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Innovations spearheading the next transformations in India's agriculture

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INNOVATIONS SPEARHEADING THE NEXT TRANSFORMATIONS IN INDIA'S AGRICULTURE

Kavery Ganguly, Ashok Gulati, Joachim von Braun

List of Abbreviations

ATM	Automated Teller Machine
BMZ	Federal Ministry for Economic Cooperation and Development
Bt	British Telecommunications
CAGR	Compound Annual Growth Rate
CAN	Combine Controller Area Network
CCI	Cotton Corporation of India
CFTs	Confined Field Trials
CHAMAN	Coordinated Horticulture Assessment using Management
CHCs	Custom Hiring Centres
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Centre
CIPHET	Central Institute of Post-Harvest Engineering and Technology
CMFRI	Central Marine Fisheries Research Institute
CRISPR-Cas	Clustered Regularly Interspaced Short Palindromic Repeats
CIMMYT	International Maize and Wheat Improvement Center
DEITY	Department of Electronics and Information Technology
DNA	Daily News and Analysis
DTMA	Drought Tolerant Maize for Africa
EMV	Europay, MasterCard, and Visa
FaaS	Farming as a Service
FAO	Food and Agriculture Organization of the United Nations
FASAL	Forecasting Agricultural Output using Space, Agro-meteorology and Land based observations
FIF	Financial Inclusion Fund
FPOs	Farmer producer organizations
FPRI	Foreign Policy Research Institute
FSSAI	Food Safety Standard Authority of India
GDP	Gross domestic product
GIS	Geographical Information System
GM	Genetically Modified
GNSS	Global Navigation Satellite System
GR	Golden Rice
GSM	Global System for Mobile communication
HPS	High Pressure Sodium
HRS	Hyperspectral Remote Sensing
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
ICRIER	Indian Council for Research on International Economic Relations
ICT	Institute of Chemical Technology
IITA	International Institute of Tropical Agriculture

IMD	India Meteorological Department
IMS	Integrated Management System
INCOIS	Indian National Centre for Ocean Information Services
IoT	Internet of Things
IRRI	International Rice Research Institute
ISRO	Indian Space Research Organization
ITC	Indian Tobacco Company
ITRA	Information Technology Research Academy
JISL	Jain Irrigation Systems Limited
KCC	RuPay Kisan Credit Card
LED	Light-Emitting Diode
LISS	Linear Integrated Self-Scanning
M.I.T.R.A.	Machines Information Technology Resources Agriculture
MASL	Mahindra Agri Solutions Limited
MCIT	Ministry of Communication and Information Technology
MIDH	Mission of Integrated Horticulture Development
MNCFC	Mahalanobis National Crop Forecast Centre
MoA&FW	Ministry of Agriculture and Farmers' Welfare
MoFPI	Ministry of Food Processing Industries
NABARD	National Bank for Agriculture and Rural Development
NADAMS	National Agricultural Drought Assessment and Monitoring System
NAIP	National Agriculture Innovation Project
NAM	National Agricultural Market
NHRDF	National Horticultural Research and Development Foundation
NRSC	National Remote Sensing Centre
OEM	Original Equipment Manufacturer
PE	Pan Evaporation
PFZ	Potential Fishing Zone
PhilRice	Philippine Rice Research Institute
PoS	Point of Sale
PPP	Purchasing Power Parity
PTI	Press Trust of India
R&D	Research and development
RML	Reuters Market Light
RRBs	Regional Rural Banks
SAC	Space Applications Centre
SBLP	Self-Help Group (SHG)-Bank Linkage Program
SENSAGRI	Sensor based Smart Agriculture
SFAC	Small Farmers' Agribusiness Consortium
SHG	Self-Help Group
Siri	Smart Irrigation Controller
SMAM	Sub Mission on Agricultural Mechanization
SMS	Short Message Service

TCS	Tata Consultancy Service
TERI	Energy and Resources Institute
TSS	Thermal Storage System
UAV	Unmanned aerial vehicle
USD	United States dollar
USDA	United States Department of Agriculture
VAD	Vitamin A deficiency

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Abstract

Innovations are fast changing the agricultural landscape driven by the increasing need to shift towards sustainable practices without sacrificing the productivity and profitability of farming. Innovations in technology, institutions, processes, and products have contributed to the growth of agriculture, globally and in developing countries including India and Africa, as observed in the cases of green revolution in cereals; and gene revolution in cotton. More recently, innovations in farm mechanization, micro irrigation, digital technology driven farm and crop management, financial services, energy efficient post-harvest management including LED and solar driven logistics, among others are gaining momentum. These have considerable potential to impact farmers' livelihood through higher productivity, better returns, more employability and in turn catalysing the shift towards sustainable agricultural practices through optimal utilization of resources. In addition to these, innovations in business models – "uberization" of agri-mechanization, direct firm-farm linkages, aggregation of farmers through producer organizations, etc. that make agricultural technology more affordable and adoptable for smallholder farmers are critical for economic and human development of people who depend on agriculture for their income and livelihood security and in effect impact poverty alleviation. For the developing world, innovations must infuse inclusive growth and deliver maximum benefits to the smallholder farmers.

The present study involves an extensive stocktaking exercise of the types of innovations that have emerged globally and in India in particular, and their increasing impact on the agricultural sector. The stocktaking exercise is based not only on peer-reviewed research from the academic fields, but also draws on recent corporate studies. This is done because we observe an accelerated innovation process in which business and startups (for instance in digital services) play an important role. The important trends and therein the lessons learnt which can be adapted to suit the local conditions in India are captured. The study also looks into the policy and institutional reforms that will catalyze the introduction and adoption of the advanced technology solutions in the context of Indian agriculture.

Keywords: Innovations, agribusiness, irrigation, agricultural technology

JEL Classifications: O32, Q 13, Q15, Q16

Executive Summary

The present study involves an extensive stocktaking exercise of the types of innovations that have emerged globally and their potentials for increasing impact on the agricultural sector, farmers and consumers. Our stocktaking draws not only on peer-reviewed research, but also on recent corporate studies. We choose this approach, because we observe an accelerated innovation process in which business and startups play important roles. Impact assessment of biological, mechanical, and organizational innovations currently lags behind actions on the ground. We report on a number of promising innovations that are mainly private sector based. In doing so we partly rely on reporting by the companies and media, although independent evaluations are still missing. The potentials of these reported innovations need further scrutiny by independent detailed research for impact assessments that capture potential positive and negative externalities. The public agricultural research systems must play a strong role in delivering such independent assessments.

INTRODUCTION

Innovation is needed because the world needs 60 per cent more agricultural production to meet the demand of a population of about 9 billion by 2050 (Alexandratos, Bruinsma 2012), because among farming communities are large segments of the world's poorest people, and because the ecology on which agriculture is based (soils, water, biodiversity, climate) is under stress. Agriculture accounts for 37 per cent of employment, 34 per cent of land use, 70 per cent of water use and up to 30 per cent of greenhouse gas emissions (Farming First 2013). Overviews of recent studies on global food loss and wastages indicate that about 27-32 percent of all food produced are lost or wasted. Globally, agriculture employs about 1.3 billion smallholders and landless workers. Nearly 80 percent of the world's food is produced on family farms that predominantly engage family labor (FAO n.d.1). Nearly 88 percent of the global 1.2 billion youth live in developing countries and account for approximately 24 percent of the working poor (FAO n.d.2). Agriculture has linkages with food and nutrition security and hence innovation matters in this context.

For India, with a population of 1.3 billion already and likely to surpass that of China by 2022, demand for food, feed and fiber will keep increasing. Rising income levels, riding 7-8 percent annual GDP growth over the next decade or more and high expenditure on food (40-45 percent) will require stepping up supply significantly to meet the expanding demand. However, with shrinking land holdings (average operational holding size at 1.15 hectares and about 85 percent farmers operating on less than 2 hectares of land) increasing productivity on smallholder farmers will be critical. The challenge is to grow more food, feed and fiber to meet the rapidly increasing demand for these commodities while rebuilding stressed natural resources, and addressing food safety and quality. Innovations for higher productivity are essential to achieve these goals. Large opportunities exist including for the small farm sectors and can be tapped through institutional and technical innovations that take agro-ecological circumstances and markets into account, as well as farming communities' capacities (Gatzweiler, von Braun 2016).

FROM GREEN TO GENE REVOLUTION

Green revolution in South Asia was instrumental in enabling the region to increase cereal production by 88 percent between 1965 and 1995. The next big transformational change was ushered in by the Gene revolution and that of Bt cotton in particular led to increased production of cotton as well as incomes of cotton growers. Since 1996, 18 million farmers across 28 countries of which 20 are developing countries have adopted biotech crops covering an area of nearly 180 million hectares in 2015 from less than 2 million hectares in 1996. The success of Bt cotton in India lies in the fact that cotton production increased from 14 million bales (of 170 kgs) between 2000-01 to 35.1 million bales in 2016-17 and yield increased from 278 kg per hectares to 568 kg per hectare during the same period. A study by ICRIER estimated a gain of approximately USD 55 billion from 2003-04 to 2014-15 to the Indian economy as a result of adopting the usage of Bt cotton in terms of savings from reduced cotton imports and increased export earning, making India the second largest exporter as a result of higher production (Gulati and Sarkar 2016).

Considering the burden of malnourishment and severe vitamin and mineral deficiencies in population, of which children account for a significant share, increasing availability of biofortified foods can be most effective. A good beginning in this direction has already been made with iron rich pearl millet and beans, Vitamin-A rich cassava and orange sweet potatoes, zinc rich wheat, rice and maize, etc. in several countries.

PRECISION TECHNOLOGIES FOR IMPROVED FARM MANAGEMENT

Precision technologies (including Internet of Things - IoT, Big Data, satellite imagery, sensors, robotics, drones, etc) are fast gaining pace in transforming the way farming is done and equipping farmers to take smart decisions based on real time information. Farm machineries including tractors mounted with sensors and connected to mobile platforms allow users to remotely capture farm information related to soil, water, and crop conditions, and calibrate usage of inputs accordingly and monitor progress. Innovative models such as “uberization” of tractors and farm machinery that make farm machinery available on rent and making mechanization more effective and affordable for the farmers are gaining popularity in the developing countries.

Noteworthy are the innovations in irrigation that have the potential to enhance water use efficiency by 80 – 90 percent as well as improve productivity levels. Gulati and Roy (2017) report that direct seeding of rice and use of drip irrigation instead of flood irrigation result in 30-40 percent water savings as observed from field trials. Also, solar driven micro irrigation systems have the potential to help reduce energy costs, and regularize availability of power, allow farmers to benefit from selling surplus energy generated, and also allow savings for the government in terms of subsidy for power allocated to agriculture.

Innovations in sustainable agricultural practices are no longer about open fields but protected cultivation sites as small as terrace tops, balcony porticos to large tracts of greenhouses, poly-houses, and vertical platforms. For instance, using aeroponics to mist the roots of greens with nutrients, water, and oxygen, in a closed loop system, can save up to 95 percent water compared to field farming, 40 percent less than hydroponics, and zero pesticides. The vertical farming market is expected to be valued at USD 5.8 billion by 2022, growing at a CAGR of 24.8 percent between 2016 and 2022. Efficient energy sources such as LED and solar are being increasingly used for such indoor farming units which brings down the cost of energy consumption as well as enhance the growth and maturity of the plants thereby saving time between sowing and harvesting.

