLUTIONS

To overcome the inconvenience of visiting their farms at inconvenient times, some farmers use auto-switch, a low-cost device, which automatically switches on the irrigation motor when power supply is available. However, this device cannot sense low and high voltages or if the water is being pumped. Hence, an auto-switch keeps the motor running under adverse conditions. Running a motor for prolonged durations during dry spells or at low/high voltages damages the motor parts, heats the motor, and eventually the copper coil

burns out. Not only do the farmers incur the cost of repairing their motors, but they also lose precious time while the motors are being repaired. More importantly, farmers must find alternate sources for irrigating their fields to protect the standing crops from stress. In some cases, farmers who have multiple motors on their farms hire labour to stay on the farm to operate them. Labour availability is however scarce, due to rapid urbanization and consequently the structural transition of labour to the non-agriculture sector.

SOLUTION

KisanRaja, a GSM-based motor pump control (MPC) system, helps farmers to remotely monitor and control agricultural pump sets using their mobile phones or landlines. It uses SMS or interactive voice response (IVR) in the local language to help farmers remotely operate their motors and sends voice alerts to farmers when there is an erratic power supply, motor malfunction, dry run, or a theft attempt. It is a combination of hardware, MPCs, wireless valve controllers, wireless sensors, data – device usage data, voltage and current fluctuation data, satellite data and software – artificial intelligence (AI), machine learning (ML), data analytics. Its MPCs come in three variants, SAMRAT, MAHARAJ, and YUVRAJ.

SAMRAT mobile motor controller: The flagship and most popular product, which can be operated remotely through a mobile phone or landline. It frees the farmers from the responsibility of visiting their farms at inconvenient hours or employing labour to operate their motors. The voltage and current sensors can detect the availability of power, voltage fluctuations and faults, to alert the farmer on how to safely operate the device to prevent damages. The data from voltage and current sensors can also be used to detect dry runs and prevent further damage. The recent versions of SAMRAT also provide the flexibility to pre-configure pump operation at specified time intervals to conserve water and power. The MPC can also track water availability and automate pump operations accordingly. If there is no water available, it automatically shuts the motor down and when water is available, it pumps water and provides an acknowledgement message to the farmer assuring him that the field is being irrigated. It also alerts farmers through a call if anyone tries to steal the controller or its connected devices.

MAHARAJ mobile motor controller: This device performs all the functions that the SAMRAT model performs and has an additional feature of being able to control three motors at a time.

YUVRAJ mobile motor controller: This is the most affordable and basic version of the product line. It performs most of the functions that the SAMRAT model performs with the exception of a few such as theft alerts, a timer feature and water supply aberrations.

KisanRaja is at the advanced stages to devise semi-autonomous and fully autonomous irrigation solutions on the existing platform and has given demonstrations during various pilot projects. In the semi-autonomous variants, wireless soil moisture sensors are deployed in fields and the device is configured to operate a pump until the soil moisture threshold is attained. A pilot project, Internet of Pumps, was successfully demonstrated in Andhra Pradesh and with the National Bank for Agriculture and Rural Development (NABARD) funding deployed 50 MPCs and soil moisture, temperature, and humidity sensors in one representative field. Based on demonstrable benefits, efforts to replicate

this pilot in other states is in progress. KisanRaja is in the advanced stages of automating valves for its end-to-end autonomous irrigation solution. The fully autonomous solution will divide the field into segments and, using valves and soil moisture sensors will precisely control quantum of irrigation in various segments of a field. A World Bank funded pilot project was deployed featuring the fully autonomous variant of KisanRaja's IoT solution.

UNIQUE FEATURES

- remote control of irrigation motors through IVR / SMS or mobile App;
- multiple motors can be controlled with one device;
- anti-theft alert messages and calls.

SOLUTION IN PRACTICE

The KisanRaja mobile MPC is presented as a solution in a box. The MPC arrives with a slot where a SIM card is inserted to enable the mobile connectivity feature of the device. At the time of installation, the farmer's phone number is fed into a controller device so that the remote device can send alert messages and also receive remote instructions from the farmer. Since signal strength, on-farm locations could be poor, an antenna with a 3 m long cable is provided with the device. The antenna can be placed at an elevated height to enhance signal strength for better connectivity. The RAKSHAK power adaptor device containing the voltage sensing is connected to the main controller. When power is available, RAKSHAK senses the presence of voltage on power supply line and informs the farmer through an IVR call or via a simple SMS in a local language. The farmer is given the option to switch the motor on and off using the keypad or touch screen of their phone. Based on inputs given by the farmer, the controller receives instructions to switch the motor on or off. Once a motor is turned on, SUJALA – a dry run preventer – senses the current and detects whether the motor is running and the water is being pumped successfully or not. The device costs less than INR 7500. A multi-motor control variant of the device can be purchased by a group of farmers. The multi-motor control variant can be attached to the main controller and operate about three motors with a single device.

CHALLENGES OVERCOME

The operating voltage provided by the grid for a domestic household user is between 180–230 V and can sometimes reach a maximum of 250 V. However, in agricultural fields the voltage varies between 120 and 600 V, which is a huge variation for a power adapter or any appliance to withstand. Also, external factors such as humidity and extreme temperatures impact circuit components of controller device. As KisanRaja worked across various geographies in India, it was able to iterate and design a robust device that can work under the harshest conditions in India.

Convincing farmers to purchase a mobile motor controller that costs nearly INR 7500 as opposed to an auto switch, which costs less than INR 750, was initially an issue. Farmers who are used to receiving subsidies for agricultural equipment were now expecting the same treatment for the motor pump controllers. KisanRaja made an interesting observation and discovered that for a farmer, a government subsidy on a device means financial benefit in addition to an indirect endorsement of the authenticity of the product. KisanRaja furthermore built a village entrepreneur model and tried to reach a critical mass of 10–15 devices per village. At this point, further sales are enhanced by word of mouth.

HIGHLIGHTS

- more than 34 200 devices sold across 10 states in India;
- six crore litre of water saved in one season on a 30-hectare pilot project sponsored by the World Bank in West Bengal;
- “AI for Good” award by NASSCOM CoE-DSAI in March 2019.

AN ENABLING ECOSYSTEM ENTAILS

KisanRaja and other products working to conserve critical resources such as water and electricity need to be included in the list of subsidized agricultural equipment. For example, drip irrigation equipment is eligible for about a 50 percent subsidy in most states in India. This will provide a platform for such devices to scale and also provide a seal of trust for farmers who are hesitant about experimenting with new technologies. Moreover, partnerships with larger farm equipment manufacturing companies that already have a vast agricultural market network can help to achieve scale, while at the same time compliment the products of their companies. Since these low-cost resource-conserving devices run on thin margins, they could be exempted from GST, which is currently about 18 percent. Tax exemptions could further lower the cost of the device and make it more affordable for farmers.

KUZA ONE

STATES OPERATING IN INDIA
Maharashtra, Bihar, Jharkhand, Andhra Pradesh, Odisha

TARGET BENEFICIARY
Farmers, youth, agri ecosystem actors

BUSINESS MODEL
B2G, B2B

WEB
www.kuza.one

PROBLEM

Governments in most developing countries have created a team of agricultural extension workers who are assigned with responsibilities for capacity building, technology transfer, as well as the dissemination of in-season agro-advisories. Despite the high cost, evidence suggests that the traditional extension has not been very effective. Furthermore, traditional extension systems are not adequately resourced and therefore do not have enough labour to provide face time for all of the farmers within a community. Consequently, the traditional model of extension has impacted only a smaller proportion of the smallholder farming community. Moreover, traditional extension has become irrelevant due to its reliance on outdated methods, and the fact that it is not set up to help farmers deal with in-season tactical advisories *vis-à-vis* crop management.

EXISTING SOLUTIONS

It is generally viewed that, while traditional extension is necessary, it needs to be supplemented with modern technology. However, most e-extension interventions are not sufficiently integrated with the existing extension systems. Furthermore, many e-extension initiatives are the cause of fragmentation in addition to an overload of information for farmers. Most solutions also fail to implement the hyper-local variations across smallholder farming systems and are therefore unable to deliver solutions that make a real impact on the farmers. Also, many digital solutions only cater to locations and communities with good network connectivity.

SOLUTION

Kuza is revolutionizing the resilience of smallholders by creating a new framework of private sector frontline extension networks, engaging rural youth as agripreneurs (agri-entrepreneur), each supporting a cohort of 200 smallholder farmers from the local community. The role of the agripreneur is to act as a one-stop-shop at the village level ensuring access for smallholders to quality information and advisory services, inputs, credits and market linkages. This system has resulted in a significant increase in productivity and income, while at the same it has addressed the challenge of rural youth unemployment.

Kuza digitized the good agricultural practices (GAP) for 42 value chains and created micro-learning videos in seven languages, and is furthermore making it available to the Agripreneurs via KuzaOne digital platform. RUKA, a portable edge computing device, carries a similar offline instance and comes

in a portable backpack with a pico-projector and tabs to provide digital extension services to smallholders and their families. RUKA is equipped with its own memory, processor and battery to last for 6 hours. It has created a local hotspot-intranet with a range of 40 m, allowing up to 40 users to connect simultaneously without internet. Agripreneurs can also stream the GAP content to smallholder farmers from the RUKA device with a digital pico-projector. Kuza is thus enabling the micro-distribution of GAP and democratizing extension by taking classrooms to farms without internet or other infrastructure. In addition to enabling extension, KuzaOne has gradually evolved its platform to cater to the market access needs of farmers. The agripreneurs are also trained and provided with tools to aggregate various input requirements (seeds, fertilizers, chemicals). The KuzaOne platform matches the aggregate demand with supply directly from manufacturers, thereby offering better prices via the economies of scale. KuzaOne is also enabling banks and insurance companies to service farmers by using this model.

UNIQUE FEATURES

- blend of digital technologies and human interface at the last mile;
- a bundled solution that solves problems regarding the challenges of smallholder farmers (rural advisory and information services, access to quality inputs, credit, markets), unemployment in the rural villages, dependable last-mile access, accountability, traceability, transparency in supply chains;
- selecting, incubating and assisting rural youth as independent agribusiness advisors connected and supported by the Kuza Network;
- KuzaEdge digital backpack solution with RUKA device provides support for agripreneurs for digital extension services, digitizes last mile transactions and services and provides actionable intelligence even in remote locations with no connectivity;
- a comprehensive business model, which solves the systemic problems of agriculture by creating pathways for other AgTech, Fintech, Precision agri and e-commerce solution players to piggyback in a collaborative way to help the small farmers learn, connect and grow at scale;
- an opportunity for the development/philanthropy, private sector and public sector actors to co-invest and collectively scale the model while meeting their own goals.

SOLUTION IN PRACTICE

Kuza's business model pivots on the following five core elements:

i. a psychometry-based selection process identifying rural youth with entrepreneurial drive;
ii. incubation and training on agronomy, business, entrepreneurial and soft skills;
iii. digital toolkit to offer agri-extension services to smallholders;
iv. KuzaOne Network to facilitate access to inputs, credit, markets, and other allied services through a network of private sector partners;
v. mentorship and business development support via qualified agronomists/business experts to create a sustainable business for agripreneuers (Figure1).

Benefits to Smallholder farmers include:

- Access to Quality Inputs
- Access to Credit
- Access to Markets
- Access to Knowledge and Actionable Intelligence
- Improved Income and
- Quality of life

Last-mile Bundled Services offered by an Agripreneur

- Skills and Capacity Building
- Farm Advisory Services
- Access to Farm Tools
- Access to Knowledge and Mechanisation services
- Aggregation of Demand/Supply
- Mentorship and Support

Ecosystem Partners

Private sector
Agro dealers, input companies, buyers/off-takers, credit, insurance, logistics, warehousing, transport, processors, Agtech and other service providers.

Governments, NGOs, Research and Academia

Donors and Investors,multilaterals

Small Farmer can be:
- an individual Smallholder
- a group of farmers
- a farmer co-operative
- a farmer federation

Agripreneur can be a:
- lead farmer
- village based agent
- farmer federation
- agriculture entrepreneur

Kuza's OneNetwork provides a Personalised, Frictionless, Matchmaking service to the Ecosystem partner based on their needs and aspirations. Partners opt-in to the Kuza platform services to avail reduced Search cost, Traceability, Transparency and Dependable last-mile services delivered via an Agripreneur Network.

one NETWORK

Figure A7
Making of an agripreneur

SOURCE: Kuza One.

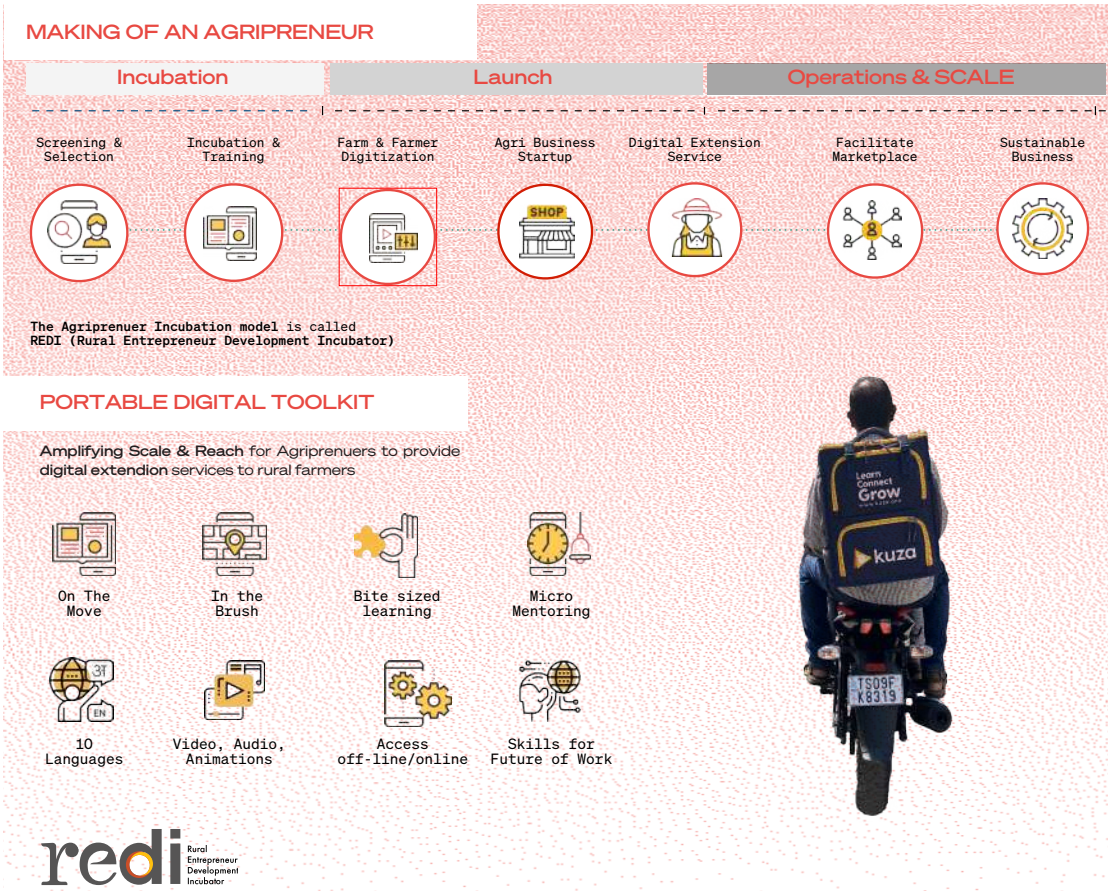

Figure A8
Portable digital toolkits

SOURCE: Kuza One.

The agripreneur establishes a relationship based on trust with farmers by providing rural advisory and information services free of charge. Furthermore, they receive a sustainable income generated by commissions from the transactions made by farmers on the KuzaOne Digital Marketplace.

KuzaOne is involved with nearly 35 private sector companies that market seeds, fertilizers, credit, and insurance. Kuza taps into donor grant and development funding institutions to fund the incubation period. During this time, agripreneurs receive a stipend and make a commitment to become financially self-sufficient from the second year onwards. While extension services rendered by agripreneurs for farmers is free of cost, agripreneurs and KuzaOne make a revenue from every sale transaction through a transaction fee. The model was designed based on the expectation that each agripreneur would facilitate input and output sales transactions for an estimated INR 20 to 25 million. A small percentage of the transaction fees will be sufficient to generate a regular income for the agripreneurs, as well as Kuza. Kuza is primarily targeting the state livelihood mission programmes. In collaboration with other partners, Kuza is working with Jeevika in Bihar and SERP in Andhra Pradesh, which probably have the largest team of community resource persons in their respective states. Kuza's model of digital CRPs without government support is very attractive to programmes that incur huge salary costs for maintaining the team of CRPs.

Kuza has successfully scaled this model to eastern and southern African countries and is currently working with the World Bank 1 million farmers' platform in Kenya, Farm2Market Alliance (World Food Programme) in Kenya, 2Scale in Kenya, Mozambique Climate Smart Agriculture Program.

Kuza is also seeing some early interest on the part of for-profit agri commodity companies who engage with farmers, especially in Kenya and Mozambique. Kuza's model benefits the agri-businesses overall through the adoption of good agricultural practices by its contract growers. If successful, this would be a rare example of a market-driven approach to create extension, unlike the most prevalent publicly funded models.

CHALLENGES OVERCOME

Kuza found that graduate youth do not enjoy working in rural areas in the long run, and that enterprising high school drop-outs have a greater success rate as agripreneurs.

HIGHLIGHTS

- operational in five states across India. Significant presence in eastern and southern Africa with a network of 3250 agripreneurs;
- onboarded 525 000 smallholder farmers cumulatively thus far;
- led to an average of 48 percent increase in productivity and 35 percent in income over a period of two years.

ENABLING ECOSYSTEM ENTAILS

- design incentives to promote public-private partnership (PPP);
- develop a concrete action plan to enable multi-stakeholder partnerships to address critical policy problems;
- incentivize private sector actors to take up this model as a collective responsibility rather than for self-serving interests.

