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Data Driven Decision-Making for Smart Agriculture

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Executive Summary

Agriculture is a very important sector of the Indian economy and it accounts for 49% of the employment and one-sixth of the GDP. Information and communication have always mattered in agriculture. Updated information allows farmers to benefit through better and informed decision making. It has been the endeavour of agencies concerned with agriculture to share such information to benefit farmers as well as a challenge for them to find effective ways of sharing. Right and timely information can help farmers in all aspects of the agricultural cycle from pre-sowing to post harvest. Information and Communication Technologies (ICTs) have emerged as a very strong tool to share the information with farmers effectively, efficiently and in a low cost ways.

We have attempted to list the possibilities, challenges and few initiatives as examples in ICT for Agriculture in the 3 major domains of agriculture namely:

- ICT in Empowering farmers through better communication and knowledge sharing
- ICT in Insurance, Finance, Remote Sensing, Weather Prediction etc.
- ICT in improving efficiency of the Agriculture Supply Chain, market access for farm inputs and post-harvest to benefit farmers

We have also reviewed the existing literature on this subject and there have been many discussions around developing decision support systems for farmers. However, a comprehensive decision support system to provide customized advisory and help an individual farmer to make choices, which crop to sow, when to sow, when to harvest (in the window available to harvest) and whether to instantly sell or go for storage, all with the objective of better price realization, in a smallholder farmer/ developing country context, is yet to emerge. It is this gap which we have identified and which we want to make efforts to address.

ICT, specially mobile phone based communication can be the tool of choice for introducing a customized decision support system, which is relevant up to the level of an individual farmer. However, such a system requires all information about the farmer and his field like the soil type, soil health, climatic conditions of that area, market conditions, crop prevalence, irrigation, farmer's economic situation, risk absorption capacity etc. All the above information, when processed with respect to the context can lead to generation of advisories which can help the farmer in his/her crop choice, harvesting and sale schedule. The effectiveness of such a decision support system depends directly on the accuracy of the data being fed into the system. ICT can play huge role first in the collection and generation of such data and then in the communication of such advisories (based on scientific analysis of these data) which farmers can use for their benefit.

Karnataka has pioneered a successful system of collection of farm and farmer data in a systematic manner using digital tools and technologies, in India. It has also built a Land Resources Inventory which is a comprehensive database with the detailed soil health details for 9.66 lakh hectares of land at a plot level. These rich databases lend themselves to scientific analysis through which appropriate decision support system can be operationalized for the farmers at the individual level. Thus, we plan to partner with the Government of Karnataka to use the data and make projections for production and prices in key producing centres, stocks in the state and country wide markets and model the implications for the local producing centres and the likely prices in harvest times, and try minimise the incidents of glut and consequent price falls, by calibrating production areas, sowing times and harvest times. We plan to pilot different strategies to communicate such advisories using ICT (phone calls, sms, mobile applications, web portals etc.) to farmers in Karnataka using the outreach infrastructure of the KSNDMC, Bangalore and study the effectiveness of the initiative in an empirical approach.

Introduction:

It is now well accepted that India has come a long way from food insecurity and dependence on foodgrain imports to food self-sufficiency. The green revolution ushered in the 60s and subsequent research into new seeds and other technologies have helped grow sufficient food and bring in food security in India. But global demand for food will rise with growing populations. Thus, there is a need to ensure accessibility and affordability for consumers (through reduced waste and more-efficient supply chain management), contribute to "smart" agriculture, and incentivize farmers (for example, through higher income) to increase their production(World Bank, 2017). India's National Policy for Farmers identifies ICT as one of the frontier technologies to overcome the prevailing technology fatigue in agriculture. Thus a strong rationale exists to study the potential of using ICTs for agriculture.

Gross Value Added by Agriculture sector (agriculture, forestry and fishing) in the Indian economy is estimated at Rs. 17.7 lakh crores (approx US $ 274 billion) for the financial year 2017-18, growing at a compound annual growth rate of 2.8% in the period from 2011-12 onwards. Agriculture accounts for a substantial part of GDP (16 percent) and employment (49 percent). Poor agricultural performance can lead to inflation, farmer distress and unrest, and larger political and social disaffection—all of which can hold back the economy. (Economic Survey of India, 2017-18)

There has been a marked shift in the Agriculture policy of India and the focus has shifted from agricultural production to increase in income of farmers. In February 2016, the Prime Minister of India gave a call for Doubling of farmers' income by 2022. This call took the shape of government policy when it was spelled out in the Union budget of 2016-17 when the finance minister declared: "We need to think beyond 'food security' and give back to our farmers a sense of 'income security'. Government will, therefore, reorient its interventions in the farm and non-farm sectors to double the income of the farmers by 2022" (Indian Union Budget speech, 2016-17).

Thus, any intervention for agriculture must have the potential of increasing farmers' income. 86% of India's farmers (125 million out of 145 million total holdings) are small and marginal as per Agriculture census 2015-16. Hence, it is imperative that any agriculture intervention has the small and marginal farmers at the centre of their focus. In fact, given that it is widely regarded that there is an acute distress in Indian Agriculture, many state governments and the Central Government have come out with direct income support schemes which transfer cash to mostly small and marginal farmers to supplement their income. The objectives of the central government scheme, the PMKISAN start thus "With a view to augment the income of the Small and Marginal Farmers (SMFs), the Government has launched a new Central Sector Scheme, namely, "Pradhan Mantri Kisan Samman Nidhi (PM-KISAN)" in the current financial year" (pmkisan.gov.in). It has been launched with effect from 1.12.2018. The hurried announcements of these cash transfer schemes, definitely point to an agrarian crisis which has brewed large scale distress in India's farmers. It is in this context that we have to discuss the possibilities of an ICT intervention for agriculture in India.