Future farms will require precision management enabled by high end automation (driven by robots, drones, etc.) ranging from drip irrigation, fertigation (combining fertilization with drip irrigation), to use of seeds determined by soil type and other conditions. Adoption of such technologies will create an ecosystem for developers; designers, and entrepreneurs in agriculture.

ICT TECHNOLOGIES ENABLING AGRICULTURAL LINKAGES

ICT platforms have emerged in the areas of connecting buyers and sellers on a virtual market platform; enhancing farmers’ access to critical information related to weather, soil health, market prices; and finance. This enables a farmer to plan his farming activities, project the potential output and hence bargain better prices. Also, importantly, advanced technologies are being used for risk mitigation and improving farmers’ access to insurance claims and payments. A plethora of such applications, largely mobile driven are becoming increasingly available globally as well as in India.

Digital transformation in agricultural finance and insurance has gained momentum in Africa, potentially benefitting a large number of smallholders. Flexible, low-cost and ubiquitous digitally enabled financial platforms such as M-Pesa, and M-Shwari in Kenya have been critical in delivering financial services to smallholder farmers in Africa. Introduced in 1998, Kisan Credit Card (KCC) in India is an innovative credit delivery mechanism that meets the short-term and term loans as well as the consumption needs. In addition to ensuring that farmers are connected to sources of finance, advanced technology such as Artificial Intelligence (AI) is enabling robust risk profiles at individual farm level and regional level.

The challenge lies in the effectiveness of these technologies in addressing the field level issues and making these applications user friendly given that farmers are not always educated or technological savvy. Hence the focus needs to be on integrating several of these applications on user friendly platforms, designed with in-built data interpretation and predetermined actions to equip users with end-to-end solutions.

INNOVATION IN AGRICULTURAL LOGISTICS FOR IMPROVED POST-HARVEST MANAGEMENT

Post-harvest losses are largely attributed to lack of advanced infrastructure facilities, supply chain expertise as well as fragmented and overcrowded markets. This adversely impacts the price realization at the farmers' end owing to the poor quality of produce marketed and the loss of output due to wastage. In this context, Government of India launched the National Agricultural Market (NAM) in 2016 with a vision to e-connect regulated markets for greater efficiency and transparency.

High value agriculture in India witnessed several direct firm farm linkages delivering higher incomes to farmers as observed from innovative business models of Nestle, Amul, Heritage foods, among others in the dairy value chain. In the vegetable value chains, companies like PepsiCo, Mahindra and Mahindra, Desai Fruits and Vegetables, Mahagrapes, etc. These ventures have been successful in scaling up their engagement with the farmers, establishing backward integration and facilitating access to key agricultural inputs and services. However, there remain issues and concerns around scaling up these and other similar ventures across value chains and geographies and maximize the benefits accruing to the farmers in a sustainable manner.

Energy efficient cold chain networks powered by IoT and cloud technologies are set to revolutionize post-harvest management and agricultural logistics. The products and solutions offered are aimed at rural users, smallholders and help users optimize their capital expenditures (capex) and operational expenses (opex). Onion storage is critical for containing the extreme price fluctuations and also deliver higher prices to onion growers preventing them to undertake distress sale. Conventional ventilation storage of onions results in high wastage up to 35 percent depending on the weather conditions, which can be reduced to less than 5 percent with cold storages.

INNOVATIONS IN AGRICULTURAL AND FOOD PRODUCTS

Considering the importance of promoting sustainable agricultural practices, innovations in agricultural inputs that help prevent further deterioration of soil and water health are gaining momentum. For instance, Mycorrhiza, a fungal micro-organism feeding host plants with nutrients from the air and soil have the potential to reduce chemical fertilizer use up to 50 percent in certain cases and improve yields by (5-25) percent. Market for algae based bio stimulants, pheromones, among others are fast expanding wherein use of chemical pesticides and fertilizers are being rationalized and gradually substituted by more natural and organic products.

Technology that enables preserve the quality of high value commodities and improve their shelf life will help address the issues related to food losses as well as provide an option to consumers to avail cheaper processed products. Dehydration of fruits and vegetables which removes the moisture and extends the shelf life without addition of any chemicals has a large potential market.

THE WAY FORWARD

While this paper identifies extremely promising biological, technical, organizational, and digital innovations that make many aspects of agriculture more efficient, a puzzle remains: what is the impact of all these innovations on growth of Indian agriculture, and for equity, and sustainability of resource use. Enabling policies, institutions and partnerships hold the key to scaling up such innovations work and achieve the desired ends. The traditional technology transfer concepts may be outdated. All can learn from all. Technological innovation can no longer be pursued separately from organizational and institutional innovations, as one depends on the other. Global platforms like G-20 can facilitate innovation led agricultural transformation and hence advance the agenda of youth employment and entrepreneurship in the sector. Triangular cooperation could be considered too, such as among India, Africa and Germany in this area.

1 Introduction

1.1 Why Innovate?

"Innovation is the process by which inventions are produced – it may involve new ideas, new technologies, or novel applications of existing technologies, new processes or institutions, or more generally, new ways of doing things in a place or by people where they have not been used before" (Juma et al. 2013). Agricultural innovations promise productivity growth through increasing efficiency in the production process and along the entire value chain. In order to be sustainable, the impacts to the effected ecological and social systems needs to be taken into account.

Innovation is needed because the world needs 60 per cent more agricultural production to meet the demand of a population of about 9 billion by 2050 (Alexandratos, Bruinsma 2012), because among farming communities are large segments of the world's poorest people, and because the ecology on which agriculture is based (soils, water, biodiversity, climate) is under stress. Agriculture accounts for 37 per cent of employment, 34 per cent of land use, 70 per cent of water use and up to 30 per cent of greenhouse gas emissions (Farming First 2013). The challenge today is to grow more food, feed and fiber to meet the rapidly increasing demand for these commodities while rebuilding stressed natural resources, and addressing food safety and quality. Innovations for higher productivity – broadly defined (related to labor, land and capital) - are essential to achieve these goals.

Innovations in seed technology, input usage, farming practices, harvesting, transportation and storage, value addition, packaging, and marketing will all come together in delivering significant results in terms of improving the availability as well as affordability of commodities. With the increasing impact of climate change in terms of rising temperatures and erratic rainfall patterns, innovations in seed technology will be important in delivering heat and drought tolerant seeds. Environmentally sustainable agricultural practices will need limiting over use of pesticides and fertilizers and hence innovations in input applications as well composition of these inputs can enable optimal input utilization. The net benefit is demonstrated in terms of higher yield, quality produce and savings in production costs.

Recent studies on global food loss and wastages indicate that about 27-32 percent of all food produced are lost or wasted. Cereal losses are estimated at 19–32 percent, root and tuber losses at 33–60 percent, and fruit and vegetable losses at 37–55 percent, yet these estimates often refer only to weights and do not capture value of produce (as per FAO estimates in Schuster and Torero 2016). Both infrastructure and practices are important to contain the losses and improve value addition in primary commodities. Innovations in transport, storage and packaging that helps control temperature variation and improves the shelf life of perishable produce are important. Innovations in marketing that allow farmers to sell directly to consumers and cut down long chain of intermediation through virtual platforms enabled by internet and mobile connectivity have the potential to deliver higher prices and benefits to the smallest farmer. Innovations in value added food products have been effective in improving the shelf life of perishable high value commodities; and making food more affordable to consumers. With changing lifestyles and increasing income levels, demand for value added foods is increasing and this incentivizes further promoting innovations in food that are affordable and at the same time safe to consume.

Globally, agriculture employs about 1.3 billion smallholders and landless workers. Nearly 80 percent of the world's food is produced on family farms that predominantly engage family labor (FAO n.d.1). Nearly 88 percent of the global 1.2 billion youth live in developing countries and account for approximately 24 percent of the working poor (FAO n.d.2). For the developing countries, innovations in agriculture play a critical role in achieving livelihood security of people dependent on agriculture as well as creating new employment opportunities for youth. Considering that the bulk of the global agricultural supply comes from smallholder farms, innovations in making solutions affordable and adaptable to local conditions and needs will be effective in delivering positive outcomes. Making agriculture a profitable and attractive enterprise for the youth will be key for achieving larger development and food security goals.

Agriculture has linkages with food and nutrition security and hence innovation matters in this respect. With a global headcount ratio of 11 percent, about 767 million people living on US$1.90-a-day (at 2011 purchasing power parity (PPP) poverty line), of which 256 million people live in South Asia and 389 million in Sub-Saharan Africa, improving global nutrition security is a huge challenge still to overcome (World Bank 2016). Around 870 million people are undernourished, globally and those suffering from hidden hunger or micronutrient deficiency are estimated at close to 2 billion. Majority of this population live in Asia and Africa with children and women most affected. Globally, 163 million children under 5 years suffer from VAD - 65 million in Sub-Saharan Africa and about 49 million in Asia resulting in stunted growth, weakened immunity, blindness, and increased mortality (CIP n.d.). Innovations in crop varieties that are loaded with essential nutrients like vitamin, zinc, iron, etc can impact nutrition in a positive way. Hence, biofortification of crops and its rapid commercialization and scaling up in regions, where undernutrition threatens a large section of population needs to be fast tracked. Also, fortification of foods like flour, rice, edible oil – staples that are consumed by a large consumer base can be an effective tool in replenishing the nutrient requirements. Innovations in fortification that do not compromise on the palatability of the foods and are affordable to the population who are most vulnerable to undernutrition can be instrumental in overcoming the challenge of hidden hunger.

For India, with a population of 1.3 billion already and likely to surpass that of China by 2022 (BBC 2015), demand for food, feed and fiber will keep increasing. Rising income levels, riding 7-8 percent annual GDP growth over the next decade or more and high expenditure on food (40-45 percent) will require stepping up supply significantly to meet the expanding demand. However, with shrinking land holdings - average operational holding size at 1.15 hectares and about 85 percent farmers operating on less than 2 hectares of land, increasing productivity of smallholder farmers will be critical. Indian agriculture faces considerable groundwater challenges in terms of depleting and deteriorating water resources owing to intensification of farming resulting in declining per capita water supply at less than 1,700 cubic meters per year. India also experiences climate change in terms of rising temperatures and erratic monsoons resulting in recurring droughts. Such droughts, as experienced in 2014 and 2015, adversely impact the crop sector and farmers' incomes. India faces a huge challenge to grow more and grow sustainably with limited resources. Agricultural resources including land, water and labor face competition from non-agricultural sectors. Hence innovations all along the agricultural value chains will be imperative for India to sustain its food security as well provide income and livelihood security to farmers. Also, India is home to a large number of poor people and has the highest number of stunted children under 3-year age, which makes innovations for attaining nutrition security even more important.

In the developing world, and India and Africa in particular, innovations must catalyze gains for the smallholders in terms of higher productivity, effective risk mitigation through access to credit and insurance and increased incomes through market linkages; access to quality information and services; boost employment opportunities for the youth; and improve accessibility and affordability of healthy and safe food. From a sustainability standpoint, it is important to ensure innovations encourage farmers to adopt climate smart agricultural practices through optimal utilization of natural resources (micro irrigation, vertical farming, etc), energy efficient power sources (like solar and/or LED), controlling post-harvest losses through better infrastructure and services, and improving value addition in fresh produce for better price realization for farmers. Innovations in policy making and institutions that encourage consolidation, greater outreach and access to input and output markets will be most valuable in achieving a holistic and inclusive growth. Also, it is critical to nurture an ecosystem that aims at incentivizing investments in research and development and innovative business models that aim at improving access and delivering the benefits in an affordable format.