MARUT DRONES

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana, Rajashtan, Maharashtra

TARGET BENEFICIARY
Farmers, input companies, Farmer Producer Organizations (FPO), government agriculture departments

BUSINESS MODEL
B2B, B2C

WEB
www.marutdrones.com

PROBLEM

The application of inputs such as pesticides during a crop-growing season is largely manual and labour-intensive in most regions of the country. For the most part, farmers either perform the spraying activities themselves or hire labour for the task. However, manual spraying of chemicals has a negative effect on the farmers' health owing to exposure to harmful substances. Furthermore, in rural India labour shortage is an acute problem, which is expected to worsen in the coming decade. Rapid urbanization in India is leading to the migration of farm labour to other sectors of the economy, especially in construction. Farmers lack the tools to identify the specific parts of a field where pest and diseases originate. As a result, they rely on their instincts and subjective observations to detect plant pest and diseases for crop management. A crop health monitoring system could help farmers address these issues before the disease spreads throughout the entire farm, and enable them to attempt a targeted application of chemical inputs. Moreover, the height of some plants found in several of the crops makes it difficult to monitor crops and apply inputs.

EXISTING SOLUTIONS

Farmers continue to rely on peer-to peer-networks, local retailers and inherited knowledge for better results in agriculture. The pathways for the transmission of scientific information from laboratories to the farmers' fields are still not entirely understood. The uptake of science-based knowledge products pertaining to weather, soil and crop suitability is still very low and consequently, farmers continue to have lower yields and incomes. Referring specifically to crop health management, farmers rely on their field observations and the local retailer's advisories on the use of chemical inputs.

SOLUTION

Marut Dronetech – a fast-growing drone company in Hyderabad – uses a combination of drones, internet of things (IoT) and artificial intelligence (AI) methods to deliver targeted services to farmers. They provide information on early pest detection, crop stress monitoring and input spraying with drones. To overcome the mistrust amongst farmers, Marut engages with FPOs and sets up early demonstrations of drone-based solutions. Through FPOs, the company aims to guide each and every farmer, providing them with real-time

data so as to facilitate data-driven decision making. Also, since most beneficiary farmers are smallholders, aggregating demands through FPO helps Marut with the economies of scale while provisioning their services at competitive prices on a per acre basis.

UNIQUE FEATURES

- farm land survey and rapid crop health diagnosis (pests, diseases and nutrient deficiency);
- targeted aerial spraying of fertilizers and pesticides at well-defined concentrations;
- post spray evaluation;
- crop yield estimation.

SOLUTION IN PRACTICE

The idea for a drone-based agricultural application was conceived after the raising of awareness on health burdens that farmers experience due to their exposure to harmful chemicals. However, considering the inability of smallholder farmers to expend significant amounts of money towards automation, Marut Dronetech started strategically engaging with FPOs as the first point of contact. First, FPOs are sensitized to the advantages of technology and how its application can reduce cultivation costs and at the same time, increase crop yields and farmer incomes. Second, FPOs become the brand ambassadors of the product communicating benefits to farmers in the local language. The application of drones also helps farmers save on labour cost in addition to indirect savings in the form of reduced health expenditures. Drones also help with the targeted application of agricultural inputs besides facilitating crop health monitoring.

CHALLENGES OVERCOME

Farmers are generally hesitant about using technology for decision-making and resort to their old behaviour, relying on local and inherited knowledge. To overcome the challenges posed by distrust towards new digital technologies and decision inertia, Marut created brand ambassadors in pilot regions who used drone applications and benefited from it. Farmers trust local peers who can help with a better understanding of such novel technologies. Furthermore, government agencies and input companies motivated farmers to use technology, especially in areas where the lack of labour force was widespread. Marut also identified the influential actors in different districts. The engagement with state agricultural universities (SAU), social activists helped Marut Dronetech to increase the uptake of products, as these influencers play a vital role in the on-ground penetration and sustained use of products.

HIGHLIGHTS

- 7800 acres of land covered;
- reduced input cost from INR 15 000 per acre to INR 11 380 per acre;
- average yield in peppermint oil and maize crop increased by 20 kg.

AN ENABLING ECOSYSTEM ENTAILS

- variation in the farm inputs used by farmers is the biggest challenge. Farmers rely on information from their own networks to decide which farm input brand they want to use in their fields. The economies of scale cannot be exploited when each farmer wants to apply a different product. The rating of farm inputs and availability of ultra-low chemical formulations will help increase the efficacy of drone-based spray;
- liberalization of drone licenses especially for the use-cases such as agriculture;
- crop-wise standard operating procedures will facilitate the standardization of technology and also the reduction of diagnosis time;
- incentives for farmers to explore and use new technologies.

NEBULAA

STATES OPERATING IN INDIA
Rajasthan, Andhra Pradesh, Telangana, Punjab, Haryana, Uttar Pradesh

TARGET BENEFICIARY
Farmers, traders, seed companies, institutional buyers, exporters

BUSINESS MODEL
B2C, B2

WEB
www.nebulaa.in

PROBLEM

In a typical agricultural spot market (mandi) where farmers sell their produce, quality assessment is performed manually and is subjective. Traders rely on the physical inspection of and attribute grades to incoming lots and pay prices based on their assessment. This creates situations where farmers do not receive a fair price for better quality produce. More importantly, bulk buyers and exporters buying this produce from secondary markets cannot be sure about its quality. Exporters run the added risk of rejection of their consignments if the produce does not meet the quality and safety standards. Recently, consumers in India have become quality conscious and are willing to pay a premium for good quality agricultural produce.

EXISTING SOLUTIONS

Instead of using subjective assessment, lab-based methods were designed and set up in mandis. However, conventional lab-based assaying methods are tedious to perform, resource-intensive, and time-consuming. Furthermore, even these methods require several manual steps thus leaving enough of a margin for subjectivity and manipulation. These conventional methods involve manually separating individual defective grains, counting, and weighing them. This method puts immense pressure and stress on the limited staff working in these laboratories. During the peak harvest season, these laboratories are unable to adequately provide services to the thousands of farmers who bring their produce to markets over a short period.

SOLUTION

MATT, the automatic grain analyser of Nebulaa, uses artificial intelligence (AI) and image processing to minimize human intervention and bring objectivity to the quality grading process. MATT, an electronic hardware device, looks like a printer. It captures images of grains placed in the device from multiple sides and creates a 3D rendering, which is used to analyse grain samples using deep learning models. These deep learning models are optimised so that they can function on a normal CPU running even on a UPS. It can capture a 360-degree image of a grain sample and provide quality analysis in under a minute. The device provides farmers and traders with accurate results on grain quality, and at the same time buyers with more information on the grain lot they intend to purchase. The device can also be integrated into online platforms such as

eNAM through MATT's UI. Quality information about the analysed lot can immediately be uploaded to the eNAM portal or any other information system as per the customer's requirements.

MATT is currently fully functional for about 18 grains where quality is defined by physical parameters that are visible. By automating this process through 3D imaging and image processing, MATT has minimized human intervention. The maximum size of the grain that MATT can work with is 12 mm. Nebulaa is in the process of developing non-invasive methods for quality analysis of fruits and vegetables, analysis of macro-molecular chemical properties, and for detecting contaminations. It also plans to develop non-chemical and invasive based solutions to identify aflatoxin contamination and curcumin in turmeric.

- **Physical analysis of fruits and vegetables**: Nebulaa is using stereo imaging solutions to capture 3D images of fruits and vegetables to make an accurate assessment of their properties. This helps to estimate size, shape, color, uniformity of sample, texture, dent and injury marks, and damaged products.
- **Macro chemical property analysis:** This analysis measures chemical properties such as moisture, protein, oil content, and fiber. Nebulaa is experimenting with the use of various handheld spectrometer-based analyses to determine BRIX content in fruits and ripeness state of perishable produce. These handheld devices perform non-invasive quantitative analysis that requires little human skill to operate.
- **Contamination detection:** Nebulaa is also working on developing methods to detect chemical as well as biological contamination of food using hyperspectral imaging analysed through AI models. This is being extended to vigor testing of seeds to reduce time of germination testing. Additionally, it is experimenting with immuno-sensor technology to detect aflatoxin in food samples.

UNIQUE FEATURES

- 360-degree image scanner for quality assessment;
- deep learning models that run on the local device and perform grain analysis in under one minute;
- robust hardware that can be used in remote locations with poor internet infrastructure.

SOLUTION IN PRACTICE

Food processing companies, agri businesses, and exporters generally purchase MATT. Its system can also be configured to define quality thresholds based on user requirements. For instance, different businesses and industries define quality specific to their own needs. Such requirements are customized on MATT so that the output from MATT can be used by food processing companies, exporters, and agri-businesses to decide if a specific lot meets its unique requirements. Nebulaa is actively working with various state governments to pilot the use of MATT in various mandis and also works towards integrating the output of MATT with the eNAM platform. While working with eNAM, MATT incorporates quality thresholds and parameters as decided by eNAM. Nebulaa conducted pilots with about seven states.

For eNAM, representative grain samples taken from a farmer's lot are prepared as per standard procedures and methods. The lot identification number can be input into the MATT device so that the results from MATT's

analysis can be directly uploaded to eNAM or any other information system. The prepared sample is placed on a weighing scale attached to MATT and then placed in the MATT device, which first does its 3D scan using high-density cameras to capture the minutest of details. The captured images are analysed by deep learning models that analyse each grain based on scientific standards. Each grain is granted a quality value and individual images are stored for cross verification. The analysis is processed in less than one minute after which a report on the grade is generated. During this process, the device can store 10 000 test data samples for future reference.

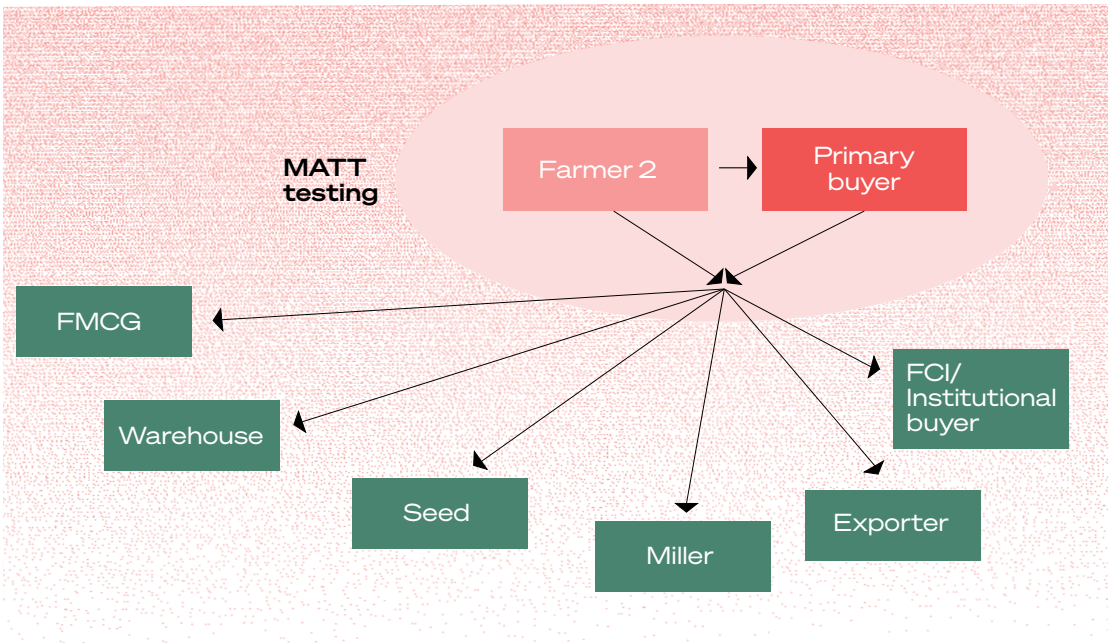

Figure A9

Prior to MATT's testing, farmer could only gather information provided by the primary buyer and the buyer could only consider selling to limited buyers. However, with MATT's universal testing report, both farmers and primary buyer can approach wider audience for trade.

SOURCE: Nebulaa.

CHALLENGES OVERCOME

Nebulaa initially faced major issues because of the unreliable internet connectivity across rural areas. All of the deep learning models that were initially developed were run mostly on Cloud or GPUs. Without an adequately functional internet, both platforms were not accessible, consequently, Nebulaa optimized its algorithms to run on a local system with limited resources. Another major challenge was with hardware development ecosystems in India. Although it was expensive, Nebulaa developed an off the shelf hardware for developing MATT. However, making the devices affordable and portable will remain a challenge due to the scarcity of hardware development facilities.

HIGHLIGHTS

- During its expansion across the primary trade hub-mandi Agriculture Produce Market Committees (APMC). Nebulaa provided accurate quality information to all stakeholders ranging from farmers to buyers (see Figure 1). Farmers are now aware of the quality of their produce and can bargain for better prices from buyers. At the same time, almost all primary buyers are secondary sellers, so they also have to deal with the insecurity of not possessing the quality required for secondary buyers. With Nebulaa's multi-client testing for the same commodity, they are able to track and ensure quality assurance as the commodity gets traded across the value chain. This helps primary buyers to plan their procurement across mandis in a more informed way. It will also reduce the number of rejections expected during secondary trade.
- Furthermore, MATT significantly reduced the time required for quality testing for industries. This helped them make faster decisions for procurement. Furthermore, it lowered the amount of the manual effort and subjectivity of testing, as well as the idle time for incoming vehicles carrying the produce. During peak season, there is a queue of vehicles waiting for quality testing to verify if the material is accepted or rejected. With MATT, this has significant savings for industries.

ENABLING ECOSYSTEM ENTAILS

When governments roll out tenders for different technologies, the pre-bid conditions such as annual turnover tend to exclude innovative start-ups. In fact, if the technology is proprietary, single bid tenders risk being excluded because of the preconditions that require a minimum of two to three bids. In sum, the public procurement processes need to be more flexible.

NIRUTHI

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana, Odisha, Maharashtra

TARGET BENEFICIARY
Farmers, insurance companies, banks

BUSINESS MODEL
B2B, B2F

WEB
www.niruthi.com

PROBLEM

Over 80 percent of the farms in India are small and marginal with an average landholding of 2 acres or less. Farmers are continually exposed to a variety of risks due to price fluctuations, climate variability, and non-availability of quality inputs in a timely manner. Furthermore, the cost of provisioning institutional credit through traditional banking means is high. Traditional banking channels still depend on bank branches and field staff accessible to farmers at the last mile to undertake activities such as risk assessment, loan disbursement, monitoring, and collection.

Crop insurance is proposed as a financial innovation to de-risk farmers and their livelihoods from co-variate risks and climate-induced shocks. Experience has however shown that pressing problems exist both in the design and administration of indemnity and index-based insurance products in India. Both the yield-index and weather-index based insurance products experience high levels of basis risk. The absence of high quality granular historical data on yields, weather, and difficulty in sourcing this data on a near real-time basis at granular levels is an important impediment in the design and administration of index-based insurance products. Also, the heterogeneity of crop choices, farming practices, and lack of field-level insights make it difficult for input companies to mobilize resources in time. These data gaps, in turn, lead to difficulties for financial institutions (FI) to quantify risks or assess the credit-worthiness of a farmer.

EXISTING SOLUTIONS

Banks and other lending institutions deal with farmer collectives and other joint liability groups as a means to de-risk their agricultural portfolio. The Kisan Credit Card has been a successful initiative but it also suffers from challenges due to insufficient data to make decisions on rollovers.

On the crop insurance side, governments continue to densify Crop Cutting Experiments (CCE) to reduce the basis risk, especially with the area yield index-based insurance. The CCE process is however expensive and also very inefficient. Furthermore, this densification does not completely rid the problem of adverse selection of farms for undertaking the CCEs.

SOLUTION

Niruthi's ZipAg platform was designed to address some of these systemic gaps impeding the uptake of crop insurance in India. Although crop insurance is the

primary aim, the platform can also cater to requirements of banks and other lending institutions. ZipAg presents field-level insights on a dashboard using big data and artificial intelligence (AI). The platform combines multiple streams of information such as remote sensing, ground truth data, climate grid models, weather forecasts (including nowcast) along with historical weather and yield data to generate insights precisely at the farm level. The plot-level insights could inform the user about the current condition of a crop and forecast the yield at harvest. Niruthi is currently working on also combing data from internet of things (IoT) devices to improve quality of its field-level insights.

ZipAg's competitive edge emerges from its unique ground truth process. Niruthi realized the limitations of remote sensing data during the early years of its inception. In fact, back in 2011, Niruthi created a system for hiring temporary field staff to deploy rapidly to collect ground truth data, which is critical for improving quality of remote sensing analysis. However, given the heterogeneity of smallholder cropping systems in India, ground-truthing could become expensive. Niruthi's smart sampling techniques was developed in response to this problem. Furthermore, Niruthi processes images of ground-truth data using proprietary algorithms. The processed images inform the current condition of a crop, time of the crop, harvest index, and estimate yield. Such high-quality information is combined with other sources of data to derive farm-level insights. Niruthi also leverages its role as co-witness in the CCEs to improve its ground truth data. Insurance companies engage Niruthi as a neutral agent to co-witness the CCEs conducted by governments.

Apart from smart sampling and processing of ground truth images, Niruthi has built its suite of weather products. Niruthi developed its climate grid models that offer historic and forecast weather data at a 3km × 3km resolution. Niruthi also buys weather station data from third-party providers to validate and improve the quality of its gridded weather data. This is another critical input data stream feeding into the ZipAg platform enabling it to provide field-level insights.

UNIQUE FEATURES

- smart sampling – identifying the locations for collecting ground truth data;
- creation of a network of trained field agents to collect images and other data from the ground;
- processing of ground truth images to compute harvest index and other important field insights;
- an inhouse database for both historical and forecasts of weather data using climate grid model;
- creation of network for stakeholders.

SOLUTION IN PRACTICE

The ZipAg platform is offered on B2B and B2G basis to customers. They can use this platform to gain insights and information of an agricultural plot. Niruthi first sources and processes satellite imagery (SI) and obtains remote sensing data. Through a combination of smart sampling and co-witnessing activities, Niruthi also sources high-quality ground truth data. On average, Niruthi engages nearly 600 part-time field workers to collect images and other information from the ground. Advances algorithms then process these images along with ground data to understand the current variety and condition of a crop. This information is processed to give a first-draft estimate of the harvest index besides predicting current and future conditions of crop. The platform

also processes the weather-based information to create field-level insights that are made available to potential customers, banks, insurance companies, and input companies.

These farm-level insights of ZipAg are provided on user-friendly dashboards. Currently, this dashboard is being provided to all insurance companies empanelled on Pradhan Mantri Fasal Bima Yojana (PMFBY). For a banker, this dashboard helps to verify if the loan has been utilized to sow the declared crop in the field. Additional data on the crop performance, projected yield helps them to deduce an overall credit rating. FIs can also take precautionary measures to minimize their risk by mobilizing resources on the field to educate and alleviate farmer stress in response to emerging risks.

