CERTIFICATE

We have the pleasure to certify that Sri Santosh Kumar Sarangi has pursued his research work and prepared the present dissertation titled "The Role of Emerging Technologies in Agricultural Governance in India" under our guidance and supervision. The dissertation is the result of his research and to the best of our knowledge, no part of it has earlier comprised any other monograph, dissertation or book. This is being submitted to the Punjab University, Chandigarh, for the purpose of Master of Philosophy in Social Sciences in partial fulfillment of the requirement for the Advanced Professional Programme in Public Administration of the Indian Institute of Public Administration (IIPA), New Delhi.

We recommend that the dissertation of Sri Santosh Kumar Sarangi is worthy of the award of M.phil Degree of Punjab University, Chandigarh.

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THE ROLE OF EMERGING TECHNOLOGIES IN AGRICULTURAL GOVERNANCE IN INDIA

Santosh Kumar Sarangi

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ACKNOWLEDGEMENTS

While working as Chairman of Agricultural and Processed Products Exports Development Authority (APEDA) and subsequently as Joint Secretary in the Department of Commerce, Government of India, I had the occasion to deal with various aspects of agricultural exports from the country. My assignment also took me to other countries and to food exhibitions which displayed the latest technology in production and processing. The participation in overseas fairs and exhibitions exposed me to the way emerging technologies like AI, IoT, blockchain, etc. were being extensively used to improve the productivity, augment farmers' income and establishing themselves as the future of sustainable farming. This had raised the curiosity in me to explore the applicability of such technologies in the context of agricultural governance in India, especially in the backdrop the Hon'ble Prime Minister Sri Narendra Modi's call for "doubling the farmers' income".

I thank the IIPA for giving me the opportunity to write my dissertation on a topic of my interest and I would like to thank the Director, IIPA, Sri S. N. Tripathy, the Programme Coordinator of 45thAPPPA, Sri Gobinda Bhattachrjee and Associate Course Coordinator Ms Neetu Jain. I would like to extend my sincere thanks to the Guide Prof Ashok Vishandass and co-Guide Dr. Charru Malhotra for their guidance and prompt response to my doubts/queries at each stage of carrying out the research. I thank official of APPPA Office for making the entire course smooth and enjoyable. I would also like to thank Dr Srivatsa Krishna, Secretary, Coffee Board and Mr. Ashwini Kumar of Coffee Board for having facilitated the field survey with coffee growers and interview with agri-tech firms using emerging technologies.

I also take this opportunity to thank my wife Aparajita, my daughter Archita and son Shikhar for standing by me during the research study and for being my pillars of strength.

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APPPA-4533

ABBREVIATIONS

AI – Artificial Intelligence
ATMA – Agricultural Technology Management Agency
CKT – Coffee Krishi Taranga
DAC & FW – Department of Agriculture, Cooperation and Farmers' Welfare
DARE – Department of Agricultural Research & Education
DFI – Doubling of Farmers' Income
DNN – Deep Neural Network
DST – Department of Science and Technology
ET – Emerging Technologies
FDI – Foreign Direct Investment
ICAR – Indian Council of Agricultural Research
ICRISAT – International Crop Research Institute for the Semi-arid Tropics
ICT – Information and Communication Technology
IoT – Internet of Things
ITRA – Information Technology Research Academy
IVRS – Interactive Voice Response System

KVK – Krishi Vigyan Kendra

MeitY – Ministry of Electronics and Information Technology
ML – Machine Learning
NABARD – National Bank for Agriculture and Rural Development
NAFED – National Agricultural Cooperatives Federation
NDVI – Normalised Difference Vegetation Index
NeGP – National e-Governance Plan
NMAET - National Mission on Agricultural Extension and Technology
NPCI – National Payment Corporation of India
PPP – Public Private Partnership
RFID – Radio Frequency Identification
SFAC – Small Farmers' Agri-Business Consortium
TCS – Tata Consultancy Services
UIAI – Unique Identification Authority of India
UAV – Unmanned Aerial Vehicle
VKC – Village Knowledge Centre
WEF – World Economic Forum

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EXECUTIVE SUMMARY

The emerging technologies like artificial intelligence, blockchain, IoT have impacted many aspects of our lives and are becoming pervasive. Most governments around the world are seized of the potential impact of these technologies on different aspects of governance and have prepared strategies/roadmap to leverage the beneficial aspects of these technologies in areas like agriculture, banking, health, education, etc. The purpose of this study has been to explore the extent to which emerging technologies could be leveraged in agricultural governance of India and whether it could play a positive role in Government's aspiration to double the farmers' income by 2022.

The Government of India, through NITI Aayog and the Ministry of Information Technology (MeitY), have also come out with strategies relating to blockchain, AI and IoT. NITI Aayog has identified agriculture as one of the 5 sectors in which AI could be leveraged to augment productivity and farmers' income. Augmenting agricultural growth is extremely vital for the overall inclusive growth because the agriculture sector sustains the livelihood of approximately 50 percent of the population. Therefore, the need for the introduction of technology in the agriculture sector has been felt in order to bridge the deficit to match productivity levels with the best in the world.

Agriculture management system in India has often been criticised for slow adaptation to modernization. The sector has been afflicted by issues of low productivity, repeated occurrences of excess and under-production reflecting a clear market asymmetry, grappling with issues pertaining to good agricultural practices since the country's agricultural products are facing sanitary and phyto-sanitary barriers, marketing of the produce, etc. Undoubtedly, the scope of applying emerging technologies (such as AI and blockchain) in providing innovative solutions to

issues confronting agriculture systems in India will help to scale growth in the primary sector. The potential application of emerging technologies at various stages of agriculture management, such as pre-, on-farm and post-harvest, is quite relevant.

The emerging technologies are being utilized in agriculture sector through 3 broad interventions:

a) Crop and soil monitoring: Use of Sensors, drones and other IoT devices to monitor condition of soil, requirement of additional nutrients and disease profiling and recommendation on ameliorative measures.
b) Predictive agricultural analytics: Using machine learning and AI to predict on weather, sowing time, irrigation schedule, etc. It is also used for analyzing global demand-supply position of different crops and issuing advisories on the crop to be farmed in a particular year.
c) Supply chain: Using data analytics and blockchain to allow smart supply chain management for seed sourcing, warehousing management, market linkages by establishing credentials and authenticity, etc.

In the Indian context, the challenges of enhanced food requirement will have to be balanced with sustainable farming and in such a scenario, the role of emerging technologies in scientific agricultural management and providing solutions across the value chain comes into play. The primary survey has been done among 80 numbers of the coffee growing farmers in Chikmaglur of Karnataka who have been using digital IVRS based applications. Based on the analyses undertaken the following results emerge:

a) The growers showed a willingness to try out new technologies and had ease in utilizing the digital technologies which required the farmers to refer the specific problems and in response, get a customized solution in the area of fertilizer, irrigation, crop and disease management in addition to getting specific price trends for international and domestic markets.

b) 91% growers found it easy to handle and found the IVRS based application to be beneficial to improve farming practices like better disease profiling and management of diseases, better fertilizer management and availability of price trends on a real time basis.

c) 54% farmers were convinced of cost reduction and income augmentation on account of use of digital technologies.

The survey among agri-tech firms showed a lot of optimism relating to use of AI, IoT and blockchain in agriculture. The field assessment reveals that integrating these technologies at the field and industry level with the current governmental schemes can help in the creation of jobs and will help in the outreach, and observes that a large network of ICAR Institutes and Agricultural Universities across the country can equip the farmers regarding techniques and best practices for getting higher production through various outreach and extension education programmes.

The broad recommendations arising out of the findings are as follows:

1. Improve the regulatory framework for widespread use of ET by creating an Authority which will be responsible for promotion of ET; create regulatory framework for creation of a digital stack for agriculture which is amenable to convergence among the different e-platforms providing services for agriculture; establish and manage a cloud based data centre for

agriculture; interact and coordinate with central and state governments to converge different schemes with application of ET; address various issues of data security and cyber security.

2. Improve the administrative management of agricultural institutions by modifying the curriculum in agri-Universities to include components of ET; focus on skill development of youth to provide different services using ET and improve the skills of extension officials.
3. Improve institutional capacity by promoting innovation and R & D; create a National Agricultural Innovation Fund and possibly similar funds at state level; encourage schematic support for ET by revising guidelines of existing Central and State Government schemes; overcome land fragmentation constraints by forming Farmer Producers' Organizations; initiate collaborative efforts between public and private sector, etc.
4. Adopt participatory approach by bringing in more citizen centricity to the application of ET in agriculture. Simultaneously, ensuring that efforts are sustainable and scalable is important and this is possible only if a participatory approach is followed.

To conclude, the study finds that the potential for application of emerging technologies in the Indian agricultural context is very high and a positive relationship has been found between adoption of digital technology and income augmentation of farmers. The initiatives of technology start-ups and initial pilots in a collaborative approach between state governments and private sector has shown encouraging results. The field survey done amongst the coffee growers under the aegis of Coffee Board reveals that the farmers' adaptability to digital and consequently, emerging technology is high and they understand the economic benefits that could accrue on account of scientific and good agricultural practices. Thus, a carefully planned government policy towards adoption of emerging technologies in agriculture has the potential to balance the twin demand of ensuring food security (through higher productivity) and

significant income augmentation for the farmers (through cost reduction and qualitative market access). If the roadmap is charted properly, this could supplement the efforts towards “doubling of farmers’ income” considerably.

CHAPTER-1

INTRODUCTION

1.1 Overview of Emerging Technologies

Considering the rapid scale at which emerging technologies (ET) such as artificial intelligence (AI), blockchain, immersive technologies, internet of things (IoT), etc. have evolved and encompassed all aspects of day to day living, the role and impact of such technologies to deliver better governance has become a matter of interest for every government. These emerging technologies are often described as 'disruptive' because of the way in which they bring about technological solutions to complex problems by enabling machines to possess and deploy high-level cognitive capabilities. Functions such as thinking, perceiving, learning, problem solving and decision making, which were unique to human beings, are being performed better, faster and accurately by machines powered with advances in data collection, aggregation, processing and analytics. This is a big shift from the manner in which normal day to day transactions or governance procedures were conducted hitherto. The use of emerging technologies like artificial intelligence, IoT in the industrial operations is often described as "Industry 4.0." A well calibrated strategy to respond to the various components of the 'Fourth Industrial Revolution'[i], which has ushered in 'Industry 4.0'[ii] as an outcome, now seems to be a pre-requisite for charting the governance initiatives in various sectors. This is typically true for the agricultural sector in India, as approximately 50% of Indian population (as per Economic Survey of India for 2017-18, it was 52%) is dependent on this sector for livelihood.

The Government of India (GoI) has taken cognizance of the huge impact and the opportunities which the emerging digital technologies can play in the Indian context. NITI Aayog (2018), quotes the estimates done by Accenture[iii] (December, 2017) as per which an addition of $1 trillion to the

Indian economy by 2035 is projected on account of use of AI.[iv] Amongst the five focus areas that have been identified by NITI Aayog, 'Agriculture' is a focus area in which NITI Aayog asserts that artificial intelligence could be utilized to bring about improvement in agricultural management in India. In the context of India's Prime Minister having set the target for 'Doubling of Farmers' Income' by the year 2022, the leveraging of the emerging technologies could facilitate the achievement of this ambitious target.

The various debates relating to emerging technologies can be broadly characterized as being based on two strands of thought (optimistic-Zuckerberg of Facebook and pessimistic- Elon Musk of Tesla, Stephen Hawking) with regard to impact on jobs and changing profile of jobs in an environment where increased automation and robotics will play a crucial role. While the pessimistic school believes that with higher use of artificial intelligence, there will be lesser dependence on manpower (leading to massive job losses), the optimistic school believes that increased use of emerging technologies will lead to creation of new job opportunities. According to The Future of Jobs Report (2016)[v], 65% of children entering education today will end up in careers that don't yet exist, and much of this will be attributable to the rapid advancements of the Fourth Industrial Revolution. In the Indian context, the impact of emerging technologies on jobs, especially in the agriculture sector, on which a large percentage of the population is dependent for their livelihood, would come for greater scrutiny in the years to come. However, the pervasive nature of these technologies can't keep any sector immune and the later part of this study examines how countries are strategizing to adapt to the impact of the ETs.

This study aims to identify the gaps in adoption of emerging technologies in India and explore the extent to which emerging technologies are being used elsewhere and in India.

Further, the study aims at understanding the role which these technologies can play in agricultural governance in India, especially in the backdrop of the target of "doubling of farmers' income by 2022."

1.2 Digital Governance in India

In the context of India, the adoption of digital technologies to improve government systems and procedures was initiated in the early 1990s and gradually expanded to include citizen centric services, delivery of services and ensuring ease of interface with government. Malhotra (2018), in her study "Role of Digital Technologies in Governance" has discussed the various e-government and e-governance initiatives in India. This study also analyses the evolution of digital technology in governance of India, National e-Governance Plan, Mission Mode Projects, National Service Delivery gateway, as well as related applications available for different stakeholders including that for farmers. The discussion concludes that "to sustain these digital initiatives, the governance agencies must provide citizens with what exactly they need and aspire rather than just an aped model where 'one size fits all'. Only a citizen-centric and citizen-inclusive approach can bridle the ever-changing facets of technology and help to design a recursively self-regulated ecosystem of e-Governance. Keeping 'citizens' as the nucleus of governance / e-Governance systems would help us to achieve a more sustainable and equitable global economy, where digital technologies act as an expedient means and not an 'end'."[vi]

1.3 Emerging Technologies with Special reference to Agriculture Sector in India

The use of technology to boost agricultural production and productivity is not new to India. The 'green revolution' in the 1960s and the 'white revolution' in the 1980s and beyond are testimony to the adaptability of Indian agricultural scientists and farmers to leverage technology and

maximise the benefits. This has enabled India to do well in agricultural production and become a leading exporter of many agricultural products.

Along with use of technology and improvement in extension machinery, there has been a high level of emphasis on increasing investments in the agriculture and food processing segments. According to the Department of Industrial Policy and Promotion (DIPP, now DPIIT), the Indian agricultural services and agricultural machinery sectors have cumulatively attracted Foreign Direct Investment (FDI) equity inflow of about $2.45 billion and the food processing sector has attracted around $7.81 billion during April 2000 to June 2017. However, it is pertinent to note that FDIs, on an annual basis, in these subsectors have actually stagnated or declined since 2013 and thereby their share in total FDI in the country has reduced thus necessitating additional steps.[vii] With an aim to boost innovation and entrepreneurship in agriculture, the Government of India has introduced a new AGRI-UDAAN programme[viii] to mentor startups and enable them to connect with potential investors.

In the backdrop of a potential increase in investment and conducive government initiatives (the 2020-21 budget outlines a 16 point agenda for development of agriculture and allied activities)[ix], the agriculture sector is increasingly looking at ways to leverage technology to achieve better productivity and to augment farmers' income. Many technology companies and startups have developed and introduced innovative technology-driven solutions using various types of emerging technologies.

Emerging technologies have the potential to be a great boon to the agricultural sector that is heavily dependent on climatic conditions that are often unpredictable. There are a number of instances of how various private organizations are using sensors for crop and soil monitoring, as well as AI and

machine learning tools for predictive analytics. Many entrepreneurs are using blockchain to create a transparent online marketplace to buy and sell crops under one platform. More and more cases of use of ET in agriculture are likely to show up in the near future because of the immense value it can add.

The most popular applications of AI in Indian agriculture can be broadly categorized into following three activities related to agriculture sector.

- Crop and Soil Monitoring – Agri-tech firms are leveraging sensors and various IoT-based technologies (drone, image recognition sensors, e-nose) to monitor crop and soil health.
- Predictive Agricultural Analytics – Various AI and machine learning tools are being used to predict weather pattern, the optimal time to sow seeds, get alerts on risks from pest attacks, fertilizer application schedules, prediction of price trends and more. Through use of smart irrigation, smart greenhouse, precision farming, the farmers are installing a variety of smart technologies to increase competitiveness and sustainability in their productions.
- Supply Chain– Companies are using real-time data analytics on data-streams coming from multiple sources to build an efficient and smart supply chain which ranges from seed sourcing to rental models for agri-equipment to marketing of produce by establishing the buyer and seller credentials and product authenticity. Initiatives like e-NAM in India would help remove the information asymmetry and establish a fair market for the farmers.

It is recognized that with vast tracts of arable land and different kinds of agro-climatic zones, there is huge potential of agriculture in India. In this context, it is imperative that technology is used to the optimum so that both farmers and consumers can make the most of it. With recent advancements in technology coupled with government policies facilitating start-ups, a number of

agri-tech startups have come up in the country and are making efforts at maximizing the benefits of emerging technologies in the primary sector.

One of the defining features of the present era has been the rapid pace at which technology is witnessing a paradigm shift in terms of efficiency of application, scale of disruption and the ubiquitous manner in which it has pervaded the day to day lives. Indeed, technologies have huge impact on a wide array of sectors and agriculture sector is not bereft of the same. Governments around the world have taken note of this impact and have been looking at leveraging these emerging technologies for improving the service delivery in this sector. Time is, therefore, ripe for India too to approach the subject with serious intent.

CHAPTER-2

LITERATURE REVIEW AND RESEARCH METHODOLOGY

2.1 Emerging Technologies in Governance - A Global Perspective:

Literature reveals that the rapid scale at which emerging technologies like artificial intelligence, blockchain technology, immersive technology, internet of things (IoT), have evolved and encompassed all aspects of our day to living, the role and impact of such technologies on governance is also going to be pervasive. For instance, Brooks (2019) postulates that the Internet of things, Artificial intelligence, quantum computing and issues relating to cyber security will have a significant impact on our lives. We have entered a new renaissance of accelerated technological development that is exponentially transforming our civilization and times.[x]

Artificial Intelligence is emerging as a central policy issue in several countries. In October 2016, during the Presidency of Mr. Obama, the White House released a report titled, "Preparing for the Future of Artificial Intelligence"[xi] delving into a range of issues including application for public goods, regulation, economic impact, global security and fairness issues. The White House also released a companion document called the "National Artificial Intelligence Research and Development Strategic Plan"[xii] which laid out a strategic plan for state-funded research and development in AI. Subsequently, US Government released a series of documents regarding the role of AI. Similarly, the United Kingdom announced its 2020 national development strategy and issued a government report to accelerate the application of AI by government agencies. In 2018, the Department for Business, Energy, and Industrial Strategy of UK released the Policy Paper - AI Sector Deal.[xiii] The European Union launched "SPARC," the world's largest civilian robotics R&D program.[xiv]Even the Japanese government released its paper on Artificial Intelligence Technology

Strategy in the year 2017. Over the last couple of years, China, the UAE, Singapore, Canada, South Korea, and France have announced national AI strategy documents while 24 member States in the EU have committed to develop national AI policies that reflect a "European" approach to AI.[xv] On 19th of February, 2020, the European Commission, the EU's executive branch, opened a 12-week period of discussion aimed at better understanding how to protect EU citizens from what it describes as the negative impacts of AI. More concrete legislation is then expected in the second half of the year 2020.[xvi]Small countries like Israel and Netherlands have adopted advanced technology and have augmented the production of high-value crops through enormous productivity breakthroughs and, even more importantly, by ensuring the optimal utilization of resources and maintaining the environmental balance.

These developments suggest that AI is quickly emerging as central to national plans not only as a means of development of science and technology but also as a means for economic and national security and development. There is also a focus on encouraging Public-Private partnerships (PPP) to bring in investments enabling AI innovation in critical domains as a means of addressing key challenges facing nations. India has followed this trend and in the year 2018 the government published two AI roadmaps - the Report of Task Force on Artificial Intelligence by the AI Task Force constituted by the Ministry of Commerce and Industry and the National Strategy for Artificial Intelligence by NITI Aayog.