Columbia University in partnership with The Energy and Resources Institute (TERI) is undertaking a project titled, "A New Indian Model of ICT-led Growth and Development", to examine the potential for a new Information and Communication Technologies-led model of growth and development in the Agriculture sector India (along with other sectors like public health, education and urbanization) The project's objective is to better understand the role of ICTs in India's future economic growth and to make recommendations for India to continue to leapfrog the development process using ICTs in key sectors including agriculture, among others. We believe that India's new growth model of ICT-led development can, with the help of new IT-based tools and a solid ICT strategy, spur India's development currently characterized by high levels of poverty and low levels of social and economic development. This paper is a part of our efforts for the above project.

For the sake of our discussion in this paper, we include a short review of existing literature, and also devote a section on the broad overview of ICT and Agriculture in India and then discuss the same in the following 3 broad thematic areas. We had used this same framework for a roundtable discussion we had organised to brainstorm on ICTs in Agriculture. The 3 themes are:

- ICT in Insurance, Finance, Remote Sensing, Weather Prediction etc.
- ICT in Empowering farmers through better communication and knowledge sharing
- ICT in improving efficiency of the Agriculture Supply Chain, market access for farm inputs and post-harvest to benefit farmers

Relevant Literature on ICT in Agriculture:

Globally, ample literature exists on the application of ICT in agriculture also defined as e-agriculture. Starting from the definition of ICT in agriculture/e-agriculture and outlining the scope of e-agriculture, some of the existing literature document various ICT initiatives, that have been initiated in different countries/geographies, some assess such initiatives for their success and/or scope for improvements, some also provide a critical assessment of ICT in agriculture in a comprehensive manner, while some touch on them in a relevant but tangential approach.

The application of ICT in agriculture in India can be generally traced to the 1960s when the All India radio and Doordarshan (television) started serving the farming community through its Farm and Home Unit and Krishi Darshan offerings since the year 1966 and 1967 respectively.(Kujur et al, 2009; Vats, 2011).

Technical Consultation on Agricultural Information and Knowledge Management, FAO (2007) provides the working definition of e-Agriculture: "E-Agriculture is a relatively new term and its scope is expected to change and evolve as understanding of the area grows. For now, e-Agriculture is seen as an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. More specifically, e-Agriculture involves the conceptualization, design, development, evaluation and application of innovative ways to use ICT in the rural domain, with a primary focus on agriculture. Standards, norms, methodologies, tools, development of individual and institutional capacities, and policy support are all key components of e-Agriculture."

Sulaiman et al (2011) first mention traditional and new ICTs and differentiate between the 2. They consider radio, TV and print as traditional ICTs and evolving applications or technologies that rely on the internet, telecommunication networks, mobile phones, personal computers and databases as new ICTs. Then they cite relevant studies which have pointed to social gaps in digital reach, gaps which are not only technological but exist in the reach of technology based of the various parameters like income , spatial distribution of networks and gender, aspects to the digital divide. They have questioned the sustainability, scalability and impact of ICT pilots and experiments in the development sector and suggested that robust evidence needs to be generated to assess the implications of ICTs for development. They also make a very important observation that to make proper use of information available through ICT tools, farmers need to have access to the recommended inputs, which are not available locally in most cases. They conclude by suggesting that ICTs, to be really effective, have to move from traditional communication tasks to more communication strategies for innovation like network and knowledge brokering, advocacy communication, visioning, process facilitation, learning-oriented monitoring, etc.

Task Force on Agricultural Development, NITI Aayog (2015) makes important and succinct remarks on raising agricultural productivity and making farming remunerative for farmers. Their report is relevant here as it captures the broader issues which have to be tackled for new technologies like ICT to be scalable and effective in enhancing agricultural progress and helping farmers realize higher income. They identify the bottlenecks hindering agricultural prosperity in India like low irrigation water use efficiency, low rate of seed replacement, non-judicious use of fertilizer (led by the existing urea subsidy), reluctance to introduce transgenic seed varieties (GM), weaknesses in our agricultural research ecosystem, legacy land use and lease issues including lack of conclusive ownership titling, failures of the agricultural marketing system through unreformed APMC acts and the Essential Commodities Act, lack of institutional support for contract farming, natural disasters and lack of immediate relief for the same and low rate of diversification to high value agriculture in spite of high demand. Specifically, the paper pitches for the digitization of the revenue and registration of land records and extensive use of technology to overcome the legacy issues around land. The Task Force also pitches for the government to create a database that identifies farmers and landless workers with their respective Aadhaar (Unique Identification number (UID) for all residents of India) seeded bank accounts.

The e-agriculture strategy guide of FAO and ITU (2016) is a comprehensive account on the subject of national policy formulation for ICT in Agriculture. It can serve as a guide for the formulation of national policies on ICTs in Agriculture.