Rosegrant et.al. (2014) report that in the developing nations, the number of food-insecure people could be potentially reduced by 12 percent if nitrogen use efficiency technologies were successfully developed and adopted, by 9 percent if no-till is adopted more aggressively and by 8 percent with widespread adoption of heat tolerance and precision agriculture. Results show that irrigation water savings on fields under drip irrigation are 24 to 27 percent, depending on crop and climate change scenario, much higher than water savings for sprinkler irrigation systems calculated at 11 to 12 percent. At an aggregate level, if all the 11 technologies (no-till, drip irrigation, sprinkler irrigation, drought tolerant, heat tolerant, precision agriculture, nitrogen use efficiency, crop protection, water harvesting, organic agriculture, and integrated soil fertility management) with positive yield impacts were adopted together for maize, wheat and rice, their prices could be reduced by 49 percent, 45 percent and 43 percent, respectively. This is equivalent to reducing the number of people at risk of hunger by 40 percent, globally.

Innovations in agriculture hold the key to ensuring agriculture is sustainable, productive and profitable. Agriculture is increasingly a business enterprise and innovations are pushing the production frontiers. However, for those countries where it plays an important role in terms of providing livelihood and income security, innovations can contribute toward further strengthening the ecosystem and harnessing different institutions and partnerships to make agriculture a sustainable, productive and profitable enterprise. Agriculture innovations across the various segments of the value chains are at different levels of accomplishment across geographies and commodities. This has attracted big and small players, both from the agriculture sector and beyond. It has also witnessed young entrepreneurs joining the foray – opening up the spectrum of technology solutions for the common challenges confronting the agricultural sector.

1.2 Scope, Limitations, and Design of the Study

This study observes how innovations are rapidly reshaping the agricultural landscape, globally and in India. It captures how the key technology solutions that may see their way into the future with the most impact, looks into business models that will ensure successful deployment, and highlights key achievements in terms of higher income for the farmers, and greater availability and affordability of agricultural produce, and its impact on the environment from a sustainability standpoint.

The present study involves an extensive stocktaking exercise of the types of innovations that have emerged globally and their potentials for increasing impact on the agricultural sector, farmers and consumers. The stocktaking exercise is based not only on peer-reviewed research from the academic fields, but also draws on recent corporate studies. This is done because we observe an accelerated innovation process in which business and startups (for instance in digital services) play an important role. Impact assessment of biological, mechanical, and organizational innovations currently lags behind actions on the ground. We report on a number of promising innovations that are mainly private sector based. In doing so we partly rely on reporting by the companies and media, although independent evaluations are still missing. The potentials of these innovations need further scrutiny by independent detailed research for impact assessments that also capture potential positive and negative externalities. We mention many specific examples at a state of early implementation to which such impact assessments should relate. The public agricultural research systems must play a strong role in delivering such independent assessments.

Important trends and therein the lessons learnt which can be adapted to suit the local conditions in India are captured. The study also looks into the policy and institutional reforms that could catalyze the introduction and adoption of the advanced technology solutions in the context of Indian agriculture.

2 Biological Innovations– From Green To Gene Revolution

2.1 Green Revolution

The journey from Green to Gene revolution in agriculture has helped South Asian countries to progress out of food aid/import dependencies and secure food availability for their people as well as export surplus in certain cases. Innovations in seed technology to enhance crop productivity, improve resilience of crops to weather shocks and pest attacks, optimize use of soil, water and energy has immensely benefited farmers, globally, through savings in costs of production, increased production and higher incomes.

Green revolution in South Asia was instrumental in enabling the region increase cereal production by 88 percent between 1965 and 1995. The adoption of high yielding varieties was so rapid that during 1965 and 1975, that percent of harvested area under modern varieties for rice increased from 0 percent to 26.6 percent; wheat increased from 1.7 percent to 72.5 percent and maize from 0 percent to 26.3 percent (Hazell 2009). On average, public spending on agriculture as a share of total government spending has been consistently low at 5 to 6 percent in Africa for over 40 years, whereas Asian countries spent 15 percent or more of their total budget on agriculture during the Green Revolution era (Hazell 2009). Similar breakthrough was not achieved in Africa and in many ways the first Green revolution did not take off in the continent for various reasons. Hazell (2009) analyzed that crops such as rice, wheat and maize contributed to a much smaller proportion of the food basket in Africa. Compared to Asia, public spending and Government coming together to ensure that farmers were able to adopt and hence benefit from the revolution was missing.

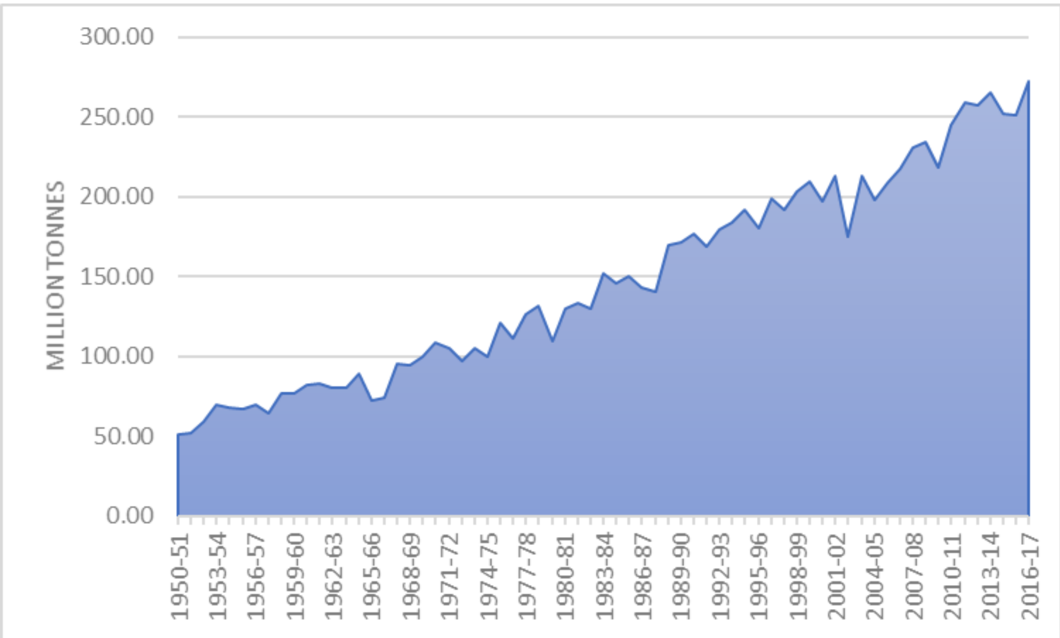


Figure 2.1: Trends in Food Grain production in India

Source: Agricultural Statistics at a Glance 2015, GoI 2016

In India, foodgrain production increased from 50.8 million tonnes in 1950-51 to 108.4 million tonnes in 1970-71 and 129.6 million tonnes in 1980-81 (figure 2.1). The productivity of foodgrains increased from 522 kg per hectare to 872 kg per hectare and 1023 kg per hectare during the same period.

The green revolution in India was most significant in enabling the nation to overcome frequent outbreak of famines and hunger related deaths. It added to the development of the agricultural sector with policy and spending focus on creating the right infrastructure and markets to handle the bulk production of grains. This resulted in both income as well as food security of the farmers, who accounted for a large section of the rural population. Noteworthy, the role of the government in catalyzing the success of the green revolution through partnerships and public spending. While progress was achieved undernutrition due to prevalence of extreme poverty and sanitation and health issues remains a large problem in rural India.

2.2 Gene Revolution

The next big transformational change was ushered in by the Gene revolution and that of Bt cotton in particular led to phenomenally increased production of cotton as well as incomes of cotton growers. Since 1996, 18 million farmers across 28 countries of which 20 are developing countries have adopted biotech crops covering an area of nearly 180 million hectares (a 100 - fold increase from less than 2 million hectares in 1996). Farmers from Latin America, Asia, and Africa collectively grew biotech crops on 54 percent of the total area i.e. 97.1 million hectares. About 6.6 million farmers in China and another 7.7 million farmers in India planted more than 15 million hectares of Bt cotton in 2015. In 2015, biotech crops helped more than 16.5 million smallholder farmers and their families worldwide. More than half the world's population, about 60 percent or nearly 4 billion people, live in the 28 countries which planted biotech crops in 2015 (Clive 2015).

Bt Cotton[1]

Between 1996 to 2014, farmers gained from reduced cost of production and significant increase in crop productivity resulting in economic gains of US$150 billion at the farm level. Pesticides use declined by 584 million kilograms. In 2014, fewer insecticide sprays reduced CO2 emissions by 27 billion kilograms, equivalent to taking 12 million cars off the road for a year (Clive 2015). Klümper and Qaim (2014) found that on average, GM technology adoption has reduced chemical pesticide use by 37 percent, increased crop yields by 22 percent, and increased farmer profits by 68 percent. Yield

[1] Photo source: https://www.indoasiancommodities.com/wp-content/uploads/2016/01/Cotton-field-720x540-720x540.jpg

and profit gains are higher in developing countries than in developed countries. It also helped conserving biodiversity in the period 1996-2014 by saving the equivalent of 152 million hectares of land. Latin America has the largest percentage of biotech crops grown in 2015, led by Brazil and Argentina. Bangladesh advanced commercial cultivation of Bt brinjal/eggplant. In 2015, South Africa, Burkina Faso, and Sudan also planted biotech crops (Clive 2015).

2.2.1 Bt cotton revolution in India

The success of Bt cotton in India lies in the fact that cotton production increased from 14 million bales (of 170 kgs) between 2000-01 to 35.1 million bales in 2016-17 and yield increased from 278 kg per hectares to 568 kg per hectare during the same period. This enabled India become the leading producer of cotton accounting for 26 percent of the global cotton production (figure 2.2).

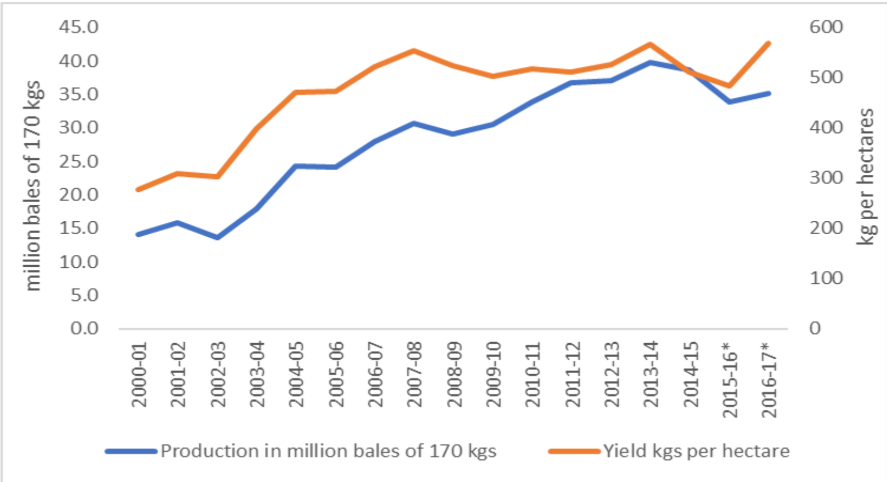


Figure 2.2: Trends in Cotton production and yield in India

Source: Cotton Corporation of India (CCI) 2017

India also emerged as a large exporter of cotton with exports rising from USD 0.9 billion in 2005-06 to a peak of USD 4.9 billion in 2011-12 and then gradually declined and slumped to USD 1.7 billion in 2015-16 (figure 2.3). A study by ICRIER (Gulati and Sarkar 2016) estimated a gain of approximately USD 55 billion from 2003-04 to 2014-15 to the Indian economy as a result of adopting the usage of Bt cotton in terms of savings from reduced cotton imports (compared to a business as usual scenario), and increase in export earnings, making India the second largest exporter of cotton.