A study by Malhotra and Anand (2019) explores current and future application of Artificial Intelligence in government. It recommends that government should adopt an explicit AI policy to drive innovation, adaptation, and proliferation attempt. The study identifies huge potential of application of AI in different sectors including in agriculture and recommends that the Government should have an AI policy.[xvii]

Broadband India Forum (BIF) along with Feedback Business Consulting Services (2019) has conducted a research based study in order to publish a report on "Job Creation Potential in Agriculture and Healthcare Sector Due to Adoption of Internet of Things (IOT) and Artificial Intelligence (AI)". While IoT is being talked about widely and many applications are coming up for usage in urban areas, the research paper concludes that IoT also has tremendous potential to create job opportunities in rural areas in a country like India. The paper identifies that the true potential of these technologies is yet to be realised. One of the major impediments identified is the absence of an eco-system to develop the required skills which has not matured at the same pace at which the adoption of IoT has accelerated in India over the years. The paper concludes that IoT could be a huge enabling tool for the Government to implement their nation-wide programs.[xviii]

Study by Anand and Khemchandani (2019) argues that though the concept of e-governance in India was started in the eighth decade of the 20th century, it entered its second phase (organised/wireless + satellite) in India with NeGP-1.0 in 2006. The earlier phase was marked by computerizing the manual processes without changing the original manual data acquisition etc. However, the effort of using e-governance to take it to grassroot level of governance took more concrete shape in Digital India initiative in 2014.[xix]

Singh and Singh (2018) in their research paper argue that in today's time the development of any country depends on the uses of e – Governance and also their penetration. They argue how the scope of E – Governance in a country could be a parameter for gauging the development and how it can help in eradication of poverty, reduction of inequality and address basic human needs. They assert that poor literacy rate in India and high number of people below poverty line has not allowed India to leverage the benefits of e-governance systems at the desired scale[xx]

Chandrashekharan and Purushottam (2019) have argued that India will need to forge a new path and bring the 20th century model of manufacturing led development into the 21st century. This new growth model requires an alternative strategy; boosting a range of labour intensive intermediate economic activities that take care of India's vast unmet demand and shift people towards more formal characteristic of work. Bridgital would be providing a way of achieving this.[xxi]

While the impact and influence of emerging technologies is unfolding and countries are embracing the new technologies in view of their disruptive impact, the academic debate has continued on whether it will have positive or negative consequences for human beings. The optimists and pessimists have argued about the beneficial and destructive aspects of technologies like AI and machine learning. While recognizing the all-pervasive impact of the emerging technologies, the debate quite logically has veered towards the public administration challenges in the context of AI, bots and blockchain. While discussing the impact of role of technology in public administration, Aggarwal (2018) summarises: "the pace of change outside our public institutions is faster than the pace of change within. That is a problem. There is an urgent need for public administration to get engaged proactively- they cannot simply wait for technology to shape the landscape before putting the fence around it."[xxii]

2.1.a. Optimists relating to Emerging Technologies

Mishra (2019), in his research paper "Artificial Intelligence: Boon or Foom for humanity" discusses the use of AI in governance, security, and policymaking and talks of extensive use of AI by National Investigation Agency of USA which uses Deep Neutral Network (DNN) to identify terrorist suspects. He discusses how AI has become a key policy initiative for all governments as they see data as the new currency to gain strategic differentiation.[xxiii]

There are others who perceive AI to be one of the biggest opportunities for mankind and feel that the technological solutions available through AI will be immensely beneficial in health, space, law and order and many other areas. Schmidt (2016) says that AI could be leveraged in order to solve major challenges, including climate change, disease diagnosis, drug discovery, microeconomics, theorem proving and protein folding.[xxiv] The World Economic Forum (WEF) estimates that 58,000,000 more jobs are expected to be created by the end of year 2022 and it is all owing to AI implementation. The report by WEF stated that the AI implementation may displace around 75 million jobs due to shift in the division of labour between humans and machines, but it is also expected to create 133 million more jobs which are new roles that are more in line with the new division of labour between humans and machines. Another study conducted by PwC[xxv] (2018) stated that technologies related to AI and robotics are likely to create sufficient new jobs to largely counterbalance the potential job losses due to automation.[xxvi]

Smith and Browne (2019) argue that technology can be a powerful tool for some but may also become formidable weapon for others. "But with the right approach to sharing data, and the right support from Governments, it is more than possible for the world to create a model for a new generation of economic growth."[xxvii]

2.1.b. Pessimists relating to Emerging Technologies

The sceptics with regard to the role of emerging technologies believe that the continuous progression in artificial intelligence (AI) and machine learning is going to create algorithms that will be so complicated that few human beings will be capable of understanding it. There are speculations that AI may soon take finances to a level where human beings cannot make sense of finance anymore. It is possible that peer-to-peer blockchain networks and crypto currencies like

bitcoin would revamp the monetary system in such a way that future transactions would by-pass the national currencies. The government might have to look at revamping the taxation structure which looks at taxing information rather than financial transaction.[xxviii] There are some who believe that the rapid growth of emerging technologies will make billions of people jobless within the next couple of decades. To the contrary, the optimistic ones believe that automation and technology will keep generating new jobs and greater levels of prosperity for human beings. While discussing the effects of the fourth industrial revolution, Baldwin (2019)contends that AI, machine learning, telemigration and holoportation would not only impact the blue collared workers but also take away white collared jobs. In the face of rapid technological progress, Baldwin (ibid) argues that the pace of progress needs to be set by humans and as technology is moving fast, we need to control the spread of disruption.[xxix]

Webb (2019), discusses the journey of artificial intelligence and the prospect of it developing into artificial super-intelligence – a stage at which human beings would remain completely dependent on machines. She believes that whether humanity would move in a more pragmatic and positive direction or in a catastrophic direction is entirely dependent on nine internet companies and two countries, namely, US and China.[xxx]

The spectre of pervasive influence of technology and its overwhelming impact on the lives and functioning of human beings has led some to believe that with increasing automation, with the confluence of biotech and infotech capable of 'hacking' human beings, the relevance of human beings in future will be marginal. Some speculate, "perhaps in the twenty first century populist revolts will be staged against an economic elite that does not need them anymore. This may well be a losing battle. It is much harder to struggle against irrelevance than against exploitation."[xxxi]

Leontief(1983) stated that the role of humans as the most important factor of production is bound to diminish — in the same way that the role of horses in agricultural production was first diminished and then eliminated by the introduction of tractors.[xxxii]

2.1.c. Emerging Technologies in Agriculture

Agriculture in India has undergone a significant structural change from traditional subsistence to a market- oriented structure, where the focus of farming has shifted from a mere consumption centric approach to creating surplus and making a profit out of crops. The rural economy has shifted from exclusive reliance on labour and machinery to services dominating the agriculture sector. ETs can be utilized in the agricultural sector to provide a range of services for information, training, diagnostic and monitoring, and to enable transactions. Various initiatives (public and private sector) have shown that ICTs can be a robust tool to capture, process and share information with farmers effectively, efficiently and in a low-cost manner with minimal transaction costs from farm to consumer. While observing that the role of ICTs in linking knowledge to innovation is crucial in addressing the information and knowledge gaps in the agricultural sector, FAO (2015) notes that agriculture is becoming more knowledge-intensive as farmers require more information to make increasingly complex decisions on land use, crop selection, choice of markets and other areas that impact the livelihoods of their families and communities.[xxxiii] However, Sulaiman (2011) notes that ICTs have to evolve from traditional communication tasks to more communication strategies for innovation like network and knowledge brokering, advocacy communication, visioning, process facilitation, learning-oriented monitoring, etc. to be effective.[xxxiv]The emerging technologies like AI and IoT have the capacity and innovative tools to fill in the aforementioned space. The future of farming lies with data powered farming in which IOT and Artificial intelligence are used to cultivate the crops. These technologies can be used to do smart farming,

in which weather, soil, and yield, etc. can be forecast and required initiatives can be taken to maximize the output of the crops. Farming, powered by data analytics is likely to maximize the profitability and yield of the crop.

With the rapid development of the fields of big data, artificial intelligence, Internet of Things (IOTs), satellite imaging, robotics, sensors, cloud computing, and other related technologies during the last about one decade, new applications of ICTs in the agriculture sector (for 'smart farming') have been effective in addressing a few sectoral constraints/bottlenecks in various developing countries. The agri-tech firms in developed countries have shown that there is potential for large-scale application of digital technologies such as remote sensing and geographic information systems for crop and soil health monitoring, livestock and farm management etc. These technologies can be utilized at various stages (on-farm examples at the production stage – crop and input selection-application (e.g. provision of irrigation), sourcing of credit and insurance, weather advisories and disease and pest-related assistance; and off-farm applications for data gathering/sharing on domestic and export markets).

Chaudhury (2015) aargues that greater engagement between government and private sector technology solution providers would help in bringing cutting-edge technologies and approaches to India's agricultural sector. IT and biotech stand to transform agriculture, raising its production levels and outputs. Farmers' access to vital information, methodologies and the latest technology to help them in areas such as weather patterns, crop rotation, fertilizer use and going organic – all at the click of a button or a simple SMS on their mobile phones can bring about massive transformation in the agriculture scenario of India.[xxxv]

The adoption of these technological innovations in India has been supported by an active startup ecosystem which is evolving due to the synergies generated from combined actions of the public

and private sectors. Digital technologies, including Artificial Intelligence, big data analytics, blockchain technology, 3-D printing, and IoTs can play a transformational role in modernizing and organizing how rural India performs its agricultural activities.[xxxvi] Some of the new and major digital technologies which have made their presence felt in the Indian agricultural sector include:

i. Big data: Big data essentially involves extensive datasets, primarily with the characteristics of volume, velocity, variety and variability that require a scalable architecture for efficient storage, manipulation, and analysis.[xxxvii] Big data, which encompasses the phases of data generation, data acquisition, data storage, and data analysis, draws its value from practices to extract economic value from very large volumes of a wide variety of data by enabling high-velocity capture, discovery, and/or analysis. The output of data analysis is being applied effectively in agriculture to analyze and understand complex agricultural ecosystems, and predict their evolution. Big data applications in farming extend beyond the primary production stage to improve the efficiency of the entire supply chain (Esmeijer et al., 2015).[xxxviii]Opportunities for Big Data applications in agriculture include benchmarking, sensor deployment and analytics, predictive modelling, and using better models to manage crop failure risk and to boost feed efficiency in livestock production (Faulkner and Cebul, 2014).[xxxix] Machine learning, cloud based platforms, image processing, modeling and simulation, statistical analysis and NDVI vegetation indices are the most commonly used techniques for big data analysis in agriculture (Kamilaris, 2017).[xl]

ii. Artificial intelligence: Kaplan and Haenlein (2018) define AI as a system's ability to interpret external data correctly, to learn from such data, and to use that learning to achieve specific goals and tasks through flexible adaptation.[xli] Agriculture offers a vast application area for all kinds of AI core technologies: Mobile, autonomous agents operating in uncontrolled environment, stand-alone or in collaborative settings, allows investigation, testing and exploiting technologies from

robotics, computer vision, sensing, and environment interaction (Dengel, 2013).[xlii] Artificial intelligence (encompassing the domains of deep learning, Convolutional Neural Networks (CNN), Artificial neural networks (ANN), and machine learning, have been utilized for crop management, pest and disease management, soil and irrigation management, weed management, yield prediction, product monitoring (crop quality), storage control, species recognition. The application of machine learning to sensor data is leading to farm management systems evolving into real artificial intelligence systems, providing richer recommendations and insights for the subsequent decisions and actions with the ultimate scope of production improvement (Liakos et al, 2018).[xliii]

iii. Blockchain technology: A blockchain is built as a linear sequence of smaller encrypted datasets called 'blocks', which contain time-stamped batches of transactions. Each block contains a reference to its precedent block and an answer to a complex mathematical puzzle, which serves to validate the transactions it contains. Blockchain can also be seen as a decentralized ledger system of transaction records, which is distributed across a network of computers or databases. Blockchain is built on various component technologies including public/private key cryptography, cryptographic hash functions, database technologies especially distributed databases, consensus algorithms, and decentralised processing. In the agricultural sector, blockchain technology can be used to assure traceability and authenticity in the food supply chain. Blockchain technology provides a means to ensure permanence of records and potentially to facilitate the sharing of data between disparate actors in a food value chain (Ge Lan et al, 2017).[xliv] FAO (2019) observes that, in the agriculture domain, self-executing smart contracts (Smart contracts are self-executing agreements that are triggered on the basis of predefined and agreed events) together with automated payments in agricultural insurance, green bonds, and traceability could be very

effective.[xlv] Potts (2019) notes that blockchain technology adoption into modern agriculture will have the following effects:

a. Increased return to on-farm digital investment

b. Price wedge between quality and commodity production, incentivizing information provision where quality exists

c. Redistribution of value along supply chain (toward farm) and

d. Promotion of market disintermediation and structural de-hierarchicalisation.[xlvi]

iv. Internet of Things (IoTs):Internet of Things has been defined as a dynamic global network infrastructure with self-configuring capabilities based on standards and interoperable communication protocols; physical and virtual 'things' in an IoT have identities and attributes and are capable of using intelligent interfaces and being integrated as an information network" (Kiritsis 2011).[xlvii] Further, IEEE (2015) recognizes that Internet of Things envisions a self-configuring, adaptive, complex network that interconnects 'things' to the Internet through the use of standard communication protocols. The interconnected things have physical or virtual representation in the digital world, sensing/actuation capability, a programmability feature and are uniquely identifiable. The structure of IoT is based on three layers; namely, the perception layer (sensing), the network layer (data transfer), and the application layer (data storage and manipulation). IoT utilizes communication technologies such as RFID, Z-wave, LTE, NFC and M2M. IoT applications in agriculture have been proposed to be feasible for monitoring and control, environment-controlled agriculture, open field agriculture, livestock applications, and food supply chain tracking (Tzounis et al, 2017).[xlviii] Advances in precision agriculture have been enabled by the evolution of sensor technologies which can be integrated with various variables to trigger

appropriate farm management actions relating to cultivation, sowing/transplanting, fertilizer and herbicide application, and harvesting.

While the four major streams of digital technologies have been explained above, rapid developments in the fields of sensors, satellite imaging and cloud computing have also enabled the faster adoption of precision agriculture and practices relating to smart farming. The details of how drone technology, predictive analysis, weather based models, block chain technology, robotics, etc. are impacting better decision support and increased productivity in agriculture is illustrated below.

Table-I-Application of different forms of emerging technologies in agriculture

1	**Drones**	• Before the crop cycle, drone can be used to produce a 3-D field map of detailed terrain, drainage, soil viability and irrigation. Nitrogen-level management can also be done by drone solutions • Aerial spraying of pods with seeds and plant nutrients into the soil provides necessary supplements for plants. Apart from that, Drones can be programmed to spray liquids by modulating distance from the ground depending on the terrain • Crop Monitoring and Health assessment remains one of the most significant areas in agriculture to provide drone-based solutions in collaboration with Artificial Intelligence and computer vision technology. High-resolution cameras in drones collect precision field images which can be passed through convolution neural network to

		identify areas with weeds, which crops need water, plant stress level in mid-growth stage. In terms of infected plants, by scanning crops in both RGB and near-infra red light, it is possible to generate multispectral images using drone devices. With this, it is possible to specify which plants have been infected including their location in a vast field to apply remedies, instantly. The multi spectral images combine hyper spectral images with 3D scanning techniques to define the spatial information system that is used for acres of land. The temporal component provides the guidance for the entire lifecycle of the plant. <u>Crop readiness identification</u> Images of different crops under white/UV-A light are captured to determine how ripe the green fruits are. Farmers can create different levels of readiness based on the crop/fruit category and add them into separate stacks before sending them to the market. <u>Field Management</u> Using high-definition images from airborne systems (drone or copters), real-time estimates can be made during cultivation period by creating a field map and identifying areas where crops require water, fertilizer or pesticides. This helps in resource optimization to a huge extent.

2	**Precision Farming**	The phrase "Right Place, Right Time, Right Product" sums up precision farming. This is a more accurate and controlled technique that replaces the repetitive and labor-intensive part of farming. It also provides guidance about crop rotation, optimum planting and harvesting time, water management, nutrient management, pest attacks and so on. Key technologies that enable precision farming are given below: • High precision positioning system • Automated steering system • Geo mapping • Sensor and remote sensing • Integrated electronic communication • Variable rate technology <u>EXAMPLES</u> • Identification of stress level in a plant is obtained from high-resolution images and multiple sensor data on plants. This large set of data from multiple sources needs to be used as an input for Machine Learning to enable data fusion and feature identification for stress recognition. • Machine learning models trained on plant images can be used to recognize stress levels in plants. The entire approach can be classified into four stages of identification, classification, quantification and prediction to take better decisions

3	**Internet of Things**	Huge volumes of data get generated every day in both structured and unstructured format. These relate to data on historical weather pattern, soil reports, new research, rainfall, pest infestation, images from Drones and cameras and so on. Cognitive IOT solutions can sense all this data and provide strong insights to improve yield. Proximity Sensing and Remote Sensing are two technologies which are primarily used for intelligent data fusion. One use case of this high-resolution data is Soil Testing. While remote sensing requires sensors to be built into airborne or satellite systems, proximity sensing requires sensors in contact with soil or at a very close range. This helps in soil characterization based on the soil below the surface in a particular place. Hardware solutions like Rowbot (pertaining to corns) are already pairing data-collecting software with robotics to prepare the best fertilizer for growing of corns in addition to other activities to maximize output.
4	**Smart farming combining AI, cloud machine learning, satellite imagery and advanced analytics**	Microsoft is currently working with farmers from Andhra Pradesh to provide advisory services using Cortana Intelligence Suite including Machine Learning and Power BI. The pilot project uses an AI sowing app to recommend sowing date, land preparation, soil test-based fertilization, farm yard manure application, seed treatment, optimum sowing depth and more to farmers which has resulted in 30% increase in average crop yield per hectare.

		Technology can also be used to identify optimal sowing period, historic climate data, real time Moisture Adequacy Data (MAI) from daily rainfall and soil moisture to build predictability and provide inputs to farmers on ideal sowing time. To identify potential pest attacks, Microsoft in collaboration with United Phosphorus Limited is building a Pest Risk Prediction API that leverages AI and machine learning to indicate in advance, the risk of pest attack. Based on the weather condition and crop growth stage, pest attacks are predicted as High, Medium or Low.
5	**Data Analytics and AI**	Based on multiple parameters like soil condition, weather forecast, type of seeds, infestation in a certain area and so on, cognitive solutions make recommendations to farmers on the best choice of crops and hybrid seeds. The recommendation can be further personalized based on the farm's requirement, local conditions, and data about successful farming in the past. External factors like marketplace trends, prices or consumer needs may also be factored into enable farmers take a well-informed decision.
6	**Precision Irrigation**	In terms of human intensive processes in farming, irrigation is one such intervention. Machines trained on historical weather pattern, soil quality and kind of crops to be grown, can automate irrigation and increase overall yield. With close to 70% of the world's fresh water

		being used in irrigation, automation can help farmers better manage their water problems.
7	**Autonomous, robotic vehicles**	Developed for mechanical weeding, application of fertilizer, or harvesting of fruits using unmanned aerial vehicles with autonomous flight control.
8	**Livestock management using Machine Learning**	Machine learning is being extensively used for animal welfare activities dealing with the health and wellbeing of animals. One of the main application being monitoring animal behaviour for the early detection of diseases. Similarly, livestock production deals with issues in the production system, where the main scope of ML applications is the accurate estimation of economic balances for the producers based on production line monitoring (e.g. prediction of the rumen fermentation pattern from milk fatty acids early detection and warning of problems in the commercial production of eggs).

2.2 Rationale

While substantial literature and research seems to have gone into the role of emerging technologies and their application in different sectors, there are certain gaps with regard to analyzing the scope of ET in specific sectors in India and the policy eco-system to facilitate their adoption in the domain of agriculture in India. In short, the prospects of further research in the following areas need to be pursued to have a clear understanding of the way in which it could be leveraged in India.

1) The ET applications have largely been in the private sector. Government needs to lay down policy framework, re-orient education policy to leverage the emerging technologies and create an enabling eco-system to allow private sector to play a meaningful role.

2) The scope of application of emerging technologies is much higher and only a few applications have been hitherto commercialized. The acceleration of this process needs to be enabled through suitable policy modifications and interventions.

3) The scope of using emerging technologies in agriculture management in India, especially in the context of the 'doubling of farmers' income' target does not have adequate literature in view of the proximity of the event and due to absence of research works in this area.

The rationale for selecting this particular topic for the research study is to gauge the possibilities of emerging technologies making a positive contribution to the Indian Agriculture Management system and its potential in supplementing the doubling of farmers' income initiative.

2.3 Methodology

Research Design

The study had been undertaken in the exploratory mode employing both quantitative and qualitative research methods. Some amount of descriptive research too had been used to capture the background information on the gaps in utilization of emerging technologies in the agricultural sector of India. The primary survey would be done among the coffee growers under the aegis of Coffee Board based in Karnataka as they have been exposed to digital technologies (based on IVRS) for improving the farming practices. Since the use of emerging technologies like AI based data analytics, IoT based applications, etc. has been few and far between in India, the survey has been conducted among farmers using digital technologies on a slightly advanced platform provided by Precision Agriculture Development and Coffee Board which allows the farmers to get specific advisories/solutions depending on their unique requirements.The research had been grounded to the following pivotal research questions.

Research Questions

1. Whether India can leverage emerging technologies in agriculture sector to align with the government's goal of doubling the farmers' income by the year 2022?

2. Whether the existing policy framework of India is adequate to attend to the opportunities and challenges posed by the application of emerging technologies in governance with special reference to Agriculture sector?

3. What issues, are perceived by the farmers and technology firms, with regard to the adoption and use of ET as well as about the related policy provisions in India?

Methods and data sources

A combination of both primary and secondary research had been employed. Secondary research was based on review of academic literature available in journals, policy documents, academic reports published by related agencies including NITI Aayog, The World Bank, NABARD and respective government departments. Primary research had been conducted on the selected stakeholders including the benefactors of initiatives using emerging technologies (the Coffee Board farmers) as well as policy makers and the implementers of these initiatives. The types and sources of data can be summarized as follows (Table 2).

Table-2- Types and Sources of Data

Type	Remarks	Source
Secondary	Secondary data has been used to characterize the context, justify the need for the study, define the objectives and identify the study variables. Secondary data/information has also been used to partly address the first study objective.	Academic publications, related reports of the Government of India and State Governments, Industry associations (including CII, ASSOCHAM studies) and consulting firms (including PWC, BCG).
Primary	A structured questionnaire based on the identified study variables has been administered to coffee farmers and agri-tech startups to collect quantitative information and perceptions (through open ended questions)	a. Questionnaire-based surveys of Agri-tech startups b. Some personal interviews of sectoral experts Questionnaire-based surveys of farmers

Primary Survey: The primary data from the end-users had been collected using a pre-designed survey tool. Further, semi-structured interviews of agri-tech firms had been obtained through e-mail. As already indicated, two kinds of primary surveys had been undertaken. The first one constituted a survey of farmers – the ultimate benefactor of digital agriculture and the second one

concerned the agri-tech firms. Both quantitative and qualitative research tools had been employed to analyse the potential uptake of digital technologies in Indian agricultural context. There are several components to the research question factored in the current study (Table-3)

Table-3_Components of the Research Question

Research Question 1	**Research Question 2**
• Challenges in the Indian agricultural sector • Strategies for doubling of farmers' income, and role of ET • Best practices and impact along the value chain	• History of e-Governance and ET-based initiatives in India (to gauge the basic profile and the awareness level of the respondent) • Legislative / Regulatory framework • Collaborative initiatives by private and public sector within existing policy framework
Research Question 3	
ET firms' perspectives • Products and services being offered • Technologies being utilized, and their source • Target customers and sectors, geographies Drivers and Barriers to introduction of digital technologies – across products/sectors and geographies • Challenges in scaling up and/or replication • Current role of State / Central Government in influencing business activities • Expected regulatory/administrative easing by State / Central Government • Desired new facilitatory interventions by State/ Central Government • Modifications required in the guidelines/ processes / implementation mechanisms • Impact of new technologies on governance mechanisms	ET users' (farmers) perspectives • Source/s of information and decision making prior to adoption / use • Financial impact on farm incomes since adoption / use • Characteristics / outcomes of technology solution/s • Impact of the adopted / aware ICT solution on – • Agricultural extension and information services • Market regulation and access • Access to farm inputs such as irrigation, electricity • Price discovery and transparency in trading • Licensing/Approvals – cost, delays etc. • Corruption

• Role of state agriculture extension machinery/ KVKs • Capacity building, training and skill development of extension officers • Privacy and security of Farmers' data • Leveraging emerging technologies in order to assist in doubling of farmers' income	

Respondents' Profile–

i. Agri-tech startups: Startups which have been incubated (live and virtual) at the NASSCOM 10000 startups warehouse, Bangalore, and have been undertaking commercial activities in the area of digital technologies for agriculture, were selected as respondents. The warehouse was launched in April 2013 by NASSCOM to scale up the startup ecosystem in India, with the objective of enabling incubation, funding, and support for 10,000 technology startups in India by the year 2023. The warehouse implements four programmes – incubate, virtual incubate, NASSCOM Industry Partnership Program (NIPP) and Integrate (Global Acceleration).

ii. Farmers: Farmers across the primary coffee growing states of Karnataka, Tamil Nadu and Kerala were selected as respondents. Coffee Board has launched a series of ICT interventions to share relevant advisories, enable pest and disease identification and forecasting, and facilitate product trading (with a transparent and robust price discovery mechanism). The Blockchain-based intervention by Coffee Board has also been noted in the Economic Survey 2019 (Ministry of Finance, Govt. of India). The first ICT-based intervention of the Board is Coffee Krishi Taranga (CKT, launched in September 2018), which is an interactive voice-over internet protocol (VoIP) IVRS facility that is being implemented in partnership with Precision Agriculture for Development, a multinational developmental organization whose work in Randomized Controlled Trials has been acknowledged globally. Thereby, some farmers out of a total numbering about 15000, who had registered under the CKT, were the targeted respondents for this survey. However, it was also attempted to identify the other digital technologies, if any, that were used by these farmers. (The sample respondent's profile is given at **Annexure—I).**

Sampling plan

The main target respondents of the primary survey were the farmers. It was important to evaluate their perceptions regarding the adoption of benefits of IVRS system- which is a digital application responding to farmers' requirement to get specific expert advice on crop management, fertilizer management, issuing advisories on stem borer and berry borer after examining the digitally uploaded photographs and giving information on price trends. The sample constituted farmers of an export-oriented agri-commodity sector, coffee, which were hence chosen because of researcher's easier access to Coffee Board extension officers and through them, to the coffee growers.