CHALLENGES OVERCOME

The first major challenge was the lack of reliable data and access to government data sets. To overcome this challenge, Niruthi collected and developed its own data sets and models to estimate crop yields. Acceptability of technology initially was a challenge, but it created the interest in users. Last, with the evolution of technology, Niruthi was able to substitute expensive GPS handheld devices with smartphones to capture ground data.

HIGHLIGHTS

- awarded best data analytics company award in Agri tech from the world bank;
- working in eight states of India;
- servicing most crop insurance companies empaneled on PMFBY, like National Insurance Company, Oriental Insurance, United India Insurance, Bajaj Alliance, New India assurance, AIC;
- created village-level daily weather forecasts for over 40 000 villages using data from four satellites and 300 weather stations;
- processes 10 Tb of satellite data, about 500 GB of climate data daily and over 100 TB of CropSnap images per season in India.

ENABLING ECOSYSTEM ENTAILS

The government could empanel and endorse technology companies for a more widespread adoption of technology in agriculture.

GRAM VAANI

STATES OPERATING IN INDIA
Bihar, Jharkhand, Madhya Pradesh, Uttar Pradesh, Tamil Nadu, besides partner collaborated platforms across thematic areas, with users from over 20 states

TARGET BENEFICIARY
Farmers, Farmer Producer Organizations (FPO)

BUSINESS MODEL
B2B2C

WEB
https://gramvaani.org

PROBLEM

Millions of people, in rural India in particular, are deprived of access to conventional media owing to infrastructural gaps or illiteracy. The consequential information asymmetry experienced by these underserved communities (which are also referred to as media dark) has important livelihood implications. Many agriculture-based communities are deprived of information on game-changing transformations in the agricultural sector.

EXISTING SOLUTIONS

The traditional media platforms television and radio are often monolingual and therefore non-interactional. Furthermore, these platforms were designed for top-down and mass broadcasting of information and are not very effective at engaging or enabling a bidirectional exchange of information. People cannot share their ideas or ask questions and seek opinions on traditional platforms. Also, these platforms do not facilitate or enable a hyperlocal information creation, curation, and exchange between communities, which could be very beneficial for agriculture.

SOLUTION

Gram Vaani, that is the "voice of the village" in Hindi, is a mobile-based community media platform based on interactive voice response (IVR) and mobile app technologies. The platform is voice-based, vernacular, and driven by the community members. It started its operations in January 2009, funded through a grant from the Knight Foundation to build a low-cost automation system for community radio stations. Gram Vaani built the vAutomate IVR platform in 2011 to mimic the functionality of community radio but in an on-demand setting on a cloud-hosted infrastructure, thus offering straightforward scaling. This solution has powered many exciting interventions including in the agricultural sector, where farmers could access and co-create relevant local information in the vernacular language by simply recuperating a missed call. Subsequently, a mobile smart application that mimics the IVR service has since been deployed targeting progressive farmers. In 2012, Gram Vaani launched the Mobile Vaani service to go beyond the role of a technology provider, and directly provide community media services in rural areas. Mobile Vaani has been extremely successful with an active user base of over 80 000–100 000 unique users each month. Through Gram Vaani, hyperlocal and contextual content about agriculture and health are delivered to people without access to

such information because they lack access to conventional media. Hyperlocal expertise is a powerful means for enabling contextual information. Gram Vaani is also building a voice-based quora, Q&A platform, by applying machine-learning (ML) algorithms.

UNIQUE FEATURES

- content delivered in different formats i.e. audio, video and text;
- connects various stakeholders such as domain experts, government and local community on a voice-based platform;
- customises content for each district in the local language and created by local people;
- enables sharing of the content across the local community;
- decentralizes the information dissemination process (e.g. community leaders can use the platform to disseminate important information within their target communities).

SOLUTION

Gram Vaani's platform is offered to local NGOs and other agencies such as Farmer Producer Organizations (FPO) in the B2B2C model and with a managed services arrangement. These agencies require a cost-effective way to not only bridge the information gaps, but also as a means to engage their target communities and facilitate dialogue, or run behaviour change campaigns. Apart from this, customers typically want to run promotional campaigns for Mobile Vaani's captive customers. The platform has catered to many partners across the social development and even commercial domains e.g. Bajaj Allianz used the platform to engage with their rural customers on topics such as Agri insurance. Since the platform uses voice extensively, it can overcome challenges of inclusion and facilitates hyper-local peer-to-peer knowledge-sharing networks. Users simply send a missed call to the Gram Vaani community station and an IVR system calls the user back. The user can use the keypad on the phone to navigate the content that is organized thematically (agriculture, health) and topically as well. Users can listen to locally relevant and contextual information on agriculture, health, and updates as well as contribute content. Crowd-sourced content is curated and moderated by a backend team and is also appropriately tagged and indexed, thus helping with suitable analytics and business intelligence. Users can also ask questions and share or like messages as done on a social media platform. Furthermore, agricultural experts can create content and micro-target the farming community through this platform. The voice-based 'quora' Q&A platform, that is being developed using artificial intelligence(AI)/ML, automates the process of farmers finding solutions readily available in the database.

Gram Vaani establishes a pool of content creators who are given basic training on creating good quality and engaging content in the vernacular. Content creators use the IVR setup to upload their content and also create a pool of citizen reporters to generate hyper-local news that is locally relevant. Since farmers access content created by fellow farmers operating under similar environments, the information is highly contextual and relevant and therefore likely to have a greater impact. Farmers who create content do so involuntarily and are motivated by the social capital in addition to the visibility they obtain in their local communities.

CHALLENGES OVERCOME

The biggest challenge with this solution was to build trust. First, Gram Vaani identified socially conscious local leaders and champions from the community, trained them on the platform and made them brand ambassadors. Second, Gram Vaani worked on streamlining the process for creating engaging content and ensuring its availability in the local language and dialects.

HIGHLIGHTS

- Gram Vaani's technology platform supports NGOs like Pradan and also the Bihar Livelihood Mission (Jeevika) programme supported by BMGF to upscale proven interventions;
- Mobile Vaani, Gram Vaani's community media service is operational in 25 districts;
- Mobile Vaani has touched over 2 million households to date;
- 50 000 impact stories shared on the platform.

ENABLING ECOSYSTEM ENTAILS

Access to investors and venture capitalists, patient capital or long gestation capital who understand the approach will be key to scaling-up such initiatives.

PRECISION DEVELOPMENT (PxD)

STATES OPERATING IN INDIA
Odisha, West Bengal, Karnataka, Gujarat, Punjab, Haryana

TARGET BENEFICIARY
Extension staff, front-line staff,farmers

BUSINESS MODEL
B2G, B2B, B2F

WEB
https://precisionag.org

PROBLEM

Farmers in India are mostly engaged in smallholder farming, which on the global level collectively accounts for more than two billion people – almost one-third of humanity and two-thirds of the world's poor. Typically, these smallholders harvest only 30 to 50 percent of what their lands are capable of producing. The difference between the actual and potential farm yields, that is the yield gap, is an immediate and direct contributor to the poverty level. As most of these farmers are involved in rain-fed agriculture, climate change poses an additional challenge and risk to their livelihoods.

EXISTING SOLUTIONS

In many countries, including India, governments provide traditional agricultural extension services to smallholder farmers. However, the traditional extension system is confronted with many challenges: i) in-person information sharing is expensive; ii) contact with farmers is irregular; and iii) it is difficult to customize and provide advice in a timely manner. Despite the significant resources dedicated to support the work of millions of extension workers, overall farmers do not get the advice they need to close the yield gap and maximize their incomes.

SOLUTION

Precision Development (PxD) leverages the information distribution opportunity implicit in increasing-mobile phone ownership among smallholder farmers, in order to provide digital agricultural advisory services to farmers across India. PxD is harnessing the potential of e-extension to empower farmers with customized information delivered on demand at a low cost, and at scale. PxD's theory-of-change relies on providing actionable information to farmers in an accessible and timely manner for on-farm practices, input utilization, pest and disease management, climate and weather resilience, and environmental sustainability as well as access to markets, to ultimately improve yields and incomes. PxD's systems provide for a two-way flow of information that delivers customized advice to farmers through mobile phones.

UNIQUE FEATURES

- Digital extension services deliver simple and effective messages that farmers can understand and act upon.
- PxD integrates the use of behavioural economics and social learning theory to maximize dissemination of information across farmers' network.
- The platform provides customized messaging at scale to ensure that the information delivered is useful, timely and actionable. Big data and machine learning techniques allow PxD to tailor information at scale, and enable the delivery of context-relevant recommendations based on geographic conditions, market conditions and farmer characteristics.
- PxD systems allow for the upgrading of content and service delivery in real time. By integrating principles of user-centred design and rigorous research methods such as A/B testing and randomized controlled trials (RCTs), PxD is able to improve user experience, deliver more appropriate information, and systematically understand impacts. PxD feeds this information back into its systems to iteratively improve them over time.
- It provides services at scale to farmers through tie-ups with local partners and governments, NGO's and for-profit agribusinesses. This enables PxD to scale their services quickly while keeping costs per farmer at an average of USD 1.55 (2019).

SOLUTION IN PRACTICE

In India, PxD primarily delivers its advisory services through a two-way voice-based mobile phone extension system. Farmers receive a customized, weekly voice-based advisory message based on crop, location, and agronomic conditions in their local language. In addition, they have access to a free IVR hotline to listen to advisory content, user FAQs, and to ask questions, which are answered by a professional agronomist within 24–48 hours. Content provided through these services is designed by agronomists, veterinarians and other specialists, and approved by government ministries and agricultural universities. This digital service is also made available to public extension workers, who in turn transmit this information to farmers. It does not have a specific title or name to its solution and instead adapts the service to the local project or state-specific solutions.

CHALLENGES OVERCOME

In the early stages, farmers might not trust the information received through a mobile phone-based service. PxD leveraged trust in government and other on-the-ground partners to more effectively reach these farmers. PxD provides training through the phone and automated messages to increase the understanding of the features of the service. Gender digital divide was observed, as culturally, men are the primary mobile phone owners in rural settings. PxD has sent targeted content to women farmers, and is exploring opportunities to encourage information-sharing within households. Furthermore, it is identifying social structures where female mobile phone owners can meet other women to share information, and partner with grassroots organizations directly engaging with women in agriculture.

HIGHLIGHTS

- provided digital extension services to more than 712 730 farmers across the states of Gujarat, Odisha, Karnataka, West Bengal, Haryana and Punjab in 2019;
- provided advisory services for the cultivation of 15 crops and spices, diversity of vegetables and pulses and animal products (fisheries and dairy);
- provided information about addressing more than 40 pests and diseases;
- Krishi Tarang (KT) – meaning agricultural wave – was scaled from a successful evidence-based trial for 1200 farmers to a state level initiative catering to 56 000 farmers in Gujarat, with the benefit:cost ratio rising from 10:1 to 34:1 due to economies of scale;
- Ama Krushi initiative in Odisha, a build-operate-transfer model in partnership with Odisha state Department of Agriculture and Farmers' Empowerment (AFE) impacted almost 800 000 farmers. Moreover, Ama Krushi saw an increase in the participation of women rise from 6619 at the beginning of 2019 to 90 180 by the end of 2019.

ENABLING ECOSYSTEMS ENTAILS

First, for mobile-based agricultural advisory services to be easily replicated and scaled across India, basic trunk infrastructure: mobile networks, mobile ownership, and access to affordable farm inputs, need to be put in place. Second, softer mobile phone literacy skills – knowledge about how to place a call and navigating an IVR menu, basic agronomic knowledge and numeracy skills – need to be inculcated. Finally, the service should be informed by sound agronomic science for the relevant crop and agro-ecological zone so that PxD and its partners can develop advisory messages that are accurate, comprehensible, and actionable.

PIATRIKA BIOSYSTEMS

STATES OPERATING IN INDIA
Andhra Pradesh

TARGET BENEFICIARY
Research bodies, agricultural companies, contract farms

BUSINESS MODEL
B2B, B2C, B2B2F

WEB
https://piatrika.com

PROBLEM

The scientific community on the whole is striving to improve the livelihood of farmers, and to maximize agricultural produce to sustain the growing population and also provide superior quality. However, transitioning cutting-edge research from the laboratory to the land is a long process. Nowadays, the scientific community has advanced tools and technologies such as high throughput genome sequencing, which can be performed at a low cost unlike in the past. Scientists however are constrained to collect high quality phenotypic data, which is vital for making informed decisions. Some scientific institutions engage trained technicians for collecting phenotyping data from farmers' fields, however at a high cost. Phenotyping-data from farmers' fields, however, significantly enhances scientists' ability to design technologies that perform equally well both on research plots as well as farmers' fields. On the farming side, a few progressive farmers would be willing to partner with scientists for such research but there are not many options or systems that provide data and insights from lab-to-farm. Collecting such data from farmers needs to be autonomous or semi-autonomous so as to minimize data-capture and translation-errors.

EXISTING SOLUTIONS

There are many agri tech companies that have been innovating and rolling out solutions for specific pain points across the Research4Development (R4D) chains. Nevertheless, there very few companies that look at the problem from a systemic point of view. Furthermore, solutions connecting farm level interventions and data back to the scientific community are very limited. These types of linkages are crucial for researchers to design contextual interventions based on science.

SOLUTION

Piatrika Biosystems is an enterprise decision-support system working towards bridging the gap between the scientific community and farmers. Piatrika is creating an ecosystem where scientific and farming communities can harness information, in addition to two different subsystems to address specific technological needs of scientists and farmers, respectively. These subsystems communicate through a robust integration. Both of these systems will be supported through the mechanization of precision operations, decision support and data management, autonomous and semi-autonomous data

collection through the internet of things (IoT) and technology integration and tools for machine learning (ML) -based predictive analytics. Drones are used within Piatrika's ecosystem for crop surveillance and monitoring, data collection and agricultural operations like spraying.

The suite of enterprise solutions works in a cyclical process (Figure 1) where a crop data management and decision support (CDMDS) system helps to monitor crop growth and forecasting yields. Based on analytical insights from this system, the crop applications, treatment and operations service (CATOS) system is equipped to support precision agricultural services. All of these services facilitate the capturing of phenotypic data autonomously or through tools developed by Piatrika. It works closely with the farming community to help them with instrumentation, drone-based crop monitoring and treatment, microfinance. The data captured during these processes is subsequently sent back to the scientific community.

For the scientific community, Piatrika provides tools for plant breeding, trait selection, bioinformatics and genomic prediction. It also helps scientists to remotely monitor localized trials and facilitates access to ML algorithms. Based on the prediction data, a biotechnology plant breeding platform experiments with selective genomic types, monitors their growth and collects phenotypes that can quickly be released to the market.

UNIQUE FEATURES

- drone-based spraying service based on vegetative index analysis of fields;
- IoT and satellite data integration;
- phenotype data collection;
- leveraging collected phenotype data for ML and genome phenome analysis;
- decision support for farmers.

SOLUTION IN PRACTICE

Piatrika works in a B2B mode through a connection with agricultural research institutions and enterprise farming companies, agribusiness and Farmer Producer Organizations (FPO). It interacts with farmers through aggregators such as enterprise farming companies and other aggregators to reduce the cost of technology access through economies of scale. Piatrika has a SaaS and PaaS based system that encompasses a robust data management system. The farm information system captures data across the whole supply chain from the farm to the factory gate. It uses autonomous satellite data, weather station data and soil data to give farmers insights to make informed decisions. These data insights are overlaid with drone data sets captured for different vegetative indices to help with planning the drone flight path and optimizing chemical applications over crops. Data captured by drones in real time is fed back to the research community that uses ML models and high-end data science to predict desired genomic types. The plants with desirable phenotypic traits are grown in an experimental setting and their traits are captured through monitoring tools developed by Piatrika. The selected plant varieties, which show desirable phenotypic traits are collected and quickly released into the markets.

CHALLENGES OVERCOME

Amongst certain crops with dense growth and canopy, detecting disease and pest infestation proved difficult. Moreover, surface spraying was not a sufficient solution to the problem. Piatrika used a combination of multispectral cameras

to generate Normalized Difference Vegetation Index (NDVI) and other vegetative indices to get insights on infected areas. In addition, contraption extensions were developed to spray beneath the canopy. For large agricultural enterprises and contract farmers, the long-term benefits of using Piatrika's enterprise systems was not convincing enough to make the required shift. Consequently, micro calculations were performed to show comparisons between the cost of production using conventional methods and Piatrika's interventions, which demonstrates the immediate cost savings to potential customers.

HIGHLIGHTS

- performed pilot studies on drone-based precision agricultural solutions for over 1000 acres;
- created a disruptive system where diverse environments and soils can be exploited by researchers. Scientists can identify the exact soil and climate projection over the experimental season and choose their land of interest for experiments. The scientific community achieves success, and farmers have a very good scope of generating parallel revenue streams while minimising the phenotype collection through instrumentation;
- working with agricultural research institutes to address specific genome phenome analysis and ML research;
- tied up with Neobanking facility for invoice, debt, credit and loan offsetting for farmers and farming companies.

ENABLING ECOSYSTEM ENTAILS

As regards the usage of drones, the policy regulations caused some disruption to drone service providers. The process of registration and compliance needs to be simplified.

PLANTIX

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana, Maharashtra, Punjab, Madhya Pradesh, Uttar Pradesh and Haryana

TARGET BENEFICIARY
Farmers, agricultural extension workers, agri-retailers, agri-input producer companies

BUSINESS MODEL
B2C

WEB
https://plantix.net/en

PROBLEM

Direct and indirect crop losses due to pests and disease attacks during crop production cycles average about 30 percent annually. In extreme cases, the entire crop is lost causing famines, food inflation, reduction in vegetables and fruit production, in addition to the loss of cereals and legumes. These outcomes adversely impacts the food and nutritional security of communities. Crop losses due to pests and diseases can be minimized through science-based interventions undertaken by farmers. Traditional human agent-based extension systems are unable to disseminate and provide advisories to support farmers in real time. Some progress in e-extension has been made but most advisories through these channels are not available when needed. Furthermore, the language and content are not user-friendly, for example, with most e-extensions the translation of scientific names of the most common pests and diseases into the colloquial parlance represents a drawback. Farmers are more receptive and likely to follow advisories when its content has been adapted to the local context of farmers.