The economic and environmental benefits of adopting Bt cotton in terms of higher net incomes, facilitating access to food and nutrition and reduction in use of pesticides and chemicals have been well studied. Controlling for other factors, adoption of GM cotton significantly improved calorie consumption and dietary quality, resulting from increased family incomes and reduced food insecurity by 15–20 percent among cotton-producing households (Qaim and Kouser 2013). Between 2002 and 2008, Bt technology resulted in 24 percent increase in cotton yield per acre through reduced pest damage and 50 percent gain in cotton profit among smallholders (Kathage and Qaim 2012).

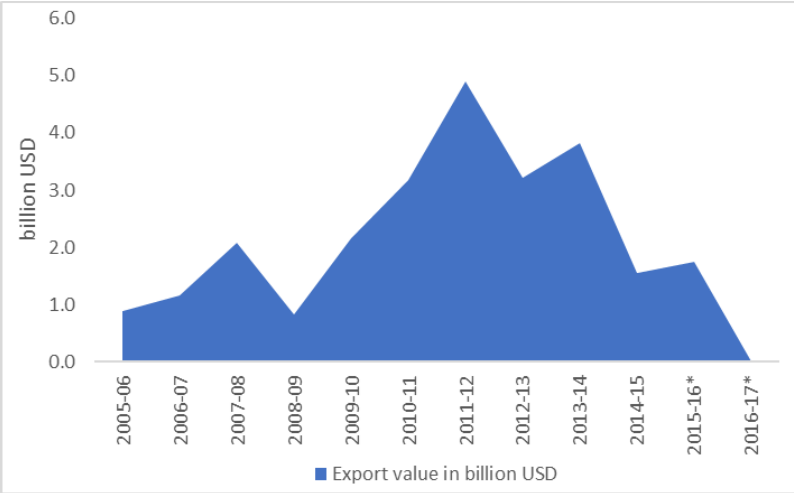


Figure 2.3: Trends in cotton export from India

Source: Cotton Corporation of India (CCI) 2017

While the Bt cotton revolution unfolded once official clearances for its commercial use were announced on March 26, 2002, India could not take it to other crops due to policy and regulatory constraints. Bt brinjal and GM mustard are a case in point, which have been approved by the GEAC in 2010 and May 2017 respectively, but so far their commercial release has been on hold. Several non-governmental organizations and civil society groups have opposed release of GM crops in India citing adverse health and environmental impacts and exposing farmers to greater risk of monopoly in seed business. Genetic Engineering Appraisal Committee (GEAC), the apex bio regulatory body constituted in the Ministry of Environment and Forests, Government of India has been reviewing the safety of GM crops in India. Recently, on 11 May 2017, it recommended approval for commercial production of GM mustard; and in 2010, GEAC had approved Bt brinjal but it could not be cleared by the Ministry and a moratorium was put in place on the release of Bt brinjal for commercial production (Aggarwal 2017).

It is prudent to encourage further R&D and field trials to gather evidence rather than being caught in regulation and policy uncertainties. Unlike the earlier green revolution, the gene revolution is being led by the private sector in terms of the massive investments in R&D which is both resource and time intensive. Hence, the government will need to play a more enabling role in ensuring the future of GM crops in India is shaped by science and not perceptions. While it is of utmost importance to safeguard the interest of farmers and consumers, the same should be aimed at through rationale policy choices and unbiased acknowledgement of the role of the companies genuinely investing in R&D.

2.2.2 Climate Resilient Hybrid Seeds

Agriculture is one of the most vulnerable sectors with respect to the impact of climate change. Increasing global temperatures are likely to take a hit on the productivity and hence overall availability of staple food crops like wheat and rice (Wheeler and von Braun 2013). Also, with increasing scarcity of water for irrigation purposes, crops are likely to be under more stress thereby impacting their output. In this regard, developing seed varieties that are resilient to extreme weather conditions and are also less water and input intensive is imperative.

Biotech Drought Gard™ tolerant maize, first planted in the US in 2013, increased more than 15-fold from 50,000 hectares in 2013 to 275,000 hectares in 2014 and 810,000 hectares in 2015, reflecting high farmer acceptance at 3-fold year-to-year between 2014 and 2015. Drought Gard hybrids are part of a systems approach that combine best agronomic recommendations, germplasm and a drought-tolerant biotech trait. They are designed to help the plant adapt to drought stress, use available soil moisture efficiently and provide the opportunity to help minimize yield loss from drought. International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA) in close collaboration with private and public sector developed over 200 varieties with preferred farmer traits to help them address the drought constraint as well as other drought-related challenges. In 2014, 54,000 metric tons of certified drought-tolerant maize seed was produced across the 13 Drought Tolerant Maize for Africa (DTMA) project countries benefitting an estimated 5.4 million households – or 43 million people with over 100 national seed companies, has made it possible to get the seed to 43 million smallholders and their families (CIMMYT n.d.).

DuPont Pioneer has been working on CRISPR-Cas to improve corn plant's ability to withstand drought stress. Field trials of the resulting elite corn hybrids exhibited an average five-bushel-per-acre increase in grain yield under water-limited stress during flowering, and no decrease in yield under optimal water availability (Shi Jinrui, et.al. 2016). Additional trials are being conducted to determine commercial potential under a variety of environments. Pioneer is establishing a CRISPR-Cas advanced breeding platform to develop seed products for greater environmental resiliency, productivity and sustainability (DuPont Pioneer n.d.).

2.3 Biofortification For Improved Nutritional Security

Technology breakthrough in staples like rice, pulses, maize, soybean, vegetables, etc will be critical in addressing both food and nutrition security, globally. Considering the burden of malnourishment and severe vitamin and mineral deficiencies in population, of which children account for a significant share, increasing availability of biofortified foods can be effective. Biofortification aims at preventing micronutrient deficiency that is sustainable and scalable. Current estimates suggest that biofortified foods reach more than 15 million people in focus countries in Africa and Asia. Cumulatively, more than 100 biofortified varieties across 10 crops have been released in 30 countries, where second and third waves of even higher nutrient lines are being tested for future release. Candidate biofortified varieties across 12 crops are being evaluated for release in an additional 25 countries (HarvestPlus 2015). The goal is to reach 100 million people with biofortified nutritious foods by 2020 and one billion people with biofortified foods by 2030 (HarvestPlus n.d.). There are examples demonstrating the potential of biofortified staples in addressing malnutrition, production of which need to be commercialized and scaled up to tackle the challenge of such a tall order. Countries like India, and Sub Saharan Africa can benefit the most given the burden of malnourished children and women. Foods like iron rich pearl millet and beans; Vitamin A rich cassava, orange sweet potato; and zinc rich rice, wheat and maize are already approved for commercial production in a number of countries. Vitamin A rich GM rice (i.e., golden rice), which has been embroiled in controversy, too has the potential to solve the global nutrition challenge. HarvestPlus focuses on three micronutrients: Iron (Fe), zinc (Zn) and vitamin A - Triumvirate for Good Health.

As of the end of 2016, HarvestPlus estimates that approximately 20 million people in four million farming households in HarvestPlus target countries are now growing and consuming biofortified crops (Bouis and Saltzman 2017). Biofortification of staple crops can be beneficial for India in tackling the problem of malnutrition widespread among children in particular. Two variants of iron rich pearl millet - Dhanashakti and Shakti 1201 are available in India. Dhanashakti was released in 2013 and adopted by 65,000 farmers in 2015. Shakti 1201 has been adopted by 35,000 farmers in 2015. Zinc rich wheat is undergoing disease trials. BHU-35 variant is ready to be released in Uttar Pradesh pending regulatory clearances (Rai n.d.). Also, zinc fortified wheat in undergoing trials in India across 70 locations with two varieties being distributed to nearly 5000 farmers. About 7 varieties of zinc rich wheat are under trial for disease testing. One of the varieties, BHU-35 has cleared the disease-testing stage and is ready to be released in Uttar Pradesh for cultivation, after a few more regulatory clearances (Mishra, Chand and Joshi 2016).

Studies have shown that vitamin A supplementation could reduce mortality in children younger than 5 years by 24–30 percent (IRRI 2017). International Rice Research Institute (IRRI) continues its collaboration with national research agencies in the Philippines, Indonesia, Bangladesh, and other countries to develop Golden Rice as a potential new food-based approach to improve vitamin A status. Screenhouse and confined field trials (CFTs) of Golden Rice are being conducted by IRRI and the Philippine Rice Research Institute (PhilRice), rigorously following all biosafety and other regulatory protocols. Similar activities are ongoing in Bangladesh using their local varieties, and biosafety data are generated as required by regulatory agencies. Women and children are the most vulnerable to vitamin A deficiency (VAD), the leading cause of childhood blindness and inability of the immune systems to combat disease. Studies have shown that vitamin A supplementation could reduce all mortality in children younger than 5 years by 24–30 percent. Vitamin A availability could prevent 1.3–2.5 million of the nearly 8 million late-infancy and preschool-age child deaths annually in developing countries with the highest risk (IRRI 2017).

2.4 Staple Food Fortification – Enriching Foods

While nutrition is linked to the type of food consumption, dietary diversification that ensures adequate intake of micro nutrients, supplementation and food fortification are often recommended to overcome the micro nutrient deficiency. The Copenhagen Consensus[2] ranks fortification as a top development priority to improve global child survival rates. Fortified foods include vegetable oil with vitamin A and D; wheat and maize flour with iron, folic acid, other B vitamins and zinc; sauces and condiments such as soy sauce with iron; and salt with iodine. Fortification of edible oil and milk with micronutrients like iron, folic acid, vitamin B12, and vitamins A and D helps deliver these micronutrients through daily diets. Fortifying wheat flour with iron and folic acid can improve the intakes of these essential micronutrients to help prevent iron-deficiency anaemia, as well as prevent most folate-related birth defects. Salt is a chosen vehicle for iodine given that it is widely consumed across populations and in fairly similar doses. Since the early 1920s, countries like USA and Switzerland have undertaken food fortification with essential vitamins and mineral and this has helped them reduce and eliminate wide spread diseases such as goitre, beri-beri, pellagra and rickets. In the 1950s, fortification of vanaspati with vitamin A and D was mandated by law in India as poor communities were unable to consume dairy products to meet their recommended daily requirements of these vital nutrients. A national policy of universal salt iodization was adopted in 1986 in India and subsequent legislation in 1997, bans the sale of non-iodized salt for direct human consumption. In October 2016, Food Safety Standard Authority of India (FSSAI) operationalized the standards for fortification of food items like salt, edible oil, milk, wheat and rice with iron, folic acid, Vitamin-D and Vitamin-A. While fortification of edible oil, milk is being done by Cargill, Ruchi Soya, Adani, Mother Dairy, Danone, among others, in varying levels, with the fortification standards in place, others are expected to join the fortification drive and bring their product portfolios under the fortification brand. There has been a lot of deliberations around making food fortification mandatory in India keeping in view the problem of malnutrition so widespread and intensive in the country. Globally 84 countries have legislation that mandates fortification of wheat flour, maize flour, or rice.[3] About 79 countries around the world have made it the law to fortify at least one major grain: 78 of them fortify wheat flour, 12 fortify maize products and five fortify rice. Comparing the cost of micro nutrient supplementation with food fortification, World Bank estimates (referenced in BMZ 2012) show that the per capita cost of a dose of Vitamin A supplementation varies from USD 1.00 to USD 2.5 compared to the annual per capita cost of fortifying food with Vitamin A, which costs USD 0.69 to USD 0.98. Similarly, a dose of Iron supplementation varies from USD 0.5 to USD 3.17 compared to the annual per capita cost of fortifying food with Iron which costs USD 0.12 to USD 0.22.