Lokeswari (2016) has studied the use of ICT among rural users in India. She studied diffusion of innovation theory and its applicability to ICT adoption among farmers. She also looks at the Technology Acceptance Model (TAM) proposed by Davis (1989) which has been widely used, accepted and tested. Davis' model is based on the premise that attitudes affect intentions, which in turn leads to certain kind of behaviour. Her study finds that the current ICT solutions offer limited scope of benefitting small landholders but that there is no difference in attitude due to difference in landholding. It also finds that despite the opportunities offered by technology when it comes to building trust and collaboration, face – to – face communication still remains hard to beat for our farmers as communication is still about credibility based on personal relationships only, not information from any source

Deichmann et al (2016) have undertaken an evaluation on how digital technologies can transform agriculture in developing countries. They identify 3 main areas of interventions where ICT can help which are aimed at improving agriculture in developing countries

- Facilitating market transparency
- Enhancing on-farm productivity (Precision farming and Agricultural extension)
- Enabling efficient logistics (agricultural supply chain management)

While they come to definite positive conclusions on the potential of ICT to better agriculture in all the 3 above areas, their review of the available evidence in each of the above areas also leads them to some sobering conclusions. First, is the gap still pervading in digital access and that it is quite some distance away from being universal. Second, even when farmers are seemingly better informed, they may not necessarily be able to act on that information because of inaccessibility of alternative markets and the complex interlinked relationships between buyers and sellers in poor developing economies, which have been corroborated by evidence. Thus, rather than just assuming ICT as a complete solution, underlying institutional environment and constraints have to be better understood. Third, demands and priorities of the intended beneficiaries and the tradeoffs imposed by resource-constrained environments should be prioritized over technology and tools. Finally, they suggest that technology and ICT policies have to be seen in the broader context of the regulatory environment in a country and not standalone.

Task force on Enhancing technology use in agriculture insurance, NITI Aayog (2016) has studied in detail the issue of agriculture insurance and the use of technology and made detailed recommendations. Some of its major recommendations are:

- Online and 24x7 enrollment and premium pay facility for agriculture insurance
- Data capture on real time basis
- Awareness campaign through use of ICT tools such as voice blasts, IVRS and SMS
- Acceptance of geo-tagged and time-stamped digital photographs of land to establish the insurable interest instead of manual certificates. Such photographs submitted by the farmers should be accepted as sowing certificates if the declared crop is changed after the payment of premium
- Digitising geo-referenced records of land holding in all states
- Replacement of CCEs in their present form with technological solutions for crop loss assessment that can be a combination of these options - remote sensing, digital photography, statistical methods, and integrated crop modeling a dedicated constellation of 3-4 satellites of high to moderate resolution(10-30 m) with 10-days frequency and with multispectral optical sensors, two microwave satellites, and one hyper-spectral satellite may be deployed to increase the precision of crop yield estimates/loss assessment at the village scale
- Mobile App for crop losses due to localised climatic events such as hailstorms, landslides, small floods and post-harvest losses
- Calculation of loss and claim estimation in real-time and end to end digital claim settlement starting from initiation of claims to payment of compensation directly in farmer bank account

Azad et al (2017) have studied ICT in the agricultural development of Bangladesh. They have briefly described the public and non-government efforts at ICT in Agriculture in Bangladesh but note that they have not had the expected impact. They believe that ICT benefits arise from reorientation of the service provision from the supply to the demand side, making it more responsive to the needs of the rural poor. Having taken note of the above aspects, they suggest that any data collection and decision support system should deliver accurate, complete, concise information well in time. The information provided by the system must be in a user-friendly form, be easy to access, cost-effective and well protected from unauthorized accesses and they see a major role of ICT in facilitating the above. They want the development of an authentic agricultural database based on soil and climate condition, crop cultivation history, farmers' interest, demand of raw material, pest and disease management technologies, storage facilities, marketing system, etc. with the help of ICT and GIS (Geographic Information System). They conclude by suggesting that the services of ICTs can be used to provide all information to the marginal users including future projections or forecasts/predictions through development of Expert Systems and Decision Support Systems for food security of Bangladesh. They have advocated that all the above mentioned issues/activities (decision support, monitoring and evaluation etc.) using ICT must be institutionalized in their National Agricultural System.

Singh et al (2017) have reviewed the role of ICT in agriculture in India. They consider the role of ICT in a Decision Support System for agriculture to widen of market access and strengthen and empower the farming community. Their review finds that a significant number of ICT projects have been implemented in India but mostly in comparatively more developed Northern and Southern parts of the country and rest have remained deprived. They, then, list a few of the ICT projects in India and find that the ICT initiatives in India are primarily focussed on dissemination of information. They suggest data mining, simulation and modeling, applying cognitive technologies, imaging and image processing in agriculture to add depth and width to the efforts and get closer to the needs of the

farmers They conclude that though ICT has revolutionizing potential in the field of agriculture, ICT projects are yet to make any breakthrough in agricultural information dissemination and other areas.

Saidu et al (2017) have studied opportunities and challenges in ICT in Agriculture in developing countries. They have reviewed various studies which outline the critical role of ICT in agricultural technology development in developing countries, centering on opportunities and challenges. Their review identifies agricultural research, improvement of market activity, exchange of relevant information, profit gain; networking agricultural activities globally, conducting research and strategizing economic growth for self-reliance as among the possible benefits of ICT. However, according to them, lack of basic ICT skills, absence of political will, inadequate and fluctuating power supply, poor internet infrastructure, insufficient personnel to handle ICT infrastructure, language (barriers) and harmonization of knowledge continue to impede ICT implementation in agricultural growth. To enhance implementation of ICT in agriculture in developing countries, they suggest action oriented research, good ICT infrastructure, adequate ICT skills, good and affordable internet connectivity, and appropriate ICT policies.

Young (2018) in his paper devotes a small section to the smallholder farm segment. He speaks primarily of harnessing the possibilities of rapidly increasing smartphone penetration among this section of the global population. He also says that though many of the challenges in both commercial farming as well as smallholder farming are similar, digital agriculture and precision farming may not be viable for the smallholder segment. He says that technology has to handle the scale but no clear roadmap has been outlined for the same.