For the second survey, interview techniques had been used on agri-tech firms A web-analytic tool (Google Form) had been used to gather data from select agri-tech firms using a pre-designed structured tool.

Because of the constraint of time as well as widely dispersed areas in which pilots using emerging technologies like AI, IoT have been used in India, the survey could not be taken up in those specific areas. Similarly, interaction with sector experts and policy makers could not be carried out because of paucity of time as well as outbreak of Covid 19 which restricted the movement of people within the country.

The sampling plan included individual farmers who were already using some digital applications of the Coffee Board as well as agri-tech service providers who had also been requested to respond to a questionnaire (Table 4).

Table-4- Sampling Plan

Respondents	Sampling unit	Sample size	Sampling method	Remarks
Farmers	Individual farmers who are using ICT solution (Coffee Krishi Taranga) of the Coffee Board (Ministry of Commerce, GoI)	80		Questionnaires were administered in Karnataka which produces about 70% of India's coffee. The farmers were selected on a convenience (purposive) based method considering their previously stated willingness to participate in surveys.
Agri-tech startups	Agri-tech startups incubated at NASSCOM 10000 startups warehouse, Bangalore.	4	Purposive	Questionnaires were emailed to about 15 agri-tech firms, and responses sought. Also, one agri-tech firm which is not legally a startup but has been offering agri-tech for just about two years now has been included as a respondent.

The data, hence collected of (farmers) had been validated with some of the agri-tech firms using structured questionnaire and discussion method.

Considering time and resource constraints a more exhaustive coverage of tech service provider and doing a focus group discussion with agri-tech firms, sector experts and policy makers could not be organized.

The relevance of emerging technologies in agricultural governance, based on the interviews and on the basis of the researcher's experience, exploratory and descriptive research has been analyzed using graphical method.

CHAPTER-3

EMERGING TECHNOLOGIES IN THE INDIAN CONTEXT

3.1.Challenges in the Indian Agricultural Sector

India is one of the leading contributors to the global food basket. As per Agricultural Statistics at a Glance of the DAC & FW,[xlix] the country's food grain production stood at 252.23 million tonnes in 2015–16 and had a record production of 285.21 million tonnes in 2018–19and is likely to have higher production at 291.95 million tonnes in 2019-20. India's horticulture output—comprising fruits and vegetables, floriculture, honey, plantation crops, medicinal plants, and spices—was around 283.4 million tonnes in 2015–16 and it reached 314.87 million tonnes in 2018-19. Thus, the horticulture production has surpassed food grains production making India the second largest fruit and vegetable producer in the world. India is also the world's largest producer of milk (155.5 million tonnes in 2015–16 and 187.7 million tonnes in 2018-19) and second largest producer of sugar, and the leading country in coconut production..[l]

The concerted focus of agricultural scientists on ensuring food security triggered the green revolution in the 1970s tripling the Indian food grains output during the last five decades and converting India from being a food-scarce nation to a food-surplus nation exporting a large variety of agricultural and processed products. The Indian Agriculture sector and rural economy, with its vast workforce, plays a significant role in ensuring food security and in providing livelihoods and supporting the growth of the country's industrial and service sectors. The farm sector in India provides livelihood to about 50% of the country's workforce and the Agriculture, Forestry & Fishing sector contributes about 14% to India's Gross Value added (GVA, at 2011-12 prices). However, in the recent past, notwithstanding the significant achievements and the country's

emergence as the fifth largest economy (in terms of nominal GDP), the share of the farm sector in India's GVA has seen a decline from 17.8% in 2012-13 to 14.4% (at constant prices) in 2018-19. The primary sector growth rate has seen an increase from 1.5% to 2.9% during the same period although the 'crops' subsector declined and other sub sectors like animal husbandry, pisciculture(the controlled breeding and rearing of fish) and many more, etc. saw a greater share in the GVA[1] growth rate. With the decline in private investment in this sector, the gross capital formation also recorded a reduction from 16.5% to 15.2% of GVA. The scenario of low growth and investments has moved in conjunction with greater fragmentation of land holding and increasing share of marginal farm holdings (less than 1hectare) which has increased from 62.9% of operational land holdings in the year 2000-01 to 68.5% in 2015-16.[li]

To respond successfully to the growing food demand both domestically and globally, India is expected to produce more with higher levels of resource use efficiency. The food production would have to diversify to take care of the changing food habits. In the wake of concerns that intensive farming could adversely impact environmental balance, India will need to adopt sustainable farming practices that include employing efficient irrigation methods with a simultaneous focus on groundwater regeneration, monitoring soil degradation, and adopting energy-efficient production methods. The challenge of adopting sustainable farming practices also will have to be seen in the background of yields of major crops being low in India compared with those in other countries. For instance, the rice yield in India is 2.6 tonnes per hectare—far lower than the 4.7tonnes/ha in China, 3.7 tonnes/ha in Brazil, 5.9 tonnes/ha in the United States of America (USA), or 9.5 tonnes/ha in Australia; that of wheat is 3.0 tonnes per hectare in India, 5.3 tonnes/ha in China, and 3.1 tonnes/ha in the USA; and the maize and soybean yields are 2.5 tonnes/ha and

[1]measure of the value of goods and services produced in an area, industry or sector of an economy

0.75 tonnes per hectare in India compared with 5.9 tonnes/ha and 1.8 tonnes/ha, respectively, in China.[lii]

Thus, a farming system based on predominantly marginal holdings and lower investments has the potential to decelerate India's transition towards an inclusive, food-secure and fast growing economy. The situation gets further aggravated with the country's inflating population growth of 1.4% per annum. Therefore, India's agricultural production would have to accelerate its momentum posing a bigger challenge to its agriculture system.

3.2 Doubling of Farmers' Income and role of Digital Tech-based ET

In the past, India's agricultural development strategy had focused on raising agricultural productivity and improving farm security and had been successful in achieving significant outcomes. However, farmers' income and how it could be augmented was not the focus of earlier strategies (NITI Aayog, 2017)[liii]. Recognizing this lacuna in India's agricultural development strategy and the role of farm incomes in the country's development, the Honorable Prime Minister of India, in February 2016, expounded his vision of doubling farmers' incomes by the year 2022. The strategy to achieving the Prime Minister's vision incorporates a series of farm and non-farm interventions guided by the seven point agenda of increasing farm production, effective use of inputs, reduction of post-harvest losses, value addition, reforms in agricultural marketing, risk, security & assistance, and renewed focus on allied activities (such as livestock, agro-forestry etc.). Further, the Committee on Doubling Farmers' Income (DFI) has defined five primary concerns: optimal monetization of farmers' produce, sustainability of production, improved resource use efficiency, re-strengthening of extension, and knowledge based services and risk management.[liv]

The inter-ministerial 'Committee on Doubling of Farmers' Income'(2016)[2]has already recognized the requirement of focusing on science, technology and their impact on agriculture. The activities of agri-tech startups have also been supported by a few technology incubators in India who are encouraging innovation in agriculture. Examples of such public-funded incubators are the agri-business incubation platform of ICRISAT, and a-IDEA (Association for Innovation Development of Entrepreneurship in Agriculture), hosted by ICAR-National Academy of Agricultural Research Management, Hyderabad (ICAR-NAARM) & Department of Science & Technology, Govt. of India (DST, GOI). Indigram Labs Foundation, founded in 2015 with assistance from the Department of Science and Technology, Govt. of India, is an example of a not-for-profit private incubator that supports agri startups. The NASSCOM warehouse in Bangalore also incubates a number of agri-tech startups who have been developing products that align with the principles of precision agriculture.

Considering the aforementioned scenario, Gulati, Kapoor and Bouton (2019)[lv] are of the opinion that reforms in four areas should be the priority if Prime Minister Modi's bold goal of doubling farmer incomes is to be accomplished in the coming years. As per the study, the four main goals are:-

"First, the focus of agricultural policies must shift from production per se to farmers' livelihoods.

Second, policies to improve the allocation and efficiency of land and water are essential if the critical resources of water and land are to be conserved.

[2]https://pib.gov.in/Pressreleaseshare.aspx?PRID=1576232

Third, reforms are needed to help farmers cope with the growing risks of weather and price volatility.

Fourth, agricultural markets must be opened to greater competition and provided with better infrastructure if farmers are to realize better returns for produce while ensuring nutritional security for low-income consumers."

Examining the growth trends and the major areas of concern in the Indian agricultural sector, the Economic Survey 2018-19, while emphasizing the relevance of resource efficiency in the sector's growth, observes that adoption of ICT in agriculture will promote market access, facilitate financial inclusion and contribute significantly to early warning signals, while also improving resource use efficiency among small and marginal farmers.[lvi] Also, effective input management (through precision farming), and Research & Development, and Information and Communication Technologies (ICT) are recognized by the Economic Survey 2018-19 as three key categories of the strategy to achieve doubling of farmers' income.

Further, it is reiterated that an increase in farmers' incomes would be enabled by empowerment of the entire agri-supply chain through the deployment of ICT, so as to facilitate the public sharing of data related to production, pests, weather, transport, markets, etc., and to allow farmers to make information-based and reasoned decisions in response to changed dynamics. Deichmann et al (2016) endorse this view by observing that digital technologies can support the growth of developing country agriculture by facilitating market transparency, enhancing on-farm productivity (Precision farming and Agricultural extension), and by enabling efficient logistics (agricultural supply chain management).[lvii] The significant potential for ICTs to create a new paradigm of e-agriculture has also been amply reflected in FAO (2007) which observes that e-

Agriculture (application of ICTs in 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.

3.3 Role of Emerging Technologies in Agriculture Sector

3.3.a. Learning from the Best practices

Agricultural production in the world tripled between 1960 and 2015 as the world's population grew from 3 billion people to 7.7 billion. By 2050, it is estimated that the world will have to feed an additional 1.5billion population. While technology has played a role in the form of innovations in pesticides, seed, fertilizers, irrigations and machines, a large part of this achievement could also be attributed to the ability to expand more cultivable land—cutting forests and diverting fresh water to fields, orchards, and rice fields. However, the ability to expand cultivable land is reaching a tipping point and factors such as climate change, population growth and food security concerns have propelled the industry into seeking more innovative approaches to protecting and improving crop yield. As a result, different forms of emerging technologies are steadily emerging as part of the agriculture industry's technological evolution. Several prominent startups using ET in agriculture in different parts of the world were noticed, some of which have been provided in this study too (**Annexure-II) .**

According to Gayle Sheppard, Vice President and General Manager, Intel @ AI *"The industry will be transformed by data science and artificial intelligence. Farmers will have the tools to get the most from every acre."*[lviii]

Despite the fact that India is one of the largest sourcing destination for IT industry, the emergence of farm technologies integrated with a robust information and communication technology (ICT)

framework is still evolving in India. It is commonly recognized that it holds tremendous potential to both positively impact agricultural performance and enhance farmers' income. In the past, Indian agriculture faced a formidable challenge to grow more food, but it faces an even more difficult challenge today and for the future: to grow more sustainably and inclusively. Major challenges confronting Indian agriculture include increasing land fragmentation, declining total productivity, diminishing and degrading natural resources (including depleting ground water), a rapidly growing demand for food (not just for quantity but also for quality), stagnating farm incomes, and unprecedented climate change. It has been established that technology adoption modernizes farmers' production practices and leads to uniform annual returns for farmers, reduced risk of crop failure, and increased yields. The growth of competitive markets and consumer choice for consistent food quality is making the adoption of such tech-based solutions a necessity for the Indian farmer. Much of the scope for application and innovation remains to be exploited. The application of digital technology in agriculture has been instrumental in promoting data generation as well as the advanced analytics that allow farmers to make smart decisions about farming and to benefit from an economical use of inputs and labour. There are several interesting instances of pilots in Indian agricultural context, some of which have been presented subsequently (section 3.6). Extensive review of literature coupled with the researcher's experience lead the study to an understanding that digital technologies may be primarily employed at three different stages of agricultural processes:

(a) Pre-harvest stage: At the pre-harvest stage, digital technologies can recommend crop and input selection and assist in obtaining credit and insurance. Based on analytics of weather pattern, it can recommend the ideal sowing period. The products and services offered by IoT systems at the pre-harvest stage also include soil moisture probes, VRI optimization, and so on. VRI

(Variable Rate Irrigation) optimization is a process that maximizes the profitability on irrigated crop fields with soil variability, thereby improving yields and increasing water use efficiency and this allows the farmer to make a cost-benefit analysis even before he takes a decision to plant a particular crop.

(b) On-farm stage: At the on-farm stage, there is a need for weather advisories and disease- and pest-related assistance. Therefore, at this stage, AI based emerging technologies including Drone-based imaging can help to conduct real time analysis of in-depth field situation, crop monitoring, scanning of fields and so on. Advanced vision technology using hyperspectral images, IoT and agriculture data captured from drone can also be combined to ensure rapid actions by farmers. Feeds from drone images can generate alerts in real time to accelerate precision farming. Private companies such as *Aerialtronics* have implemented IBM Watson,[3] IoT Platform and the Visual Recognition application program interface (APIs) in commercial drones for image analysis in real time. Remote sensing techniques along with hyper spectral imaging and 3D laser scanning are essential to build crop metrics across thousands of acres. It has the potential to bring in a revolutionary change in terms of how farmlands are monitored by farmers both from time and effort perspectives. This technology can also be used to monitor crops along their entire lifecycle including report generation in case of anomalies.

(c) Post-harvest stage: At the post-harvest stage, real-time data on both domestic and export markets can be generated, collated and analytical reports could be used for predictive decision making. With the help of IoT devices and AI technology, blockchain can track and process information related to food items right from their source to the end consumer. This level of traceability is likely to increase the trust of customers and enhancing the

[3]Watson is IBM's suite of enterprise-ready AI services, applications, and tooling.

transparency/credibility of the whole supply chain in the long run. This has the potential to connect the farmers with different levels of stakeholders in the supply chain for marketing of their produce.

3.3 (b) ET and Agriculture Academics in India:

For any digital initiative to succeed, a strong academic foundation is a pre-requisite. While India has established itself as a major source for IT manpower in the world, the use of digital technologies in agriculture and the related syllabi framework of agricultural universities have not kept pace with the industry trends cited in other sectors such as health , manufacturing and so on. The present academic framework for agriculture can be conceptually delineated as below:

It was in the year 1905 that the Indian Agricultural Research Institute, Pusa, Delhi, had been established. It was subsequent to this that India saw the development of an extensive network of Central and State institutions, including State Universities, that impart agricultural education and training. India now boasts of the Department of Agricultural Research and Education (DARE), a department of the Ministry of Agriculture and Farmers Welfare which coordinates and promotes agricultural research & education in the country through its academic arm of Indian Council of Agricultural Research (ICAR) and three central agricultural universities. DARE, through ICAR, guides and manages agriculture (including horticulture, fisheries and animal sciences) research and education through an extensive network of sixty three state agricultural universities, three central agricultural universities, four deemed universities and four central universities with agriculture faculty, along with several ICAR institutes, National Research Centers, project directorates, and all India coordinated research projects spread across the country. ICAR's Directorate of Knowledge Management in Agriculture aims to promote ICT driven information

dissemination systems for quick, effectual and cost-effective delivery of messages to all stakeholders in the Indian agriculture sector.

ICAR also periodically appoints Deans' Committees, which, in consultation and deliberations with all stakeholders, make recommendations on updating academic norms and standards towards meeting the challenges and opportunities in the agriculture and allied sectors. The 5th Deans committee (ICAR, 2017) had clearly identified six common courses related to climate smart agriculture, agribusiness, marketing, and ICT to be included across agricultural sciences. The committee recommended that ICT and agri-informatics should be common academic courses that must be taught across all disciplines of agriculture, and that incubation centres should be created in research university campuses. The Committee also recently recommended a new course titled 'Geoinformatics, Nano-technology and Precision Farming' to be introduced at the undergraduate level.

The reference of government published literature affirmed that the public policy regime in India has been supportive of technology-led agricultural growth and has been trying to institutionalize ease access and affordability of technology adoption among farmers.The Information Technology Research Academy (ITRA), Hyderabad, set up by the Ministry of Electronics and Information Technology, in consultation with the Indian Council of Agricultural Research (ICAR), had long ago (in the year 2013) identified key research areas with respect to robotics, sensors, interpretation and use of sensor data.[lix]Since then, many more emerging technologies have been tried out in various states like Karnataka, Kerala, Andhra Pradesh, Gujrat, etc. albeit on a pilot scale, but this is a good indicator of technology adoption as well as innovation.

3.3. (c) Extension Mechanism in Indian Agriculture

The DAC & FW of Government of India supports extension activities carried out by the state agricultural machinery through National Mission on Agricultural Extension and Technology (NMAET) – Sub-Mission on Agriculture Extension (SMAE). The following four components are being implemented as part of this sub-mission:

i. Support to State Extension Programmes for Extension Reforms:

- ✓ Under implementation in 652 districts of 29 states & 3 UTs of the country.
- ✓ Promotes decentralized farmer-driven and farmer-accountable extension system through an institutional arrangement for technology dissemination in the form of an Agricultural Technology Management Agency (ATMA) at district level.

ii. Agri-Clinic and Agri-Business Centres:

- ✓ Two months' training is imparted to eligible selected candidates through Nodal Training Institutes identified across the country.

iii. Kisan Call Centres (KCCs):

- ✓ Provides agriculture related information through toll free telephone lines.
- ✓ A countrywide common eleven digit number 1800-180-1551 has been allotted for Kisan Call Centre. The number is accessible through all mobile phones and landlines of all telecom networks including private service providers. Replies to the farmer's queries are given in 22 local languages.
- ✓ Calls are attended from 6.00 AM to 10.00 PM on all seven days of the week.

iv. Information and Communication Technology (ICT) Interventions:

- ✓ DAC has developed 80 portals, applications and websites covering both the headquarters and its field offices/directorates.
- ✓ The important portals include SEEDNET, DACNET, AGMARKNET, RKVY, ATMA, NHM, INTRADAC, NFSM and APY.
- ✓ A Farmers' Portal has been developed to provide advisories to farmers under different subject matter areas up to block level after integrating large number of websites across the country. A SMS portal has also been under operation since July, 2013 providing SMS based advisories to farmers as per their priority.

3.4 Growth of e-Governance and the Related Regulatory Framework in India

The notion of 'e-Government' evolved into 'e-Governance' to denote the transition from use of digital technologies for various types of service delivery to using digital technologies with higher citizen centricity and higher participation of citizens. The aim of e-governance was to empower information and service delivery, encourage citizen participation in decision making and make Government more accountable, transparent and responsive.

The financial crisis in the year 1991 led India to adopt liberalisation, privatisation and globalisation to catapult its economy from an abyss. The series of economic reforms adopted by the Government of India paved the way for bringing in private sector professionalism and expertise into the governance structure and ICTs emerged as an important policy priority. The use of digital technologies to facilitate citizens and ensure service delivery was started on a big scale by the Indian Railways in the 1990s. Online railway reservation system (irctc.co.in) became one of the prominent initiatives. In many other government Ministries and Departments, use of digital technology for internal automation as well as for public service delivery was initiated.

In the year 2000, Indian government enacted the 'Information Technology Act, 2000' that accorded 'legal sanctity to all electronic records and activities carried out by electronic means'; gave 'legal recognition to the digital signatures'. This Act prescribed punishment for hacking by recognizing it as a cybercrime.

In the year 2006, the Government of India announced National e-Governance Plan, referred to as NeGP. It comprised of twenty-seven Mission Mode Projects (MMPs-Passports, Land records, e-courts, e-procurement, etc.) and eight components to "make all Government services accessible to the common man in his locality, through common service delivery outlets and ensure efficiency, transparency and reliability of such services at affordable costs to realize the basic needs of the common man".

In the year 2013, Government of India announced "GI Cloud" christened *'Meghraj'*. It was rolled out to utilise and harness the benefits of Cloud Computing in governance domain. In the same year, Mobile Seva (the national mobile-Governance initiative) was started with an intention to provide an integrated platform for all Government departments and agencies for delivery of public services to citizens and businesses over mobile devices.