EXISTING SOLUTIONS

Farmers, especially in the developing parts of the world such as India, are largely dependent on traditional manual extension services supported by state governments. The public sector extension system is designed to hire one agricultural extension staff to support nearly 20 000 farmers. However, it is unrealistic for an extension worker to address the issues of such a large number of farmers during a crop season; and more importantly, alert or disseminate advisories in real time to cope with short-term risks linked to weather, pests, and diseases. Apart from knowledge and advisory dissemination, extension staff is also engaged in cropped area data collection, crop cuttings, yield estimation, and the delivery of departmental schemes and related administrative activities. It is, therefore, impractical to expect extension staff to provide real-time crop and location-specific advisories to smallholder farmers.

SOLUTION

Progressive Environment and Agriculture Technologies (PEAT) Gmbh is a German start up that developed an android-based artificial intelligence (AI) and

deep neural network (DNN) mobile app called Plantix that helps farmers with plant pest and disease diagnostics, control, and crop management. Farmers are vulnerable because of their dependence on traders for plant protection. Plantix performs like a plant doctor by providing accurate diagnosis and advisory on crop protection leading to the reduced use of agrochemicals to manage pest and disease attack on their crops. This directly affects the cost of production with lower input costs for managing pests and diseases. By following science-based advisories, farmers have increased their income and crops productivity by minimizing yield losses due to pests and diseases. The indiscriminate use of agro-chemicals can also be reduced leading to lower environmental toxicity from pesticides and fungicides.

Plantix uses images captured by mobile phone camera to detect crop diseases and recommends crop treatment solutions. The app can be downloaded free of cost from Google Playstore and users can upload a picture of the affected plant that is processed by the DNN algorithms. The app gives the user insights into the most probable disease, nutrient deficiency, and pest infestation. This insight is coupled with actionable instructions that help farmers treat the affected plants, minimize damage, and thereby improve the overall yield. Plantix recently added a new feature to help users buy inputs to deal with the identified pest/diseases. Moreover, the app enables users to communicate with their peers, scientists, subject matter experts in real time to seek crop-related advice. The platform provides access to a large repository of solutions and also alerts farmers on the disease, weather, and pesticide application. Using the Crop Calendar feature, farmers receive customized crop management recommendations based on their sowing dates. Although the app is currently available only for android phones, it has recently been updated with a chatbot through WhatsApp. Users wishing to benefit from Plantix's services can simply send the pictures of the affected plant to a designated WhatsApp number and the app immediately responds with the name of the pest along together with chemical and natural remedies.

UNIQUE FEATURES

- detects more than 500 types of plant diseases across 35 crops in 2–3 seconds;
- library of more than 20 million image data sets of plant damages;
- available in 18 languages including 13 Indian languages;
- Plantix's services can also be accessed through WhatsApp.

SOLUTION IN PRACTICE

Plantix partners with local state agricultural universities (SAU), agricultural departments, the private sector, and other agencies to expand the use of its app. Plantix has had a very strong collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) since 2016 with the objective to improve the app and also expand its usage amongst farmers and agricultural extension services. Plantix's farmer outreach in new geographies commences with focus group discussions and workshops and generally relies on local partners and extension departments to mobilize farmers for these sessions. During such sessions, Plantix field coordinators would help few farmers who have smartphones download the Plantix and train them with the app navigation. In a field demonstration farmers are taken to a nearby field, a picture of the affected plant is taken, the image uploaded, and the artificial intelligence (AI)-image recognition system (powered by deep learning models) identifies the disease or problem in the local language. It also provides

suggestions on what fertilizer or pesticide/fungicide should be used to address the identified problem. Over time, farmers become familiar with the app and understand its utility. Farmers can also use the app to post their queries along with an image in the community space where other farmers, experts, and Plantix team members can provide responses in their local language. To create a sustained engagement beyond pest and disease diagnostics, the Plantix app also has a crop calendar that allows farmers to feed in the crop they are planning to take up along with the sowing date. The app generates a customized events calendar through which a farmer receives several push notifications on fertilizer application, pesticide spraying, weeding, and other crop production related advisories.

CHALLENGES OVERCOME

Every crop disease and pest infestation showed regional variations and visual symptoms based on prevailing geographic and climatic conditions. It was challenging to obtain the accurate prediction levels initially but with minor tweaks in the software and training the machine learning (ML) models through more picture and data libraries, Plantix achieved over a 90 percent accuracy. Farmers using the app were mostly illiterate or semi-literate, so getting them acquainted with it was difficult. Consequently, it was made more user friendly for even a semi-literate person. Finally, the Plantix team based out of Germany dealt with the issues involving scaling the user base to masses with the help of the institutional partnership with ICRISAT, Hyderabad. ICRISAT gave Plantix access to its network of government, non-governmental, and research institutions, which helped the Plantix app scale rapidly with nearly 80 percent of its user base located outside of India.

HIGHLIGHTS

- more than 10 million app downloads in India;
- more than 50 000 images being uploaded daily during crop season;
- training dataset of 1.2 Mn pictures created for training the DNN;
- over 500 pest and diseases across 35 major crops covered by the app.

ENABLING ECOSYSTEM ENTAILS

Most agritech start-ups comfortably sustain themselves until the proof of concept stages, nevertheless it is difficult to upscale without the backing of sufficient capital. A platform where tried and tested models demonstrating sustainability can get funding from investors or funding agencies is urgently required.

SUCCESS STORIEs

Harish, a young farmer from the Fasalwadi village, district Sangareddy, Telangana, grows cotton and paddy on 3.5 acres. Two years ago he heard about the Plantix app through Facebook. Harish immediately downloaded Plantix during kharif 2018, and used the disease detecting plant doctor feature of Plantix app by uploading an image of damages in his paddy field during the season (Figure 1). He was amazed by the results of a detecting stem borer and carbosulfan chemical recommended by Plantix with an application rate. The pest damage was reduced and his yield losses mitigated. Harish stated that previously, when he had a similar problem the shopkeeper recommended elevated doses of chemicals at a high cost. He is certain that Plantix saved him INR 4000 per acre on pesticide costs for his paddy that season, and protected him from yield losses due to the paddy stem borer.

PURESCAN AI

STATES OPERATING IN INDIA
Prototype stage

TARGET BENEFICIARY
Food processing companies, traders, exporters, farmers

BUSINESS MODEL
B2C, B2G

WEB
https://purescanai.com

PROBLEM

Contamination of aflatoxin, a fungal toxin found in cereals, nuts, and spices, occurs as a result of improper post-harvest storage and moisture management. In India, such practices have led to an aflatoxin contamination in peanuts that is 40 times higher than permissible (15 parts per billion) as per a study conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Similar is the case with maize, dry fruits, and chilli. Classified as a group A carcinogen, aflatoxin is one of the two major causes of liver cancer in the world. It also leads to immunity loss, poisoning, and even stunting of growth among children.

The food processing industry, traders, and commodity aggregators encounter difficulties when checking for aflatoxin contamination at the point of procurement because testing is lab-based, time-consuming and expensive. The existing lab-based methods are not only destructive but rely on expensive chemical reagents as well. Furthermore, farmers who follow good post-harvest and storage practices and sell aflatoxin-free produce receive no premium, since buyers have no way of testing for aflatoxin.

EXISTING SOLUTIONS

Currently, the enzyme linked immunosorbent assays (ELISA) and the high-performance liquid chromatography (HPLC) biochemical testing methods (Figure 1), are used for aflatoxin testing. These methods are destructive and performed in wet-chemical laboratories, which are expensive and can only cater to less than 10 percent of the market. Even though the testing infrastructure has been made available, skilled technicians are required to perform these biochemical tests. As food procurement occurs in a dynamic and remote environment, trading stakeholders do not have the time or resources to send food samples for testing and wait for the results to make a trade purchase.

Features	ELISA	HPLC	Pure Scan AI
Equipment Cost	₹100 000 (~USD 1400)	₹600 000 (~USD 8400)	₹50 000 (~USD 700)
Test Cost	₹800/test (~USD 11)	₹2500/test (~USD 35)	₹8/test (~USD 0.11)
Test time	Few hours	Few hours	30 seconds
Accuracy	2 ppb	2 ppb	10 ppb
User Skill	Technician required	Technician required	Anyone can use
Equipment Size	Table-top, portable	Table-top, non-portable	Hand-held, portable
Ease of use	Laboratory required	Laboratory required	Use Anywhere
Technique	Wet biochemical	Wet biochemical	Dry, spectroscopic

Figure A10
Different testing methods are used for aflatoxin testing

SOURCE: Purescan AI.

SOLUTION

Purescan AI was founded with the vision to make food on our plate safe, one ingredient at a time. Its multidisciplinary approach includes near infrared (NIR) spectroscopy, artificial intelligence (AI), machine learning (ML), cloud computing and sensors to rapidly detect aflatoxin contamination levels in food samples. There is scientific evidence proving that aflatoxin contamination can be detected from the fluorescence property of its toxin in contaminated foods. Purescan AI's innovation scans a product for traces of fluorescence in samples placed in a custom-made device that is portable and can be mounted on a conveyor belt. Purescan AI is also working on a handheld version of this device. The testing process is non-destructive, rapid with cost for testing that is almost negligible (~INR 1 as against INR 400 for a conventional test). Targeted predominantly at food processers, traders, and exporters, this technology can enable quality checking at different touch points of food storage and handling. PureScan AI plans to deploy this device at the Agricultural Produce Market Committee (APMC), to help farmers and traders attain the right prices. This is possible through collaboration and partnerships with start-ups, agri-businesses and Farmer Producer Organizations (FPO).

UNIQUE FEATURES

- extremely economical with per sample test pegged at INR 1;
- non-destructive and enables 100 percent testing;
- testing is rapid, and results can be viewed in under 30 seconds;
- testing device is easy to use and no training is required.

SOLUTION IN PRACTICE

Purescan AI uses custom devices to scan for aflatoxins. The basic model has a 20 × 20 cm scanning box in which around 200 g of peanuts, maize or chilli can be placed for a rapid scan. The spectroscopic device exploits the fluorescence property that aflatoxin exhibits to display contamination levels in under 30 seconds. These results are displayed directly on the portable scanning device. A handheld version, which is in development stage, can be dipped into a sack of peanuts to capture the levels of aflatoxins. Similarly, the technology could be customized to be mounted on a conveyor belt to provide real-time test results

of aflatoxin contamination for much larger samples. Purescan AI plans to engage with the larger ecosystem to operationalize this innovation in a context-specific system. It proposes organizing training programmes for farmers on post-harvest storage and moisture management and also partnering with global players working in similar areas. Furthermore, Purescan AI's hardware and the software application can be re-purposed to address quality assaying and chemical contamination in several crops.

CHALLENGES OVERCOME

Data collection for different varieties of maize was a challenge because it required making changes in the technology. Purescan AI tweaked its technology to ensure that the internet of things (IoT) devices could capture data for variable conditions. It was also important to understand handling and storage practices across the food value chain. Pruescan AI worked with industry leaders such as Mars to get deeper insights into the industry pain points and subsequently designed its products for different stakeholders. Moreover, working with ICRISAT helped Purescan AI understand the life-cycle of the fungus, the ideal conditions for its growth, and as a result develop its technology accordingly.

HIGHLIGHTS

- amongst the top 10 Indian start-ups selected by Venture Lab, Switzerland and SINE, IIT Bombay for the AIT programme 2019;
- amongst the top 20 Indian agri start-ups at the idea stage for the ARISE programme 2019 of IARI and supported by Ministry of Agriculture and Farmers' Welfare, India.

ENABLING ECOSYSTEM ENTAILS

The most important factor for food processing industries is the availability of a reliable supplier who adheres to safe food handling practices. Making rapid testing devices available at different procurement points in the food value chain will incentivise stakeholders to adhere to good practices. Also, regulatory bodies such as the Food Safety and Standards Authority of India (FSSAI) need to certify technology that can be used by industry stakeholders for quality assessment. This will provide a strong platform for tech start-ups to scale their products, while at the same time adding value to the food chains.

SATSURE

STATES OPERATING IN INDIA
Punjab, Haryana, Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, Odisha, Andhra Pradesh, Maharashtra, Karnataka, Jharkhand, Kerala, Telangana

TARGET BENEFICIARY
Financial institutions (banks, insurance companies), government

BUSINESS MODEL
B2B, B2G

WEB
https://satsure.co

PROBLEM

In developing countries, the lack of high frequency granular data for risk identification and management in the agricultural sector poses a huge challenge to financial institutions (FI) and policymakers. This not only negatively impacts larger financial inclusion goals with respect to agriculture, but it also makes it difficult for smallholders to access institutional credit. At the same time, FIs find it expensive to monitor and quantify the risks in agricultural loans, as a result, banks may end up with a high number of non-performing assets (NPAs) on their balance sheet.

EXISTING SOLUTIONS

FIs rely heavily on surveys undertaken by their own field staff in addition to the limited historical farmer data to assess the credit riskiness of the farmers. However, the data is often not plot specific, and since covariate risks such as weather play an important role in agriculture, it is important for FIs to have localized historic weather data along with local yield data to assess risk. The absence of such granular datasets exposes banks and FIs to potential NPAs, which could feasibly be avoided with access to high quality information.

SOLUTION

SatSure leverages advances in satellites, machine learning (ML) and big data analytics to provide answers to large-area questions to sustainability problems of food security, financial inclusion, clean energy, sustainable infrastructure and climate change action. SatSure's SPARTA platform combines satellite imagery (SI) with weather, internet of things (IoT), social and economic datasets to generate timely and location-specific real-time insights. SatSure also partnered with IBM's Weather Company to get weather data at the granular level of 500 m2 in the Indian context. SatSure ensures the accuracy of ML algorithms by performing a lot of ground-truthing. SAGE Banker, the flagship product of SatSure, is an enterprise SaaS tool for farmer lending institutions. It helps them with early risk identification, remote loan monitoring, product diversification and improving the agility of business operations. The platform of SatSure is used by insurance companies to smartly select plots for conducting crop cutting experiments and ensure high accuracy and representativeness of the results.

UNIQUE FEATURES

- bespoke big data platform;
- proprietary machine learning algorithms.

SOLUTION IN PRACTICE

The distress migration of labour from the agricultural sector to non-agricultural sectors in cities motivated the SatSure team to study the challenges facing the agricultural sector and how technology can address some of the issues. Based on this background, SatSure came into existence. SatSure SPARTA analyses a large aggregated dataset to detect cropping patterns, market movement and risks in crop health. SatSure SPARTA generates real-time actionable insights into sowing window, harvest window, crop stress and crop yield. SatSure's continual engagement with FIs directly from the conceptualization stage to a commercial rollout of the solution has played a large part in its success. "We co-innovated our products with our clients," states Prateep Basu, co-founder and CEO, SatSure.

CHALLENGES OVERCOME

On the technology front, data infrastructure was a key challenge since a huge volume of data is necessary for the development of ML algorithms. Furthermore, heterogeneity in crops and management practices in India, a common scenario across developing countries, compound the problem of crop classification and monitoring at a granular scale. The accuracy of ML classification algorithms depends on land-use and land-cover change (LUCC) maps. Intercropping and cropping pattern variations across India require the frequent update of LUCC maps and ground truthing. The SatSure team deals with these challenges by employing a combination of supervised and unsupervised learning algorithms to generate aggregate statistics at the village level, where accuracy levels are reasonable.

HIGHLIGHTS

- 486 000 farmer loans disbursed and monitored using SatSure platform;
- NPAs reduced for clients by 15 percent;
- 20 million dollars of insurance claims settled to date.

ENABLING ECOSYSTEM ENTAILS

- Large data-based ML platforms, especially those using remote sensing data need to be customized for each region given the huge variations across India in terms of language, culture and agricultural behaviour. As a result, there is some cost for adapting and operationalizing these platforms for various regions and geographies. Governments may provide seed capital and financial support for such customizations and localization of solutions.
- Start-ups and other emerging value-based players do not have access to public datasets that are especially available within government institutions. Rich open data could spur innovation in particular as regards the use of AI and ML in agriculture.
- A better industry and academia collaboration should be fostered by promoting active collaboration between industry, academia and government through innovation grants.

SENSEACRE LABS

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana, Karnataka

TARGET BENEFICIARY
Advocacy and scientific community, domain experts, Farmer Producer Organizations (FPO)

BUSINESS MODEL
B2B, B2G, B2C

WEB
www.senseacre.com

PROBLEM

Nowadays, satellite imagery (SI) can identify land parcels and predict macro-level data, but it lacks the precision to predict crop level data. For example, SI can identify a particular crop only when the land parcel has a crop that is uniform, while marginal farmers tend to practise intercropping or multi-cropping on a small parcel of land. Farmers resort to using crop protection chemicals such as pesticides, weedicides, and fungicides to fight biotic risks such as weeds and pests. Due to lack of adequate knowledge and training they might use too much or too little of the prescribed chemical dosage. In either case, farmers are bound to harm the crop when they apply crop protection chemicals inappropriately. By the time they become aware of excessive weed growth or a pest attack where remedial pesticide spraying is required, the shortage of agricultural workers forces them to take immediate action. Such time lags can cost a small landholding farmer dearly.

EXISTING SOLUTIONS

Traditional methods of responding to crop damage are manual – first, a farmer personally identifies weeds or pests, decides on remedial measures based on either their traditional experience or by consulting a retail pesticide vendor. The farmer sprays these pesticides or weedicides as per the instructions of the retailer or based on their intuition. During this activity farmers tend to spray 5–6 times more than required quantity of pesticides, which adversely affects crop health and human health. Additionally, this entire process is time-consuming, labour-intensive and increases the overall input cost for each farmer.

SOLUTION

Senseacre is a visual intelligence company that uses unmanned aerial vehicles (UAV) imagery analytics along with machine learning (ML) and artificial intelligence (AI) to provide a 360-degree solution for crop analysis and symptomatic treatment. High-resolution images captured by a drone are put through an analytical model using a convolution neural network (CNN) and deep learning algorithms. The trained model quickly identifies the weeds and pests from a spectral image library developed by Senseacre. A drone is then used to spray precise amounts of pesticides at the specific locations identified by the algorithm. Currently, Senseacre provides drones as a service at the village panchayat level.