Gulati et al (2018) have undertaken a comprehensive review of the agricultural extension systems in India. They have reviewed the Indian agriculture extension system at the national level and in six selected states to see how agricultural research, education, and extension contribute to growth of agriculture GDP. They state that ICT has a significant potential to reach a large number of farmers in a cost-effective manner and it can also facilitate 2 way information between farmers and different extension agencies. They also list some examples of ICT initiatives in extension like mKisan, Kisan Call Centre, Kisan TV, community radio, private sector initiatives like e-chaupal. Their review finds that any scalable intervention leveraging ICT has yet to emerge and that none of the initiatives listed reaches out to more than a few thousand farmers and that too mostly in short periods.

The reviewed literature on ICT in agriculture points to various initiatives in the developing countries which have been implemented with the use of ICT in agriculture and how farmers are using them. We can conclude that the existing literature on ICTs in agriculture supports the positive potential of the use of ICTs in Agriculture. Farmer attitudes towards adoption of technology is also positive but at the same time technology can't act as a replacement for the trust factor that human interaction provides and e-agriculture for smallholders is a need but comes with challenges of its own.

A broad overview of ICT and Agriculture in India:

There is a general agreement that use of information and communication technologies (ICTs) and digitisation in general, leads to increase in efficiency and reduces transaction time and costs. ICTs comprise a wide spectrum of applications and devices starting from radio, television, telephone and mobile , satellites etc. to more sophisticated and emerging technologies like smartphone applications, multimedia messaging platforms like whatsapp, drones, blockchain, Machine to Machine [M2M], Internet of Things [IoTs], Cloud computing, Big Data and data analytics, etc. Digitization has provided the capability for convergence of the traditional network technologies which when combined with

data availability, required applications and the right enabling environment, can unleash the tremendous innovation potential of the agriculture sector responsibly (FAO and ITU, 2016).

Yet, for the introduction of new ICTs in agriculture, we also need to assess the telecom access in the rural segment. In rural India, mobile penetration is at 59.2% and internet penetration is 23.9% as of December 2018 (Economic Times). Along with low penetration of internet, another area of concern is extremely low ability to spend on mobile services. Average revenue per user is less than Rs 40 per user per month for all consumers, urban and rural, combined; it means that only for rural markets, the number is going to be still lower. The implication of this is very clear, rural consumers can only be expected to pay for ICT technology if they see a definite potential of better return on investment. Thus, any paid initiative in the sector has to be extremely lucrative for the farmers for them to subscribe and keep paying.

One of the major challenges to harnessing this potential in the Indian Agriculture sector is lack of availability of a proper updated dataset. For proper data driven decision making in Indian Agriculture, a key and foundational database with details of geo-tagged Farm Identification, Farmer Identification and mapping of the crops grown by the farmers (we could call it an Agristack) is required. In the absence of such a dataset, any national consensus on any policy reform whether it is in subsidies, financing and information through ICT are non-starters. Given that the total number of operational holdings in India number 145 million (Agriculture census 2015-16), the development of such a national level Agristack has to be necessarily be a government initiative. Here it is most important to note that every aspect related to agriculture and agricultural land is covered in the state list of the Seventh schedule to the Constitution of India (https://www.mea.gov.in/Images/pdf1/S7.pdf). This means that the federal government generally assumes an advisory/facilitative role and the statutory power rests with the various state governments of India. This is the first structural limitation to a nationwide Agristack. However, Agristack at the state levels is definitely implementable if the concerned state government decides to develop it.

We now explore the 3 themes in e-agriculture we have identified above.

ICT is empowering farmers through better communication and knowledge sharing:

Agricultural extension, we observe, is seasonal and once the farmers have become adept at a crop and related agronomic practices, they may not seek advice or information unless affected by disease/pest any other previously un-encountered risk event. It is during such times that they want information; the short point being that demand for agronomic advice is only generated then. Some of our subsequent exploration on the existing ICT extension methods reveals that on such occasions, the farmers need specific troubleshooting help but very often are not able to find the right solutions. Thus, there is a need for a demand driven solution which could harness ICT to assist farmers. In this context, we list some initiatives both in the public and private sector (including startups) which are engaged in extension activities in India.

The Central government has many initiatives for farmers, we list below some of the prominent Central government initiatives around ICT for Agriculture and then analyse their effectiveness.

Government is implementing a Mission Mode Project: National e-Governance Plan–Agriculture (NeGP-A) for helping farmers access information related to latest technology. Many Portals for dissemination of Information to the farmers have been developed under NeGP-A such as:

- mKisan Portal (https://www.mkisan.gov.in/default.aspx) to enable the extension machinery of the government all over the country to disseminate uniform information (especially topical & seasonal advisories and providing services through SMSs to farmers in their local languages) on various agricultural activities to registered farmers. mKisan is an agricultural value added service (Agri-VAS) which, in addition to push sms also offers access to two pull channels, an IVR menu and a helpline, on purchase of a subscription package which costs 1INR per day, purchasable in packs of 10, 20 or 30 days.
- Farmers' Portal (https://www.farmer.gov.in/) for all the farmers for accessing information on agricultural activities. Farmers can get information about package of practices; crop/seed varieties; common pests; dealer network for seeds, fertilizers & pesticides; machinery and tools; agro-met advisories etc.
- Soil Health Card Portal has been developed for registration of Soil samples, recording test results of soil samples and generation of Soil Health Card (SHC) along with fertilizer recommendations
- Kisan Call Centres: Main aim of this project is to answer farmers' queries on a telephone call in their own dialect. These centres are working in 14 different locations covering all the States and UTs with countrywide common Toll Free number 1800-180-1551 which is accessible from both mobile and landline from 6.00 AM to 10.00 PM on all 7 days a week. Recent additions to KCC services include technological features such as Voice Media Gateway, Dedicated Internet Bandwidth, Provision of Voice Mail during call waiting period and SMS to farmers (conveying gist of advisories given). Presently, farmer queries are answered in 22 local languages.