In the year 2014, an Indian citizen engagement platform called 'Mygov.in' was established. Further, in the year 2015, e-*Kranti:* National e-Governance Plan version 2.0, was initiated with the vision of "Transforming e-Governance for Transforming Governance" and had 44 Mission Mode Projects (MMPs) that were to be implemented with substantially revised models of service delivery.

In the year 2014, the Government of India announced its umbrella programme called Digital India and launched it in the year 2015 with an aim to "transform India into a digitally empowered society

and knowledge economy" for deriving economic, social, and environmental benefits from digital technologies.

Evidently, digital technologies and its applications in public sector in India received a fillip with the establishment of the Ministry of Electronics and Information Technology (MeitY) in the year 1999. This was simultaneously followed by the formulation of the National Telecommunication Policy, NTP 1999 and the Information Technology Act, 2000 as well as by its subsequent amendments in the year 2008. The amendments in the IT Act 2000 were made to make provisions for - enabling central government to issue rules from time to time with regard to electronic signature; stringent provisions on Data Protection and Privacy; provision of stringent punishment to address child pornography, etc.

In the year 2012, 'the National Policy on IT' was approved to encourage adoption of ICTs; to create a pool of ten million additional ICT skilled manpower, and several IT focused national goals. Recognizing the huge scope of Internet of Things (IOT) applications in governance, Government of India released its "IoT Policy" in the year 2015 to develop connected, secure and smart IoT based system for the country's economy, society, environment and global needs. Government of India's policy think tank, NITI Aayog, had been mandated in the year 2018 to establish the R&D- based national program on AI for establishing Center of Research Excellence (CORE) that would focus on pushing technology frontiers through new knowledge creation and to establish International Centers of Transformational AI (ICTAIs)[lx]. This initiative focuses on the development and deployment of application-based research in collaboration with the private sector for AI based solutions for key sectors including agriculture. Also, in the year 2018, Government of India announced its National Digital Communications Policy (NDCP, 2018). This policy aims to create a roadmap for the emerging technologies in areas like IoT and AI to improving the

sector's efficiency and economic benefits. It has set futuristic goals and undertaken crucial policy initiatives to address the problem of communications and access of digital services and it will lead India towards a vibrant digital economy. In addition, the Government of India has been proactive in bringing out policy documents/roadmaps for Internet of Things (2016), AI for all (2018), Strategies for Blockchain Technologies (2019), etc.

Digital Stack in India: In computing, a stack is a data structure used to store a collection of objects. Individual items can be added and stored in a stack using a push operation. Objects can be retrieved using a pop operation, which removes an item from the stack. At present, we have several IT enabled public sector applications which run independently and on different platforms. However, to bring better synergy and output, a compound matrix of multiple technology stacks is the need of the hour. 'Digital stack' helps to converge various applications offered to the citizens at different point of time and put all applications available on a single platform, accessible through APIs. At the bottom of the stack, non-differentiating technologies such as infrastructure, platform, and standard software packages are now often sourced from external service providers, reducing costs while improving security, stability and uptime. At the top of the stack are highly specific and differentiating product and service technologies that give companies access to innovation, agility to accelerate market reach, and flexibility to enable customization including application of emerging technologies, such as robotics and Artificial Intelligence, the Internet of Things, and advanced analytic solutions. The data for the stack is added by related agencies as well as collected real time from the source itself (citizens/ end users). Public sector in India has already realized the relevance of creation of new, richer citizen experiences by building up digital stack that would ensure efficient, low-cost speed to scale public service delivery mechanisms. India Stack

(indiastack.org) is already a unified software platform developed by GoI to smoothen public service delivery (Fig 3.1).

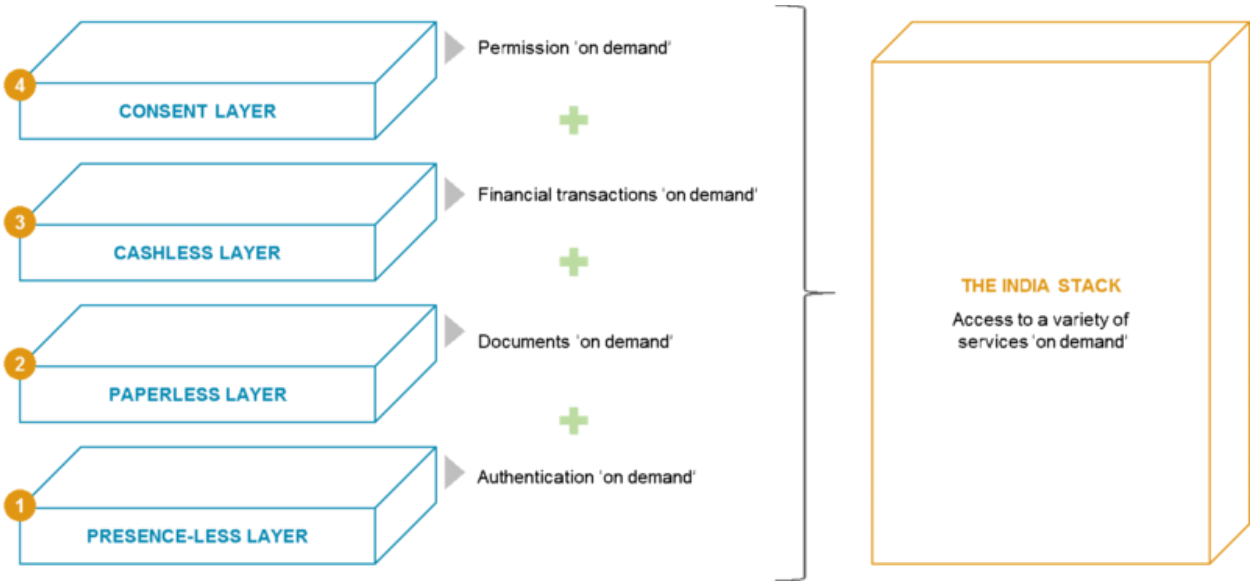

Fig 3.1 India stack/ Aadhar stack

The base layer of India stack is ‘presence-less layer’ that has been implemented through unique digital biometric identity of Aadhar owned by Unique Identification Authority of India (UIDAI). The second layer is ‘paperless layer’ that provides e-documentation through implementation of Digi-locker and e-Sign for signing the documents digitally implemented by Ministry of Electronics and IT (MeitY) as well as e- know-your-customer provided through Aadhar e-KYC. The third layer is the ‘cashless layer’ that offers digital payments through implementation of digital facilities of IMPS , AEPS, APB, Unified Payments Interface (UPI) owned by National Payments Corporation of India (NPCI). The last layer is ‘consent layer’ that serves as a modern privacy data sharing framework that operates through open personal data store, owned by Reserve Bank of India. IndiaStack offers a set of APIs that allows a user in India (governments, businesses, startups, and developers) to utilise this digital Infrastructure for their respective verticals. All service

providers including banks, healthcare providers, non-profit organizations and others can use this stack, also popularly known as Aadhar stack, to build value-added services to benefit the end consumers using open application programming interface (APIs).

In the Indian governance context, the digital stack would look like the following:

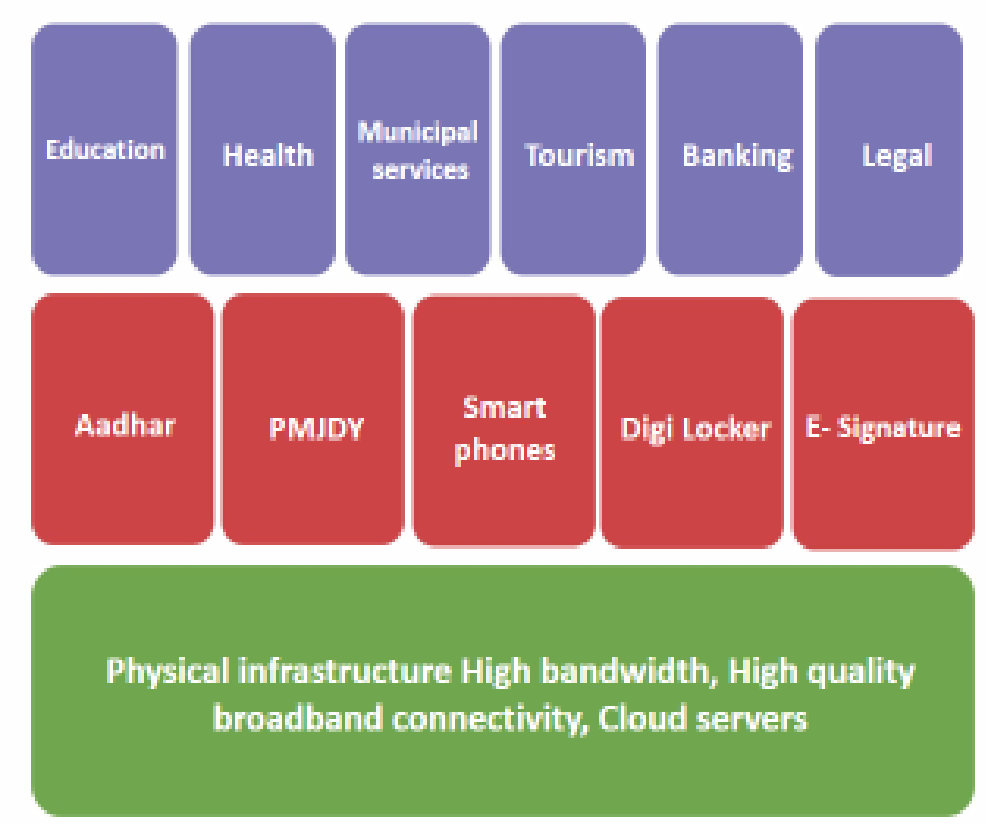

Figure 3.2 BCG model of Indian Digital stack

Source: Boston Consulting Group, India

According to research from MIT, an effective digital foundation has three key elements.[lxi]

An operational backbone:

Modular architecture ensures secure and stable operations, supports seamless end to end transaction processing, accesses "a single source of truth," and automates repetitive business processes.

A Digital Services Platform:

This provides access to business and technology services, facilitates data analysis, is accessible to external and internal partners, and leverages the cloud and open source software.

Digital Linkages:

These link the operational backbone with the digital services platform so that digital services can access customer and product master data and transaction processing systems.

As the foregoing literature suggests, the e-governance initiatives in India will have to be developed on a modular architecture which makes them amenable to be used in an integrated platform where digital linkages can be easily established.

3.5 e-Governance Initiatives in Agriculture in India:

Though all these e-governance initiatives and the related regulatory instruments of India (section 3.4) did not explicitly make a reference to 'smart farming' or 'digital agriculture (agri-tech)', but the roadmap envisioned for national digital framework did lay down the foundation for a robust digital agriculture ecosystem too.These policies / IT Act together helped to remove any legal or bureaucratic obstacles to the scalability of innovations using emerging technologies when they would eventually appear just a few years later in the agriculture sector.

Propelled by a conducive digital ecosystem and emulating best practices from other sector-based digital advents, the Department of Agriculture, Cooperation and Farmers' Welfare (DACFW) also

launched in early 2000s, several digital initiatives in agriculture sector including later additions like mKisan, e-NAM, some of which are enumerated here. In July 2013, mKisan portal was launched for farmers by Department of Agriculture Cooperation and Farmers' Welfare (DAC&FW) to enable all Central and State government organizations in agriculture and allied sectors to provide information/services/advisories to farmers by SMS. These services are contextualized as the farmer could opt to receive this information in choice of their language, agricultural practices and location. The portal also provides IVRS with callback facilities. Under the aegis of Digital India , e-National Agriculture Market (e-NAM), had been launched in the year 2016 as a pan-India electronic trading portal that networks the existing APMC (Agriculture Produce Marketing Committee) *mandis* (the local market place where the buyers and sellers congregate)to create a unified national market for agricultural commodities. e-NAM portal enables farmers to obtain a remunerative price for their produce through a transparent mechanism. This portal has been complemented with a mobile –app, *Kisan Suvidha,* which is deemed as India's first mobile application to bring APMCs, farmers and agents on one platform. The app enables farmers and commodity merchants to see, on their mobile phones, the proceeds of live auctions of any commodity and APMC, price variations- maximum, minimum and average price of any commodity for any day/ month/ year.

The *Kisan Suvidha* mobile application also facilitates dissemination of information to farmers on critical parameters including weather, market prices, plant protection, input dealers (Seed, Pesticide, Fertilizer),farm machinery, extreme weather alerts; soil health card, cold storages & godowns, veterinary centres and diagnostic labs apart from market related information such as prevailing market prices and quantity demanded in the market. There have also been several initiatives of autonomous bodies of the Government of India; for instance, Coffee Board has

launched an initiative on 'Precision Agriculture for Development' and 'a Blockchain initiative,'[lxii] State governments too have taken some strides such as '*Rashtriya* e-Market Services Private Limited' by the Government of Karnataka, and e-*Rythu* in Andhra Pradesh[4] and many more. On similar lines, the private sector (and start-ups) too hastaken considerable strides in digital agriculture of India.

3.6 Collaborative Public-Private Digital Initiatives in Indian agriculture

The digital agriculture ecosystem in India has been bolstered by several collaborative initiatives (public-private) too, for instance, in January 2018, Indian Council of Agricultural Research (ICAR), had collaborated with Tata Consultancy Services (TCS) to launch a national initiative that offers Krishi Vigyan Kendra (KVK)-based digital agricultural extension services. It proved to be a harmonious collaboration where ICAR provides technical inputs and related agriculture advisory through its KVK network and TCS provides its digital platform *mKRISHI* for two-way interactive digital extension services to the farmers.

Indeed, the growing penetration of mobile phones in rural regions of India is driving the development of several mobile based applications by government departments, entrepreneurs, and the private sector.[lxiii]In another example of a public-private partnership in June 2019, the Kerala State IT Mission (KSITM) partnered with Cisco to develop an Agri-Digital Infrastructure (ADI) Platform and set up Village Knowledge Centers (VKCs) for knowledge delivery and provide access to e-learning and advisory services to the farming and fishing communities in Kannur

[4]**Rythu bazaar**, or **raithu bazaar**, is a type of farmers' market in Indian states of Andhra Pradesh and Telangana to facilitate direct marketing between consumers and farmers. It is run by the Governments of Andhra Pradesh and Telangana for small scale farmers with small landholdings. The first market started in January 1999 by N. Chandrababu Naidu. 'Raithu' in local language (Telgu) translates to 'farmer' in English.

district of the State. The Cisco ADI Platform uses IoT sensors, Non-IoT databases, Satellite/UAV images to gather and relay real-time intelligence on soil content, moisture, weather conditions and other parameters.[lxiv]

In July 2019, the Ministry of Agriculture, Cooperation and Farmers Welfare partnered with IBM to deploy the Watson platform that utilizes Artificial Intelligence (AI) and weather technology solutions to provide weather forecast and soil moisture information to help farmers in three districts to take decisions regarding water and crop management for better production and productivity. As an additional, competitive initiative, the Ministry of Agriculture and Invest India have, since 2017, been organizing the Agriculture Grand Challenge which provides opportunities for Agri-tech start-ups to solve some key challenges which are being faced by the Agriculture sector in India. In collaboration with Coffee Board of India, Precision Agriculture Development (PAD),[lxv] a non-profit company founded by Nobel laureate and Harvard economist Michael Kremer, is advising on the design and roll out of an IVRS service for coffee farmers in the state of Karnataka to support the routine FAQs of the 350,000 coffee farmers across all major coffee growing states in India (details at Para 4.1). In another instance, this non-profit organization, PAD is also advising, Government of Odisha's Department of Agriculture and Farmers' Empowerment, on the design and roll out of an IVRS service for rice farmers across the state of Odisha with the ambition of reaching 1 million farmers. The service includes providing responses to mobile phone-based agricultural extension queries so as to help the farmer in adopting the appropriate farm management practices, and has assured yields, and hence increased incomes.

The agri-tech start-up ecosystem in India has been receiving renewed interest from investors, and an estimated 34 ventures received US$295 million in investments in 2016 in the country—the highest investment amount recorded in India in the past three years.

The most active geographies—those countries with the highest number of agriculture start-ups—remained consistent year-over-year, with the USA, India, Canada, the United Kingdom, Israel, and France remaining the top six by number of deals. Among the prominent ventures backed by large conglomerates in India is ITC's e-Choupal, a comprehensive digital knowledge hub for farmers, which has 6,100 installations covering over 35,000 villages and serving over 4 million farmers. Launched in the year 2000, this first-of-its kind initiative has not only benefited the farmers doing business through their network, but this model also led to a ripple effect on the public sector–managed food grain management systems that resulted in an up-gradation

A host of Indian technology startups and small businesses have been making attempts, with a considerable degree of success, to accelerate the country's transition towards precision / smart agriculture. The emerging technologies are being used in the agricultural domain in a host of areas, starting from decision support system regarding sowing of seeds to fertigation (precision irrigation combined with required fertilizers doses by taking into account the stress level in plants or in individual land parcels within the agricultural field). Many farmers managing large scale operations in Europe, US and Japan are trying to take advantage of innovative technologies like self-driving tractors that use GPS, satellite imagery and AI to plant seeds more efficiently, drones, sensors and machine learning to make smarter decision about irrigation, quantity of fertilizer and pesticide to be applied. Microsoft India's experimentation with 175 groundnut farmers in a pilot project in Andhra Pradesh used an AI sowing app which was developed based on 30 years of climate data that used sophisticated forecasting models powered by Azure AI to determine optimal timing of plantation, ideal sowing depth, manure to be applied, etc. The average increase in production in this pilot increased from 10 to 30%.

Mahindra & Mahindra (M&M), one of India's leading producers of tractors and farm equipment, is innovating alongside expanding its core business. M&M's Trringo, a mobile based app enabling farmers to rent tractors, is a unique example of leveraging technology to help farmers use machinery without having to make the large investment (US$7,500) of buying tractors.

The technology thrust of these ventures has been on reducing the time duration of crop cycles, saving on water and energy, reducing the usage of agro-chemicals, automating for efficient farm management, strengthening farmer market linkages, and improving cold chain logistics for higher value addition.

While feeding the world's growing population is a challenge which is to be met through increased productivity, there is also a need to curtail the food waste happening around the world. The Food and Agricultural Organization (FAO) estimate that 1/3rd of all food produced for human consumption – 1.3 billion tons – is wasted annually.[lxvi] Microsoft has taken up a pilot project in Girgarre, Australia, to handle 200 million litres of milk by using a state of the art information system to minimize the wastage. The system built on Microsoft Dynamics 365 and Azure Cognitive Services aims at automating the process of pumping milk from tanker trunks to silos – monitoring quality and creating a rich data trail so that the milk could be traced from the firm to the source. Microsoft has been exploring similar initiatives in the Indian context. Similarly, the use of ETs in the area of supply chain management and marketing is also widespread. Indeed, several prominent Indian tech-companies and startups have joined the bandwagon of providing tech-based solutions in agriculture value chain, some of which form a very interesting reading (Annexure-III).

CHAPTER-4

PRIMARY SURVEY: FINDINGS & OBSERVATIONS

This study has deployed mixed method approach to assess the role of digital technologies and ET in promoting agricultural development in India, and the learnings gleaned from the literature have been presented in the last two chapters. Taking cue from those learnings, this chapter analyses primary survey findings on use of digital technologies / ET in agriculture. And also presents the anticipated opportunities and challenges from the perspective of both the farmers and the agri-tech firms.

This chapter summarizes the overall findings of the study and presents frameworks for widespread use of ET in the country. This study has attempted to explore extant issues with respect to the policy environment, adoption and use of ETs by collecting perceptions / opinions of select agri-tech firms and farmers who have been utilizing an ET which meets the function of knowledge/information dissemination. Issues relating to the policy environment have been analyzed with a focus on the additional interventions that could be taken up by policymakers to address constraints/barriers to adoption and use of ETs.

4.1 Coffee Board of India - Background of the Initiative Being Surveyed

Founded in the year 1942, The Coffee Board of India is an autonomous organisation managed by the Ministry of Commerce and Industry of Government of India (GoI) to promote coffee production in India. With its head office in Bangalore, the Board comprises of 33 members including the Chairman, who is the Chief Executive and appointed by the Government of India. The remaining 32 members represent various interests such as coffee growing industry, coffee trade interests, curing establishments, interests of labour and consumers, representatives of

governments of the principal coffee growing states, and Members of Parliament (indiacoffee.org). Approximately, 200 extension workers of Coffee Board of India serve around 300,000 coffee growers across India. These extension workers are often overburdened and do not have the capacity to improve the quality and frequency of extension they provide to the coffee growers. This constraint of limited human resources particularly obstructs the livelihood / existence of smallholder farmers in particular given the fact that they face higher barriers to information. Therefore, easier and equitable access to actionable and timely information can help to improve the productivity for all coffee farmers, and also help to improve their livelihoods. This situation clearly creates a scope of implementing digital technologies (and other best practices too) to help revitalize the coffee industry, which is already sagging down in its overall coffee yields at a global levels; as per a non-academic source as of 2009, Indian coffee made up just 4.5% of the global production. (Coffee Board) and as per the academic source, referring to the global statistics of 2003-04 "India produces about 2.5 per cent of world's coffee on almost the same percentage of coffee plantations.[lxvii]

In a bid to sail over these concerns , the Coffee Board decided to leverage the promise of digital technologies and for doing so entered into a collaboration with 'Precision Agriculture for Development India Foundation' (PADIF). PADIF is a non-profit (Section 8) organization with a mission to support smallholder farmers in developing countries by providing customized agricultural information and services that is expected to increase productivity, profitability, and environmental sustainability. PADIF is pioneering an evidence-based model[lxviii]for agricultural extension and delivering farmers personalized agricultural advice on their mobile phones. PADIF implements this model in collaboration with partner organizations and gathers evidence on its impact. With active projects in Gujarat, Odisha and Karnataka, PADIF provides customized

advisory to farmers on their registered mobile phones. As part of Coffee Board's initiative to transform the industry using technological innovations, PADIF brought its expertise in digital extension to coffee growers in Karnataka with the goal of strengthening the existing extension machinery.