[2] http://www.copenhagenconsensus.com/
[3] http://www.gainhealth.org/programs/initiatives/

3 Precision technologies For Improved Farm Management

Agricultural technology innovations, which aim at sustainably increasing productivity growth for smallholders are a set of technologies that need to consider a set of matching conditions (Gatzweiler and von Braun 2016):

1. match the attributes of the smallholders, i.e., they need to be able and wanting to increase land or labour productivity by means of technology.
2. match the strategies of the smallholders, i.e., the use of the technology needs to match a viable strategic option of the smallholder. (Smallholder strategies may be to intensify production, to diversify income from agriculture, to diversify income from agriculture and non-agriculture).
3. match the institutional environment, i.e., property rights which guarantee the smallholder a flow of benefits or a reduction of costs.
4. match the agro-ecological environment in which smallholders are operating without creating undue risks.

We take stock of a diverse set of innovations below, that offer promise if appropriately mapped into such matching conditions. Further research on each of these would be useful to identify their actual scope and opportunities for scaling.

3.1 Relevance of Precision Technologies in High Value Agriculture

Precision technologies equip farmers to take smart decisions (allowing them to optimize resource utilization and maximize output per unit of resources) based on real time information by guiding them on input application, sowing and harvest time, post-harvest management conditions and recommended practices. Considering the rising demand for high value commodities such as horticulture, livestock and marines, and their high perishability and susceptibility to diseases and contamination, it is important to ensure that farmers adopt safe farming and post-harvest management practices. Hence, the role of precision technologies is of growing importance and infrastructure and services need to complement the technology adoption.

Some of the emerging applications of precision technologies in horticulture include automated grading of fruits and vegetables, automated systems with specific parameters to assess quality based on color, size, shape, acidity, sugar content, external defects, etc (Zarco-Tejada , et.al. 2014). Variable pesticide spraying can be based on size and density of tree crown, environmental conditions, among others, building crop quality and yield maps, which allow to segregate crops based on different potential processing qualities. Variable rate application helps reduce ground water contamination and precision tillage reduces soil erosion thereby promoting sustainable agricultural practices.

With respect to livestock sector, emerging precision technologies include Integrated Management System (IMS) used to identify each animal, particularly pigs, poultry and dairy livestock. The processes include monitoring animal growth, milk and egg production, diagnosing diseases, animal behavior, emission of gaseous pollutants, robotic feeding systems, weighing systems, robotic cleaners, feed pushers, and imaging systems that reduce direct contact with animals. Global Navigation Satellite System (GNSS) helps tag animals and track them. It can also detect behavior, illness, fertility, monitor ruminal pH in cows (nutritional status and disease). Advanced technology enabled e-tracking helps remote monitoring and management of animals; virtual fencing and GNSS (satellite) location of animal and sound/electrical stimulus allows one to confine animals to a geographical area without physical fencing. Automatic Milking Machines connect animals to vacuum milking line and on an average, milks 65 or more cows for 2.7 times a day (more than usual twice a day, which is beneficial for cow and may increase milk yield). Milk Monitoring Systems check fat and microbial levels enabling early checks for infection. Sensor technology provides real time data on alert birthing and fertility via SMS. Sensor on animal collar helps detect oestrus and indicates readiness for fertilization and the information is then sent to the farmer through SMS which helps him plan insemination (Zarco-Tejada, et.al. 2014).

From the economic point of view, a review of 234 studies published from 1988 to 2005 showed that precision agriculture was found to be profitable on an average of 68 percent of the cases (Zarco-Tejada, et.al. 2014). Market for digital-based services, known as precision agriculture is expected to grow at a CAGR of 12.2 percent between 2014 and 2020 to reach $4.55 billion. According to the USDA, over 60 percent of U.S. agricultural input dealers offer some kind of variable-rate-technology services. However, less than 20 percent of acreage is managed using the technology due to the high cost of gathering precise field data. Depending on the crop, the Precision Agriculture Service can help increase overall profitability by USD 55 to USD 110 per acre (Accenture Digital 2015).

3.2 Innovations in Farm and Crop management

In the following we review specific examples of early implementation to which such impact assessments might be linked.

3.2.1 Digitizing Farm Mechanization

Digitally driven precision agriculture is gaining prominence not just in countries with huge tracts of agricultural land and cash rich farmers but also in countries with very small tracts of land. The focus is on developing innovative business models that make adoption economically feasible for the farmers. Coupling farm mechanization with real time data collection and assessment of farm conditions to allow precision farming. Countries such as Netherlands, Japan, USA, Israel, among others have been leading in the adoption of advanced technologies in agriculture. Agribusiness giants like John Deere, Monsanto – Climate Corporation, CLAAS, and others have introduced digital devices such as sensors compatible with tractors and other field machineries, UAVs to collect real time farm data and with the help of Internet of Things (IoT) and Big Data use real time field information for precision farming. John Deere has developed precision technology specifically for their tractors, combines, sprayers, planters, hay, and tillage products. John Deere Operations Center is a centralized online portal that allows one to access, view, archive, manage, and share the operation's information such as average yield, total yield, average moisture, seeding variety and rates and machine location. All this information can be seen and analyzed using Field Analyzer tool on the portal. JD-Link is a telematics system designed to remotely connect owners and managers to their equipment, providing alerts and machine information including location, utilization, performance, and maintenance data to manage where and how equipment is being used (John Deere n.d.).

Claas Telematics is a management tool that collects all important operational data of a self-propelled harvester and transfers it to a web page to give the owner unlimited access using just an internet connection. It helps analyze the efficiency of the harvester and offers other features like live remote GPS tracking and tracing, yield monitoring and mapping, and checking the status of machine maintenance (Farm Equipment 2011).

The Climate Corporation's latest offering Field-View Drive provides seamless data connectivity for farmers by easily transferring field data from their equipment into their Climate Field-View account. The Field-View Drive connects to a tractor or combine controller area network (CAN) diagnostic port and uses blue-tooth technology to wirelessly map a farmer's data onto an iPad. Field-View Drive captures key planting data including hybrid and planting population as well as key harvest data such as yield. When Field-View Drive is partnering with Field-View Plus, data is digitally displayed as a farmer passes through his field enabling him to easily understand hybrid performance by field, soil zone and population with side-by-side views of planted and yield data (Monsanto 2016). While these technologies are being adopted worldwide, these are yet to be seen in countries with small tracts of land and farmers who do not have financial resources to invest in these hi-tech solutions.

Climate Fieldview – Monsanto[4]

In India, Mahindra & Mahindra Limited part of the USD 17.8 billion Mahindra Group launched DiGiSENSE 1.0 offering a unified, cloud-based technology platform for its entire mobility sector. This is an integrated technology platform powered by telematic device for vehicle connectivity across a wide range of mobility products, tractors and businesses. It will enable the customers to digitally build knowledge 24x7 about the performance and location of their mobility products and tractors. Key features of this model include route planning and delivery tracking; vehicle utilization reports; trip optimization; alerts and machine hour operations; and geo fencing. Recently, DiGiSENSE technology has been made available in the 57HP – 605DI-i Arjun Novo, a leading tractor brand. Farmers will be able to avail live tractor tracking, while remote diagnostics and reports will enable them to monitor the tractor's health and productivity parameters. With this venture, Mahindra has become the first Original Equipment Manufacturer (OEM) in India to offer a cloud-based technology platform in the tractor category (MahindraRise 2017).

CropIn Technology, a "Make in India" startup through its IoT based mobile application is helping more than 500,000 farmers and managing over 1 million acres of farms for more than 70 client users across 5 countries. SmartFarm provides end to end operations, guidance system and alert for food processing, contract farming companies, etc working with farmers. The tool provides simplified remote control of farms including geo tagged information about people, produce and operations. SmartSales is a technology solution for input companies like seeds and fertilizers. It helps companies track sales order, stock and payments. It also helps them identify potential sales points basis the farm operations and output. mWarehouse provides traceability to the last mile for companies engaged in exports and logistics including packaging services. The application records and reports the journey of harvest produce from planting to harvesting and to the initial packaging, until the last mile of delivery (CropIn 2017).

3.2.2 Uberization of Farm Machinery

One of the major impediments to rapid adoption of mechanization in India has been smallholdings which do not allow utilization of large machines and equipment on the field. Also, majority of the

[4]Photo source: https://pbs.twimg.com/media/C7c_UnnWwAEBJi3.jpg

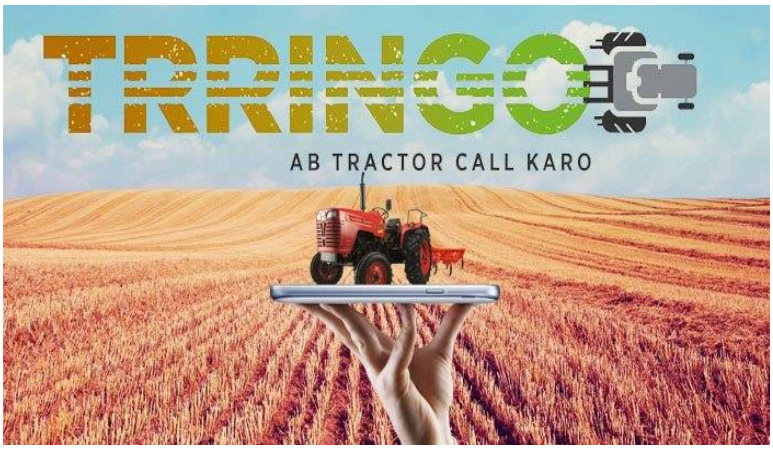
Indian farmers are not cash rich and neither do they have access to formal sources of finance to invest in buying farm machinery. To address this challenge, innovative models that make farm machinery available on rent have come up making mechanization more effective and affordable for the farmers. The key benefits of *uberization* include benefits to the farmers in terms of access to various types of machines and farm equipment suited to the crop and soil profile. It provides farmers the freedom to pay for the service used and not lock up capital resources. This has the potential for greater adoption of farm mechanization which in turn saves time and cost of farming and also improves the net output.