An evaluation of mkisan reveals 2 particular aspects "Push content users have access to traditional information sources such as other farmers, agro-dealers, government extension and mass media. The majority reports no pressing need for the information but they try mKisan, out of curiosity. The majority of users who only receive push content from mKisan are not satisfied with the information they receive. They need better education about the breadth of the services and the pricing model through engagement messages; IVR users need complete advice and tailored solutions utilising currently available methods such as the helpline and video content. Linking with an on-the-ground organisation would allow more practical demonstrations of methods. But even among the IVR users, only around a third of these users adapted their farming practices based on mkisan advice. "(mKisan Midline Evaluation, GSMA mAgri Programme, 2014).

The Centre for Management in Agriculture at IIM Ahmedabad has studied the Kisan Call centre scheme. They report positive findings about the same. The kind of information required varies from state to state but weather and plant protection are major in all of them – indicating that concerns of risk are a major reason for calling. However, the point to note is the finding about information with respect to weather and general information, the information is easily available and is easy to understand and process. However, there are problems with respect to the reliability and timeliness of the information. Even though about 60 percent report that the farmers are satisfied with the information, many indicate that this is not so and there is scope for improvement. Regarding the farmer's portal website, the information available is not found to be up to date, the server prone to failing/ crashing, and about one third users indicate that there is dissatisfaction with its working (IIMA, 2017).

Regarding the soil health card portal of the government, it reports that more than 83 million soil health cards (SHCs) have been distributed to farmers in 2017-18 to 2018-19. However, in the roundtable that

we conducted, there was unanimous agreement that the effectiveness and quality of SHCs are in serious credibility deficit. A randomized controlled trial conducted by IFPRI is the first evaluation of the effectiveness of the SHC program as currently implemented. This study found no evidence of any impact of soil testing and customized fertilizer recommendations on actual fertilizer use or the willingness to pay for lacking nutrients. The evidence from this study suggests lack of confidence is the main factor inhibiting farmers' response towards using SHCs (IFPRI, Can Information Help Reduce Imbalanced Application of Fertilizers in India? Experimental Evidence from Bihar, 2016).

SHC linked Fertilizer Direct benefit Transfer (DBT) subsidy pilot project: The central government undertook a pilot in 2 districts of India to study fertiliser consumption at farmer level and bring in rationalisation via soil health card recommendation. In a subsequent bigger pilot, they had to delink the soil health card and land record databases and use only Aadhaar database for authenticating transactions because of a) high transaction time due to coordination with three different kind of databases (land record, soil health card, and Aadhaar) at the same time and b) incomplete digitisation of land and soil health card databases (Microsave, 2018).

Both the above points (IFPRI study, Fertilizer DBT pilot) point to serious credibility issues in SHCs. Also, the present SHC project is on a grid basis and recommendations are not on land parcels of individual farmer basis yet. Thus, the SHC scheme requires complete overhaul to include individual farmer centric approach to soil testing as well as evolving an institutional structure which inspires confidence in the farmers. This is one avenue where the end to end application of technology, if harnessed seamlessly, can lead to tremendous economic, environmental and health (in quality of food produce) benefits to all consumers, farmers and government. It is reported that the government is considering a significant update to its scheme of soil health cards, based on the various inputs it has received.

We now list some startup initiatives actively using ICTs in Agricultural extension. (Source of information: Company websites/ social media accounts, news articles, personal communication)

Cropin: This Agriculture start-up, uses remote sensing, AI and ML for data analysis of crop health, pest and disease surveillance to help in yield prediction. They are focused on B2B SaaS solutions to agribusinesses. Their solutions are suited for minimum land parcels of 200 acres and above and thus their clients are farming companies, FPOs, commodity traders and F&V exporters, agro seed and chemical companies, CSR arms of corporates, government bodies, NGOs, and development agencies who in turn provide and help their partner farmers with Cropin solutions.

Jayalaxmi Agrotech: All info about the crop cycle for a particular crop is available on their app in audio and video format and local language. Farmers can see their crop disease and pest/irrigation and fertiliser needs all in the app.

Precision Agriculture for Development (PAD): 2 way communication with farmers through Krishi Tarang service which provides farmers with free, customized information in two ways: via weekly voice messages sent to a farmer's mobile phone and a direct response to any agricultural question that a farmer logs. They have also jointly, with Coffee Board, developed Coffee Krishi Taranga, an IVR-based digital mobile extension service. Any coffee planter with a feature phone will be able to access this service, which will provide customised information and services to coffee growers to increase productivity, profitability and environmental sustainability. They presently work in Orissa and Gujarat and with farmers affiliated to the Coffee board of India.

PEAT: It provides plant disease and pest diagnosis through a smartphone application. The App captures geo tagged photo of crop disease and/or pest attack and suggest remedies instantly. Piloted and used in Andhra Pradesh, the app has 1 million downloads and it works for 15 crops.

FarmBee: Previously known a Reuters market Light Ag Tech. The app gives info on 450 crop varieties, 1300 markets, 3500 weather locations for farmers.

Agrostar: They implement a missed call solution and android app for the farmers to use for advisory as well as to buy agricultural inputs.

Nubesol: It is an initiative for the sugarcane farmers and sugar industry. Nubesol's Crop Management Information System is a Remote Sensing solution for Agriculture, which can be used by the Farmer or the Farm Extension worker to make intelligent decisions to increase farm productivity while decreasing the input costs. It also works on harvesting and transportation solutions to minimize tonnage loss and sugar recovery loss.

Destaglobal: Destatalk and Siddhi App are initiatives of Destaglobal for farmers. Destatalk is an extension platform to harness social media platform like facebook and whatsapp along with phone calls to reach to farmers with advice. Through Siddhi App farmers can see farm inputs for procurement and best prices available in their vicinity for the same. Services are free for farmers and charged only on buyers and sellers from/to farmers. They work with around 60000 farmers.