Senseacre initially started with the digitization of land records and slowly started to scaffold into training its model to identify the net sown area, crop identification, weed and pest identification, and sensing surface soil moisture. Senseacre was created out of the need to establish scientific data libraries on weeds, pests, and multi-crop data. By working with domain experts such as the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), scientists and subject matter experts from agricultural universities and governments, it was able to develop prototypes for weed and pest identification and management (Figure A11).

UNIQUE FEATURES

- symbolic computing-based deep learning software that has gone through a robust development process;
- data libraries on weed, pest, and multi-crop data;
- completes spraying of pesticide in a one-acre farm in nine minutes.

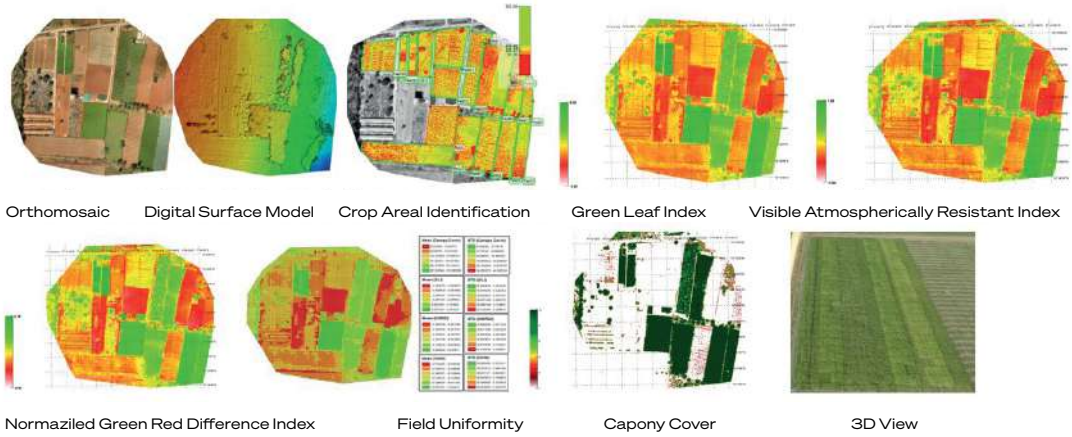

Figure A11
Weed and pest identification and management

SOURCE: Senseacre Labs.

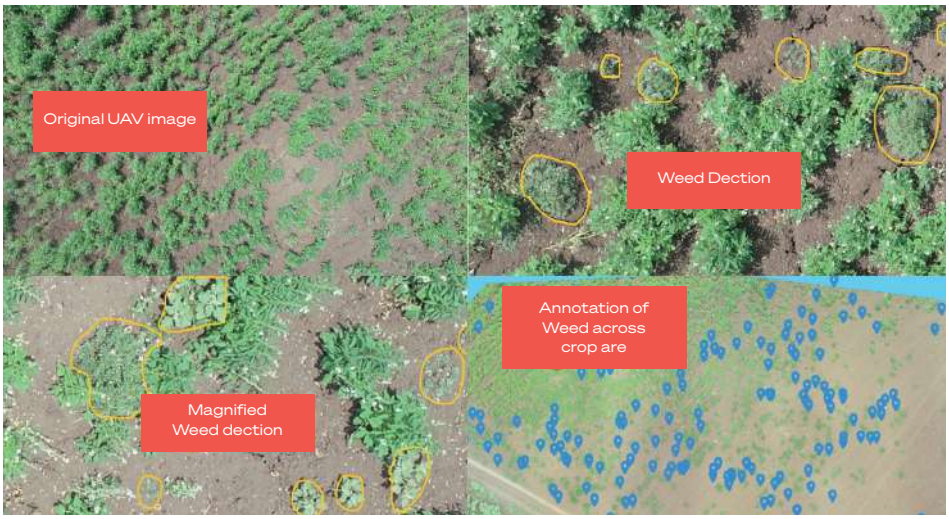

Figure A12
Weed identification

SOURCE: Senseacre Labs.

SOLUTION IN PRACTICE

Senseacre is the only UAV system aggregator in India that delivers full life cycle services such as land planning, areal image capturing, weed and pest detection, aerial spraying and crop analysis using UAVs. It has two main services: the first being direct sales of UAV machines, the second service is a survey-on-service function under which crop health is monitored by an aerial survey followed by spraying. For each given field, first a drone captures high-resolution images, scrutinized by CNN models, to identify weeds, pests, and other growth-inhibiting factors (Figure A12). A quarantine map is generated as per the areal image analysis, and a drone is flown to do precision spraying of protective chemicals in the quarantined area. Post spraying, the drone is flown again to monitor the crop health and progress. Before harvest time, this enables farmers to do a volumetric analysis of the final crop as well.

Although Senseacre works predominantly through channel partners such as FPOs, individual requests from farmers continue to pour in because of a sense of urgency during pest attacks. Because of the labour shortage issues, farmers find it difficult to administer pesticides quickly and precisely. This is where Senseacre's UAV machines can efficiently substitute humans and administer quarantine solutions.

CHALLENGES OVERCOME

The main challenge was to make farmers believe that a drone can cover an entire acre of land in less than nine minutes and furthermore, achieve better outputs by simply using less than 50 percent of the amount of crop protection chemicals currently used. The strongest motivator for any farmer to adopt a new technology is the age-old adage, "seeing is believing." The initial pilot demonstration trials in individual farms had satisfactory results and helped Senseacre to convince the farmers. The lack of knowledge and awareness on drone usage makes this a complex task, but through training resource persons, this barrier was overcome.

HIGHLIGHTS

- surveyed 100 square kilometres;
- provided customized surveying and spraying services to 1000 farmers covering an area of 2000 hectares;
- 50 percent reduction in pesticide usage and 70 percent reduction in water consumption.

ENABLING ECOSYSTEM ENTAILS

Drones in India are a very new technology, especially in agriculture and for crop health monitoring CAPEX for drones, sensors, training pilots is expensive. Since the Directorate General of Civil Aviation (DGCA) has imposed stricter guidelines for obtaining licenses, there is some ambiguity concerning the application process as well as the speed with which these licenses are granted. With only six companies authorized to supply drone hardware currently, it becomes a constraining environment for players who wish to bring advanced machinery into the country and scale at speed. A 360-degree ecosystem for design, manufacturing, supply of spares and service and upgrading facilities needs to be made indigenous by inviting industry leaders to establish themselves in the country, either through joint ventures or through direct investments. In addition, training facilities need to be set up across the country either by private players or through government skill-building initiatives to train youth to operate drones and provide data analysis. Operating a drone requires three people – two pilots and one data analyst. In the case where each of the 250 000 villages across the country needs a drone, the employment potential would be 750 000 jobs across the country.

SKYMET WEATHER SERVICES PVT. LTD.

STATES OPERATING IN INDIA
Across 24 states in India

TARGET BENEFICIARY
Financial institutions, farmers, agri-business

BUSINESS MODEL
B2B, B2C, B2G

WEB
www.skymetweather.com

PROBLEM

Dearth of high-resolution data has led to several challenges in the agriculture sector. The absence of high-resolution spatial and temporal data (historic, current and forecast) for weather and crop yields severely restricts the ability of banks and insurance to quantify risks in their agricultural portfolio and credit assessment. For instance, the insufficient network of automatic weather stations (AWS) leads to a basis risk in the process of insurance claims settlement. Furthermore, with the emergence of climate and weather induced shocks to agriculture, financial institutions (FI) are supplementing historic data with sophisticated forecasting tools to better quantify financial risks. Reliable weather forecasts downscaled to high resolutions can also help farmers with better management of their crops, and thereby partially mitigate weather risks.

EXISTING SOLUTIONS

Skymet Weather was started to provide the most accurate weather information for the Indian public. The first privately owned weather provider in India, it has since moved on to become an agri-tech company. Skymet provides the best technical solutions for farmers, banks and agri-businesses based on data, artificial intelligence (AI), machine learning (ML) and on the ground deployment of AWS. Skymet owns and operates 6500+ automated weather stations, 675 agricultural sensors, 400+ air pollution sensors and 23 lightning sensors across India.

Skymet deployed a network of AWS in 2011, as the crop insurance industry required these for their business. India Meteorological Department (IMD) was the only agency maintaining a network of weather stations at that time. Given the importance of weather data for planning and development, state governments (Telangana, Andhra Pradesh, and Karnataka) embarked on creating their own network of weather stations. This helped states to reduce the basis risk for crop insurance and also improved the quality of their short-range weather forecasts. Apart from high-resolution observed weather, there was a strong demand from the insurance sector for historic and forecasted weather products, as well as historic and forecasted yield for insurance pricing and settlement. Suggestions were also made to replace the Crop Cutting Experiments (CCE) system, performed on sample plots to estimate yields and crop loss with a more cost effective and technology-based system. The CCE based system also had a high basis risk and was prone to moral hazards.

SOLUTION

SkySense is a ML-based software platform developed by Skymet, which blends data generated from sources such as the internet of things (IoT) sensors (including AWS), remote sensing, drones, crowd sourced ground truth data and governments, to provide real-time observed weather, historic and forecasted weather data, historic and forecasted yield data and crop health monitoring services at high spatial and temporal resolutions across India. Various outputs from SkySense are packaged into their product suite based on the needs of the end customer.

With 6500 AWS deployed across 24 states, Skymet has the largest network of AWSs. Pivoting a unique public-private partnership (PPP) model to create this network, Skymet partnered with the Government of Maharashtra to deploy over 2100 AWS across the state. The data from the AWS is provided free of cost to the state government however Skymet is allowed to charge private players for use. Skymet believes such PPPs can galvanize investment and help transform the Indian agricultural sector. Skymet also invested in lightning and air quality sensors at a few locations to monitor the atmosphere. Furthermore, it has deployed about 675 agricultural sensors primarily to measure soil moisture, soil temperature, leaf wetness and solar radiation, which assist in crop health monitoring. SkySense fuses all of these datasets and uses ML methods to deliver customized information products catering to banks, insurance companies and agri-businesses. Skymet also created a farmer-devoted mobile app to allow them to consume some SkySense products. Interaction with farmers, banks, insurance companies, agricultural universities and governments combined with a strong ground presence helped Skymet design products with wider acceptability. Yogesh Patil states, “The interaction with end user and partnership with agricultural universities helped us to avoid duplication of work and provide customized solutions based on local needs.”

UNIQUE FEATURES

- granular weather information – observed, historic and forecast;
- robust ML platform that combines multiple datasets such as remote sensing, IoT sensors, ground-truthing, drone and government;
- customized solutions matching local needs and partnerships;
- API based data access to all ecosystem users;
- collaborative partnerships with agricultural universities and government.

SOLUTION IN PRACTICE

Sensing the need for granular real-time data, Skymet entered the agricultural sector to enable data-driven decision-making. Skymet started with the deployment of AWS across India to generate real-time weather data. Over the years, in addition to weather sensors it deployed lightning, air quality, soil moisture, soil temperature, leaf wetness and solar radiation sensors to provide real-time information on crop health. The innovation and evolutionary journey of Skymet’s products involves serious field-testing and customization of products based on the needs of an end user. Product suite of Skymet comprises:

i. **Skymet Weather Information Management System (SWIMS):** This provides historical, current and forecasted weather information products. More recently, Skymet has been issuing seasonal forecasts on the Indian monsoon which is attracting a lot of attention.

ii. **Agriculture Risk Monitoring System (ARMS):** This product helps quantify risk associated with a parcel of land and primarily caters to banks and insurance companies.

iii. **Customized solution for agri-businesses:** This typically caters to agri-businesses and value chain companies that seek data on crop acreage and crop yield estimates. B2B customers are offered these products on a subscription basis.

In addition to the vast network of AWSs and sensors, its comparative advantage is due to the way it collects ground truth data through primary surveys and farmer interviews. Skymet's engineering team (who visit the AWSs for periodic maintenance) or a cadre of temporary staff called SkyMitra collect data through the field visits. SkyMitras, the temporary staff, are trained to collect on-ground information such as crop signature and crop health on behalf of Skymet on their mobile phones. SkyMitras are deployed based on both the request from insurance companies (who typically solicit staff to provide oversight to CCEs conducted by governments) and the necessity for periodic surveys by Skymet internal teams. SkySense, also leverages on published datasets of governments combining them with sensor data, remote sensing, and ground-truth data to provide real-time forecasting and crop health monitoring services to different players through SWIMS, ARMS or other interfaces. Skymet also uses drones to supplement existing datasets wherever necessary. Drones are deployed to provide crop loss estimates for crop insurance. Skymet has recently started delivering services directly to farmers through a mobile app that provides information on past, current and future weather data together with crop health indicators based on their location.

Skymet's rich source of ground data collected through its sensors and surveys is a key differentiator. This enables Skymet to deliver weather products possessing a higher reliability *vis-à-vis* those depending purely on statistical modelling based on gridded satellite data. To give an example of the perspective, it is estimated that the accuracy levels of satellite-based weather data especially rainfall was as low as 10 percent.

CHALLENGES OVERCOME

In addition to an uncertain policy environment, obtaining capital was a key challenge that Skymet overcame. AgriTech was still at the initial stages in 2011. One of the initiatives such as the new PPP model for the state of Maharashtra enabled companies such as Skymet to participate and contribute to the agricultural growth story. Another big challenge was the non-availability of high-quality and high-resolution historical weather and yield data. Skymet started collecting data as early as 2011, which included data on the efficacy of crop cutting experiments through both surveys and sensors. The predominance of small-size plots in the Indian agricultural sector makes it difficult to apply drones and high-resolution imagery, which in turn drives up the cost of the solution for common application. Government partnerships can help bring down the cost of solution to the end user.

HIGHLIGHTS

- 75 percent of India's agricultural land is monitored as frequently as every fortnight through a combination of IoT sensors and remote sensing data;
- 30 million farmers consume Skymet services;
- all major banks disbursing Kisan Credit Card loans utilise Skymet services.

ENABLING ECOSYSTEM ENTAILS

- promotion of PPPs for deployment of IoT sensors and solutions across the country. Government assistance will help push technology solutions developed by the private sector to reach remote users;
- enable data sharing across government wings and also within the private sector. There is a need to promote data democracy.

CASE STUDY

PCSRA: A unique partnership between USAID and Skymet

Plan

USAID, under its global initiative Feed the Future, works to combat hunger, poverty and malnutrition across the world through various partnerships. In India, USAID created a unique collaboration with Skymet named Partnership in Climate Services for Resilient Agriculture in India (PCSRA). PCSRA supports farmers in such a way that they are fully protected from the effects of weather on crops. PCSRA was a four-year project (October 2015 to September 2019). The project encompassed 31 districts in nine states of the country and was targeted to benefit 84 000 farmers during the four-year period.

Approach (Skymet - farmer mobile app)

Skymet Installed 675 new AWS dedicated to USAID project, they also developed a co-branded app for the farmers.

- The SkyMitras conducted farmers' meetings across the states to register farmers and gave a demo of the app. They told farmers about the latest developments in agricultural technology and how to benefit from the app by asking questions directly to the experts. This was aimed at small and marginalized farmers and women farmers.
- Weather information is provided to farmers through IVRs, weather display boards and WhatsApp groups.
- About 70 000 farmers are registered under the project.
- The registered farmers reported lesser crop losses due to timely help and support.
- Farmers reported that they are getting better yield, facing lesser losses and able to take proactive steps. They also reported that they are more aware now of the latest innovation and trends in agriculture owing to the workshops conducted by experts in association with PCSRA.

SOURCE TRACE

STATES OPERATING IN INDIA
Odisha, Maharashtra, Telangana, Haryana, Andhra Pradesh, Telangana

TARGET BENEFICIARY
Small and marginal farmers, Farmer Producer Organizations (FPO)

BUSINESS MODEL
B2B

WEB
www.sourcetrace.com

PROBLEM

Agriculture in developing countries suffers from low yields and low returns typical of resource poor environments. Also, the current agricultural practices are unsustainable in the long run "generating enough food to feed the growing world population sustainably with limited resources is a challenge for our times" as stated by Venkat Maroju, CEO of SourceTrace. Effective knowledge, quality extension services, facilitation of traceability from farm-to-fork, and strong market linkages can intervene at various levels in the food value chain and improve the system level outcomes, while eventually addressing the above-mentioned issues.

EXISTING SOLUTIONS

Digital technologies have integrated only very slightly into agriculture. Traditional extension services are largely manual and depend on field visits by public extension officers. Agricultural advisories are largely disseminated through these extension officers. However, there has been some recent progress with the emergence of text and interactive voice response (IVR) based extension services. The traditional model suffers from issues of scalability and among farmers e-extension models have brought negligible change due to the very generic nature of advisories. Promising pilots indicated a greater uptake and engagement with customized advisories according to each farmer's needs as well as a two-way communication system. Moreover, certain aspects such as traceability are demanding without the use of technology. In the existing ecosystem actors operate in silos, but the results have proved to be ineffective. Most of the existing digital solutions do not recognize the local context or background of smallholder farms.

DATAGREEN, a digital platform offered by SourceTrace, connects food and agriculture with a solution at every touchpoint – from farm to retail. Its suite of services includes farm digitization, certification, traceability, supply chain management, market linkage and financial services. Increasing productivity, making agriculture sustainable, making supply chains more efficient by bringing in traceability and food safety issues to the fore are the core issues that SourceTrace addresses.

UNIQUE FEATURES

- traceability;
- multi-lingual;
- online/offline mode of data collection;

- built-in survey tools;
- complete solution suite for all actors in the agricultural value chain.

SOLUTION IN PRACTICE

DATAGREEN is catering to various stakeholders in the agricultural sector. It digitalizes various activities in the value chain through web and mobile interfaces. The suite of DATAGREEN includes: farm management, farmer advisory services, certification, traceability, supply chain management, monitoring and evaluation (M&E), market linkage, and financial services. SourceTrace observed that rolling out digital solutions to individual smallholder farmers could be difficult considering the scale, low literacy levels and language barriers. SourceTrace, therefore, engages with farmers through large agribusinesses, financial institutions, developmental organizations, food majors, governments and farmer collectives.

DATAGREEN is an expansive platform with modules that can be deployed according to the specific requirements of different stakeholders across the value chain. For example, SourceTrace enables agribusinesses enrol their farmers, build their profiles and digitize all their programs, such as training and financial aid. For global food companies, SourceTrace digitizes their procurement and supply chain processes.