Precision Agriculture for Development India Foundation (PADIF) and Coffee Board of India collaborated on a pilot project to provide this mobile phone-based advisory to coffee farmers in two districts in Karnataka, India. The pilot leveraged PADIF's flagship two-way interactive voice response (IVR) service, Coffee *Krishi Taranga*, to provide customized, relevant and timely advice to coffee growers in Chikmagalur and Hassan districts. The target of this pilot project was to cover 15,000 coffee growers in Chikmagalur and Hassan district in Karnataka from July 2018 to March 2019.

Through this service, coffee growers received a weekly two-minute long voice message providing advice and recommendations based on the crop cycle ("outbound service"). Additionally, farmers could also give a missed call to access a toll-free helpline that would allow them to ask questions answered by coffee experts, listening to local and international price information, weekly advisory and access their own history of questions asked through the service ("inbound service"). The messages covered information on topics ranging from pest and disease management (for instance, white stem borer identification and control for arabica coffee and coffee berry borer control for Robusta coffee), fertilizer management (including lime application and post-monsoon fertilizer application), soil sampling and coffee estate management. On the inbound end, PADIF provided information across a variety of parameters for coffee. Among these, PADIF answered farmer queries across a variety of farming practices including irrigation management, coffee post-harvest practices, etc. PADIF, through its empanelled agronomists, provides daily updated price

information on farm practices and for both international and local coffee markets. In case of routine queries, the agronomist provided by PAD responds to the query, but in case of more specific or complex issues, the Agronomist consults the scientists of Coffee Board and provides a customized reply. Once farmers are profiled and registered on the service, they are also trained on how to use this service. This training is done either in person or over phone, by PADIF or Coffee Board staff with the goal of ensuring farmers understand all the benefits of this service.

The Reported Usage Patterns of CKT **:** As per the information available from secondary sources **(**Coffee Krishi Taranga, PAD-Coffee Board Pilot Report, February 2019), approximately 15000 farmers in the pilot districts of Chickmaglur and Kodagu of Karnataka were reported to be the active users of the service out of total 43588 farmers in these districts during that period.[lxix] 64% of these total 15000 user farmers were profiled as small and marginal farmers, 9% of them were reported to be female farmers, 69% of these 15000 user farmers had irrigation facilities in their farms, and 34% of them had then reported to own a smartphone (ibid, Pg 5). The report further presents that the farmers had picked up 81% of the total were weekly advisory calls and the average listening rate for messages had been around 66% of the total time for advisory calls (ibid. Pg 6) . The report further provides that the PADIF and Coffee Board agronomists had been answering 200-250 calls on average per month. As per the assurance given, PADIF had been expected to answer all questions within 48 hours. Their report highly vouches for fulfillment of this assurance. It affirms that 50% of questions had been answered within 3 hours (Ibid. Pg 8). Such a low response time of a query answered is surely very empowering for the farmers as it provides near-immediate access to information through their mobile phones. Further, the most popular questions had been related to pest and disease management (30% of questions), market information (10%) and fertilizer management (5% of questions).

Further, as per the same secondary source, for pest and disease management related information, 33% of farmers considered Coffee *Krishi Taranga* their primary source of information, while the other sources of information were attributed to be self-experience (25%), input dealers (22%) and Coffee Board extension staff (16%). Similarly, for the issues related to fertilizer management, 29% of the farmers considered Coffee *Krishi Taranga* their primary source of information while the other sources of information were self-experience (28%), input dealers (21%), Coffee Board extension staff (18%). 83% farmers said they had adopted a recommendation from the *Krishi Taranga* service while 44% said they used price information from *Krishi Taranga* to make a selling decision (ibid. Pg 10). It was also seen that knowledge across recommended practices was substantially higher after having received Krishi Taranga information across an entire season. It was found that 91% of coffee growers said they would recommend the service to their friends or family to use as a source of information. These interesting facts about the low response time, nature of queries handled, general acceptance and usefulness of the IVRS system set the context of the initiative for the researcher and also provided him inputs for designing his own primary survey tool.

4.2 FINDINGS

The detailed analysis of the survey responses of agri-tech firms, technical experts and farmers/ coffee growers (respondent details in Annexure VI) about CKT was gathered using a pre-designed, pilot-tested tool (Annexure-IV for farmers and Annexure – V for agri-tech firms) These findings vouch for the positive claims reported by the secondary source (section 4.1). Apart from basic aspects reported in the secondary data source, additional issues such as the use of any other digital initiatives and many more were also examined in the survey. The detailed findings for both

the target groups of respondents (farmers/coffee growers and agri-tech firms) are presented simultaneously:

Findings: Perspective of Farmers

The survey tool to gauge the competitiveness / usefulness of CKT was administered to almost 100 coffee growers, also henceforth referred as 'farmer respondents', out of which 80 valid responses were received.

Profile of the Farmer Respondents: The farmer respondents were primarily from two districts, i.e. from Chickmagalur and Kodagu and of the 80 respondents, 41 (51%) were cultivating coffee in irrigated lands (Table 4.1).

Table 4.1 Location and Type of Farms of the Farmer Respondents

	Chikkamagalur				Madikeri			Mudigere			Total		
District/Taluk	I	R	T		I	R	T	I	R	T	I	R	T
Chikkamagalur	25	35	60					15	4	19	40	39	79
Kodagu					1		1				1		1
Grand Total	25	35	60		1		1	15	4	19	41	39	80

I = Irrigated, R = Rainfed, T = Total

Coffee is grown largely in small holdings and in earlier times, the number of educated growers was limited. However, over time, coffee did bring some degree of prosperity to the area and consequently the educational level and awareness level has seen an increase. Table 4.2 depicts the educational profile of the respondents and their frequency of use which also indicates a positive co-relationship between higher educational level and greater awareness regarding CKT.

Out of 76 who responded regarding frequency of use, it seen that 70 (92%) of the farmer respondents were using CKT on a weekly and monthly basis whereas 6 were using it rarely. Out of the 80 respondents, 49 farmers were cultivating coffee in less than 6 acres (2.4 hectare) land and a total of 70 farmers had less than 15 acres (6 hectare) land. Since, coffee, traditionally was grown in large estates, people cultivating coffee in less than 10 hectare land (25 acres) are considered small coffee growers as per the definition adopted by Ministry of Commerce, Government of India. Out of 80 farmers, 63 (80%) owned a smartphone and that gave them better leverage to use and benefit from CKT.

Perceptions of the farmer respondents – As already mentioned, the perceptions of the farmers were captured using a pre-designed and pre-tested structured survey tool (Annexure -4) , The overall perception of the farmer respondents give us a clear idea of acceptance of this digital initiative , henceforth abbreviated as CKT –

a. Usage of CKT

i. ***Usage Pattern vis-à-vis Educational Profile***- The farmers, who had completed graduation or whose family member had a technical qualification (e.g. a degree in engineering) were more eager to try out and experiment with the emerging technologies in comparison to farmers who were illiterate. The farmers with graduation and above were more frequent users and out of 41 farmers who were using CKT on a weekly basis, 30 (73%) were graduates, post-graduates and technical professionals (Table -4.2).

Table 4.2. Educational attainment in family and Frequency of CKT use

	Weekly	Monthly	Rarely	Total
Matriculation	3	4	1	8
12th Standard	5	5	1	11
Diploma	3	1		4
Graduation	18	12	2	32
Post-Graduation	8	2		10
Professional	2	2		4
Technical	2	3	2	7
Total	41	29	6	76

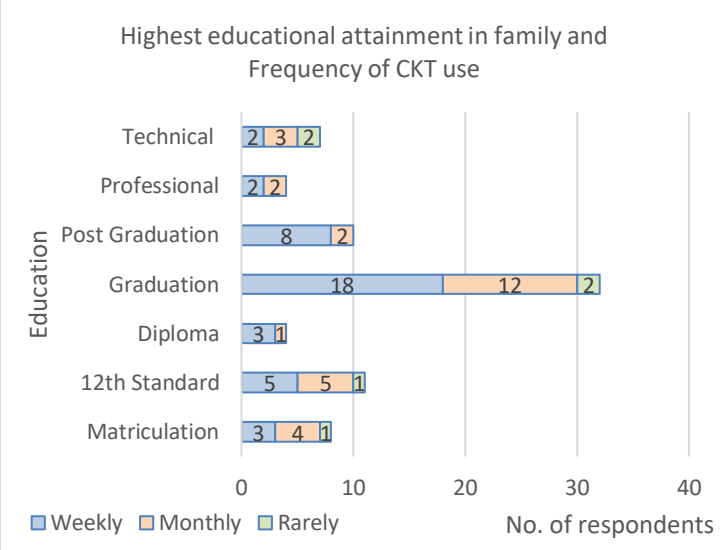

Figure 4.1. Usage Pattern vis-à-vis Educational Qualifications

ii. ***Usage Pattern vis-à-vis Landholding Size***- All the respondents recognized that CKT had the function of providing coffee-related information and it was seen that those with small landholdings were also frequently using CKT (Table 4.3).

Table 4.3- Usage Pattern vis-à-vis Landholding Size

Landholding (in Acres)	Weekly	Monthly	Rarely	Total
<3	11	5	3	19
3-6	16	12	2	30
6-15	9	11	1	21
15-30	3	2	1	6
>30	4			4
Total	43	30	7	80

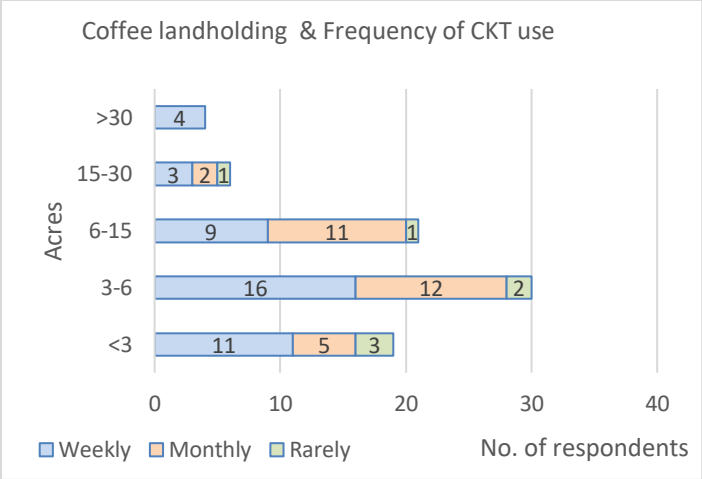

Figure 4.2. Usage Pattern vis-à-vis Landholding Size

iii. ***Popularity***– (Very Popular) : 96% of the total 80 respondents were using none of the other digital initiative except CKT. Only two (out of 80) respondents were reported to be using M-Kisan and one more respondent was using another app provided by private players. .

iv. Only three of the 80 respondents were aware of another ET viz. e-NAM and an app provided by a private player which provides an online trading platform. This indicates that the level of awareness regarding other form of ETs was extremely low.

b. ***Ease of Use and other Technology Characteristics of CKT***–

With regard to the ease of use (Para 4, Annexure IV), the respondents found CKT fairly easy to use and affordable, ease of understanding, and scalable too (Figure 4.3).

As the Figure 4.3 shows, maximum farmer respondents 91% (70 out of 77) found it easy to use (rated as High and Medium). However, there were seven farmers (9%) who thought the ease was relatively low. Thus a large majority of the respondent farmers who were using CKT found the advisories to be very useful and opined that this helped them to do scientific sowing and adopt good agricultural practices through timely irrigation and appropriate fertilizer and pesticide application.

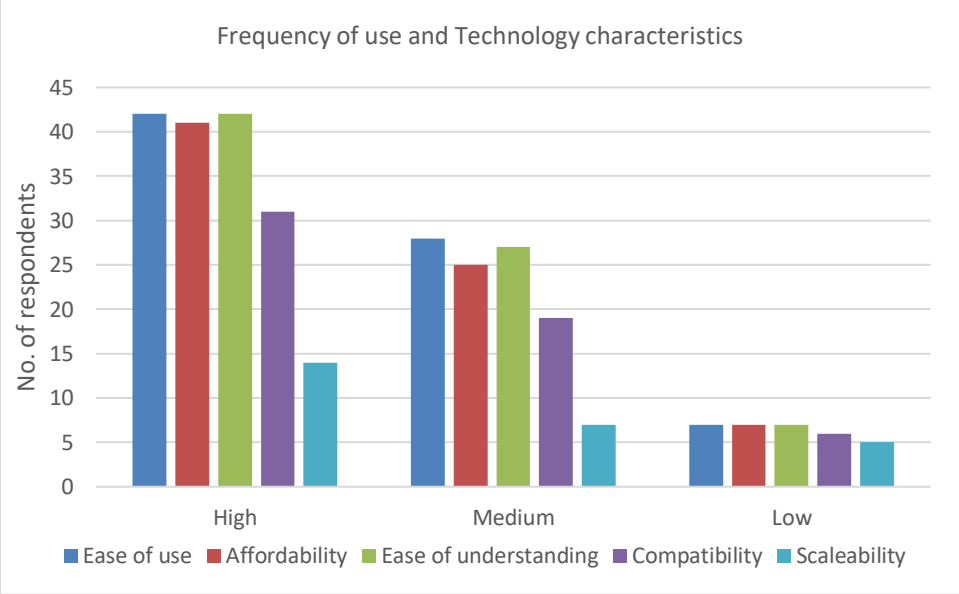

Figure -4.3 - Ease of use and other Technology characteristics

v. ***Onboarding Time***- 87.5% of the respondents mentioned that they had started using CKT within a month of learning about the service, vouching for the fact that the on-boarding time for CKT is minimal, further affirming the 'Ease of Use' aspect of the initiative.

vi. ***Easy Interfaces*** - 100% of the respondents were of the opinion that the service was useful but 7 numbers (9%) out of 80 were still found to be infrequent users (Para of Annexure IV). For the 73 out of 80, the adaptability of these farmers to the new technology platform

was smooth and they did not find any difficulty in using the new technology. They found the navigation systems quite user friendly and the farm advisories or the linkage with an external buyer was relatively smooth. All respondents also felt that the service was compatible with existing processes or infrastructure.

vii. ***Affordable***–A total of 73 farmers responded to the issue of affordability and 56 of them (72%) found it affordable while 7 found it non-affordable and 10 did not respond.

viii. ***Support System*** (Para 7 Annexure IV) – 49 out of the total respondents (61%) of farmers were of the opinion that agriculture extension workers should be in a position to guide them in case of certain teething troubles pertaining to use of technology.

c. Usefulness –

CKT was perceived to be a useful product and farmer respondents expected it to lead to quite high time-saving, medium changes in 'input-use', 'higher productivity' and 'lower costs', (in terms of descending order of preferences) (with least weightage given to 'social recognition') (Table -8).

Table 4.4 - Extent of Perceived Usefulness on Several Indicators*

	Time saving	Higher productivity	Higher revenue	Lower costs	Input use	Social recognition
High	22	6	7	6	6	5
Medium	25	17	10	14	19	8
Low	7	6	3	4	6	6
No Response	10	9	4	5	4	6
Total	64	38	24	29	35	25

*** - Since this was a multiple choice question , all the respondents had not ticked all the options; therefore, the total number for each of the options varies**

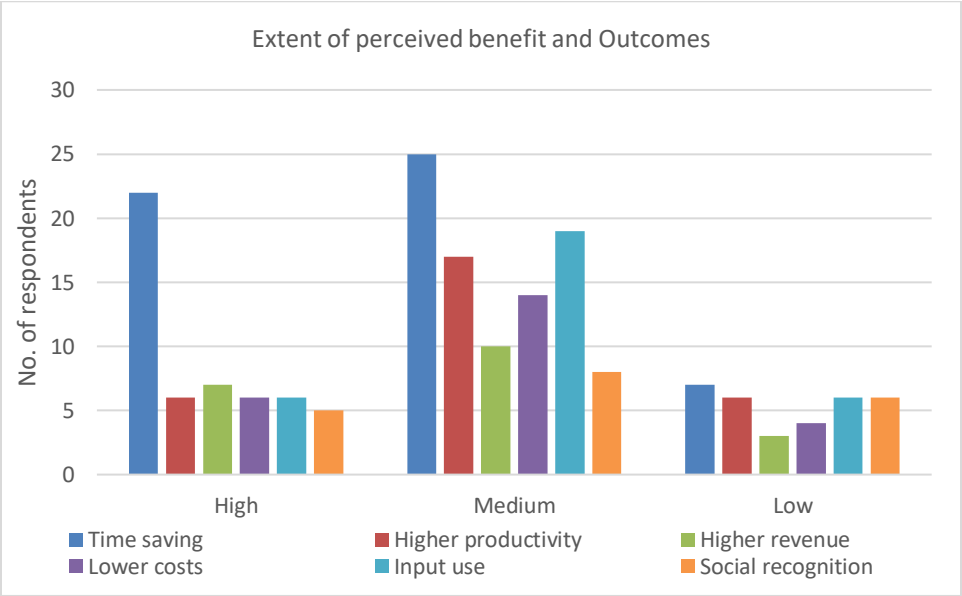

Figure 4.4 – Extent of Perceived Usefulness on Several Indicators*

ix. ***Increase in Profit***–43 (54%) out of a total 80 respondents felt that they have had a medium to high increase in their profits on account of use of CKT (Para 3 of Annexure-IV). The reduction in costs was due to the good practices promoted through CKT and the guidance regarding the optimal quantity of fertilizers to be applied.

Table 4.5- Extent of perceived benefit and Change in profits

	Unchanged	Decrease	Increase	Total
High	1		16	17
Low			4	4
Medium	2		16	18
NR		1	7	8
Total	3	1	43	47

x. ***Increase in Productivity***–Out of 38 farmers who responded on the issue of productivity 23 found it to have gone up on a medium to high scale while 6 found it to be low and 9 did not respond. Low response or non-response could have on account of the farmers' inability to quantify the benefits in terms of higher productivity. To that extent, it is understood that some of their response regarding positive benefits of ET was subjective in nature.

On the whole, 92% of the respondents perceived that CKT had been beneficial for them through the bouquet of services it offered. As pointed at point (viii) above, 61% of the farmers felt that CKT has met, albeit to a limited extent, their requirement of agricultural extension and information services and has helped in raising their profitability in existing operation.

Perspective of Agri-tech firms

Almost 15 agri-tech firms were sent the survey tool (Annexure V) using Google forms , out of which four of them replied to the survey too; all four of them were very optimistic of the role digital initiatives like CKT can play in improving productivity and augmenting farmers' income. They vocalized that the scaling up of use of drones, IoT and Artificial Intelligence would come up in a big way once the proof-of-concepts (PoCs) had been well-tested and recognized. The responding Agri-tech firms suggested that –

a. ***Need to Essentially Train Extension Workers*** – Majority of the agri-tech firms opined that that there must be an essential administrative mandate to deliver high quality capacity building initiatives with special emphasis on digital / emerging technologies for the extension workers. Once trained well, these extension workers could educate the farmers to meaningfully utilize ET. Extension workers should also be skilled to issue quality certificates to the farmers based on the globally defined market-based standards. This would have a positive ripple effect on the buyers who too would be reassured of the quality standards imbued in the products they are buying. It is pertinent to point out that the need to incorporate the use of digital technologies in the curricular framework and capacity building of existing extension workers had been deemed critical by the farmer respondents too.

b. ***Integrate Digital/ Emerging Technologies in the Existing Schemes*** – Compulsory integration of digital / emerging technologies in current governmental schemes/programmes will not just advance the agriculture sector but it would also improve the acceptance and adoption of these state-of-art technologies at the field level. For example, insistence could be laid by government on utilization of smart irrigation technologies as a component of *Pradhan Mantri Krishi Sinchayee Yojana* to accelerate adoption of smart technologies by all the farmers at the national level. Similarly other existing schemes like *Rashtriya Krishi Vikas Yojna* (RKVY), *Paramparagat Krishi Vikas Yojana*, etc. too could insist on adopting newer formats of agricultural intervention using ET. It was felt that due to the integration with existing schemes, there will be adequate support from central government in reaching out to more farmers and other stakeholders in the industry. Further, in their response, the agri-tech firms had optimistically reassured about the farmers' better acceptance of digital / emerging technologies tools with just a little impetus from the government.

c. ***Incentivize the Small & Marginal Farmers*** to Adopt Digital/ Emerging Technologies: It was suggested that the adoption of digital / emerging technologies by small and marginal farmers would be enabled by the provision of some form of incentives (including making smartphones available to them) to use the same.

d. ***Institutionalize Awareness Activities Among Farmers using KVKs etc*****:** The existing network of ICAR and other agricultural institutions should be leveraged to promote digital/ ET among farmers and other target groups. This would require a set of policy interventions that enable the use of KVK resources as demonstration centres and to also mandate KVKs' scientists to serve as 'evaluators-cum-extension agents' or 'change agents' to encourage farmers to adopt and adapt smoothly to digital / emerging technologies. The current research and training focus of KVKs and the institutional network should be extended to increase the focus on ET.

e. ***Incentivise Start-Ups*** – Majority of the agri-tech firms were upbeat about the prospects of employing ET as a tool in the agricultural sector. They revealed that of their pilots had been tested successfully in Karnataka, Andhra Pradesh and Maharashtra.

f. ***Need for Supportive Regulatory Framework:*** Assured by these success stories, majority of the tech firms also vocalized a need for supportive government policies that could provide additional product commercialization funds to start-ups to encourage innovation in this sector. This support could be rendered on basis of some assessment or criteria offered by related institutes including ICAR. Such policies could be ideally implemented in partnership with incubators that have been established with government assistance such as Atal Incubation Centres, Technology Business Incubator (TBI) of Department of Science and Technology (DST) and so on.

g. ***Multi-Stakeholder Partnerships and Collaborations*** : All four of agri-tech respondents put forth a need to encourage partnerships between ET startups and the agricultural research and extension system. Policies that enable partnerships between startups and the agricultural institutions, including agricultural universities, should be formulated and implemented. This would also help in creating a pool of talented manpower that is aware of ET skills.

The response of the agri-tech firms indicates that majority of these respondent firms were time and again reaffirming the need for strengthening the prevailing regulatory framework of the government to accelerate the agricultural productivity through prudent adoption of digital / emerging technologies. The field survey among the farmers and the agri-tech firms substantiates that use of emerging technologies can lead to better productivity, sustainable farming practices and higher incomes for the farmers and may contribute to supporting the 'doubling farmers' income' initiative.