Mycrop/Agrichain: They have a platform as well as farmer mitras for those without a smartphone to provide inputs and also gather data. Based on the data they gather, they generate insights and deliver advisories.

Kulivate: It provides a software platform (mobile, web apps, portals, cloud computations) which is customizable and which an enterprise or government body or an individual can use locally to disseminate agricultural information. State Departments, Krishi Vigyan Kendras (KVKs), private consultancies or small contract farming companies, FPOs can, by using the services of Kultivate, set up an ICT-advisory system for their farmers. (https://www.f6s.com/kultivate/about)

The above is just an indicative list. Most of the B2C platforms in the list above dealing directly with farmers don't have a client base over some thousands and almost all of them are suited for horticulture/ high value crops. Moreover, similar to these, around 500+ startups are working in India on different parts of the value chain including horticulture. Most of these are proof testing concepts or running pilots. These private sector projects are currently running on external funding and grants with no significant demonstration of a business case.

ICT in Insurance, Finance, Remote Sensing, Weather Prediction etc.:

Credit is a very important indirect input in agriculture. It enables the farmer to buy inputs like seeds, fertilisers, pesticides, insecticides, etc., which has a bearing on what happens in his field and, ultimately, on his income. Thus, agricultural credit serves a critical purpose and is the most powerful indirect input (Bhanwala & Mehrotra, 2019, Financial Express). Utilising National Sample Survey Office (NSSO) data from the 70th Round (NSSO, 2013), a recent study found that more than 50 per cent credit comes from the informal sector in India. Small and marginal farmers face a high modal interest rate of 36 per cent, and most loans are taken for income-generating activities, thus indicating that there is a shortage of formal loans even for productive purposes. Landholding size was found to be directly related to the accessibility of credit from commercial banks such that while 83 per cent of large farmers' loans came from institutional agencies, this figure was around 60 per cent for small and marginal farmers (Meenakshi R. and Vani B.P., 2019). On the other hand, due to growth in families

over generations, landholdings have become fragmented and unviable. Due to onerous leasing laws, both consolidation of land as well as access of institutional credit to tenants is extremely constrained (Niti Aayog, 2015). Both these issues make smallholder agriculture extremely challenging in India with no easy solutions.

Farmer producer organisations (FPOs) are gaining prominence to overcome some of the aspects of the problems of institutional agricultural finance and land leasing, more as a workaround than a proper solution because the proper solution requires major legislative and policy level changes. FPO refers to a collective of farmers (mostly small farmers) who come together and organize themselves primarily with the objective of benefiting from collective bargaining in the purchase of inputs as well as while selling their produce. The principle is to harness economies of scale in inputs and marketing, processing and disposal of end product so that the ironical situation in smallholder agriculture viz., "the farmers buy their inputs at a retail price and sell their produce at a wholesale price" is tackled. FPOs provide some scope for building an ICT integrated solution that can:

- Help them identify the best basket of crops to choose from with approximate acreages suggested
- Help in aggregating information from public sources on weather, infestations
- Scheduling of use of shared equipment
- Scheduling sowing, applying Fertilizers/pesticides based on precision farming data inputs
- Scheduling harvesting to minimise oversupply in the short term
- Sorting and aggregation by quality
- Finding buyers online through existing market places
- Finding partners for contract farming
- Finding partners for land leasing

Coming back to private sector initiatives in the area of agricultural financing, there are some experiments and claims regarding digitisation and remotely sensed satellite imagery and data being used for credit profiling. While this is definitely an evolving and very important area, nothing concrete has been piloted so far, details of which are in the public domain. For instance, Skymet claims that it has developed an innovative agricultural credit risk analysis system for banks, insurance companies and various other businesses associated with rural India. It integrates individual farmer details from cadastral maps with cropping data from satellites and weather data from Skymet's proprietary network of Automatic Weather Stations (AWSs). The software helps banks to digitally sanction and renew KCC loans, making direct farmer lending more efficient, objective and transparent. Any other information beyond this is not available in public domain. Another company, US based Harvesting claims to be driving financial inclusion for farmers in the emerging world through remote sensing satellites and machine learning platforms which help financial institutions better understand risks associated in lending to farmers and thus produce and provide agriculture intelligence.

Regarding weather, we have seen above in our review of Kisan Call Centre, the importance that reliable and timely weather forecasts have for farmers. We have not come across any initiatives which relay weather forecasts sufficiently reliably to the farmers. It is an urgent need and there is tremendous demand for good quality weather forecasts. A higher density of weather stations and more frequent data collection could provide more granular data at the field level, but the costs involved may be prohibitive.

ICT in improving efficiency of the Agriculture Supply Chain, market access for farm inputs and post-harvest to benefit farmers:

The post-harvest value chain in India remains long and the farmers often do not get a fair share of the value. Despite increased procurement by state and central govt. agencies and private sector players, the vast majority of farmers find themselves at the short end of the stick. Ensuring remunerative price to the growers also ensures implicit coverage for tenants and sharecroppers and not only land owning farmers.