The foundational module of DATAGREEN captures the socio-economic, demographic and landholding information of farmers including details of FPOs collected by the field staff, or sometimes by FPOs using mobile phones. This information is immediately made available to the stakeholders involved in the value-chain to enable data-driven decision making. Its advisory module is used to synthesize data from sources such as satellite, on the ground and survey. Advisories on weather forecasts, crop calendars, pest and disease prevention and control, in addition to market alerts are then communicated through audio or text messages.

The platform combines advanced technologies such as machine learning, remote sensing and the internet of things (IoT). For instance, using harvest date, yield estimates and crop calendar, DATAGREEN can estimate crop volumes. Crop volume data in turn can be used to predict the market price and empower farmers on timing for their sale operations. The digitalization of transactions across the agri-value chain provides data to the platform that can also be used for assessment of credit-worthiness of an individual farmer.

The Certification module is the most popular and used feature of DATAGREEN. Certification was the initial service/module launched by SourceTrace as the certification process (organic, good agricultural practices [GAP])) was largely paper-based and involved field inspections. The process was set up to digitally capture all transactions on a farm, ranging from input application to management practices that went into crop production. Laudes Foundation (formerly C&A Foundation) uses SourceTrace's certification platform to certify organic cotton farmers in India, Pakistan, United Republic of Tanzania and China. Furthermore, the certification process also captures compliance with fair labour practices. Ready-to-use certification templates are made available to FPOs and farmer groups to democratize and make the certification process more affordable.

The platform also facilitates traceability through the adoption of QR code-based tracking. SourceTrace successfully implemented the most complex traceability projects that span commodities, geographies and multiple stages of processing. The solution is robust, easy to deploy and existing staff can handle it without any significant increase in cost or overheads. A case in point is how the platform can easily trace commodities such as flavours and fragrances, which otherwise pose the most complex problems for traceability.

CHALLENGES OVERCOME

The challenges faced and overcome are:

i. network bandwidth constraints – a big challenge, especially in developing countries; the platform is designed to work in offline and online mode seamlessly, especially to facilitate data collection in remote areas;
ii. lack of digital skills on the ground – resolved by making the application easy to use, intuitive and basic; diversely skilled people with ease e.g. farmers, extension worker, organizational staff;
iii. need to support local languages – working in 28 countries around the world combined with low literacy levels necessitated supporting many local languages; it supports more than 15 local languages on mobile applications and English, French and Spanish for the mobile applications;
iv. low adoption amongst farmers – but farmers could be reached and impacted by aligning with businesses and developmental organizations;
v. keeping costs and complexity low – as DATAGREEN is an expansive platform with solutions across the value chain, keeping the solution simple for all stakeholders was a key priority. Solving complex requirements in traceability without being asset-heavy and keeping costs low has been a major achievement.

HIGHLIGHTS

- DATAGREEN grew from five customers in 2015 to 145 customers in 2020. The solution is now impacting over a million farmers from 28 countries across Asia, Africa, Latin America and now Europe.
- Organic palm oil farmers in Sierra Leone are receiving 10 percent more payment than before.
- Organic cotton growers in India are receiving 10–15 percent more per kg of organic cotton.
- In Nigeria, farmers have been successfully linked with financial institutions for inputs and credit.
- Farmers growing organic coconut in the Philippines are able to access global markets and get premium pricing due to digitization of the first mile including certification and procurement transactions.
- The technology enabled a system that helped eliminate deforestation and child labour in Cocoa value chains in Cote d'Ivoire, Cameroon and Ghana.

SUCCESS STORY

Chetna Organic Producers Company based in Hyderabad works with 15 000 organic cotton farmers. They deployed SourceTrace solutions to digitize their end-to-end processes including seeds distribution, loan distribution, organic certification inspections, procurement, payments, and traceability. Clothing brands based in the United States of America and Europe who source this cotton were able to trace their cotton bales to the origin, and also record the socio-economic data of the farmers who produced their cotton. As a result, more than 20 highly ethical fashion brands formed a coalition to buy all of the organic cotton produced by Chetna farmers and furthermore pay a 10–15 percent premium for the produce.

STELLAPPS

STATES OPERATING IN INDIA
Karnataka, Andhra Pradesh, Punjab, Rajasthan

TARGET BENEFICIARY
Farmers, milk processing companies

BUSINESS MODEL
B2B, B2F

WEB
www.stellapps.com

PROBLEM

The Indian dairy sector is highly fragmented and a large part of the milk economy is still in the informal sector. While India produces over 500 million litres of milk per year, only about 143 million litres are sold or processed within the organized dairy sector. The milk producers are mostly small and marginal farmers that are rearing about two to three cattle. Consequently, dairy farming in India has one of the lowest productivity levels *vis-à-vis* the more developed countries. Also, owing to the prevalence of a large number of small farmers selling very small quantities, maintaining quality, consistency and enabling traceability in the organized dairy value chains is costly and difficult as well. Hence, dairy value chains are not able to incentivize farmers to adhere to quality milk production, nor are they able to penalize some of the actors for practices such as adulteration. Apart from this, smallholders are underserved by extension systems on animal health monitoring, and timely vaccinations.

EXISTING SOLUTIONS

Organized institutions in the dairy value chains (public, private, and co-operatives) tried to innovate through institutional mechanisms in order to overcome the challenge of having to deal with large numbers of small farmers producing small quantities of milk. Most institutions created village level collection centres, which in turn were linked with chilling units and finally processors. However, at most, village-level collection centres manual processes for milk quality testing are used and transactions are still paper-based. Some digital innovations that address activities at various nodes are also in use. These largely came from hardware and software players who tried to address only a specific part of the dairy value chain.

STELLAPPS SOLUTION

Stellapps is an internet of things (IoT) based solution that is primarily sold to the milk processors. The Stellapps suite offers the following digital solutions:

i. **Farm management:** This comprises the MooONTM device, a sensor-based accelerometer designed as a wearable device for cattle. Real-time data from this device, combined with machine learning (ML) algorithms on the cloud can provide real-time information to farmers on the health of their animals. This device can undertake preventive health care measurements and detect when an animal is in heat in order to administer artificial insemination. The MooONTM mobile application of Stellapps is used to digitally record vaccinations,

artificial insemination, deworming, and pregnancy detection. The extension staff of dairy processors uses the MooONTM application to work closely with dairy farmers for better quality control. This ecosystem is also used to facilitate support services to farmers for animal nutrition and animal health.

ii. **Collection centres:** SmartAMCUTM (Automatic Milk Collection Unit), Stellapp's solution for digitizing activities in milk collection centres, is an IoT based solution that enables real-time acquisition and dissemination of milk procurement data at the collection centres. The solution comprises a device that can detect fat content and the SNF from a milk sample brought to a collection centre. The data from the IoT device are instantly uploaded to the cloud, and based on the quality grade milk price to be paid, is instantly computed. In addition, the SmartAMCUTM has integrated a payments gateway and farmers are paid through a bank transfer as well. SmartAMCUTM has solved a major challenge pertaining to rate cards. The price of milk to be paid to farmers is seasonally adjusted by the milk processors, to incentivize higher production during festivals and holiday seasons when demands are higher. In the past, rolling out this type of seasonal rate cards required a lead time of months and was also difficult to enforce. With the SmartAMCUTM, however, processors can do this dynamically and have the capacity to rollout a farmer-specific rate card based on history of farmer's contributions.

iii. **Chilling units:** Any delay in the chilling of milk after procurement from farmers could degrade the quality of the milk. SmartCCTM (chilling centres) is also an IoT based solution to digitally monitor chilling units and also digitalize procurement operations between the collection centre and chilling unit. The link between collection centres and chilling units is prone to adulteration and malpractices and furthermore high total solid loss. SmartCCTM enables the grading of milk for fat and SNF at the collection centres. When this data is tallied with the data from the collection centres collected by SmartAMCUTM, possible adulterations or malpractices can instantly be identified. SmartCCTM is directly connected to the bank payment gateways and can make payments to the collection centre agents, once the grade and quantity of milk have been ascertained. Since penalties could be levied for adulteration, the system has a built-in disincentive for collection centres to avoid adulteration.

Milk is best preserved at 4°C, deviation from this temperature results in reduced milk-quality. Pilferage, adulteration and improper cleaning of bulk milk coolers (BMC) are hard to detect due to absence of traceability. Preventive-maintenance is also difficult due to lack of real-time data on BMC functioning. ConTrak® is a cold-chain management solution which enables real-time monitoring of BMCs and collects data on milk-temperature, volume, power-status and BMC-functioning. All BMCs connected with ConTrak® can be tracked on an interactive portal, which displays their real-time-chilling-graph, BMC-rating and auto-generates reports. ConTrak® can automatically shut down the compressor and agitator to prevent over or under-chilling of milk, switch between diesel generators and power grid depending on power-status to ensure optimal chilling of milk. It also alerts BMC operators through SMS/email about over/under-chilling, power-failures, BMC malfunctions, cleaning protocol adherence etc. Adulteration and pilferage are prevented due to real-time monitoring

enabled by ConTrak®. It also helps reduce chilling costs, increase chilling efficiency, enable preventive maintenance and increase the lifespan and efficiency of cold chain infrastructure.

Fintech solutions

Farmers struggle with accessing formal credit owing to lack of access to financial services, difficulty in understanding of the process, lack of collateral and documents. Even though loans to farmers comprise priority sector lending, difficulty in assessing farmers' credit worthiness keep banks at bay as well. Stellapps' mooPayTM solution bridges the gap between farmers and financial institutions (FI). mooPayTM was also recognized as the "Financial Inclusion Initiative of the Year" in 2019 by the India FinTech Forum. mooPayTM offers lending products such as milk receivable financing, sachet loans and cattle financing. Apart from the credit products, mooPayTM also enables direct farmer payments and banking. Loan repayment is simplified through mooPayTM as repayment amount is directly deducted from the farmers' milk receivables money from a dairy company. Thus, farmers can pay through milk. The collection centre agent acts like a bank correspondent and facilitates the KYC and documentation for farmers. Thus, the village milk collection centre acts like a banking point for farmers.

Stellapps has developed its own farmer credit-worthiness index called mooScoreTM. It is computed based on the farmers' milk pouring data collected through the smartAMCUTM and mooONTM. Farmers taking good care of their cows and consistently pouring milk to the dairy, have a higher mooScore.

Apart from credit and payment, mooPayTM can also facilitate insurance solutions for farmers. Stellapps is developing facial recognition technology for cattle and it is in advanced stages of testing. Facial recognition in addition to the mooONTM device for insured cattle will help insurance companies curb fraudulence by providing real-time updates on animal health status. mooONTM sends alerts when the device is taken off or tampered with to prevent misuse.

All these applications are integrated on a single platform, hence, this data could be used to incentivize good practices and adherence to quality milk production. Data from the MooONTM device and MooONTM app along with the data from SmartAMCUTM could be used to identify farmers who are taking good care of their cattle and consistently providing high-quality milk. They could be incentivized through higher prices. This also has a consequence on their financial creditworthiness. For instance, such farmers could be perceived as less risky by banks and FIs. Similarly, the Stellapps suite also enables penalizing the farmers and collection centers engaged in adulteration and malpractices. Hence, when the complete system is in operation across a value chain, it can embed incentives to tackle issues of productivity, quality, and traceability of the dairy value chain.

UNIQUE FEATURES

- integrated solution (hardware and software) enabling traceability of the dairy value chains in smallholder context;
- real-time monitoring of animal health;
- digitalization of extension and linkages with inputs and other service providers;
- integration with bank payment gateways;
- dynamic rate charts to cater to demand fluctuations;
- real-time analytics for CXOs of dairy processors.

SOLUTION IN PRACTICE

Stellapps solution is typically offered in a SaaS model. The buyers are processing companies who are quality conscious and driven by an aspiration to have better quality control on their milk production process. These companies find it challenging to do this when dealing with thousands of smallholder farmers. The processors also hire extension staff to support their producer farmers and also as a means to monitor activities of their producer farmers. The MooONTM IoT device is distributed to farmers and MooONTM app is used by the extension staff. The device data in combination with machine learning algorithms can give real-time insights on animal health. The aggregated data are then analysed and targeted advisories are sent back to the dairy farmers so they can improve productivity. For example, nutrients are based on IoT animal health data or a schedule for vaccinations are suggested. The extension staff can accordingly arrange for suitable interventions based on this. Furthermore, vaccination schedules can also be set up and extension staff and farmers can be alerted so that animals receive the best possible care. All intervention data such as vaccination, insemination, pregnancy detection, demographics, deworming and diagnostics are recorded on the cloud platform. Agents of a collection centre for example, are alerted if a farmer has used an antibiotic, after which the collection centre can proactively segregate milk received from the farmer if the dairy value chain demands antibiotic-free milk.

The Stellapp solution also enables transparent and quality-based pricing of milk lot from each farmer based on grading at the milk collection centre. Since the quality gradation is performed by IoT sensors, there is no human intervention and therefore no risk of compromising data. A similar grading and testing of milk at the chilling centre enables detection of any adulteration. In case of any quality issues, the solution can trace back it to the exact node and trace it to a smaller group of farmers. In the past, processors penalized the entire collection centre even in the case of small group of farmers, or collection centres engaged in malpractice.

Furthermore, Stellapps positively influences financial inclusiveness and credit rating of small farmers. Transactional information on a farmer minimizes information asymmetry and especially helps banks to avoid adverse selection. At the same time, the farmers who contribute consistently good quality milk and take better care of their cattle can be provided with easy access to credit.

CHALLENGES OVERCOME

The challenges regarding the low capacities of milk collection agents and management, especially concerning technology, were overcome by providing multiple training sessions and on-site support. Furthermore, problems with network connectivity were solved by providing local data storage and the transmission of local data when network connectivity improved. Another key challenge was the misalignment of incentives of frontline staff, especially at the collection centres. Although senior management and CXOs were keen to have such solutions, collection centre agents and staff who were used to malpractice were resistant.

HIGHLIGHTS

- currently operates in more than 25 000 villages and fetches 7 million litre of milk per day;
- 200 clients are onboarded to the platform over the last three years who could raise revenue up to USD 12.8 million.

ENABLING ECOSYSTEM ENTAILS

- while selling solutions to private processors is relatively easy, government tendering process norms for milk cooperatives in the dairy sector needs revamping. The government tendering process enables only hardware procurement. However, the government needs to realize the value of software and accordingly alter the tender process;
- enable formalization of the dairy sector.

THANOS

STATES OPERATING IN INDIA
Andhra Pradesh, Telangana

TARGET BENEFICIARY
Farmers, agri chemical companies, agri service providers

BUSINESS MODEL
B2B2C

WEB
http://www.thanos.in

PROBLEM

Manual crop spraying is a labour-intensive activity that consumes about 100–150 litres of pesticide solution per acre; it is time consuming and harmful to the sprayer's health. Most of the farmers or labourers carrying out this activity are not trained nor do they wear appropriate protective gear, as a consequence they are prone to short-term and long-term illness. Health problems can aggravate when spurious chemicals are used.

Finding skilled agricultural labour during the peak of the agricultural season can be difficult. Migration of agricultural labour to urban areas for better work and livelihood opportunities is one of the key reasons for labour shortages. Manual spraying activities also lead to significant shedding of fruits and flowers caused by the workers in the fields while spraying pesticides. As a result, this leads to yield losses as well as income losses to the farmers.

EXISTING SOLUTIONS

Autonomous methods of crop spraying services have emerged to address the issues of labour shortage, adverse health effects, and crop losses, which are mechanical in most of the Indian states. The ground-based machine spraying using tractors and other autonomous vehicles have their limitations because of waterlogging and canopy height. Also, a new generation of AgTech entrepreneurs has made drone services popular with farmers. They import expensive drones that do not have a local after-sales service, therefore maintenance and availability of spare parts are a major challenge. Their profitability model depends on the number of acres sprayed per day, but fragmented and small land sizes pose problems for achieving scale.

SOLUTION

Thanos began its journey as an aerial surveying drone service that worked with off-the-shelf drones. Over time, it developed various drone service product lines catering to the needs of the Indian market. To overcome the shortage of after-sales service and spare parts for drones, Thanos started to manufacture drones in India. It also reverse-engineered various components to build in-house expertise to repair and maintain imported components and drones.

Thanos' core expertise lies in the manufacturing and maintenance of agricultural drones. It primarily generates revenue from the manufacturing of agricultural drones and by providing aerial spraying services. Since it manufactures its own sets of batteries, it assures a 20-minute flight span.

The "Autonomous Aerial Spraying Platform" is the primary revenue-generating service. For this product line, Thanos uses an app to mark the boundaries of the farmland where chemical spraying is required. After feeding location-specific parameters into the app, the drone sprays the required chemical autonomously and returns to the designated location. To maintain the economic viability of services it works primarily with agrochemical companies and farmer groups to ensure scale in order sizes. Thanos, however, has a criterion for deciding whether to accept or reject an order. This criterion depends on the obstacles present in the field, as well as the size and shape of the field. Spraying services are currently offered for rice, cotton, and chilly. Thanos only sprays chemicals that have been tested for drone spraying and have a prescribed dosage, which varies by crop and its growth stage. Consequently, Thanos works with a limited number of chemicals, as not many pesticides have been subjected to drone-based trials.

UNIQUE FEATURES

- local manufacturing and after-sales services;
- autonomous flights;
- height sensing radar;
- in-house built lithium-ion battery energy system;
- on-board cooling system of batteries;
- longest flight span – 20 minutes – for an Indian built, battery powered, agriculture drone.

SOLUTION IN PRACTICE

Thanos operates in a B2B2C model where it works with agricultural companies and agri service providers to generate demand. Once the work order is received, the Thanos team maps the boundaries of the collective farm plots that require spraying. Based on local weather and crop conditions, the drone flight variables such as speed and height are fed into the app. The drone tank is filled with the pesticide solution (a mix of the crop protection chemicals and water in the prescribed ratio). Using the mobile app, the drone flight can be programmed in autonomous mode, where the drone uniformly sprays the pesticide across the fields without human intervention and returns to a pre-designated landing spot. Although it is an autonomous spraying platform, Thanos drones can be controlled manually in case of obstacles and unforeseen emergencies.

CHALLENGES OVERCOME

Thanos initially worked with imported off-the-shelf drones for surveying and related applications. However, due to maintenance issues and long waiting periods for imported spare parts, the Thanos team undertook the arduous process of manufacturing their own drones. During this process, they created an after-sales support system and also provided support for other foreign manufactured drones. Furthermore, Thanos was confronted with the technical issues concerning imported flight controllers. The imported flight controllers, which were not compliant with No Permission No Take-off (NPNT) guidelines of the latest drone regulations, could not be readily used for agricultural drones. Thanos overcame this problem by reprogramming and reengineering these controllers for agricultural purposes.