As part of the Sub Mission on Agricultural Mechanization (SMAM) guidelines brought out in 2014, the Government of India introduced Custom Hiring Centres (CHCs) at the village level to make mechanization accessible and affordable for farmers and boost mechanization in low mechanized regions. The process of deployment was targeted towards creating rural entrepreneurship who run these CHCs. Government provides subsidy (40 percent upto Rs 10 lakhs for each CHC) to the entrepreneurs willing to set up these CHCs who are required to invest a margin money and the remaining amount is financed through bank loans. Each CHC has a target to serve 10 hectares per day and 300 hectares in a season. Equipment needed for land preparation up to residue management are made available to the centres. In 2014-15, about 568 CHCs were set up all over India and another 143 centres were set up in 2015-16. In addition to these, 41 hi-tech CHCs were set up in 2014-15 (GoI 2014). Madhya Pradesh has been a leading state in setting up of CHCs and Hi-tech centres with the Government playing a very proactive role in promoting CHCs in the state.

Custom Hiring Centre (CHC) in India[5]

The benefits of CHCs have emerged in terms of improved access to machinery and hence lesser time spent by the farmers in the field, overcome the problem of increasing labor shortage and increase in productivity. It is important to strengthen this model by addressing the common challenges faced, such as: shortage of machines and equipment at the centre (particularly during peak seasons), maintenance and servicing of the machines and equipment and availability of skilled manpower, lack of monitoring of usage and hence revenues generated at these centres, and lack of flexibility in choice of equipment to suit the local requirements and needs of farmers. It is important to leverage the existence of large agribusiness players in the farm mechanization space and create partnerships to help scale up these centres, both in terms of structure, scope and functioning. These CHCs could become the village level hubs for all types of technology related demonstrations and piloting and field testing of new innovation.

[5] Photo Source: https://dipr.mizoram.gov.in/uploads/posts/11Aug2015/agri(5)_1439283474.jpg



Mahindra Trringo – Now Call a Tractor![6]

Private players have also forayed into providing farm machines on rental basis as well as providing related services. For instance, Mahindra TRRINGO – Ab Tractor Call Karo launched in 2016 is making farm equipment available on rental basis for farmers. A call to '1860 266266 8', (the toll-free number) connects the farmer to the TRRINGO call-centre. According to the requirements, appropriate services are provided through the nearest centre. In October 2016, M&M Limited setup custom hiring centres in the villages of Koregaon and Karad talukas of district Satara in Maharashtra. Until March 2017, 7,200 hours of services has been provided to around 6,000 farmers through 33 hubs operational in Karnataka, Maharashtra and Gujarat. The company has aggressive expansion plans in Karnataka, Maharashtra, Madhya Pradesh, Rajasthan and Gujarat. The revenue model involves commission paid by the service provider. Mahindra is positioned in this space as a leading manufacturer of high end farm machineries. Estimates suggest that the informal farm equipment rental market can be pegged at roughly Rs 15,000 crores which is about 35 percent of farm mechanization level in India. Hence here lies an opportunity to organize the market as well as expand services to the non-mechanized regions (BWDisrupt 2017). Another private venture, EM3 Agri Services provides services aimed at increasing agricultural productivity by bringing technology and mechanization for the farming community on a pay-for-use basis. Samadhan - FaaS (Farming as a Service) Centres are operational in Rajasthan, Madhya Pradesh and Uttar Pradesh. Started in 2014, the venture has already covered 35,000 acres of land in terms of its service offerings. EM3 Agri Services has tied up with several major agribusiness players that has allowed access to technical expertise, advanced farm technology and a large farmer base. For instance, John Deere provides technical support to EM3's tractor and harvester fleets. Trimble, a provider of advanced location-based navigation, provides satellite-based technologies to EM3. Its tie-up with the agri-business division of ITC allows EM3 to use ITC's e-choupal platform to reach out to farming communities (Mathew 2017). Similarly, in Africa, Hello Tractor venture in Nigeria reduces the time taken to farm and also improve productivity through greater adoption of mechanization. For a daily USD 75 fee, tractor owners could earn five times the average wage (Karidis 2015). GPS enabled smart tractors can be remotely managed and data related to their utilization, location, energy consumption, etc can be recorded with the help of digital technology. A whole range of innovations in the farm management sector including mechanization in India are emerging at the individual entrepreneur level. Startups are increasingly venturing into this sector offering unique technology led solutions to issues related to mechanization, pest management, and crop management.

[6] Photo source: https://i1.wp.com/www.indianweb2.com/wp-content/uploads/2016/03/trringo.jpg?resize=700%2C340

3.2.3 Digitizing Farm Management

Nubesol, a precision agriculture start-up uses satellite remote sensing technologies to help sugar companies get plot level cane map for their command areas, accurate plot level yield forecasts and regular cane balance or disposal reports during harvesting. Key features of the technology include grower and land record management; geocoding and remote sensing; reliable cane acreage prediction; crop care and advisory; yield threat advisory; yield forecasting; dynamic harvest planning; efficient transport management; cane disposal advisory; advanced analytics for operational efficiency metric reporting and online grower payments. It aims at improving revenues by targeting (1-5) percent increase in sugar recovery; (5-10) percent increase in cane yield; (10-25) percent increase in field staff efficiency; and (10-25) percent decrease in operational cost (Nubesol n.d.).

Eruvaka incorporated in 2012 has developed on-farm diagnostic equipment for aquaculture farmers to reduce their risk and increase productivity by integrating sensors, mobile connectivity and decision tools for affordable aquaculture monitoring and automation. Using mobile applications, farmers can monitor their pond data from smart-phone, enabling them to access data remotely to ensure the best output. Cloud analytic platform suggests farmers to adjust the feed, based on water quality data on a regular basis, empowering them to get a better feed conversion ratio. Intelligent algorithms control the aerators automatically. This leads to a reduction in power bills for farmers up to 20 percent, thereby increasing their profit margin. When water quality drops, real time voice alerts are sent to the farmer's mobile, thus reduceing the risk of shrimp mortality and increasing the quality of the produce (Eruvaka n.d.).

For instance, Khedut Agro Engineering, a manufacturer of seed drill machines in India since 1996 has progressed from manufacturing bullock drawn seed drills to tractor driven seed drills in 2002 and further onto pneumatic planters in 2015. It is the first company in India to manufacture pneumatic planters that allow automatic seeding with precision thereby enabling savings of resources (Khedut Agro Engineering n.d.). Machines Information Technology Resources Agriculture (M.I.T.R.A.) develops new machines to serve farmers growing high value crops like fruits and vegetables. It is the largest manufacturer of automated orchard sprayers and dusters in India and also a leading exporter. In 2017, M.I.T.R.A. launched boom sprayer for vegetable and plantation crops, and India’s first fully automated potato harvester. The machines enable both savings in human labour as well as post-harvest losses (M.I.T.R.A. n.d.)

Under the Mission of Integrated Horticulture Development (MIDH), the Department of Agriculture, Cooperation and Farmers’ Welfare initiated the project CHAMAN (Coordinated Horticulture Assessment using Management using geoiNformatics). The project is being implemented by Mahalanobis National Crop Forecast Centre (MNCFC) in collaboration with ISRO Centres (SAC & NRSC) and 12 state horticulture departments, NHRDF, IMD, ICAR Centre and State Remote Sensing Centres. This program envisages the use of satellite remote sensing data for area and production estimation of 7 horticultural crops (Potato, Onion, Tomato, Chili, Mango, Banana and Citrus) in 12 major states in 180 districts. The programme also uses GIS (Geographical Information System) tools along with remote sensing data for generating action plans for horticultural development (site suitability, infrastructure development, crop intensification, orchard rejuvenation, aqua-horticulture, etc.). Another component of CHAMAN is to carry out research activities on horticultural crop condition studies, diseases assessment and precision farming.[7]

[7] Some of the salient features of the project include Potato Production Forecast at National/State Level and Final forecast (F2) at District Level for 5 states (Bihar, Gujarat, Punjab, Uttar Pradesh, West Bengal); Mango and Citrus Orchard mapping: Using LISS III and LISS IV and Cartosat dataset object based/Pixel-based classification was done for Fruit Crop Mapping (Mango and Citrus) in selected districts of Bihar, UP & Punjab; Post-harvest infrastructure planning by assessing the potential of cold storage capacity for fruits and vegetables in Bihar state; Aqua-horticulture: Remote sensing based assessment of wetlands for Makhana (Foxnut) cultivation in

Other initiatives include NADAMS (National Agricultural Drought Assessment and Monitoring System) developed by National Remote Sensing Centre. It provides near real-time information on prevalence, severity level and persistence of agricultural drought at state/ district/sub-district level. FASAL (Forecasting Agricultural output using Space, Agro-meteorology and Land based observations) generates crop forecasts using optical and microwave remote sensing data including crop area enumeration, crop condition assessment and production forecasting. In 2015-16, 16 forecasts were generated for 8 crops - Jute, Kharif Rice, Sugarcane, Cotton, Rapeseed & Mustard, Rabi Sorghum, Wheat and Rabi Rice. The KISAN (Crop Insurance using Space technology and geoiNformatics) project envisages the use of high resolution remote sensing data from satellites and UAVs for optimum crop cutting experiment planning and improving yield estimation.

Access to advanced technologies for improved farm management through real time information enables farmers to benefit from savings in pre-and post-harvest losses through timely intervention in addition to achieving the overall goal of sustainable agricultural practices. While the advanced precision technologies are more suited to highly developed farm conditions and ability of farmers to adopt these practices, similar technologies customized to developing conditions are emerging. The benefit of indigenous technologies lies in the ease of adoption at the farm level and not too capital intensive. Further innovations in scaling down the cost of adopting technologies, customizing solutions to the last mile, and ensuring adoption across value chains and geographies can catalyze fast track adoption of technology in India.

3.2.4 Micro Irrigation Systems

The global market of micro irrigation was valued at USD 2.9 billion in 2016 and is projected to grow at a CAGR of 18 percent from 2018 to 2023. Drip irrigation systems have optimum accuracy in delivering the precise amount of water needed for crops at the roots of the crops thus saving highest percentage of water. The crop types considered in the micro irrigation market are orchard crops & vineyards, field crops, plantation crops, and others. The market is dominated by orchard crops & vineyards with the highest market share. These types of crops make highest use of micro irrigation techniques. It is estimated to be the fastest growing crop types due to increasing usage of micro irrigation in vineyards, as well as green-house fruits and vegetables. North America dominated the market with the largest market share followed by Asia- Pacific and Europe. The leading players in this sector include Jain Irrigation Systems Limited (India), Lindsay Corporation (U.S.), The Toro Company (U.S.), Driptech Incorporated (U.S.), Hunter Industries Incorporated (U.S.), Nelson Irrigation Corporation (U.S.), Netafim Limited (Israel), Rain Bird Corporation (U.S.), Rivulis Irrigation (Israel), T-L Irrigation Company (U.S.), among others (ABNewswire 2017).