To address these issues and to create a unified national market for agricultural commodities the government of India launched the eNAM initiative. National Agriculture Market (eNAM) is a pan-India electronic trading portal which networks the existing APMC mandis to create a unified national market for agricultural commodities. It integrates APMCs across the country through a common online market platform to facilitate pan-India trade in agriculture commodities, providing better price discovery through a transparent auction process based on quality of produce along with timely online payment. It was launched in April, 2016. Niti Aayog reports that though e-NAM currently covers more than 500 mandis, cross-mandi purchases are few and far between. Even in Karnataka, which was the first to introduce online auctions at APMC mandis, with rare exceptions, majority of the sales are within a mandi, confined to buyers, who are physically present. Buyers show a strong preference for physical inspection of grain over quality assessment through assaying while farmers are reported to fear that assaying reduces the price of their produce. It suggests that for eNAM to succeed , third party assaying and quality certification mechanisms, dispute settlement mechanisms, systems for forwarding goods to buyers, digital infrastructure to enable the national market are necessary (Niti Aayog, Three Year Action Agenda). Thus, e-NAM is an initiative with a lot of potential to improve the lot of farmers; but it needs to be steered ahead negotiating the complex web of the cartels of the middlemen in India's mandis. There have been repeated calls for the dismantling of the APMC regime in agricultural marketing by the states and despite many attempts at reforming the APMC system, the system has prevailed. In spite of these constraints, there are also many private sector startups trying to optimise the market access to ensure higher returns to farmers. Some of them are listed below (Source of information: Company websites/ social media accounts, news articles, personal communication):

Ninjacart: This startup connects vegetables and fruits farmers directly with businesses. They serve around 3000 farmers and 4000 retailers around Bangalore and Chennai.

Crofarm: Crofarm is another agri-supply chain startup that buys fresh vegetables and fruits directly from farmers and supplies them to online and offline retailers like BigBazaar and Big Basket.

Ravgo: Ravgo, a Punjab based startup is an agri-equipment rental marketplace, which aims to bring access to modern technology for small farmers who cannot afford ownership of expensive machinery. Its business model is based on the now popular cab aggregator 'uber model'.

BigHaat Agro Pvt Ltd: BigHaat is a Bengaluru-based startup empowering farmers through an e-commerce platform, which lets them buy seeds, crop protection nutrients and solutions, and agro instruments online.

Intello Labs: They have developed a smartphone application for quality grading of commodities, pest/disease detection in crops, yield estimation using image processing and AI.

Bigbasket: bigbasket.com is India's largest online food and grocery store with doorstep delivery. For its sourcing of food items (cereals, fruits and vegetables), it procures products from three sources – farmers, vendors and national sourcing. Farmers deliver their produce like fruits and vegetables at the

collection centre nearest to their village from where the produce is transported to be aggregated at the Bigbasket distribution centre or the warehouse for sale.

Most of the post-harvest initiatives are catering to fruit and vegetable farmers around major cities in India (Delhi-NCR, Bangalore, Chennai, and Mumbai). At some level, this implies that these initiatives are building their own setup and chain from the farmer to the end consumer. Regarding changes in the traditional supply chain which they bring can only be understood once more time elapses and we have some of these initiatives scaling to tier 3 and 4 cities of India.

Karnataka as a pioneer state:

The state of Karnataka is a pioneer in several aspects related to digitisation of land records, digitisation of crop survey data collection and also in automated weather data collection and forecasts (through KSNDMC). Under its Project Bhoomi, all land related documents such as Record of Rights, Tenancy and Crops (RTC) or Pahani, Mutation Report were digitized and are being made available to citizen/farmer, accessible even in rural areas through dedicated Kiosk Centres. Thus, the state of Karnataka is closest to building the AgriStack.

It is now implementing a Land Resource Inventory (LRI) for site-specific planning and development of watersheds on scientific basis, under Sujala-III project sponsored by the Watershed Development Department of Karnataka and funded by the World Bank, in 11 districts covering 9.66 lakh ha across 2531 microwatersheds covering 7.02 lakh households in the state. By interfacing land resource data with remote sensing via over 6000 weather sensors installed through the state, and GIS and GPS, different management scenarios have been analysed to arrive at the best management alternatives (optimum land use plans). This data handling system will be useful for making land use decisions and providing proactive advice to farmers on a real time basis protecting the health of natural resources (Hegde R., et al, 2018).

Conclusion and Way forward:

Given the need of decision support systems to aid the smallholder farmer in making informed decisions, and the objective of our project being to identify initiatives that harness the power of ICT to aid agricultural development, we have approached the state government of Karnataka for collaborating on such an initiative.

As explained above, Karnataka is undertaking some impressive initiatives, which will help immensely in reducing input costs and boosting production based on land features and weather. However, their project has not addressed the issue of market dynamics. Farmers in India have often failed to realise their fair price especially if there is a glut in the market, even if temporary. Advisories based on what is best grown in a plot of land, necessarily must be put into perspective of global and national factors like the global and national production estimates and existing stocks in the domestic and international markets, to allow for a more considered choice by the farmer.

We propose to look at the big data and try to ensure that farmer incomes don't fall by assessing national/international acreages/production that can be used to get some farmers to switch to or away from a crop. We will use past data and projections for production and prices in key producing centres, stocks in the state and country wide markets and model the implications for the local producing centres and the likely prices in harvest times, and try minimise the incidents of glut and consequent price falls, by calibrating production areas, sowing times and harvest times.

While there have been attempts to do this, the dearth of credible data on exact acreages and production, have hampered these efforts. Aligning the pilot to the Geo Portal/LRI project, will be symbiotic in that it brings in the missing piece in the project and boosts the chances of helping farmers even more.

We, thus, propose to ally with the state government of Karnataka with respect to giving farmer information on market parameters including stocks in the national and global markets, currently and at the time of harvest and allow for a more informed choice of crop selection. This ensures a data driven and customized decision support system which helps them diversify/choose crops to enhance/safeguard their incomes depending on prevailing circumstances.