On the service side, Thanos realized that catering to every individual request from farmers was a daunting task, due to the complexities of the shape and size of farms, existing obstacles, and the distribution aspect of farm plots

of even the larger farmers. Hence, in order to make it economically viable, Thanos works with agrochemical companies and the agri-service providers that would handle demand aggregation.

Farmers do not easily adapt to change when it comes to risk mitigation activities, such as pesticide spraying. Historically, they are accustomed to expensive high volume spraying. Thanos conducted field demonstrations displaying the impact of low volume spraying and as a result, was able to gain the trust of farmers.

HIGHLIGHTS

- 1800+ acres sprayed and over 80 farmers benefited;
- 90-95 percent reduction in water usage;
- annual revenue of more than INR 4 million.

ENABLING ECOSYSTEM ENTAILS

Although India has one of the world's most robust drone regulatory policies, its intricacies have slowed down the growth of drone-based services for various reasons. On the manufacturing side, the manufacturing of drone parts has not taken off in India because there is not enough local demand. Most of the motors used in manufacturing drones are imported; however, regulatory clearance for the import of such components is quite stringent and slows down the entire process. As regards investments, the industry is highly regulated and potential investors are reluctant even though this is a promising sector in India. Finally, as far as skills are concerned, trained technicians who can operate and maintain these devices are scarce.

In order to set up drone-based agri services in India, there is a dire need to:

- address the regulatory complexities over usage, import, and manufacturing of drones and drone components;
- ensure investors' confidence to make capital available for local manufacturers;
- make available more technical training facilities to train youngsters on how to operate and maintain drones.

SUCCESS STORY

In the Warangal district of Telangana, Thanos ran a drone spraying exercise as part of a pilot study. One of the small farmers, who grows chili in his field, benefited from the drone spraying service and paid INR 400 per acre. Not only was he happy with the drone spraying service but he also had an unexpected insight into the accomplishments of the Thanos team.

- Drone spraying helped to save approximately one quintal of fruit dropping. During manual spraying, when a farm labourer moves between plant rows, they involuntarily brush against the plant canopy that leads to fruit dropping.
- In less than 30 minutes, an entire hectare can be sprayed as opposed to a half-day of when done manually.
- Sprayed and unsprayed areas can be tracked when the drone service is used, but when done manually farmers cannot track the spraying activity.

TRACEX TECHNOLOGIES PVT LTD

STATES OPERATING IN INDIA
Karnataka, Jharkhand, Bihar, West Bengal, Uttarakhand

TARGET BENEFICIARY
Farmer Producer Organizations (FPO), agri-businesses, food brands, NGOs

BUSINESS MODEL
B2B

WEB
http://tracextech.com

PROBLEM

Heightened consumer awareness and activism on topics such as sustainability and food and safe practices have created new challenges. Consuming safe food that is sustainably grown is as important as food security, in fact, nearly 600–700 million people across the globe fall sick due to food contamination. The absence of any formal information systems to trace the food from farm-to-fork has implications, such as determining accountability. Furthermore, it is difficult to create incentives/disincentives for actors in the food supply chain to comply with safe practices. Traceability of food is extremely complex due to fragmented and unorganized agriculture value chains coupled with the shallow penetration of technology in Indian context. Information systems are not available to record transactions such as inputs applied, management practices, and harvest dates and yields for an individual farmer. Since the aggregation of produce from individual farmers occurs across many small and large intermediaries, there is no system to clearly separate good quality produce from the bad quality ones. Therefore, no one in the value chain, especially the farmers, has any economic incentive to produce high quality and safe produce. The changing of consumer consciousness and mistrust of big brands, however, is stimulating agricultural stakeholders to create more transparency and traceability in the supply chain. Companies are looking for ways and means to trace their supply chain to the first mile, for example, the first supplier.

EXISTING SOLUTIONS

In the traditional mode, traceability is often facilitated through companies that link farmers to consumers with very little intermediation. Quality checking and assurance is often done manually through in-person field checks while trust in the ecosystem is achieved through social capital, for example being part of a small and tightly knit group. Jivabhumi, a pre-cursor to TraceX, is an example of the many small agri-businesses that are attempting to address food safety issues by creating a close network of consumers and farmers in coupled value chains. This traditional model, however, is not scalable. Furthermore, establishing trust through non-social means in a fragmented and unorganized supply chain poses its own challenges.

SOLUTION

TraceX aims to connect stakeholders across the supply chain and enable transparency, traceability and provenance using its blockchain platform called FOODSIGN. Anil Nadig, Co-Founder of TraceX states: "blockchain is very powerful because there is a single version of truth, which no one party can modify unless there is consensus." FOODSIGN, designed as an internal system to help Jivabhumi upscale, was diverted into TraceX and is now offered to potential customers for a subscription fee. TraceX digitalizes and enables traceability as its primary goal, but it also addresses problems faced by the average Indian farmer such credit access,and market access. TraceX promotes efficient money management as the entire chain of interactions across the value chain are digitalized.

UNIQUE FEATURES

- multi-lingual;
- online/offline data collection;
- traceability and provenance;
- configurable workflow for various crops and region-specific supply chain nuances;
- configurable package of practices for effective farmer advisory.

SOLUTION IN PRACTICE

The TraceX founding team launched Jivabhumi, an agribusiness, in 2016 to accomplish transparency for the end consumer in a food value chain. Jivabhumi started by sourcing over 80 organic products from nearly 20 FPOs and delivering directly to the consumers in Bengaluru. They visited fields several times to check quality and assure customers of the reliability of Jivabhumi. The founders also noticed that most farmers practising organic agriculture maintain a diary, as had been stipulated. This experience and the realization that technology is inevitable for upscaling led to acceptance of the idea of FOODSIGN and eventually TraceX. FOODSIGN was built as a permissioned blockchain system that connects all stakeholders-farmers, FPOs, food processors, financial institutions (FI), and logistics providers involved in the value chain, the first step being the digitalization of the farmers' diary processes. With initial grant support from the Government of Karnataka and subsequently from the Yes Scale acceleration programme, FOODSIGN was adopted by early customers such as MTR Foods, Aditi Organics, IFHD and SLAY Coffee. Blockchain creates a distributed digital ledger, which is secure, transparent and establishes trust across the entire supply chain. Permissioned access ensures that only the specific parties with requisite permission can access the data (Figure 1).

TraceX system has two primary modules – pre-harvest and post-harvest. The pre-harvest has the FPOs information including the directors' names and member details (including farm details, location), along with farmers' profiles and landholding details. First, it is digitalized and made available on the blockchain. The farmer's crop is geofenced together with crop cycle information that is, the types of inputs applied and practices adopted. The standard package of practices to be followed are also made available to each farmer on the platform. The information during the pre-harvest stage is collected through a user-friendly mobile application, which is used by FPO members themselves or field coordinators. Digital inventory is also made available for FPOs to keep track of the produce as it is aggregated from the member farmers. The modules of platform keep track of this produce while it

moves through various processers and aggregators. The platform uses QR code interfaces to track the produce as it moves from farm-to-fork. Consumers can use the QR code on their package to trace details of their food from farm-to-plates by simply scanning the QR code. "QR code eventually embeds trace id, which is a representation of the blockchain hash", states Srivatsa TS, Co-Founder of TraceX.

Information curated on that platform provides actionable insights, which are being leveraged to facilitate value added services – credit access and market linkages to farmers. The easy disposability of liquid cash for purposes other than agricultural ones is a problem for lenders in the agricultural sector. To prevent such behaviour, TraceX is currently running pilots with financial institutions and input suppliers. Under this agreement, FIs provide demand credit for input suppliers for product transfer to FPOs, rather than give cash directly to the farmers. This ensures that the credit made available for agriculture is not diverted to other non-income generating purposes. Furthermore, aggregation of input quantity requirements at FPO level leads to economies of scale, which translates into savings for FPOs and member farmers.

CHALLENGES OVERCOME

Finding financial resources to build the product was one of the key challenges the TraceX team had to overcome. The Government of Karnataka start-up support grant helped to build the minimum viable product and subsequent grant from Yes Bank's Yes Scale accelerator programme, which helped scale the product development and customer adoption further. The next big challenge encountered was training farmers and other ecosystem partners who needed to interface with the platform. In addition, it was important to incentivise some supply chain participants to increase the adoption. TraceX overcame this by partnering with NGOs and development institutions and also trained farmers to use the TraceX platform. Moreover, TraceX has built-in intelligence to capture the farmer's engagement in the app, which can be leveraged by their customers to identify digitally savvy farmers and mark them for incentivization.

Last, there is huge variation of agricultural practices and human capacities across various states. Building one monolithic solution that could cater to various crops and value chains meant upgrading human capacities to enable scaling to other states with relative ease.

HIGHLIGHTS

- 10 percent increase in farm productivity, 15 percent reduction in cost of cultivation and 10 percent improvement in market price realization.

ENABLING ECOSYSTEM ENTAILS

- attract venture capitalists who can bring in financial resources through a design of long-term policy and vision for Indian agriculture sector;
- stronger enforcement of food safety regulations;
- human and institutional capacity development especially of the FPOs.

SUCCESS STORIES

MTR Foods | Byadagi chilli traceability

TraceX is working with MTR Foods in sustainable production and procurement of authentic, traceable Byadagi chillies through its platform. TraceX is a technology partner in the Public Private Partnership for Integrated Agriculture Development (PPP-IAD) project where they work alongside an FPO in the Dharwad district, Karnataka. MTR uses the platform to completely track and trace chillies directly from production until they are procured from the FPO. The FPO field staff (an outsourced agency) and farmers use a TraceX platform for digitizing their information, starting from the farmers' profile, crop planning, field activity monitoring, production planning, procurement quality monitoring and final procurement. Once the chillies are procured from farmers, every bag is tagged with the digital code, which can specifically trace every bag to its origin.

SLAY Coffee | Bean to cup traceability of coffee

Slay's objective of a blockchain traceability is to enable their customers to easily verify the authenticity of the claims made across sourcing, roasting and brewing. TraceX enables this by bringing in multiple participants such as planters, plantations, coffee curers, coffee roasters, central warehouse ops, and Slay operated cafes on the blockchain. This procedure creates a generation of a unique blockchain identified QR Code through which the customers can check the entire journey of the coffee.

IFHD | Traceability of aflatoxin free production of maize

TraceX is the technology partner for a PPP-IAD project led by IFHD for sustainable development of the maize value chain with around 5000 farmers in Belgaum, Karnataka. The objective of the project is to enable FPOs for production of aflatoxin-free maize, and help them with digitization so that the entire production practices can be traced and tracked. Roquette, one of world's largest maize companies, is the maize buyer in the PPP consortium.

TRITHI

STATES OPERATING IN INDIA
Karnataka, Himachal Pradesh, Maharashtra

TARGET BENEFICIARY
Farmers, co-operatives, plantation businesses

BUSINESS MODEL
B2F, B2B, B2G

WEB
www.3thi.com

PROBLEM

The Indian farmers usually spray high volumes of pesticide, fungicides, and other chemicals to protect their crops from pests and diseases. The quantum of chemicals to be sprayed is not calculated scientifically, as a result, farmers unintentionally end up using chemicals in higher doses than required. This increases the cultivation cost, endangers the sprayer's health and increases the presence of harmful chemicals in the environment and the agri-produce. Water and soil pollution and chemical residues in food products are some of the negative external factors linked to the excessive use of chemicals in agriculture. The spraying process is more complex in plantation crops such as coffee, oranges, apples, mango, sugarcane. This problem is due to the lack of understanding of the crops, climate, and pest and disease behaviour. Spraying needs to be done scientifically and practices should be based on scientific facts rather than intuition.

EXISTING SOLUTIONS

Chemical applications and spraying activities in agricultural fields are mostly manual and performed by untrained labour. Certain crops, however, pose more problems than others due to their physical traits. For instance, in plantations with tall trees the workers must climb the trees and manually apply chemicals to the infected areas. This is time-consuming and dangerous because proper safety measures are generally not followed. Recently, drone-based spraying service providers have been working in some pockets and clusters. However, most of these service providers lack the technical expertise to understand crops, climate pest behaviour, and climatic favourability of risk growth. Consequently, most of them do not demonstrate sufficient value to sensitivity of farming system.

SOLUTION

Trithi provides farm gate crop-care services through agricultural drones. It is an NPNT compliant drone manufacturer and offers drones as a service across different industry verticals. In the agriculture sector, two kinds of drones are in operation – monitoring drones and spraying drones. The imagery and sensor data from its drones are processed and analysed with software to generate the Normalized Difference Vegetation Index (NDVI), the Normalized Difference Water Index (NDWI), and indices. These indices can be interpreted to understand the crop growth stage, crop health, and crop stress. The spraying

drones can be programmed to autonomously spot spray the regions marked as stressed in the processed imagery. These images can also be processed to count the number of standing crops using the row-based counting method. The three main service lines in agriculture are:

i. The aerial surveying service accurately identifies a land parcel and generates 3D, GIS, DEM, and contour maps for crop planning and land preparation.
ii. The multispectral imagery with a five-band (RGB-Red edge and Infrared) sensor drone provides crop health analysis for more than 30 crops.
iii. Affordable on-demand crop spraying services use low or ultralow volume nozzles that reduce chemical usage by up to 50 percent. Also, they assist large farms and research institutes to test the efficacy of different spraying methods and chemicals for durations ranging from 3 to 18 months.

Trithi works directly with farmers, companies, or co-operatives to provide crop spraying services or crop monitoring services. It has an aerial fog sprayer system for forest crops and plantation crops. Fog spraying in large acreages of mango, areca nut, and orange reduces the risk of accidents and is 60 percent faster than traditional spraying methods. The Trithi drones can cover over 10 acres with an adjustable fog flow in 17 minutes.

Trithi's T6-25+ drone can carry 25 litres of any liquid at any given time. It has furthermore developed a hybrid fuel-based drone with a tank capacity of 2.5 litres and can fly for 30 minutes covering at least 4.5 ha. A spray swath of 8–10 m can be achieved by flying the drone 3–5 m above the crop canopy. The speed of the drone can also be adjusted from 1–7 m per second and can reach a maximum of 10 m per second. The drone is equipped for autonomous obstacle avoidance in addition to failsafe functions with LED indicators. It can continuously fly from to ten hours a day and requires inspection after 100 hours and maintenance after 300 hours of operation.

UNIQUE FEATURES

- compliant with the Directorate General of Civil Aviation's (DGCA) No-Permission No-Takeoff (NPNT) policy;
- fog spraying and custom nozzles;
- one country one price service model;
- provides spraying solutions for nearly 30+ crops;
- its drones can cover 6000 acres in a 20–day cycle.

SOLUTION IN PRACTICE

In India, Trithi operates through the agriprenuer model where it trains rural youth to operate, maintain; it offers various drone-based services to farmers. The staff who operate the drones receive 100+ hour training and are certified as drone pilots. They are trained to fly manual flights as well as to conduct autonomous flights, calibrate field parameters, adjust row sequencing, drone speed, flight height, and spray nozzles. Each drone team consists of two pilots and an assistant who surveys a farm plot and marks the farm boundaries on a mobile phone app. Once the boundaries are drawn, a survey drone first hovers over the land parcel to capture multispectral crop data to analyse stress levels and the status of the crop. After the data has been captured the spraying drones' tank is filled with a pesticide or micronutrient solution, and the spraying

nozzle size is selected as per the farmer's requirement. Farmers provide the chemicals for spraying and Trithi only offers the spraying service. Trithi also engages with local crop experts who recommend the appropriate chemical interventions based on the processed images from its drones. It only recommends chemical names to the farmers, leaving to their discretion the choice of the preferred brands they wish to buy. Based on the necessity of a farmer, the spraying drone can be flown in two modes (spot spraying and uniform spraying). In the spot spraying mode, precise spraying is done only in infected regions with an accuracy of 0.2 mm. In the uniform spraying mode, spraying is done uniformly across the field. Small farmers prefer the uniform spraying mode, as they do not want to risk the possibility of the disease spreading with spot spraying. Ideally, Trithi team flies a drone for only six hours per day, two to three hours in the early mornings, and two to three hours in the evening. This is the best timeframe for crop spraying as well. Trithi's drone can cover 72 to 90 hectares in low volume sprays or 125+ hectares in ultra-low volume sprays per day.

CHALLENGES OVERCOME

The blanket DGCA ban on drones grounded Trithi for a few years. With the new DGCA regulations, Trithi improvised its hardware to make its drones compliant with DGCA's NPNT policy. Also, in the recent past many small stand-alone drone spraying services have appeared on the scene and created confusion amongst farmers. To withstand the competition, Trithi specifically focussed on providing a simple spraying service to farmers without overwhelming them with data, software, and apps. This made it possible for them to cover over 30 000 acres of crop plantations.

HIGHLIGHTS

- winner of the Agriculture Grand Challenge – 2018 organized by the Ministry of Agriculture and Farmers Welfare, Government of India;
- received INR 10 million as a prize after winning the Atal Innovation Mission 2018 award from NITI Aayog GOI;
- 30 000 acres of crop spraying done to date.

ENABLING ECOSYSTEM ENTAILS

Different government functionaries have sent conflicting signals to the potential drone market. For example, on one hand, drone start-ups are awarded grant funds from the Ministry of Agriculture to develop indigenous technologies while on the other hand, there are sudden court orders claiming that using drones to spray for pesticide is illegal. This confusion sends mixed signals to investors who want to fund this space. Clear guidelines must be set and disseminated across all levels of the administrative bureaucracy involved in the regulations concerning agricultural activities and unmanned aerial vehicles.