CHAPTER-5

RECOMMENDATIONS AND CONCLUSIONS

Effective governance is based on three key pillars viz: knowledge, infrastructure, and a robust delivery mechanism, the same being very apt for agriculture vertical too. The 'knowledge' component of the agriculture sector gets strengthened by the related research and development activities; such R&D activities could be undertaken by the related agricultural universities, agencies associated with Department of Science & Technology, by startups and also by some enterprising farmers and would help to prepare all the stakeholders of the system for the future. To strengthen the supporting 'infrastructure' for growth, it is important to focus on creating new agricultural and livestock markets, improving storage and transport facilities, making better roads, and ensuring continuous supply of electricity (through separate grids for rural areas as in Gujarat as an example) and irrigation. These system components also facilitate delivery mechanisms as well as the monitoring of relevant government schemes and extension services that are likely to accelerate the pace of development. It is in this area of 'servitization'[5] of many on-farm and off-farm activities that ET has the potential to play a significant role. Experience in developed economies like US, Europe and Israel as well as successful pilots in Karnataka, Andhra Pradesh, etc. has shown that there is a lot of promise in digital applications to improve farmers' livelihoods. Finally, for strengthening all these three components ('knowledge', 'infrastructure', and a robust 'delivery mechanism'), Indian agriculture needs to be made more market-oriented and farmer-centric by ushering inpolicy reforms, even as government provides enabling environment for digital innovation.

[5]refers to industries using their products to sell "outcome as a service" rather than a one-off sale

5.1. Proposed Conceptual Models: Frameworks and Implementation

Based on review of literature (Chapter 2), study of best global practices (Chapter 3) as well as after analyzing the findings of the primary survey (Chapter 4), a conceptual framework is proposed by the researcher that suggests a digital stack for agriculture based on three pillars viz. i) digital infrastructure, ii) digital services platform and iii) digital linkages to facilitate more effective and efficient use of ET in agriculture.

5.1.a. An Integrated Farmers' Stack - Indian Agriculture Stack

Digital Stack in the context of Indian Agriculture

The digital stack in the context of Indian agriculture will have to factor in the driving forces which propel the public and private sector to look at more value creation in agriculture and the challenges which we need to overcome through such value creation. The idea would be to create an operational backbone with good digital connectivity, and availability of digital equipment with the farmers to take advantage of this stack coupled with creation of a cloud based server dedicated for agriculture. The digital services platform will provide various services (e-NAM, Kisan Suvidha, e-Raythu, etc. by government and host of services offered by private sector and NGOs). There is a need for development of these platforms in open access platform and also sharing of data to encourage innovation by start-ups. Development of these platforms through a modular architecture would assist in development of linkages that the MIT model postulates above.

The digital stack in the context of Indian agriculture would look like the following (Figure5.1).

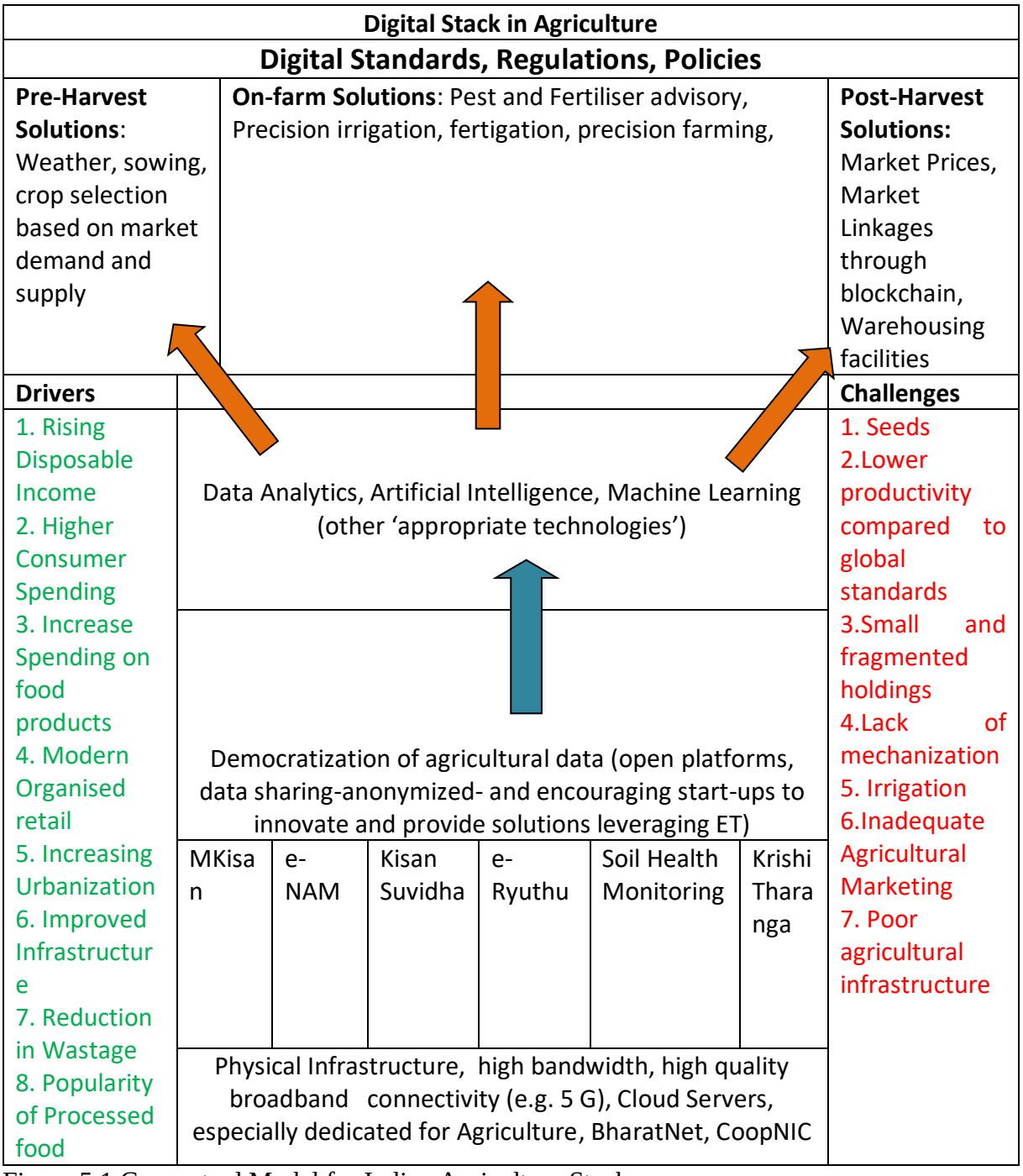

Figure 5.1 Conceptual Model for Indian Agriculture Stack

The first layer of the stack is the 'hardware layer' that would comprise of all prime infrastructure components including physical infrastructure, research and development activities, related nodal

agencies that would serve as enablers of processes and capacity building. . This layer insists on collaboration between agricultural universities, innovation centres as well as private industry. Further, there would a need to create a dedicated cloud server for agriculture to support innovative enterprises in agri-sector.

The second layer could be deemed as the 'software layer'; there would be different software available from the government as well as private sector players who would as act as the 'gatekeepers' to entire data and technologies to ensure a 'level-playing' field for all the related organizations irrespective of their size or share prices to avert 'data parity problem' (Calo , 2017) .'Data parity problem' - is described as aa situation in which dominant companies, due to greater access to data, can create better ET based systems, which enables them to amass even more data. As a result only a few well established leaders in the field have the ability to acquire data and build datasets.[lxx]

Although India has a National Data and Accessibility Policy (NDSAP, 2012)[6], it still does not have a robust and comprehensive open data sets across sectors and fields. It has often been debated how even private companies could allow access to researchers and developers to encrypted data without sharing actual data. Data sandboxes (access to large anonymized data sets) are being promoted as tools for enabling innovation while protecting privacy and security. This principle of providing sandboxes with anonymized data sets to encourage innovation has also been described as the need for greater democratization of data in order to encourage start-ups to be more creative in offering a variety of solutions using ET.

[6]https://dst.gov.in/national-data-sharing-and-accessibility-policy-0

The third layer is the 'policy layer', which will provide all frameworks, guidelines, policies and Acts to make the whole unit legally robust. It will ensure that most of the software at the second layer is developed in a modular manner and is amenable to open, agile, accessible, inclusive, interoperable, secure and legally sound platform that permits equal access and social equity to all the stakeholders of the agriculture ecosystem. While ensuring that the third layer is able to provide integrated solutions and a bouquet of options to the stakeholders, the emphasis on adherence to digital standards, regulatory framework, cybersecurity issues would be of paramount importance.

The success of technology adoption lies in customizing the technology packages to address particular challenges at the local level, supporting institutions and policies to create an enabling ecosystem, and harnessing the potential of these technologies to scale and commercialize them within a defined time period. It is in this context that Harold Leavitt's (1964) change management model - 'diamond model' involving people, process and technology; comes into being. In addition, a robust legal framework will ensures the availability of a strong regulatory support system for such change management. Thus, the recommendations with regard to application of ET in Indian agricultural context can be analysed in terms of a) People, b) Processes, c) Technology and d) Legal Framework.

5.2 People

'People' are the key to ensure that all changes that emanate from technology-uptake are successful. This is especially true in Indian context where farmers may be on the 'wrong side' of digital divide due to inadequate resources, exposure, literacy etc. As an example, many hinterland farmers would not be having access to smartphones which is crucial to use of emerging technologies in agriculture.

5.2.a. Upgrading the Extension Functions

While various activities and advents of government of India (Chapter 3) could be useful to promote digital/ emerging technologies across the country's farming community, it is most crucial that the extension machinery is familiarized with various types of emerging technologies, the tools and techniques required for data analysis, the ways in which IoT devices operate and talk to each other and the way in which the advisories, based on intensive data analytics have to be explained (interpretation) to the farmers. If the full benefits of digital agriculture including application of ET for good agricultural practices, enhanced income and market reach for farmers are to be realized, then the extension machinery has to keep abreast of the latest developments in technology and have the ability for effective dissemination of such knowledge. The role of ICAR institutions and KVKs in acting as decentralized training centres for providing on-the-job training to extension officials across the country would be crucial in this regard.

5.2.b. Skilling People

Working with emerging technologies would require skilling at three levels,

a) the farmers who would be using it: As the field experiment shows, the farmers who are well educated would have better adaptability in using ET in different agricultural and marketing operations.
b) the extension officials of Agriculture Department and private entrepreneurs: The central and state governments of India must step up efforts to equip its citizens with the multidisciplinary and STEAM skills—science, technology, engineering, arts, and mathematics - demanded by AI. The focus will have to be on enterprise learning skills where government officials will have to promote a constant learning mindset. This would require:
    - Invest in re-skilling the extension officials at all levels-state, district, block and GPs

- Expand accelerated learning and certification- this would incentivize government officials to learn and use the skills for career enhancement as well.
- Make skill development financially affordable so that employees as well as village level entrepreneurs find it easier to re-skill and update their knowledge level. This will allow extension officials and village entrepreneurs to skill themselves even without government sponsorship and will open up income generating opportunities for many youth in rural areas as they will provide the interface of ET with illiterate or semi-literate farmers.

c) The tech workers of the tech service providers: For working with the emerging technologies, people will need an entirely new set of skills and capabilities. Companies as well as educational institutions must make radical changes to their curriculum, training, performance and talent acquisition strategies. Tech workers need to have the critical skills of understanding the business requirements (including farm operations) and translate them to system requirements for the coders and other developers to work upon while constantly obtaining feedback from end-users and other stakeholders.

5.2.c. Participatory Approaches

The transformative potential of emerging technologies lies in their ability for widespread usage. Technologies like drone-based image monitoring for disease detection, big data analytics for weather prediction and advisories on sowing of seeds and irrigation schedule etc. will make these technologies ubiquitous. The farming practices in India are different from that in the West which follows a more corporatized farming model. Thus use of emerging technologies in the Indian context will have to bring higher citizen –centricity, i.e., factoring for fragmented land-holdings, dealing with farmer-producer organizations, dealing with farmers who may not have had very high degree of formal education, economizing costs, etc. There is also a dire need to develop analytics

models that would take into account inputs of the users as well as build effective communications strategy with the farmers is likely to make the use of emerging technologies more effective and efficient. The advantages of emerging technologies would lie in the flexibility of services which they offer. While some tech service providers could offer an end-to-end solution from pre-harvest to on-farm and post-harvest stage, there could also be an option to choose a particular service at a particular stage. Thus, the farmers and other stakeholders involved in agricultural processes would have a greater choice in opting for a module which is most relevant for them. To that extent, the participation level of the stakeholders is going to be much more as they do not have to be dependent on a one-size-fits-all scheme. As Malhotra (2018) observes, "This would enable citizens to achieve their full potential in promoting sustainable development and improving their quality of life using emerging technologies. Such a citizen-centric approach, where citizens' expectations serve as the starting point, cannot be isolated from citizen-inclusive approach that would rely on citizens' themselves to help in identifying the appropriate technology components required for fulfilling governance outcome. Citizen-centric focus essentially coupled with citizen-inclusive design approach to e-governance would together go hand-in-hand to lend a more realistic flavour to attainment of good governance wherein the newer and newer forms of emerging technologies would just serve only as means to the end and never the end itself."

5.3. Processes

In the Indian context, the use of ET in agriculture would require a series of processes to be adopted, starting from addressing the agri-University curriculum to changing the governmental schemes to encourage adoption of ET.

5.3.(a) Strengthening the agri-University curriculum:

If India has to take advantage of the transformative potential of the emerging technologies, then creation of a pool of trained manpower in digital agriculture is essential. It requires drastic changes in the agricultural education curriculum to make it more multi- disciplinary with additional expertise in digital agriculture, viz. AI, IoTs, big data, farm mechanization, supply chain automation etc. To develop a workforce prepared for the changes that are brought about by the use of ET, agricultural Degree and Diploma institutions need to de-emphasize rote skills, and stress on education that helps humans to work better with machines—and do what machines cannot. This entails a greater focus on developing students' digital skills, as well as an increased emphasis on experiential learning. This would require large-scale capacity building of academic staff in these universities.

In addition, the agricultural universities need to be encouraged to establish and operate agri-tech incubators either on a stand-alone basis or in partnership with an established incubator in the region. Similarly, encouraging these universities to engage the agri-tech start-ups in a mentor-mentee relationship where start-ups are tied to established players and mentored to navigate through the initial years will be crucial to the success of ET in agriculture. The recent initiative of Government of India to bring in a National Education Policy needs to factor in the integration of emerging technologies into the curricular framework to prepare our students for the future.

It is very evident that to keep pace with the disruptive nature of technologies, it is essential that academic institutions in Agriculture and Indian Council of Agricultural Research dedicate more funds and resources for the ETs. While being open to public applicants, most agribusiness incubators in India are housed in agricultural education and research institutions which are primarily funded by Central and State Governments. It is apparent that the pipeline of incubatees/deals for such agri-tech incubators needs to be robust in order to ensure viability and sustainability of the incubators. The agricultural education network in India can play an important role in inspiring graduates in agricultural sciences and related fields to explore agri-tech entrepreneurship as an option.

While introduction of technology oriented courses by ICAR is a step in the right direction, it is essential that the capacities of faculty members in the Universities are also developed so as to ensure effective achievement of desired outcomes of the course. Validated data / information regarding the number of agricultural graduates who went on to establish agri-tech businesses that focus on precision / smart / digital agriculture, and staff / students feedback regarding the new courses is unavailable through secondary sources.

5.3.b. Schematic Support for ET in Agriculture

Many of the schemes run by the Central Government and state governments, in their current form, may not be amenable to application of emerging technologies in agriculture. Making provisions to allow operational flexibility to promote adoption of ET as part of the schemes will go a long way in promoting agri-start-ups and also help in farmers' adoption of the new technologies. The Government of India could set up large incubators, possibly on a public-private partnership basis, in states/regions which are lagging in agriculture and related fields, or where significant untapped potential exists. It is seen that about half of agri-tech start-ups offer supply chain solutions like

market linkage, better access to inputs etc. In this context, agri-industry players in regions that are lagging behind should be supported to provide integrated solutions in crop production and value chain to benefit marginal and small farmers. The Authority proposed (Section 5.2) could partner with State level institutions to identify growth triggers for each agro-ecological zone.

5.3.c.Working through FPOs for Adoption of Smart Agriculture

The adoption of digital agriculture in India is constrained by factors such as small and marginal landholdings, lack of capital and lack of information. In such a scenario, additional policies that promote the use of digital agriculture through FPOs can be considered as such initiative would help in aggregating fragmented land parcels and taking up crops which are amenable to ET interventions. Such interventions could be facilitated by state governments and organizations such as SFAC, NAFED and NABARD. All states should be encouraged to convert a certain pre-determined percentage of area to be brought under emerging technology and digital interventions with the active involvement of the extension network. State agricultural universities should be given time-bound targets to promote digital agriculture through FPOs in their areas of activities, with the state governments supporting these institutions to forge partnerships with the private sector. It may be possible to encourage state governments to allocate a minimum portion of their agriculture budget to digital agriculture-related interventions. It would also be useful if the Governments work with the banking sector to enable easy flow of funds for investments in the area of digital agriculture, especially in contexts of collective or contract farming.

5.4. Technology

Use of ET in agriculture obviously involves taking a substantial leap towards use of technology and ways of adoption of among farmers and other stakeholders involved in supply chain.

5.4. a. Sustainability

For any technological initiatives to be successful it has to remain sustainable and it has to remain secure. Use of ET in agriculture implies dealing with huge number of farmers and other stakeholders in the supply chain. Ensuring a successful transition of use of ET and scale up in the Indian context would require decisive decision of Central and state governments to back these technologies, build in the use of such technologies into different government schemes in vogue and a massive capacity building of government, village level entrepreneurs and a greater thrust on collaborative initiatives.

Embrace transformative technology to power growth:

The debate on whether ETs will lead to job losses and whether India can afford to adopt technologies wherein a lot of automation is built in has to be put to rest. Policymakers have to expand their focus beyond generic job creation by placing tech-driven productivity gains at the center of India's growth strategy. High productivity in agriculture can generate more output per worker, reduce prices, increase market share, and bring in better remuneration for farmers. According to Acemoglu and Restrepo (2018), the productivity effect—resulting from the cost savings and output gains—increases the demand for work and wages in new tasks. These effects push directly against the "displacement effects" of technology, which tend to reduce the demand for labor.[lxxi]Thus, sustainability of initiatives in use of ET in agricultural domain would require

Indian policymakers to overcome any form of dilemma and support the widespread use of tech-driven initiatives.

It is evident that while India has made rapid inroads in promoting digital agriculture and promoting agri-tech start-ups, sustained growth in this direction would require additional policy interventions that address bottlenecks and facilitate availability of resources. Thus addressing the issue of academic restructuring to bring in elements of emerging technologies into curricular framework, a regulatory regime which is capable of maintaining an oversight, supporting an eco-system which promotes innovations, start-up incubation, etc. are essential for sustainability of the use of ET in agriculture.

5.4.b. Supporting Innovation and R & D

NASSCOM (2019) reports that India in 2019 is home to about 450 Agri-tech startups in India, which are growing at about 25% Year-on-Year, and that the startups received USD 248 million in first 6 months of 2019 which is about 300% more than total funding in 2018 .[lxxii] Although 35 startups were established during 2018, raising funds to meet working capital requirements remains a challenge for new start-ups (ibid). The situation is rendered more difficult as many clients expect the startups to implement Proof of concept (PoC) on a *pro-bono* or on cost basis. Therefore, as done in a few states (e.g. Karnataka), it would be useful if a dedicated Agriculture Innovation Fund (AIF) is created by the State and Central Governments to exclusively promote and scale-up agri-tech startups. Through the fund, Governments can also facilitate partnerships between agribusinesses and agri-tech startups by supporting investments in smart farming.

5.4.c. Collaborative Research

Considering the way in which application of emerging technologies in agriculture is unfolding, the potential for tremendous growth through partnerships and collaborations is becoming evident. Startups provide an agile and lean approach towards developing new solution prototypes but often, these enterprises do not have enough bandwidth to take up research (for development, proof-of-concept or productization) which requires resources and depth of knowledge. The governments, both at Central and state level can play an enabling role for these startups to access quality research institutes and researchers. Partnerships between the academia/researchers with the industry and startups using the research findings will only facilitate further promotion of emerging technologies in the sectors such as agriculture, education, healthcare, etc. Commercialization of AI based technologies as services, applications or embedded hardware can be promoted by connecting the industry players in the venture capital / private equity firms and trade bodies.[lxxiii]

The Indian Agriculture Research Institute (IARI) has formulated a collaborative research project entitled "SENSAGRI: Sensor based Smart Agriculture" - involving six partner institutes under the ITRA Project Funding, to develop Indigenous prototype for Drone based crop and soil health monitoring system using hyperspectral remote sensing (HRS) sensors, so as to be integrated with satellite-based technologies for large scale applications. The Committee on Doubling Farmers' Income has recommended that, "such joint research efforts are recommended, to be undertaken and completed as per timelines."[lxxiv]

5.5. Legal Framework

5.5.a. Emerging Technologies and Regulatory Framework of India

The real power of emerging technologies lies not merely in the financial gains that can accrue to the economy but also in the tremendous transformative potential to address socio-economic challenges. Be it healthcare, education, banking, land registry or agriculture, emerging technologies hold the potential for bringing disruptive changes to the existing processes and maximize gains in all sectors.

The growth in emerging technologies and their application in different sectors are still taking shape in India. In this context, strategy documents on how India could leverage AI, IOT, block chain, etc. are being brought out by MeitY or by the NITI Aayog. However, the larger question of creating a regulatory framework which facilitates the growth of these technologies in a constructive and ethical manner is of paramount importance.

The usage of emerging technologies is pre-supposed on big data and digital connectivity. Thus, facilitating implementation of 5G is extremely crucial to take advantage of AI, machine learning and to ensure that internet of things work more efficiently. The area of digital connectivity also brings up the risk of potential cyber-crime/hacking which might shut down the entire range of applications being run using ET. Similarly, the enormous amount of private data will always remain an area of concern and protecting privacy will be one of the primary ethical concerns in usage of emerging technology.