References:

- Aggarwal, P.K., Chand, R., Bhutani, A., Kumar, Vijay, Goel, S.K., Rao, K.N., Poddar, M.K., Sud, U.C., Krishna Murthy, Y.V.N., Ray, S.S., Murthy, C.S., Sikka, A., Shirsath, P.B., Mishra, J.P., Choudhury, M., Chaudhury, O.P., Joshi, A.K., Sen, G., Tarpara, C.N., Kumar, D., Sahoo, R.N., Kumar, N.S., Yadav, A.K., Singh, T.P., Kannan, H.,SatishRaju, G., Sudhakar, M., Singh, K.K., Agarwal, N., Reddy, P.K., Shukla, A., Shanbaug, A., Srivastava, A.K., Mehta, S., Gupta, P.K., Gopalakrishnan, A., Chandel, B.S., Duggal, R.K., Deshmukh, V., Kotwaliwale, N., Vora, P., Kumar, S. and Lochan, R. 2016. Report of the Task Force on 'Enhancing Technology Use in Agriculture Insurance'. NITI (National Institute for Transforming India) Aayog, Government of India.
- Agriculture Census 2015-16 Provisional Results, 2018. Ministry of Agriculture & Farmers Welfare, Government Of India
- Azad M. M., Liton A. I., Naseer K M., 2017. The ICT in Agricultural Development of Bangladesh, International Journal of Engineering and Applied Sciences
- Decision-Oriented Information Systems for Farmers: A Study of Kisan Call Centres (KCC), Kisan Knowledge Management System (KKMS), Farmers Portal, and M-Kisan Portal, 2017. IIM Ahmedabad
- Deichmann U., Goyal A., Mishra D., 2016. Will digital technologies transform agriculture in developing countries? , Agricultural Economics
- Economic Survey of India, 2017-18
- FAO and ITU 2016. e-Agriculture Strategy Guide: Piloted in Asia-Pacific countries. Bangkok
- Fishman R., Kishore A., Rothler Y., Ward P. S., Jha S., Singh R.K.P., 2016. Can Information Help Reduce Imbalanced Application of Fertilizers in India? Experimental Evidence from Bihar, IFPRI
- Giri A., Aadil A., Malhotra R., Rautela R., Sharma V.P., Roy S., 2018. Assessment of AeFDS (Aadhaar enabled Fertilizer Distribution System) Pilot , Microsave (report submitted to NITI Aayog)
- Gulati A., Sharma P., Samantara A., Terway P., 2018. Agriculture Extension System in India: Review of Current Status, Trends and the Way Forward, ICRIER
- Hegde R., Niranjana K. V., Srinivas S., Danorkar B.A., Singh S.K., 2018. Site-specific land resource inventory for scientific planning of Sujala watersheds in Karnataka, Current Science
- http://ksndmc.org/
- http://precisionag.org/uploads/cole-sharma-july1-2017.pdf
- https://chromaway.com/cases/
- https://economictimes.indiatimes.com/industry/telecom/arpu-pressure-likely-to-tell-on-jio-in-rural-push/articleshow/68959776.cms
- https://landrecords.karnataka.gov.in/service2/RTC.aspx
- https://soilhealth.dac.gov.in/
- https://www.enam.gov.in/enam/
- https://www.financialexpress.com/opinion/how-to-address-regional-imbalances-in-agriculture-credit-in-india/1454326/
- https://www.indiafilings.com/learn/bhoomi/
- https://www.mea.gov.in/Images/pdf1/S7.pdf

- https://www.thehindu.com/news/national/karnataka/cards-mapping-soil-profile-of-lands-distributed-to-farmers/article25017850.ece
- India, The Three Year Action Agenda, 2017. NITI (National Institute for Transforming India) Aayog, Government of India
- Information and Communication Technology (ICT) in Agriculture: A Report to the G20 Agricultural Deputies, 2017. FAO
- Kujur G., Jha M.N., Chaudhary B.N., Kabdal D.C., Deepkumar V.S., Singh R.C., Deshmukh P.A., 2009. Success Stories of All India Radio, Prasar Bharti
- Lokeswari K., 2016. A Study Of The Use Of ICT Among Rural Farmers, International Journal of Communication Research
- Meenakshi R., Vani B.P., 2019. Interest Subvention for Short-term Crop Loans in Karnataka (study for RBI), Centre for Economic Studies and Policy, Institute for Social and Economic Change
- mKisan Midline Evaluation, 2014. GSMA mAgri Programme
- Raising Agricultural Productivity and Making Farming Remunerative for Farmers, 2015. Task Force on Agricultural Development, NITI Aayog, Government of India
- Saidu A., Clarkson A.M. Adamu S. H., Mohammed M., 2017. Application of ICT in Agriculture: Opportunities and Challenges in Developing Countries, International Journal of Computer Science and Mathematical Theory
- Singh S., Ahlawat S., Sanwal S., 2017. Role of ICT in Agriculture: Policy implications, Oriental Journal of Computer Science and Technology
- Sulaiman R., Hall A. J., Kalaivani N.J., Dorai K., Reddy T.S.V., 2011. Necessary, But Not Sufficient: Critiquing the Role of Information and Communication Technology in Putting Knowledge into Use, Research Into Use Programme (RIU), DFID
- Technical Consultation on Agricultural Information and Knowledge Management. 2007. FAO
- Vats A., 2011. The Role of Doordarshan and Private Broadcasters (NDTV) in Social Development in India: A Comparative Study from year 2000 to 2008, University of Pune
- World Bank 2017. ICT in Agriculture: Connecting Smallholders to Knowledge, Networks, and Institutions. Updated Edition. Washington, DC: World Bank
- World Bank. 2016. World Development Report 2016: Digital Dividends. Washington, DC: World Bank
- www.mkisan.gov.in
- Young M., 2018, The Age of Digital Agriculture, Climate Corporation