VASSAR LABS

STATES OPERATING IN INDIA
Andhra Pradesh, Kerala, Haryana, Telangana, West Bengal

TARGET BENEFICIARY
Governments

BUSINESS MODEL
B2G, B2B

WEB
www.vassarlabs.com

PROBLEM

Indian agriculture is characterised by the presence of large numbers (> 80 percent) of smallholder farmers and agriculture departments within various state governments. The various policy and operational instruments such as subsidies, MSP, inputs and extension, influence cropping choices and the acreage of various crops. Agriculture departments need inter- and intra-seasonal data at various spatial and temporal scales for their planning and operations activities on a near real-time basis. Important datasets necessary for these activities are collected by different departments however, agriculture departments seldom have a unified platform that can aggregate such datasets and facilitate a more data-informed approach to planning and operations. There are numerous data gaps and in many cases, policymakers have to operate with limited or no data. A unified database is necessary to set up and operate a contextualized and granular extension system that offers actionable advisories ranging for pre-seasonal planning (choice of crop, acreage) to in-seasonal tactical planning on issues such as soil moisture stress, pest infestation, and fertilizer applications. Governments need data about farmers' decisions on crops and fertilizer application, as agriculture departments play a key role in ensuring the availability of seeds, inputs, and fertilizers through linkages with public and private sector input companies. While the macroeconomic factors affecting agriculture may not be in the locus of control of a farmer, good quality information through a crop lifecycle is a great advantage.

EXISTING SOLUTIONS

Agriculture departments have been trying to digitize various workflows, processes, as well as improve data collection systems, but there is no comprehensive solution that can unleash the power of aggregation for government departments or extension. For instance, agriculture departments create purpose-built solutions to create indents for fertilizers without linking this system to the database on Soil Health Card (SHC) schemes. Consequently, fertilizer indentation at a block level does not address the soil health issues that might be apparent from the soil health database. On the agricultural extension side, most agri-tech companies tend to work on specific pain points at very small scales. For example, a weather forecasting application for agriculture might delve deeper into the same domain using historical weather data and nowcasting to devise intelligent artificial intelligence (AI)-based

weather prediction models. Since agriculture is a function of multiple variables such as soil health, availability of water, vulnerability to pest and weeds, and weather, a single advisory might not be sufficient for farmers to reduce the risk probability of their crop. Digital solutions that complement and improve the efficiency of traditional extension system could lead to a better uptake and engagement of farmers throughout the entire cropping season.

SOLUTION

Vassar Lab's foray into agriculture began with Water Resources Information and Management Systems (WRIMS) piloted with the Andhra Pradesh Government. The WRIMS gives near real-time information on water availability at the administrative and hydrological levels (Figure 1). WRIMS solution brings sensor data, mobile input data, a mathematical model derived data, satellite data, web-based data and all other data relevant to water, onto one platform to present near real-time visibility of all water-related assets for a large state, district or a block. Since agriculture is the largest consumer of water resources, Vassar received first-hand input from agriculture departments concerning other challenges besides water availability. These interactions provided a base for the conceptual framework for the Vassar Labs Agricultural Information Management System (AIMS). AIMS is a comprehensive integrated digital platform that brings together data sources in silos with different departments and third-party systems onto a large unified data platform. Using various machine learning (ML) algorithms, scientific models, processed data, AIMS creates comprehensive dashboards and offers granular insights for policymakers to undertake agricultural planning and activities such as crop and irrigation planning, fertilizer indentation, inventory planning, and storage.

The e-extension module of the AIMS platform provides real-time actionable advisories to farmers and extension workers based on weather, internet of things (IoT) sensor data, satellite imagery, crowdsourced data from field extension functionaries. These advisories are very customised and sent across as SMS or a call. A brief description of a few modules of AIMS is given in the following sections.

Agro-climatic zone planning

This module ingests various datasets satellite imagery (SI), historical weather datasets to understand historical cropping patterns, climatic conditions, frequency of dry spells, coupled with the latest information on irrigation sources and seasonal water availability to advise on agro-climatic zones planning. It also factors in the increased land utilization, crop intensity, productivity, and efficiency in land and water usage to recommend a customized cropping pattern advisory for specific land parcels. Furthermore, it assists policymakers in operationalizing this planning by providing farmers advisories on crop choices for the specific climatic zone.

Sowing date advisory

This module was one of the earliest modules of AIMS to have been developed. The crop sowing date is an important decision in rainfed agriculture, as it has a bearing on the success of a crop since the availability of sufficient soil moisture at the time of sowing leads to successful germination. This solution uses historical weather data (30 years or more) as well as the current short-range weather forecast at a block level to estimate available soil moisture, and generates advisories on the suitability of the ensuing week for sowing a crop.

These advisories are disseminated to extension functionaries who in turn disseminate to farmers. This module uses soil moisture data, rainfall forecast, historical rainfall data, crop type, and phenology to determine the probability of environmental stress on a crop during key growth stages as well.

Crop soil moisture stress advisories

This module identifies soil moisture stress of a specific crop or farm and provides timely advisories so that farmers and extension workers can act within the next 7–10 days. These advisories are provided by running crop balance models that use various data points from observed weather and rainfall, weather forecast, soil moisture observations, crop sowing dates, phenology, and critical growth periods. While observed weather and forecast information is available from meteorological agencies and weather stations, soil moisture data is sourced from extension functionaries who are given sensor probes to collect this data from sample fields and input the observed data through a mobile app.

Sowing date advisory

This module was one of the earliest modules of AIMS to have been developed. The crop sowing date is an important decision in rainfed agriculture, as it has a bearing on the success of a crop since the availability of sufficient soil moisture at the time of sowing leads to successful germination. This solution uses historical weather data (30 years or more) as well as the current short-range weather forecast at a block level to estimate available soil moisture, and generates advisories on the suitability of the ensuing week for sowing a crop. These advisories are disseminated to extension functionaries who in turn disseminate to farmers. This module uses soil moisture data, rainfall forecast, historical rainfall data, crop type, and phenology to determine the probability of environmental stress on a crop during key growth stages as well.

Crop pest/disease advisories

Pests and diseases are a major risk and lower drastically the crop yields for farmers. This module uses observed and forecasted weather data, crop phenology, and knowledge about various crop stages, environmental conditions making the crop susceptible to pests and disease infestation. Vassar convened workshops with scientific and research organizations to evolve models and algorithms to develop this module. Advisories from this module are disseminated as crop-specific alerts to extension officers and farmers. It can generate advisories at a very granular level to advise farmers if a pest attack has reached the economic threshold limit (ETL) – the point beyond which the cost of saving a crop is higher than the value of profit that a farmer can make by saving this crop. This module also provides actionable advisories on the remedial actions that need to be taken for mitigating crop losses.

Crop soil-health card analysis and planning

This solution analyses data on cropping patterns, soil health data, crop cutting experiments, and fertilizer consumption to generate a geospatial dashboard on soil health and nutrient status. It takes stock of the current fertilizer usage patterns across the state as against the soil heath card recommendations and predicts the financial and productivity impact due to excess or low usage of fertilizers. It factors in major nutrients like N, P, K and micronutrients like boron, zinc, and the pH values of the soil while providing remedial advisories.

Crop acreage estimation

This solution uses remote sensing data for crop type monitoring and crop acreage estimation. Using both optical and microwave remote sensing data, crop acreage is estimated for different crops such as paddy, groundnut, and maize

UNIQUE FEATURES

- The cloud-based solution suite is built using open-source technologies and amalgamates big data, IoT, satellite data, and ML to embed crop models, hydrology models, pest prediction models, crop selection models.
- It has 15 modules that cut across the entire agricultural life cycle starting from crop planning to crop harvesting.
- The AIMS and WRIMS are interoperable solutions that enable governments to manage their water resources as well as agriculture, which is the biggest consumer of freshwater resources.

SOLUTION IN PRACTICE

The typical agricultural season planning begins in March when a state-wide simulation is performed using 30 years of rainfall data and weather data, soil moisture conditions, soil types, irrigation sources available in each farm, village, cluster, or block. The simulation model also factors in the market dynamics for a crop to arrive at the village level allocation of land to various crops so as to maximize gross value added (GVA). This overarching aim of this exercise is to support farmers maximize profits according to the extent of arable land and estimated available water resources in an ensuing season. This exercise could be undertaken iteratively with the engagement of the field extension functionaries. It concludes by the end of April and the field enablement in May and June. During this time, Vassar works with the agricultural department, local agricultural bodies, block, and village level bodies to translate these plans into farmer advisories. Proper training is provided for the Agriculture Extension Officers (AEOs)/Multi-Purpose Extension Officers (MPEOs) and field extension staff on the dissemination of these advisories to farmers. An exclusive mobile app is provided to MPEOs, AEOs, and extension using, which they can access location-specific advisories in vernacular languages. The front-end agricultural functionaries can provide feedback on the advisories through feedback mechanism in the app. The protocols and standard operating procedures (SOPs) for such a system were developed in collaboration with the Government of Andhra Pradesh on a pilot basis in few blocks. Once the pilots worked well and the system was stable for two seasons, the solution was rolled out for the entire state.

The e-extension module of the AIMS platform provides real-time actionable advisories to farmers and extension workers based on weather, IoT sensor data, satellite imagery, crowdsourced data from field extension functionaries. These advisories are very customised and sent across as SMS or a call. A brief description of a few modules of AIMS is given in the following sections.

CHALLENGES OVERCOME

One of the primary challenges Vassar labs overcame was concerning the data gaps and interoperability issues. Data was lying in silos with different departments, different formats, and at various spatial and temporal resolutions. Much effort went into understanding data collection systems and also in locating, collating, and cleaning data. Additionally, there were gaps in the data that needed filling before an analysis could be made. For example, in the case where there was information on rainfall, the information on soil moisture was absent. Information on what crop was sown at block level was in some cases available but the same data at the cluster level would be missing. As a result, Vassar labs had to use satellite data and models to fill in these gaps.

Another critical challenge concerned the spatial and temporal resolution of existing data. Although the concept of agricultural climatic zones (ACZ) has been in existence for about the last three decades, most agricultural universities and central level organizations tend to publish agricultural bulletins at a district level. However, each district has a wide range of soil types, irrigation sources, and climatic conditions and furthermore, advisories flowing in from multiple sources were confusing farmers. Therefore, Vassar Labs first started to create a one-stop-shop for all advisories and route it through an authoritative channel, which by default was the state agriculture department.

AIMS was first piloted in two blocks of Andhra Pradesh before scaling it to the entire district. Nearly 10 000 MPEOs received advisories in the vernacular language to subsequently be disseminated to farmers. Finally, a system was developed for raising weekly advisories on soil moisture, stress, pest and disease stress, and other advisories through these MPEOs.

HIGHLIGHTS

- advisories provided to more than 10 million farmers across 18 000 villages in Andhra Pradesh as part of the Andhra Pradesh Primary Sector Mission (APPSM);
- prevented pest infestation across 800 000 hectares of farmlands;
- won the AI Innovation Challenge 2019 – agri category – organized by NITI Aayog, Government of Maharashtra, Amazon, Intel, and HP;
- Gold Skoch Award 2018 for Andhra Pradesh Water Resource Information Systems (APWRIMS).

ENABLING ECOSYSTEM ENTAILS

For macro policy decisions, governments could adopt data-driven approaches. Governments could foster an ecosystem where different tech companies, agricultural universities, and research institutes collaborate and create integrated platforms for agriculture-based information management.

WADHWANI AI

STATES OPERATING IN INDIA
Maharashtra, Gujarat, Tamil Nadu, Karnataka

TARGET BENEFICIARY
Middle management, extension staff, front-line staff, farmers

BUSINESS MODEL
B2B2C, B2G

WEB
www.wadhwaniai.org

PROBLEM

In India, cotton is the third largest crop produced, mostly by smallholder farmers. Owing to the high cost of agricultural inputs in cotton cultivation, farmers borrow large amounts of money from institutional and non-institutional lenders for cotton production. Pest infestation, however, poses great risks to these farmers and their livelihoods. Pink bollworm, one of the most commonly occurring pests that attacks cotton, leads to about 40–50 percent loss in the yield and income of farmers. There are cases where not even the application of heavy doses of pesticides can protect the crops from damage. The current systems for pest detection are manual and therefore slow. In the case of pink bollworm, by the time symptoms or pest infestation are visible in the field the crop has already suffered significant damage. The absence of an early warning system, therefore, results in considerable damage and aggravates the losses incurred by smallholder farmers, putting them under social and mental stress. Nearly 1000 cotton farmers in India committed suicide during the 2018–19 season after a pink bollworm attack destroyed 40 percent of their cotton crop yield.

EXISTING SOLUTIONS

Farmers predominantly rely on fellow farmers, local input retailers, and government extension workers for advisory on crop health diagnostics and management. A smallholder farmer usually goes to a nearby extension staff or pesticide shop to get advice. Some programmes install a pest trap sheet such as for example, a yellow sticky trap sheet, to capture pests or pheromone traps to capture bollworms. Periodically they count the number of pests that have been captured by the trap for monitoring. Some lead farmers and extension staff also send the data and pictures to an agricultural expert for identification of the pest and information on its intensity. Furthermore, farmers expect to receive advice on the application and suggested dosage of pesticides. Since the analysis and advisory are not automated, there is some lead time before farmers receive an advisory, which can cause additional damage. Integrated pest management (IPM) principles are available for minimizing pest-related damage, but this requires significant skills training and education of smallholder farmers.

SOLUTION

Wadhwani AI is a non-profit artificial intelligence (AI) research institute aiming to work with governments, non-profits, and for-profit companies to harness the power of AI for the social good. Agriculture is one of its five focus areas. Wadhwani has a well-evolved infrastructure called the seven questions framework, which helps it to identify the pain points and build AI-based solutions. Wadhwani works closely with NITI Aayog and the governments of Maharashtra, Gujarat, and Tamil Nadu together with other foundations working in agriculture. In early 2018, Wadhwani AI identified the need for an AI-based early pest detection system based on stakeholder consultations with the State Government of Maharashtra, Central Institute for Cotton Research (CICR) as well as secondary research. Wadhwani AI has since collaborated with partners for data collection and built an AI-based solution, which was piloted and underwent multiple iterations until the emergence of a concrete solution.

The solution comprises a smartphone-based app where a farmer or an extension worker can capture images of pest traps on a farm. A compressed image-processing algorithm on the app runs the inference locally on the mobile phone to provide the user with a real-time advisory. For each image, object detection algorithms identify the pest, density, and provide real-time recommendations based on the economic threshold limits (ETL), as defined by agricultural scientists.

Currently, Wadhwani AI is working with the Maharashtra government and the Better Cotton Initiative (BCI). There are other mobile applications assisting farmers with crop diagnostics, nonetheless, Wadhwani AI's differentiator has the ability to provide an early warning and help farmers minimize damages to their cotton crop. In the case of pink bollworm in cotton, the larvae penetrate the cotton bolls and inflict damage. These larvae emerge from eggs that have been laid by moths. By the time symptoms of the pink bollworm are visible, farmers are left with no remedial measures to minimize crop damage. The mobile app searches for the presence of moths and their density in images uploaded from a phone.

UNIQUE FEATURES

- WAI-based approach for integrated pest management (IPM) in cotton;
- compressed object detection algorithm for early detection of pests;
- works offline as algorithms run locally on the phone;
- co-creates solutions by working with agencies working directly with farmers;
- zero user fee model.

SOLUTION IN PRACTICE

Wadhwani AI works through partnerships and does not directly deliver interventions for farmers. It works with governments and grassroots institutions those interact with farmers, and seeks to understand their specific pain points before creating custom-built solutions. Its solutions are usually exposed as APIs and software development kits (SDK), which can be integrated into existing technology platforms of governments and other farmers facing organizations. Although API and SDK are free, access is available on the condition that the partners agree to share the data collected from the partners' app. The data helps Wadhwani improve the algorithms and crowdsourced data can be used to create dashboards for large programmes that can monitor the spatial and temporal flow of pest infestation on a real-time basis. The dashboards can

support policymakers and programme managers to prioritize and focus on interventions based on real-time data.

In its basic form, Wadhwani AI's interaction begins when a farmer or an extension staff member downloads the partner organizations' app onto the location where Wadhwani's API has been integrated. During the early stages of this application, the image analysis appeared on Cloud. Based on the feedback of internet connectivity challenges at farm locations, the algorithm was compressed to be run on the smartphone to provide real-time advisory.

CHALLENGES OVERCOME

Most intended users, in these case farmers, are either illiterate or semi-literate. Furthermore, digital literacy can be challenging even amongst farmers who have had a formal education. Although smartphone penetration in rural India is encouraging and evidence shows that farmers use popular social media applications such as WhatsApp and YouTube. Nevertheless, they can be overwhelmed by the complexities of the user interfaces of other applications. Simple features such as drag, drop, select, and enter text are very intuitive for a digitally literate user, but for digital-novice farmers this could prove difficult. Designing AI-based solutions for the farmers poses its own set of problems. Wadhwani AI worked with the "people+AI" design research group at Google to overcome some of these challenges. It currently uses an image-based UI system that is much simpler for farmers to follow. Indeed, recommendations are not deterministic and sensitizing farmers to the nature of these recommendations requires training.

Another challenge for Wadhwani AI was its initial dilemma over partnerships other than governments. Questions concerning partnerships with for-profits, pathways to scale, and IP rights were constant unknowns. Over time, Wadhwani AI built strong partnership management skills, while taking into consideration the importance of partnerships to achieve scale and better understanding the problem at micro- and macro- levels.

HIGHLIGHTS

- winner of the Google AI impact challenge;
- worked with NITI Aayog to draft India's AI policy;
- works with the extension staff of the governments of Maharashtra, Gujarat and Tamil Nadu reaching 5000 farmers.

ENABLING ECOSYSTEM ENTAILS

In order to build any AI-based solution or model, the availability of high quality and standardized open data sets is critical. In most cases, multiple data sets needed to build a robust AI or machine learning (ML) algorithm that was generally spread across multiple sources and in varying formats. An open data ecosystem with appropriate governance and regulatory oversight could catalyse AI-led innovation for the social good. In order to enable technocrats, researchers, and for-profits to explore intelligent AI-based solutions for the benefit of farmers, a one-stop-shop of an aggregated stack of datasets could play a fundamental role.

Agriculture is becoming more knowledge-intensive. Access to timely, accurate information tailored to specific locations and conditions is critical to helping farmers make the most of their resources in changing circumstances. Digital technologies help overcome these challenges by bridging the information gap, improving access to market information, enhancing access to micro-finance, providing actionable advisories on managing pest and disease as well as improving agriculture human capital. However, sustaining digital interventions needs a holistic approach that includes the right policies, frameworks, ecosystem and capacities. This publication highlights some successful initiatives in leveraging digital technologies, improving value-chain processes and building capacity to bring about positive change among agriculture stakeholders and improve livelihoods. This publication is part of the Country Investment Highlights series under the FAO Investment Centre's Knowledge for Investment (K4I) programme.

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