The stakes for artificial intelligence and machine learning in India are high, yet it trails behind many other developed countries in ET capabilities. This is despite the fact that India has a large talent pool with skills in ET. However, Indian companies are quickly catching up with adoption of

ET, making investments in tech infrastructure and conscious efforts to improve the skills of their manpower in different aspects of emerging technologies. To fully seize the opportunities presented by ET, India's policy makers, universities, corporations, entrepreneurs and extension workers need to come together and do much more. The regulatory frame work for the emergent technologies in India need to focus on following areas:

(1) To pursue a balanced approach to AI, blockchain and IoT development across stakeholders, India needs to encourage an innovative private sector with a supportive eco-system, policy and regulatory framework.

(2) The debates among the optimists and pessimists relating to ET make it evident that governments will have to follow a set of guiding principles on "responsible technologies"[lxxv]—based on strong ethical foundation, human-centric by design, and with accountability, fairness and transparency.

(3) Indian policy makers need to pursue the twin goals of promoting trust and preserving maximum flexibility to innovate and this requires smart regulation that adapts to the shorter innovation cycles of AI and other forms of ET. One example could be the creative manner in which UK is trying to regulate its autonomous vehicle insurance.[lxxvi] Looking to the future, the UK Department for Transport has proposed new two-way insurance policies that cover motorists whether they are driving or not. When the car is in driverless mode, insurance companies would recover the costs of claims from the party responsible for the crash, which may be the manufacturer.

(4) There is a need for greater accountability of the tech companies using AI, IoT and block chain. They are in possession of huge volume of personal data including financial transactions, bank details and personal preferences. Any data breach is likely to impact a large number of

individuals and to that extent, the accountability needs to be ensured. Recently, EU has come up with draft Regulations prescribing huge financial penalty for such data breach and other adverse consequences for the tech firm. India needs to adopt similar policies for regulation of tech companies.

Policy makers and standards bodies in India should work with businesses to learn how they are developing their own responsible ET practices. These private sector efforts will help inform future public policy. Creating standardization around IoT/AI technologies developed in the country would allow global and national participation of industry and promotion of research bodies.

5.5.b. Creation of an Authority to Steer Digital Agriculture

Currently, a multitude of public (central government, state governments, ICAR, KVKs and so on) and private sector organizations are involved in promoting digital agriculture in India. Towards prioritizing interventions and implementing a roadmap for use of emerging technologies in agriculture sector, a significant additional policy intervention in India would be the creation of an independent Authority with joint participation of Department of Agriculture, Cooperation and Farmers' Welfare and Ministry of Electronics and Information Technology. The mandate of the Authority would be:

a) To facilitate, promote and administer digital agriculture in the Country. The Authority would recommend enabling policies, guidelines, promotional measures for facilitating wider adoption and use of emerging technologies in agriculture.
b) To organize a digital stack by looking at digital infrastructure (connectivity of all GPs under Bharatnet, connectivity of more than 10,000 cooperatives under COOPNIC, etc.); monitor and plan data management activities, existing ICT applications and portals, adoption of innovative technology and convergence among different portals in agriculture and allied

sectors. The Authority could also implement activities relating to monitoring and evaluation so as to measure achievements (e.g. area under digital or precision agriculture, impact on productivity/incomes etc.) and identify priority/focus areas

c) To establish and manage a dedicated cloud-based data centre for agriculture which would help in ensuring timely knowledge dissemination, interoperability of applications, data security, and data sharing policies. NIC's data centre could be used in the interim so as to avoid rollout delays.

d) To ensure a distinct regulatory framework for use of drones/UAVs in agriculture as drone startups in India are currently constrained by ambiguities/regulatory barriers in this respect.

e) To interact and coordinate with various State Governments to design schemes/programmes that leverage resources, manpower and success stories in India and elsewhere.

f) The Authority could also address various issues such as data ownership, security (as envisaged under the proposed Personal Data Protection law and other Indian laws including under IT Act) and sharing mechanisms considering the large amount of data generated through sensors and other data generation technologies.

5.5.c. Security Framework

Implementation of the use of ET in agriculture would mean massive amount of data flowing and stored across the networks which would be exposed to vulnerabilities in the infrastructure that can be exploited by hackers. This would require strong security architecture and the Government of India, in partnership with the State Governments, should create regulation for data sharing. There has to be security in accessing of data of individuals, organizations etc. however, access can be given to the related technology in order to reap the true benefits of the cutting edge emerging technologies in the agricultural domain.

Conclusive Remarks

All countries in the world have to balance the twin challenges of ensuring food security for a growing population with that of ensuring sustainable farming practices. An insightful growth strategy for agriculture will need to treat agriculture as a business enterprise involving constant innovation and must cater to dynamic market demand. The Governments around the world as well as technology service providers, startups have come forward to provide smart farming solutions wherein farmers are able to enhance productivities by increasing inputs and efficient management of farm enterprises. Although agricultural technologies are fast evolving in India and a mix of business models are driving the ecosystem, there is a need to design the pathway to successful commercialization and to scale it up by utilizing the right incentives and policy support. Governments will have to play a catalytic role in encouraging the private sector to bring in investment, technology and expertise in use of ET in agricultural operations.

The private sector innovation in farm management techniques has resulted in reduced energy consumption, higher precision intervention in fertilizer, pesticide and irrigation management and overall cost-effective operations and resource-efficient approach. As a result, the smart farming industry is anticipated to grow at a much faster pace than the traditional methods.

In India and in various other countries, agricultural startups and technology innovators are developing numerous sustainable farming systems. Innovations in ET have the potential to improve efficiencies of the agricultural extension system and reduce the cost of extension services. At times, they have the potential to replace physical presence while sending advisories based on a very scientific and objective assessment of ground situations. Further, digital agriculture (geo-tagging, satellite data, and drone technology) can enable the provision of risk management services such as crop insurance, while e-markets can lead to better price discovery for farmers.

Technologies such as blockchain can address trust deficiencies in the supply chain and also enable differentiation of farm produce through traceability and help in marketing.

Similarly, other policy interventions including the establishment of an Authority to support the growth of ET in agriculture in the country would facilitate the transition of India's agriculture from a traditional, low productivity, low income state to one that is characterized by use of digital technologies to achieve higher productivity, income efficient, climate smart and resource efficient. Digital technologies in produce markets would also facilitate the achievement of the Government's other programs such as enabling cashless transactions and inclusive banking. It would also be useful if a core database with details of geo-tagged farm identification, farmer identification and mapping of crops is set up by the coordinated action of state and central governments.

The global market for precision agriculture is expected to grow at an annual growth rate of 13.09% up to the year 2022, with India and China expected to clock annual growth rates of 18.29% during this period (BIS, 2018).[lxxvii] The private sector, especially agri-tech startups, can play a major role in enabling India to ride this growth wave successfully. New and innovative incentivizing structures to support startups could consolidate the country's achievements in the startup / incubation sector. However, towards tapping the potential for precision agriculture in the smallholder-dominated Indian agriculture sector, digital technologies are expected to offer cost-effective solutions which can address critical issues such as soil management, productivity challenges and optimizing inputs. Adoption of digital technology solutions and benefiting from their adoption also requires Indian farmers to be digitally literate to an extent, and this can be achieved by a pro-active extension network, that must be supported by collaboration between public and private sector Thereby, it is apparent that the accelerated and widespread adoption of emerging technologies in agriculture in India would benefit from additional interventions

leveraging the strengths of the public and private collaboration with an active role being played by the academia and other knowledge institutes. The study reaffirms the need for strengthening the prevailing regulatory framework of the government to accelerate the agricultural productivity through prudent adoption of digital / emerging technologies.

To conclude, the potential for application of emerging technologies in the Indian agricultural context is very high and a positive co-relationship was found between adoption of digital technology and income augmentation of farmers. The initiatives of technology start-ups and initial pilots in a collaborative approach between state governments and private sector has shown encouraging results. The field survey done amongst the coffee growers under the aegis of Coffee Board reveals that the farmers' adaptability to digital and consequently, emerging technology is high and they understand the economic benefits that could accrue on account of scientific and good agricultural practices. Thus, a carefully planned government policy towards adoption of emerging technologies in agriculture has the potential to balance the twin demand of ensuring food security (through higher productivity) and higher income levels of the farmers (through cost reduction and qualitative market access). If the roadmap is charted properly, this could supplement the efforts towards "doubling of farmers' income" considerably.

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ANNEXURES**Annexure-I**

Location of respondents and Nature of farms (No.)

	Chikkamagalur				Madikeri			Mudigere			Total		
District/Taluk	I	R	T		I	R	T	I	R	T	I	R	T
Chikkamagalur	25	35	60					15	4	19	40	39	79
Kodagu					1		1				1		1
Grand Total	25	35	60		1		1	15	4	19	41	39	80

I = Irrigated, R = Rainfed, T = Total

Land holdings and area under Coffee (acres)

	Chikkamagalur		**Madikeri**		**Mudigere**		**Total**	
District/Taluk	Total	Coffee	Total	Coffee	Total	Coffee	Total	Coffee
Chikkamagalur	12.42	11.95			6.53	6.01	11.00	10.52
Kodagu			2.30	2.30			2.30	2.30
Grand Total	12.42	11.95	2.30	2.30	6.53	6.01	10.89	10.42

Average landholding = 4.17 ha

Mode of output sale

District/Taluk	**Chikkamagalur**	**Madikeri**	**Mudigere**	**Total**
Chikkamagalur				
Curing unit	19		2	21
Local agent	36		16	52
Trader	5		1	6
Sub-Total Chikmagalur	60		19	79
Kodagu		1		1
Local agent		1		1
Sub-Total Kodagu				
All respondents				
Curing unit	19		2	21
Local agent	36	1	16	53
Trader	5		1	6
Total	60	1	19	80

Participation in training programmes

District/Taluk	Chikkamagalur	Madikeri	Mudigere	Total
Chikkamagalur	60		19	79
No	43		18	61
Yes, Coffee Board	11		1	12
Yes, GoKDoA	3			3
Yes, Spices Board	1			1
Yes, Growers Assn.	2			2
Kodagu		1		1
No		1		1
Total	60	1	19	80

Crop Loans

	Chikkamagalur		Mudigere		Total	
District/Taluk	No. of respondents	Average Loan (Rs.)	No. of respondents	Average Loan (Rs.)	No. of respondents	Average Loan (Rs.)
Chikkamagalur	18	527765	9	366111	27	471808

Income from Coffee and Total farm income

	Chikkamagalur		Mudigere		Total	
District/Taluk and Income from Coffee/All farm income	No. of respondents	Avg. Annual Income (prev. year) from all farm outputs (Rs.)	No. of respondents	Avg. Annual Income (prev. year) from all farm outputs (Rs.)	No. of respondents	Avg. Annual Income (prev. year) from all farm outputs (Rs.)
Chikkamagalur	18	896667	12	200000	30	853125
Rs. 50,000 to Rs. 1 Lakh	4	150000	2	N.A.	6	150000
Rs. 1 Lakh to Rs. 1.5 lakh	3	150000			3	150000
Rs. 1.5 lakh to Rs. 2 Lakh			6	N.A.	6	N.A.
More than Rs. 2 Lakhs	11	1270000	4	200000	15	1172727
Kodagu						
Total	18	896667	12	200000	30	853125

Based on a sample of 30 respondents who were willing to provide information regarding incomes from coffee as well as from the farm, it was seen that the average annual income of all respondents from all farm outputs was Rs. 853125 during 2018-19. 50% of the farmers reported earning an income of more than Rs. Two lakhs from Coffee. 61% of respondents of Chikkamagalur taluk reported earning an income of more than two lakhs from coffee while 50% of respondents from Mudigere taluk earned an income of Rs. 1.50 to 2.00 lakhs from coffee. The difference in income between that earned from coffee and the entire farm is attributable to intercrops (pepper, cardamom, coconut, arecanut etc.).

N.A. = Not available

Holding size and Annual Income (2018-19) from all farm outputs (Rs.)

Acres	Chikkamagalur	Mudigere	Total	No. of farms	Avg. farm size (acres)	Avg. farm income from all farm outputs (Rs.)
Chikkamagalur	896667	200000	853125			
<=3	300000		300000	1	3.00	300000
3-6	1300000		1300000	4	4.67	325000
6-15	1800000	200000	2000000	5	11.80	400000
15-30	2200000		2200000	2	22.67	1100000
>30	7700000		7700000	3	64.00	2566667

Farm size and change in annual farm income (vis-à-vis previous year)

	Chikkamagalur				Kodagu	Total			
Acres/Districts	D	I	NC	N.A	D	D	I	NC	N.A
<=3	7	6	2	3	1	8	6	2	3
3-6	16	8	6	0		16	8	6	0
6-15	14	6	0	1		14	6	0	1
15-30	4	1	1	0		4	1	1	0
>30	3	0	1	0		3	0	1	0
Total	44	21	10	4	1	45	21	10	4

D = Decline ; I = Increase ; NC = No change ; N.A. = Not available

About 56% of the respondents reported a decline in farm income during 2018-19 as compared to the previous year. The proportion of such farms, which have reported a decline in incomes, is higher among larger farm holdings with about 28% of farms which are less than 30 acres in size reporting an increase in incomes. This is largely attributed to increasing labour costs with wages typically constituting about 60% of the cost of cultivation in coffee farms.

Ownership of durables

	Smartphone	Computer	Broadband	DTH	4-wheeler
<=3	14	5	4	18	12
3-6	20	6	4	20	17
6-15	20	9	7	24	20
15-30	5	3	1	6	6
>30	4	4	4	4	4
Total	63	27	20	72	59
% (n=79)	79.74	34.18	25.32	91.14	74.68

The high percentage of 4-wheeler ownership is due to the remote location of the coffee farms with low access to regular public transport facilities.

Highest educational attainment in family and ownership of durables

Highest education	No. of Respondents	Smartphone	Computer	Broadband	DTH	4-wheeler
Matriculation	8	4	1	0	6	5
12th Standard	11	7	0	1	9	6
Diploma	4	4	2	1	4	2
Graduation	32	29	14	11	30	25
Post Graduation	10	9	4	2	9	9
Professional	4	2	0	1	4	4
Technical	7	7	5	4	7	6
Total	68	58	25	20	63	52

Higher penetration of smartphones and computers in families with higher educational attainment

Annexure - II

Global Companies providing agri-solutions using ET

Sl.No.	Name of the firm	Technologies and application thereof
1	Prospera, https://www.prospera.ag/	Founded in 2014, this Israeli startup has revolutionized the way farming is done. It has developed a cloud-based solution that aggregates all existing data that farmers have like soil/water sensors, aerial images and so on. It then combines it with an in-field device that makes sense of it all. The Prospera device which can be used in green houses or in the field, is powered by a variety of sensors and technologies like computer vision. The inputs from these sensors are used to find a correlation between different data labels and make predictions.
2	Blue River technology, http://www.bluerivertechnology.com/	Founded in 2011, this California-based startup combines artificial intelligence, computer vision and robotics to build next-generation agriculture equipment that reduces chemicals and saves costs. Computer vision identifies each individual plant, ML decides how to treat each individual plant and robotics enables the smart machines to take action. The company claims that its precision technology eliminates 80 percent of the volume of chemicals normally sprayed on crops and can reduce herbicide expenditures by 90 percent. In September 2017, major manufacturing company John Deere announced its acquisition of Blue River Technology.
3	FarmBot, https://farm.bot/	Founded in 2011, this company has taken precision farming to a different level by enabling environment conscious people with precision farming technology to grow crops at their own place. The product, FarmBot comes at a price of $4000 and helps the owner to do end-to-end farming all by himself. Ranging from seed plantation to weed detection and soil testing to watering of plants, everything is taken care of by this physical bot using an open source software system.
4	Agrisource Data https://agrisourcedata.com/	Bbased out of Atlanta, this start up is using intelligent in-field sensors for measuring water levels, soil moisture, in-field crop health, fuel levels, storage temperatures and data analytics to provide farmers with detailed crop and field information and ensure more efficient field management

5	Harvest CROO Robotics http://www.harvestcroo.com/	Harvest CROO Robotics has developed a robot to help strawberry farmers pick and pack their crops. Lack of laborers has reportedly led to millions of dollars of revenue losses in key farming regions such as California and Arizona. In the Hillsborough County, Florida region which has been described as the "nation's winter strawberry capital," between 10,000 and 11,000 acres of strawberries are typically harvested in a season. Harvest CROO Robotics claims that its robot can harvest 8 acres in a single day and replace 30 human laborers.
6	PEAT https://peat.technology/	Berlin-based agricultural tech startup PEAT, has developed a deep learning application called Plantix that reportedly identifies potential defects and nutrient deficiencies in soil. Analysis is conducted by software algorithms which correlate particular foliage patterns with certain soil defects, plant pests and diseases. The image recognition app identifies possible defects through images captured by the user's smartphone camera. Users are then provided with soil restoration techniques, tips and other possible solutions
7	Trace Genomics https://tracegenomics.com/#/	California-based Trace Genomics, provides soil analysis services to farmers. Lead investor Illumina helped develop the system which uses machine learning to provide clients with a sense of their soil's strengths and weaknesses. The emphasis is on preventing defective crops and optimizing the potential for healthy crop production. According to the company's website, after submitting a sample of their soil to Trace Genomics, users reportedly receive an in-depth summary of their soils contents. Services are provided in packages which include a pathogen screening focused on bacteria and fungi as well as a comprehensive microbial evaluation.
8	SkySquirrel Technologies Inc. https://www.f6s.com/skysquirreltechnologiesinc	SkySquirrel Technologies Inc.(Canada) is one of the companies bringing drone technology to vineyards. The company aims to help users improve their crop yield and to reduce costs. Users pre-program the drone's route and once deployed the device will leverage computer vision to record images which will be used for analysis. Once the drone completes its route, users can transfer a USB drive from the drone to a computer and upload the captured data to a cloud drive. SkySquirrel uses algorithms to integrate and

		analyze the captured images and data to provide a detailed report on the health of the vineyard, specifically the condition of grapevine leaves.
9	FarmShots http://www.syngenta-us.com/agriedge/farmshots	Based in Raleigh, North Carolina, FarmShots is another startup focused on analyzing agricultural data derived from images captured by satellites and drones. Specifically, the company aims to "detect diseases, pests, and poor plant nutrition on farms." For example, the company claims that its software can inform users exactly where fertilizer is needed and can reduce the amount of fertilizer used by nearly 40 percent.
10	Gamaya https://gamaya.com/	Switzerland-based Gamaya offers a drone-mounted hyperspectral imaging camera, which the company claims combines remote sensing, machine learning, and crop science technologies. The camera may also be mounted on light aircraft. The company explains that hyperspectral cameras measure the light reflected by plants. It claims to capture 40 bands of color within the visible and infrared light spectrum, 10 times more than other cameras which only capture four bands or color. The company also explains that plants with different physiologies and characteristics reflect light differently. This pattern changes as the plant grows and is affected by stressors. Gamaya's technology is capable of mapping and distinguishing the weeds from plants. It is also able to identify other plant stresses such as disease and malnutrition, as well as chemical inputs in the soil.
11	SenseFly https://www.sensefly.com/	SenseFly offers the Ag 360 computer vision drone, which captures infrared images of fields to help farm owners monitor crops at different stages of growth and assess the condition of the soil. This could enable farmers to keep track of plant health and determine the amount of fertilizer needed to be applied to avoid wastage.Using the data captured by AI-equipped drones and analyzed by collaborative software, farm owners are able to monitor crop growth and crop health and evaluate the condition of the soil. In turn, this information enables them to make decisions about managing weeds, diseases, and pests, as well as the amount of fertilizer and pesticides to apply to crops.

12	DroneSeed and Bio Carbon https://www.dronesseed.com/ https://www.biocarbonengineering.com/	Both companies are developing drones that can carry a module that fires tree seeds into the ground at optimal locations. While currently designed for reforestation projects, it's not hard to imagine that the modules could be reconfigured to suit various agricultural seeds. With IoT and software for autonomous operation, a fleet of drones could complete extremely precise planting into the ideal conditions for growth of each crop, increasing the changes for faster growth and a higher crop yield.
13	SourceTrace https://www.sourcetrace.com/	A multinational providing different kinds of tech-services in agriculture. Has its India HQ at Hyderabad.