Innovations in irrigation have the potential to enhance water use efficiency by 80 – 90 percent as well as improve productivity levels. With nearly 9 million hectares under micro irrigation (sprinkler and drip combined), India stands to benefit immensely by optimizing water utilization in the agricultural sector. Large parts of the country are already under water stressed conditions and continued intensification of farming activities have been aggravating this further. Potential lies in introducing micro irrigation in water intensive crops like paddy, sugarcane in addition to high value crops such as fruits and vegetables. In the case of onions, it is observed that drip irrigation at 100 percent pan evaporation (PE) significantly improved the marketable bulb yield at (15-25) percent with higher percent A grade bulbs, enabled water savings of about 35-40 percent and labor saving of 25-30 percent. Fertigation is an effective and efficient method of applying fertilizers through drip irrigation, which is used as the carrier and distributor of irrigation water and crop nutrients. The drip

Darbhanga district of Bihar; Signature study of vegetable crops using hand-held spectro- radiometer; Phenology assessment of grapes using multi-date remote sensing data in collaboration with ICAR-NRC Grapes (MNCFC n.d.).

irrigation system not only helps in water saving but also reduces nitrogen losses by leaching into ground water, as in fertigation, fertilizer nutrients are applied in root zone only (ICAR n.d.). Bose 2016 reports that drip irrigation in sugarcane cultivation can result in 65 percent saving in water and 45 percent in electricity, and improve crop productivity by 40 percent, compared to flow irrigation. Gulati and Roy (2017) report that direct seeding of rice and use of drip irrigation instead of flood irrigation result in 30-40 percent water savings as observed from field trials. JISL reported that sugarcane farmers using drip irrigation have witnessed average yield more than double to around 60 tons per acre as against the country's average yield of around 25 tons per acre. There are some farmers, who are even reaping a yield of 100 tons per acre (Business India 2015).

Jain Irrigation Systems Limited (JISL), India's largest and world's second largest micro irrigation company has played a major role in promoting micro irrigation among farmers (large and small) in India. Over the years, the company's efforts have enabled farmers to switch from flood irrigation to more water-efficient systems, which reportedly yield water savings of 30-65 percent over the traditional surface irrigation systems. JISL has implemented large scale micro-irrigation projects in Karnataka, Himachal Pradesh, Rajasthan and Maharashtra. One such project includes the Karnataka government awarding a Rs 385 crore contract to the company to implement a micro-irrigation project where a 30,381-acre command area, comprising 7,000 farmers in 35 villages of Bagalkot district, will be covered under micro irrigation (Business India 2015).

With massive investment in R&D, JISL introduced gravity pressure operated drip irrigation system most suitable for cultivation of vegetables and can be used for cereals, pulses, cotton and other closely spaced crops. This irrigation technique can be used for irrigation in open fields, green house/ net house and nurseries as well as suitable for kitchen gardens and also Himalayan/ hilly terrains where land holding is very small. It is also useful as a survival irrigation tool in rainfed areas or regions with acute water scarcity or when there is a prolonged gap between rains and/or electricity is not available. This irrigation system operates on gravity and hence no electricity is required. It is portable, easy to install and can be carried from one place to the other. The technology seems also affordable for smallholder farmers. JISL designed solar power operated drip irrigation systems are available in surface and submersible types. Solar powered pump will give freedom from the power cuts and load shedding. No manpower is required to operate the system. System starts automatically with the first ray of sun and shuts off when the sun sets. No power and /or fuel costs occur to operate the pump/drip system. Over the last few years, JISL has installed more than 15,000 solar agri pump sets across India in 8 to 9 states which is more than 50 percent of the total installations in the country (as reported in 2015). JISL has been awarded a project on installation of solar agri pumps in Maharashtra covering 20 districts including drought hit districts such as Buldhana, Akola, Washim, Yavatmal, Amravati and Wardha. Under this project various capacity pumpsets comprising of 4,559 AC Pumps and 4,400 DC Pumps are to be installed according to beneficiary farmer's water requirement, crop pattern and land availability, etc. The beneficiaries of this project include small and marginal farmers based out of drought hit areas and traditional farmers not having access to electricity. (JISL n.d.)

Netafim, an Israeli micro irrigation company is also in business in India. The company is providing wireless control, cloud based farm monitoring techniques, enabling farmers to remotely control irrigation and fertigation in their farms. Some of the noteworthy projects in India include Ramthal community drip irrigation project that is located in Hungund, Karnataka and is Asia's largest community drip irrigation project. Out of 24,000 hectares of the project, Netafim, in association with infrastructure partner, MEIL has installed automated drip irrigation system over 11,700 hectares, covering 22 villages and nearly 6,600 farmers. Erravalli drip irrigation project located in Telangana wherein the entire village spanning 1,100 hectares has been drip irrigated and entirely automated. Netafim has also piloted drip irrigation in sugarcane in Maharashtra which has huge potential in terms of saving water particularly in the water scarce regions of India (Free Press Journal 2017).

Further innovations in optimal utilization of resources and capturing field results for appropriate intervention are being pioneered by startups and individual entrepreneurs. For instance, FlyBird Farm Innovations, a social impact agriculture enterprise uses sensor based devices for smart control of irrigation and fertigation. Smart Irrigation Controller (Siri) is programmed to automatically regulate water and fertilizer according to the crop and soil requirements. It helps improve crop yield and production; saves water and labour and also reduces weeds. In protected as well open cultivation, temperature and relative humidity are measured and crop irrigation is done based on those readings. This also takes the help of rain sensors to postpone or reschedule the irrigation to crops if rain is received. The Volume Based Irrigation Controller is based on prefixed quantity of water to irrigate crops and this helps farmers optimize water utilization. Crops that are sensitive to higher amount of water, for instance grape vine in which too much water reduces the quality of end produce and less water stresses the crop, volume based controller offers an easy solution. Mobile app and web based irrigation controller is aimed at next level farmers and corporate firms engaged in farming, wherein irrigation and fertigation are controlled via mobile GSM technology and all related data are available to customers in a graphical format. It allows farmers to remotely control and monitor irrigation/fertigation/fogging/misting and maintain a record of these activities in a graphical display. Data analytics of past irrigation can be done according to which precise planning can be undertaken. It is projected that with the use of Siri, farmers can optimize utilization of water and other inputs and improve yield levels by 15 – 20 percent. These devices are priced at Rs 15,000 (basic model) up to Rs. 26,000 (sensor based). Farmers can get returns in less than 6 months with assured reduction in cost of power, labour and water (Agriculture Information 2014).

3.2.5 Unmanned Aerial Vehicles – Drone Technology

Further advanced technologies such as unmanned aerial vehicles - drones are yet to take off in the Indian agricultural landscape. While drones can monitor crop and soil health and save on the time and cost of physically going around the fields, the biggest advantage with this technology is that it is able to detect any abnormality in crops and potential pest infestation much before it is visible to human eyes. This allows farmers to take corrective measures in advance and prevent crop loss. Farmers will also benefit from information about yield and quality of the produce before actually harvesting which can in turn help them to price and market it appropriately.

The Indian Council of Agricultural Research (ICAR) through the Indian Agricultural Research Institute (IARI) under a collaborative research project is developing indigenous prototype for drone based crop and soil health monitoring system using Hyperspectral Remote Sensing (HRS) sensors. The project entitled SENSAGRI: Sensor based Smart Agriculture" involves six partner institutes (Agriculture & IT) to be funded by Information Technology Research Academy (ITRA), Department of Electronics and Information Technology (DEITY), Ministry of Communication and Information Technology (MCIT) and ICAR. SENSAGRI proposes advanced proof-of-concept services i.e. yield and biomass, tillage change, irrigation and advanced crop maps (Mail Today 2016).

Agnext, a startup in the advanced technology space specializes in spectral and imaging analytics. Spectral Analytics can provide strong noninvasive techniques to analyze various physical and chemical properties of agricultural constituents using spectral imaging. AgNext is focused on building spectral analytics of soil, leaf and food and intends to build handheld spectrometers for collecting crowdsourced GPS stamped spectral. AgNext’s unique proposition to combine imaging platform using remote sensing, drones imaging and smartphone based imaging analytics provides comprehensive insights for agricultural stakeholders. Future plans to integrate IOT sensor networks for combining other data can help in crop growth analytics (Agnext n.d.).

4 ICT Applications Enabling Agricultural Linkages

ICT platforms have been quite successful in the areas of connecting buyers and sellers on a virtual market platform; enhancing farmers' access to critical information related to weather, soil health, market prices; and finance. This enables a farmer to plan his farming activities, project the potential output and hence bargain better prices. Also, importantly, advanced technologies are being used for risk mitigation and improving farmers' access to insurance claims and payments. A plethora of such applications, largely mobile driven are available globally as well in India. The challenge lies in the effectiveness of these technologies in addressing the field level issues and appropriate interventions. Also, interpretation of information is a challenge with farmers who are often not as educated or technological savvy. Hence the focus is on integrating several of these platforms with other applications and designed with in built data interpretation and predetermined actions to equip users with end-to-end solutions.

4.1 Innovations in Agricultural Finance and Insurance

Access to formal sources of finance is a critical component in empowering farmers particularly in the high value sector, which is highly susceptible to damage and post-harvest losses and hence farmers are more vulnerable to income shocks. Digital transformation in agricultural finance and insurance has gained momentum in Africa, benefitting a large number of smallholders. Flexible, low-cost and ubiquitous digitally enabled financial platforms such as Smart-Money, M-Pesa, and M-Shwari in Kenya have been critical in delivering financial services to the smallholder farmers in Africa. Kenya ranks highest in terms of financial inclusion with 8 out of 10 adults using mobile money services. About 70 percent of the world's registered 81.8 million mobile money customers are in Sub- Saharan Africa. M-Farm operational in Kenya is connecting buyers and sellers. Africa is also much advanced in the use of satellite technology for empowering farmers with social protection and insurance mechanisms. Index-Based Livestock Insurance program in northern Kenya, and micro-agricultural insurance scheme 'SUM Africa' based in Mali and Uganda are some of the emerging programs. As and when through the satellite imagery, the threshold level of crop damage or loss of yield due to droughts or the like is observed, farmers are made payouts (Mudenge and Otieno 2016).

In India, Institutional sources account for 64 percent of the agricultural credit, which leaves a considerable proportion of farmer population dependent on informal sources and pay exorbitant interest rates as compared to the formal sources (Hoda and Terway 2015). Due to lack of collaterals and land titles, farmers are often locked in with the local moneylenders, market intermediaries and the like. Innovative steps taken by the Government has resulted in increase in the flow of agricultural credit. During 2016–17, banks disbursed Rs 9598.3 billion (provisional) credit to the agriculture sector (including agriculture and allied, agri-infrastructure and ancillary activities), against a target of Rs 9000 billion (NABARD 2017).

Introduced in 1998, Kisan Credit Card (KCC) is an innovative credit delivery mechanism that meets the short-term and term loans as well as the consumption needs. The cumulative number of KCC cards issued since inception (1988-89) till March 2015 had reached to 146.4 million of which 74.1 million cards are active i.e. about 51 percent of the total KCC issued (Mani 2016). Once the farmer is issued a KCC after determining his eligibility after due process, he can easily avail loans from financial institutions from the second year onwards. With the help of technology, passbook loan system has been replaced with ATM enabled debit cards with withdrawal and loan disbursement facilities. As the Government emphasizes on digital empowerment and cashless transactions, NABARD through its Financial Inclusion Fund (FIF) will support banks deploy to two point of sale (PoS) devices per village in 100,000 villages of tier 5 and 6 areas with a population up to 10,000. This will entail investment of nearly Rs 1.2 billion. Nabard will also support regional rural banks (RRBs) and rural cooperative banks in procuring EMV chip and PIN-based RuPay Kisan Cards for the farmers, who are already on RuPay Kisan Credit Card (KCC) platform. At an estimated cost of Rs1.08 billion, this move is claimed to provide a secured technology that can be adopted by farmers (Roy 2016). The Self-Help Group (SHG)-Bank Linkage Program (SBLP), pioneered by NABARD more than 2 decades ago, starting with a pilot of 500 SHGs, covers about 7.9 million self-help groups (SHGs) and nearly 101 million poor households in India (as on 31 March 2016). About 1.8 million SHGs availed credit support of Rs 372.9 billion from various banks during 2015-16, at an average of Rs 200,000 per SHG. During 2015-16, there was net addition of about 200,000 SHGs with savings linkage. Credit disbursement during the year increased by 35.2 percent over previous year, the outstanding of institutional credit to SHGs as on 31 March 2016 increased by 10.8 per cent over the year and SHGs' savings balance with banks went up by Rs 110.60 billion during the period. The progress combined with reduced NPA level from 7.4 percent to 6.5 percent confirms growing strength of SBLP (NABARD 2017).