Annexure-III

Indian Companies using Emerging Technologies

Sl.No.	Name of the firm	Technologies and application thereof
1	Stellapps Technologies http://www.stellapps.com/index.php/aboutstellapps/,	Providing dairy farm optimization and monitoring services with a special focus on small- and medium-herd farms. Their applications and tools leverage the Internet of Things, big data, the cloud, mobility, and data analytics to improve milk production, milk procurement, and the cold chain, and to boost animal insurance and farmer payments.
2	Ekagon Technologies http://ekgaon.co.in/ekg/index.php	An IT-based network integrator, offers a range of services to farmers, rural businesses, and women. The ekgaon One Village One World Network is leveraging mobile communication technology to encourage the sustainable development of women-self-help-groups (SHGs) and small farmers across India. The platform has over 900,000 women and 300,000 farmers spread across villages in India.
3	Agnext https://agnext.com/	An Indian start-up, has developed drones among other digital technologies with the objective of creating an integrated hyperlocal farm data collection and crop analytics platform.
4	Skymet Weather Services http://www.skymetweather.com/	Involved in monitoring and predicting weather and providing agri-risk solutions. Skymet can measure and predict yield at the village level for any crop with a high level of accuracy and can also accurately forecast the weather in the short, medium, and long term.
5	BarrixAgro Sciences http://www.barrix.in/	Offers eco-friendly crop protection methods that have the potential to minimize a significant proportion of the damage caused by pests and diseases without overdosing crops and plants with chemicals, thus preventing soil and water contamination.
6	EM3AgriServices http://www.em3agri.com/	Founded in 2014, has quickly risen to become a pioneer in the farming-as-a-service (FaaS) model. EM3's *Samadhan techno kheticentres*offer machines needed to perform all critical farm operations on a pay-for-use basis.26 At their centres, the organization employs agri-professionals who are well versed in the agronomy of the target area.
7	eKutir Global http://www.ekutirsb.com/	Offers an online and mobile based platform to connect marginal farmers with stakeholders across the value chain such as soil-testing labs, suppliers of seeds and fertilizers, banks, exporters, food-processing units, and branded retailers. Agri Suite by eKutir offers a one-stop solution

		for all the needs of a farmer; their field partners also train farmers to use their application.
8	Opencube Labs (OCL), Bengaluru https://opencubelabs.com/	Developed hand held device to check crop health, smart sensors to get real time soil health, smart irrigation system and smart livestock management system.
9	Cropin Technologies, Bengaluru https://www.cropin.com/	An intuitive, intelligent, self-evolving system that delivers future-ready farming solutions to the entire agricultural sector • Robust & flexible system for Farm Management • Traceability & Output Predictability • Accountable & Efficient Operations • Standard package of practices • Alert Log & Management (pest infestation, diseases etc.) • Incorporates end-to-end solutions • Satellite and weather input based advisory • Crop reports & insights – easy reporting on-the-go • Geo tagging for accountability & accurate predictability • Adherence to Compliance & Certification CropIn uses AI technologies to analyze and interpret data to derive real-time actionable insights on standing crop and projects spanning geographies. Also, Cropin offers 'SmartRisk', an agri-business intelligence solution that provides risk mitigation and forecasting for effective credit risk assessment and loan recovery assistance.
10	Intello Labs, Gurugram https://www.intellolabs.com/	This startup, founded in 2016, provides advanced image recognition technology that provides insights on crops' health during the growing season and its final harvested quality by using images. Intello provides smart digital solutions for farm produce's image-based grading, and alerts on crop infestation. Intello offers Intello track that uses a AI platform for grading farm produce based on size, colour etc., while Intello Sort is integrated into machines to sort multiple commodities. Intello Pack monitors colour, size and visual defects of fresh produce while optimizing packing efficiency, and Intello Deep uses an handheld NIR scanner which detects Brix, pH , TSS, dry matter, moisture and pesticide residue in agro produce.
11	Gobasco, Uttar Pradesh	A startup founded in 2017, provides digital solutions that improve efficiencies in the Agri Supply Chain. Gobasco employs real-time data analytics on data-streams coming from multiple sources across the country aided with AI-optimized automated pipelines to dramatically increase the efficiency of the current agri supply chain. Gobasco uses

		AI and related technologies for transaction discovery, quality maintenance, credit risk management and agri-mapping.
12	Gramophone, Madhya Pradesh https://www.gramophone.in/	Founded in 2016, Gramophone technology platform uses AI and machine learning to predict pest and disease, forecast commodity prices for better price realizations and recommends products to farmers. Data on temperature, humidity and pathology / entomology are utilized to provide actionable information for the farmers to provide personalized farm management solution which would guide farmers across the cropping cycle. Gramophone also offers a telephonic advisory service which has a toll-free number, where the farmer can give a missed call and receive a call-back from a Gramophone agriculture expert who provides crop advisories.
13	FASAL (https://fasal.co/)	Fasal, founded in 2018, is an AI-powered IoT platform that delivers insights and analytics to farmers who practice precision agriculture. Fasal's platform offers microclimate forecasts that are tailored to each farm location and are performed at a point scale. The AI-based microclimate forecasting algorithm incorporates real in-field information and relates it to publicly available weather forecasts to guide day-to-day farm operations.
14	Jivabhumi http://jivabhumi.com/	'Foodprint' is a produce aggregation and food traceability solution which aggregates the farm produce, provides e-marketplace services and implements traceability. It claims to use technologies such as blockchain to capture the information of the produce at various levels in the supply chain.
15	Aibono http://www.aibono.com/	Aibono smart farming, founded in 2013, has positioned itself as India's first AI-powered aggregator of fresh produce in India, Aibono's Seed-to-Plate platform shares critical insights, derived from AI & shared farm intelligence, with farmers to increase yields while also enabling retailers & consumers to source super fresh farm produce all year round from a traceable aggregated source.
16	SatSure https://satsure.co/	Founded in 2016, SatSure has developed technology solutions that use satellite image processing, big data capabilities, and IT for delivering information on supply statistics of crops and crop stress to farmers. This information can be used to decide regarding the suitable time for sowing, application of fertilizers, irrigating farmland and prepare for harvest.
17	Acyclic labs	Founded in 2018, Acyclic has developed products utilizing decentralised distributed ledger technologies space, Blockchain and IOTA Tangle, primarily on Ethereum,

	https://acycliclabs.com/	Indium and Tangle networks. Acyclic Labs' product, Sentinel, is a blockchain-powered platform enabling a connected and inclusive world by building powerful, compliant and easy-to-use smart contract solutions.
18	IoTrax http://www.iotracx.com/	Incubated at IIIT Bangalore, IoTrax has positioned itself in the areas of process automation, traceability and analytics by deploying IoT, machine learning and blockchain technologies. IoTracx's product, Agroblock, is a Traceability-as-a-Service Platform for Agro Supply Chains, with the platform being powered By Hyperledger Fabric & AWS.
19	Waycool Foods & Products http://waycool.in/	Founded in July 2015, Waycool has developed products based on artificial intelligence and machine learning to reduce food wastage and production costs. Waycool sources its products directly from the farmers through a technology-enabled, mechanized, and partially automated supply chain. WayCool'sapp platform, RAPID, houses multiple farmer-facing applications such as MySoil, Farm Management systems, MyPrice, MyTransactions, supply chain applications such as forecasting and planning, warehouse management system, digital quality platform and logistics optimization platform, and customer-facing applications such as order capture, tracking and supply performance measurement.
20	Trithi Robotics http://www.3thi.com/	Founded in 2017, Trithi has specialized in offering drones and data for precision agriculture with the drone technology enabling farmers to monitor crops in real time.
21	FrontalRain Technologies http://www.frontalrain.com/	FrontalRain, now renamed as Tier One Digital, offers high-impact software solutions for Agribusinesses and Food Processing companies to achieve supply chain excellence. Tier One Digital's cloud-based applications are deployed along the agribusiness and food value chain by including various stakeholders / participants including farmers, cooperative societies, seed and fertilizer suppliers, food processors, exporters, food testing and certification agencies.
22	Microsoft India	In October, 2017, Microsoft signed an MoU with Government of Karnataka and the MoU will experiment with the Karnataka Agricultural Price Commission (KAPC), Department of Agriculture to help improve price forecasting practices to benefit farmers. Microsoft with guidance from KAPC would develop a multivariate agricultural commodity price forecasting model considering the following datasets - historical sowing area, production, yield, weather datasets and other related

		datasets as relevant. For the first season, Tur crop was identified for this prediction model. The MoU also aimed at using digital tools that have the potential to deliver cutting edge innovations and artificial intelligence to help farmers get higher crop yields in the state. Technology partner Microsoft in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has deployed a Sowing Advisory Service in the kharif season on a limited pilot, under the Bhoochetana project.
23	NinjaCart (https://www.ninjacart.in/)	is a marketing and delivery digital platform for agricultural produce that connects farmers with retailers
24	Ugaoo.com	is a gardening farming platform that works closely with the farmers and provides them with high-quality organic seeds through its portal.
25	SourceTrace https://www.sourcetrace.com/	SourceTrace is a SaaS (Software as a Service) company that focuses on sustainable agriculture and empowerment of farmers. As the world population is estimated to grow to 9 billion by 2050, 50% more food will be required to feed the world. SourceTrace is helping farmers rise to the challenge through digital innovations that improve productivity and predictability in a sustainable manner. SourceTrace's advanced technology platform 'Datagreen' provides comprehensive solutions to manage all aspects of the agricultural value chain.
26	Blocmatrix https://blocmatrix.com/	Blocmatrix, a technology firm, focused on providing innovative solutions using cutting edge technologies like blockchain, Artificial intelligence and IoT. We have been providing impactful solutions in supply chain, logistics/ transportation, agriculture/ livestock, and the entertainment industry.
27	Sense It Out Intelligent Solutions Private Limited https://www.senseitout.com/	A Pune-based start-up, has come up with a solution which aims to optimize water usage using sensors and on-field connected devices, which is known as Sensor-based Intelligent Crop Centric Automation (SICCA) system. This smart irrigation system, can improves the yield per acreage by 1.2-2 times and reduces water wastage by almost 60-70 percent. They monitor the soil conditions and water condition in the field, and according to the input given by the sensors the water supply to the crop are managed.

Annexure IV

Farmer Questionnaire on Role of Emerging Technologies in Agricultural Governance in India

A. Respondent's profile

- Name: Contact Ph. number:
- Village/Town: State: District: Taluk:
- Area under crop/plantation (acres): Dryland: Irrigated:
  Mode of irrigation:
- Main crop /plantation: Area under main crop (acres): Irrigated: Yes / No
  HYV/Hybrid: Yes / No Cultivating since:
- Mode of farming: Independent / Contract If contract for main or secondary crop,
  Name of contracting firm:
  Contract farming since:
- How and Where do you sell your main farm output?

Distance (kms) to i. Market ii. Main road

- What type of processing is done before selling the output?
- Have you attended any agri-based training programs? If yes, details -
- Have you availed loans? Yes / No If Yes,
  If more than one loan has been availed, provide details separately
  Source:

  Amount:

  Purpose:
- Annual Income (previous year) from main crop (tick any one)
  (a) Rs. 50,000 to Rs. 1 Lakh (b) Rs. 1 Lakh to Rs. 1.5 lakh
  (c) Rs. 1.5 lakh to Rs. 2 Lakh (d) Rs. 2 lakh and above
- Annual Income (previous year) from all <u>farm</u> activities incl. animal husbandry (Rs.):
- Annual Income (previous year) from <u>non-farm</u> activities incl. crop processing on job work basis(Rs.):
- Has farm income increased or decreased during last three years? Why?
- Are you or is your family a <u>direct</u> beneficiary of any farm-related government scheme (grant or subsidized loan) during the last three years? *Do not include indirect benefit schemes such as fertilizer/fuel subsidies/PDSbut include PM-Kisan* Yes / No If yes,
  Name/type of Scheme / Program: Year:

  Purpose: Amount/s:
- Highest educational attainment: Self: Family member:
  Relation:
- Do you or does your family (for HH durables) own the following:
  Smartphone: Y / N Computer: Y / N Broadband: Y / N DTH: Y / N 4-wheeler: Y / N

- Does the village have a CSC any other IT-enabled common facility (e.g. info kiosks)? If yes, provide details:

B. Use of Digital Technologies

1. Which of the following ICT-based Solutions / Products do you currently use or have used?

Sl. No.	Solution / Product	Use since	Use upto	Extent/Frequency of use*	Main benefit derived or problem solved	Extent of benefit*
1	E-NAM					
2	FASAL					
3	M-KISAN					
4	Coffee Krishi Tharanga					
	Any other (specify)					

*High (H), Medium (M), Low (L)

2. Source/s of information and decision making prior to adoption/use

Sl. No.	Solution / Product	First source of info	Additional sources referred*	Costs incurred in obtaining information**	Time taken to adopt/use since awareness
1	E-NAM				
2	FASAL				
3	M-KISAN				
4	Coffee Krishi Tharanga				
	Any other (specify)				

*Sources referred/consulted by farmer or exposed to **Costs include direct and indirect tangible costs and intangible costs such as time. Describe the costs, constraints/difficulties faced in obtaining information

3. Financial impact on farm incomes since adoption/use (attributable totechnology solution)

	Impact during previous year*		Extent (H, M, L)	Reason	Impact felt from (year after adoption)	Max. annual impact (%)	Avg. annual impact (%)
	R / C	P					
E-NAM							
FASAL							
M-KISAN							
Coffee Krishi Tharanga							

*R = Revenues, C = Costs, P = Profits. Mention as Increase in Revenues = IR ; Decrease in Revenues = DR ; Increase in Costs = IC ; Decrease in Costs = DC ; Increase in Profits = IP ; Decrease in Profits = DP. Each applicable box to be filled. If respondent is unable to calculate %, interviewer should do so.

4. Perceptions of .characteristics/outcomes of technology solution/s (write H, M, L as applicable in the boxes)

	Characteristics					**Outcomes/benefits on respondent**					
	Easy to use	Affordable	Easy to understand	Can use with existing processes or infrastructure	Modular (scaleable)	Saves time	Higher productivity	Higher Revenues	Lower costs	Lower input use	Social recognition
E-NAM											
FASAL											
M-KISAN											
Coffee Krishi Tharanga											

Explanation: Provide an explanation below regarding the reason for making entries in the table's boxes. Write in detail with key words/numbers

Sub-question regarding outcomes/benefits: What would have happened if the respondent had not adopted/used the tech solution/s?

5. Which ICT-based farm solutions are you aware of and have planned <u>to adopt/use</u> in future?

Sl. No.	Solution / Product	First source of info	Reason/s for non-adoption yet	Planning to adopt by	Process to be followed for adoption/use
1					
2					
3					
4					

6. Which ICT-based farm solutions are you aware of and have planned <u>to not adopt/use</u> in future?

Sl. No.	Solution / Product	First source of info	Reason/s for decision to not adopt/use	Will adopt/use if….
1				
2				
3				
4				

7. What have been the impacts of the ICT solutions on Agricultural governance and the overall sector?

Provide an explanation of the respondent's perceptions regarding impact of the adopted/aware ICT solution on –

a. Agricultural extension and information services
b. Market regulation and access
c. Access to farm inputs such as irrigation, electricity
d. Price discovery and transparency in trading
e. Licensing/Approvals – cost, delays etc.
f. Corruption

Consider the impact on both public and private sector mechanisms

Interviewer name **Interview Date** **Interviewer Ph. No** **Farmer signature**

Annexure - V

Technology Service Providers Questionnaire on the Role of Emerging Technologies in Agricultural Governance in India

C. **Respondent's profile**:

i. Name of the firm:

ii. Year of establishment: Current legal status:

iii. India HQ address: Web URL:

iv. Name of respondent: Contact Ph. Number: Email:

D. Products and Services

i. Thematic areas in which services based on emerging technologies are being provided (e.g. supply chain management, input use efficiency, product trading):

Sl. No.	Area	Technology	Source of technology*	Offered since (year)	Share in revenue increasing (I) or decreasing (D) or constant (C) since last 3 years? Why?
1					

*e.g. developed in-house / by acquisition / licensing etc

ii. Specific products and services in Agriculture sector

Sl. No.	Product / service	Technologies utilized	Primary problem addressed	Target customers*	Current no. of users**	Main crops / agri products for which now used	Major region/s of use (current)
1							

* end-user segments e.g. individual farmers. **Pl. include estimated number of customers of your B2B clients also

E. Drivers and Barriers

i. What has been your experience in introducing emerging technologies/digital technologies among farmers? (e.g. ease of adaptation, cost-benefit expectations, market characteristics)

Product / Service	Enabling factors	Barriers to adoption / use	Overall observations

8. Among the different regions wherein you are providing services, in which region have you been most successful, and why?

Region	Major Products / Services promoted	Factors contributing to success	Constraining factors / inhibitors	Other observations

9. What are the current and/or emerging major challenges in scaling up or replicating the success stories across all regions and farm outputs?

F. Administrative / Regulatory environment and Governance mechanisms

i. What kind of additional support/facilitation/ or administrative & regulatory easing can be provided by the State Agriculture department or the Agriculture Ministry in the Central Government to accelerate technology adoption and promote sustained use of new technologies (ICT-based)?

Problem / barrier to technology adoption / use	Current role of State / Central Government	Expected regulatory/administrative easing by State / Central Government	Desired new facilitatory intervention by State / Central Government

ii. Among the current schemes which are being implemented with the support of Central Government (*Viz.* RKVY, Soil Health Card, PKVY, e-NAM, etc.), are any modifications required in the guidelines / processes / implementation mechanisms to facilitate use of emerging technologies in Agriculture?

iii. What has been the impact of new technologies on governance mechanisms (Market regulation &d access, Access to farm inputs (e.g. irrigation, electricity), Price discovery & transparency in trading, Licensing/Approvals – cost, delays etc., Corruption) relating to Agricultural extension and information services in the agri-based sectors in which you operate?

iv. How do you see the role of state agriculture extension machinery/KVKs evolving in response to use of emerging technologies?

v. Suggestions on capacity building, training and skill development of extension officers

vi. Views on the privacy and security of Farmer's data (Possibility of Data Manipulation, Leakage of sensitive information etc.)

vii. Any other suggestion for leveraging emerging technologies in order to assist in 'doubling of farmers' income'

viii. What has been the impact of new technologies on governance mechanisms (Market regulation &d access, Access to farm inputs (e.g. irrigation, electricity), Price discovery & transparency in trading, Licensing/Approvals – cost, delays etc., Corruption) relating to Agricultural extension and information services in the agri-based sectors in which you operate?

ix. How do you see the role of state agriculture extension machinery/KVKs evolving in response to use of emerging technologies?

x. Suggestions on capacity building, training and skill development of extension officers

xi. Views on the privacy and security of Farmer's data (Possibility of Data Manipulation, Leakage of sensitive information etc.)

xii. Any other suggestion for leveraging emerging technologies in order to assist in 'doubling of farmers' income'

Annexure -VI

Name	Contact Ph. number:	Village/Town	Taluk
Vikram Narendra	9449918333	Byravalli	Chikkamagalur
Yogesh HC	9482160717	Hukkunda	Chikkamagalur
Shankaregowda BH	9448944850	Huigere	Chikkamagalur
Musheer Ahmed	9480221642	Devadara	Chikkamagalur
Basavaraj AR	9449265785	Arenoor	Chikkamagalur
Prakash Kumar CP	9448865211	Arenoor	Chikkamagalur
Vasant Kumar AK	9449421224	Arenahalli	Chikkamagalur
Sandeep	9480029234	Arenahalli	Chikkamagalur
Jayanth AR	9483551274	Arenahalli	Chikkamagalur
Subhadramma		Huigere	Chikkamagalur
Jayaram KC	9449896674	Aralaguppe	Chikkamagalur
Nagaraj	9980772427	Aralaguppe	Chikkamagalur
Girish Kumar	9449305090	Bannur	Chikkamagalur
Ashok	9481150537	Arenahalli	Chikkamagalur
Rathish BN	9448447223	Bettagere	Chikkamagalur
Narayanagowda TK	9480487537	Taruve	Mudigere
Mallesh	8277661314	Vasthare	Mudigere
Puttegowda TN	9902269144	Chiruguna	Chikkamagalur
Chandregowda AR	9481622719	Avathi	Chikkamagalur
Lokesh JD	8762436026	Aralaguppe	Chikkamagalur
Manjunath	9731141135	Anoor	Chikkamagalur
Vidhay	9448493355	Anoor	Chikkamagalur
Padmesh	9449304957	Anoor	Chikkamagalur
Sudheer	9449924635	Anoor	Chikkamagalur
Lalitha KJ	9449418823	Muthamudi	Madikeri
Sheshegowda	9449618011	Aldur	Chikkamagalur
Halappa A	9242869270	Allampura	Chikkamagalur
Venkatesh SM	9480283208	Saragodu	Chikkamagalur
Irfan Ahmed	8105445313	Anoor	Chikkamagalur
Dhruvesh	9242874904	Allampura	Chikkamagalur
Gopal Krishna	7760228998	Allampura	Chikkamagalur
Omkar Murthy AN	9481071299	Anoor	Chikkamagalur
Poornima	9448270208	Aldur	Chikkamagalur
Mallesh DK	9449701823	Aldur	Chikkamagalur

Nagesh DM	9482037284	Banakal	Mudigere
Gopal HK	9242856717	Halikere	Mudigere
Prathap BC	9448900286	Bankenahalli	Mudigere
Devanna Shetty	9480251240	Banakal	Mudigere
Ravikumar	8277373543	Doddamegaravalli	Chikkamagalur
Shivakumar BL			Chikkamagalur
Nagesh	9483072420	Devadara	Chikkamagalur
Nataraj	9535358295	Banavara	Chikkamagalur
Jayaprakash	9480283421	Byaravalli	Chikkamagalur
Pradeep	9481623008	Kadrimidri	Chikkamagalur
Manjunath HR	9481837992	Haliyur	Chikkamagalur
Rathnamma SD	9449701213	Halasumane	Chikkamagalur
Gururaj	8105295587	Vasthare	Chikkamagalur
Raghu	9481619463	Saraguru	Chikkamagalur
Mahesh TA	9449583410	Aralaguppe	Chikkamagalur
Kalyankumar HS	9449741567	Hirerigara	Mudigere
SusheelaJeevala		Jogannanakere	Mudigere
Sandeep HP	9482788508	Jogannanakere	Mudigere
Shylesh KP	7019957605		Mudigere
Shivegowda GS	9449137892	Gonibeedu	Mudigere
Rudresh AD	9483634492	Anajooru	Mudigere
Karunakara Murthy HG	9483811988	Haaluru	Mudigere
Gopalgowda KA	9480251163	Jogannanakere	Mudigere
Manjunath MN	9449170911	G Agrahara	Mudigere
Cyril Pinto	8762711464	Anajooru	Mudigere
Kishore HV	9448340910	Mudigere	Mudigere
Anudeep DM	9480736495	Dinnekere	Mudigere
Bhanuprakash MC	9880322499	Shiragunda	Chikkamagalur
Girish V		Vasthare	Chikkamagalur
Jayamma HD	8277645105	Mathavara	Chikkamagalur
Madan KM	6363878198	Anoor	Chikkamagalur
Manjunath MP	9535283929	Mylimane	Chikkamagalur
Thammaiah CP	9448900396	Arasinaguppe	Chikkamagalur
Nanditha	9448759238	Aralaguppe	Chikkamagalur
Prasanna TM	9844277500	Muthinapula	Chikkamagalur
Padmakshe Gowda KN	9482671857	Arasinaguppe	Chikkamagalur
Pearl Moraes	9480144193	Bindiga	Chikkamagalur
Harsha PC	9741905197	Chamagondanahalli	Chikkamagalur
Manjaiah	9481480271	InamDattatreya Peeta	Chikkamagalur

Darshan GP	9448511296		Chikkamagalur
Cyril Correa	9480157471	Jagara	Chikkamagalur
Baptist Peter Correa	9482787418	Jagara	Chikkamagalur
Poornesh DS	9449206823	Dinnekere	Mudigere
Prakash HC	9481620053	Vasthare	Chikkamagalur
Ramaswamy MC	9480759123	Shirgunda	Chikkamagalur
Teckesh	9945182212	Hukkunda	Chikkamagalur

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