In addition to ensuring that farmers are connected to formal sources of finance, advanced technology such as Artificial Intelligence (AI) is enabling build robust risk profiles at individual farm level and regional level. CropIn, a Bengaluru based six-year-old venture launched SmartRisk is a digital platform which helps micro finance, banking and non-banking financial institutions to identify and minimize risks associated in lending and insurance business. At a macro level, it leverages the remote sensing technology supported by data science, machine learning and AI to analyze cropped farm areas and to identify high risk and low risk zones. At a micro level, it has capabilities to monitor a specific farm and help enterprises identify and intervene in taking timely measures, to minimize the issues in crops (CropIn 2017). This application could help farmers avail agricultural credit and insurance in a transparent manner. India has several mobile based technology interventions delivering agri inputs and advisory services to the farmers to enable them to take informed decisions regarding farming practices. Both the private sector as well as the Government has brought several applications for the delivering information and services to the farmers at the tap of a phone call or SMS.

4.2 Innovations in Improving Access to Agricultural Inputs and Services

Mkrishi, a mobile agro advisory system of Tata Consultancy Services (TCS) aims at reaching out to farmers individually to understand their farm related needs and provide important information about pesticides, fertilizers and soil and water conservation, micro-climate, weather information, etc. in order to plan farming operations. It also strives to facilitate better production and cultivation practices and improve market access. This application has been further developed by Mumbai Research Centre of the CMFRI and materialized by Indian National Centre for Ocean Information Services (INCOIS) and the Tata Consultancy Service (TCS) under the National Agriculture Innovation Project (NAIP).

mKRISHI@AFisheries is a mobile advisory service providing information related to the sea, with the app making fishing activities less expensive and environment friendly, the developers said. The app provides information on Potential Fishing Zone (PFZ), sea surface temperature, weather and the presence of phytoplankton, which form the food of several fish species. The app consolidates this information and presents advisories in local languages, with easy to use icons on Java and Android mobile phones. A study conducted by the CMFRI in 13 fishery societies in Maharashtra found that the fishermen could save up to 30 per cent of fuel consumption with the help of this new app. The reduction of the fuel consumption has benefits in terms of environmental impact. Information on the presence of potential fishing zone has helped fishers reduce unnecessary trips and the associated cost of diesel, ice and labor. This app also helps the fishermen to get to know the wind speed and direction, wave heights in a color-coded band helping them identify the unsafe regions in sea. Fishermen are advised to go only when the information map on the app is blue in color and it predicts five days upfront forecast which will help even trawlers who go for multi-day fishing trips. Lack of data signal availability in deep sea was a major challenge for the fishermen. However, TCS and Tata Teleservices conducted a pilot to extend the mobile signal up to 30-km in the deep sea in Raigad district of Maharashtra. This helped the fishermen in price negotiations while they were in the sea itself and the fresh catch could be directed to desired port, optimizing the overall transportation (FirstPost 2017).

MyAgriGuru launched by Mahindra Agriculture Solutions Limited is a wholly owned subsidiary of Mahindra and Mahindra. The company has tied up with IMD to source weather forecast for a five-day period in order to ensure that crucial farming activities are aligned with the climatic conditions. It has also tied up with NCDEX to share real-time prices of various markets across the country. This initiative is in line with the Digital India program of the Government of India, aiming to digitize agriculture and contribute towards the vision of doubling farmers' income by 2020. Mahindra aims to positively impact the lives of 75 million farmers by 2025 through the widespread use of this application (DNA 2017).

E - choupal (village level internet kiosks) a pioneering initiative leveraging internet by ITC Limited started in 2000. Managed by farmers known as *sanchalaks*, it allows the village community to access critical information related to weather, market prices in their local language, disseminate knowledge on scientific farm practices and risk management, facilitate the sale of farm inputs and purchase farm produce from the farmers' doorsteps. While the farmers benefit through enhanced farm productivity and higher farm gate prices due to improved access to information and advisory services, ITC benefits from the lower net cost of procurement despite offering better prices to the farmer, having eliminated costs in the supply chain that do not add value. E - Choupal services reach out to over 4 million farmers growing a range of crops - soyabean, coffee, wheat, rice, pulses, shrimp in over 35,000 villages through 6,100 kiosks across 10 states - Madhya Pradesh, Haryana, Uttarakhand, Karnataka, Andhra Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Kerala and Tamil Nadu) (ITC n.d.).

The problems encountered in setting up and managing these kiosks were primarily of infrastructural inadequacies, including power supply, telecom connectivity and bandwidth, apart from the challenge of imparting skills to the first-time internet users in remote and inaccessible areas of rural India. Several alternative and innovative solutions have been deployed to overcome these challenges. For instance, providing power back-up through batteries charged by solar panels, upgrading BSNL exchanges with RNS kits, installation of VSAT equipment, mobile choupals, etc. to improve the effectiveness of this model. Going forward, ITC plans to integrate bulk storage, handling & transportation facilities to improve logistics efficiencies. It also plans to channelize other services related to micro-credit, health and education through the same infrastructure. Version 3.0 offered personalized crop management advisory services to individual farmers as well as served as a rural employment exchange connecting rural youth with jobs through our *rozgaarduniya* initiative (Ibid).

Choupal Pradarshan Khet brings the benefits of agricultural best practices to small and marginal farmers. Backed by intensive research and knowledge, this initiative provides Agri-extension services which are qualitatively superior and involves pro-active handholding of farmers to ensure productivity gains. The services are customized to meet local conditions, ensure timely availability of farm inputs including credit, and provide a cluster of farmer schools for capturing indigenous knowledge. This initiative, which has covered over 64,000 hectares, has a multiplier impact and reaches out to around 70,000 farmers (Ibid). The public policies related to procurement and marketing resulted in ITC going slow with their expansion plans and diversifying into rural service related activities to leverage the existing infrastructure and expertise acquired over a period of time.

The Government of India has also launched mobile applications for farmers, delivering information about weather, agricultural inputs, pests and diseases, market prices, and advisory services. Krishidoot was launched by Small Farmers' Agribusiness Consortium (SFAC) and Reuters Market Light (RML) are delivering these information to farmers. Launched in February 2014, 350 farmer groups availed the Krishidoot for transactions worth Rs 300 million until September 2014. A combination of mobile interface, internet and people on the ground to collect data enables linking the farmer producer organization directly to the markets thereby bypassing the long chain of intermediation. The farmers trading through this application have benefited from savings in transportation costs, payments made to intermediaries and a margin on demand supply match. Newer applications, like Kisan Suvidha and Pusa Krishi were launched by the Ministry of Agriculture and Farmers' Welfare in 2016 which are aimed at providing similar services and market linkage to the farmers.

In addition to large agribusiness players and government, digital technology solutions are being taken forward by young entrepreneurs. A large number of startups have ventured into this space and at different stages of evolution. AgroStar, a direct-to-farmer technology platform aims at leveraging their expertise in agronomy, data analytics and m-commerce to deliver customized solutions to the farmers and help them digitize their farms. With a missed call or accessing their mobile application, farmers can access advisory services, agri inputs and machineries and have these delivered at the farmers' doorsteps. AgroStar sells nearly 1,000 products including various quality brands of seeds, fertilizer, pesticides and agri-implements through its mobile-commerce platform. The company claims to receive 1,500 to 2,000 calls every day with an average transaction size of Rs 1,500. Between 2013 and 2015, Agro Star received 900,000 missed calls. Currently operational in Maharashtra, Gujarat and Rajasthan, it has plans for all India expansion (Mishra 2015). Ekgaon Technologies (an IT based network integrator) offers a range of services to farmers in rural areas including financial, agricultural inputs and advisory services. The ekgaon One-Village-One-World Network is leveraging mobile communication technology for encouraging sustainable development of women-self-help-groups (SHGs) and smallholder farmers across India. The platform has over 900 000 women and 300 000 farmers spread across villages in India (ekgaon n.d.). Digital platforms for delivering market intelligence services like Esoko, AGRO FIBA, Airtel Kilimo venture, among others are helping farmers access information in Africa. Platforms like Transzam and Multiflower in Tanzania are transforming agri logistics and making it more accessible to the smallholder farmers (Mudenge and Otieno 2016).

Skymet Weather Services Private Limited has emerged as India's largest weather monitoring and Agri-risk solutions company with high end expertise in measuring, predicting and limiting climate risk to agriculture. It has a captive network of more than 3500 automatic weather stations spread over 20 states. In addition to weather information, Skymet provides agriculture solutions, crop surveillance, agriculture insurance and re-insurance, agri credit risk indexing, monitoring of crops loans and repayments through web based tools, among others. Predicting weather correctly is of utmost importance and further making the information available to the farmers to plan sowing, harvesting as well as storage and transportation. The integrated information base of Skymet about weather, and farms allows it to actually identify the sensitive agricultural areas and issues around which farmers are most vulnerable and allows policymakers to take suitable actions (Skymet n.d.).

The ICT segment in agriculture has witnessed a large number of players offering almost similar kind of information and facilitating access to agricultural inputs and resources. While some have thrived, and scaled up operations, others have fizzled out over time. It is perhaps not just enough to provide information to the farmers but also help them implement the solutions by providing access to the right set of resources. Efforts must be made by service providers to facilitate capacity building and education of the farmers to utilize the information for making smart decisions. They should be given orientation on how to interpret the information available to them or else it will be a mere dump of information for the farmers (ICRA 2011). Also, application which are customized to address local farm conditions, soil and crop health, market and other input related issues have had better acceptance. Continuous innovation to upgrade these applications in terms of how farmers can utilize the information to take smart decisions is the key to sustainability and scalability of these interventions. The current penetration of smart phones in both urban and rural India will make it a lot easier to reach these ICT related interventions to the farmers in remote areas and link them effectively to the value chain.

5 Innovation In Agricultural Logistics For Improved Post-Harvest Management

Post-harvest losses are common and enormous in the Indian agriculture value chain. According to the CIPHET (Central Institute of Post-Harvest Engineering and Technology) study conducted in 2015 (as reported by MoFPI 2016), losses in cereals were estimated to 4.7 – 6 percent, that in fruits and vegetables were 4.6-15.88 percent, 6.7 percent in poultry and 10.5 in marine fisheries. The study considered the quantitative loss as the material rendered unfit for human consumption. The different stages considered for assessment of losses were harvesting, collection, thrashing, grading/sorting, winnowing/cleaning, drying, packaging, transportation, and storage depending upon the commodity. In value terms, losses were estimated to be Rs 927 billion (calculated using production data of 2012-13 at 2014 wholesale prices) (MoFPI 2016). Post-harvest losses are largely attributed to lack of advanced infrastructure facilities, supply chain expertise as well as fragmented and overcrowded markets which render appropriate handling, transportation, storage and marketing of perishable commodities almost impossible. This adversely impacts the price realization at the farmers' end owing to the poor quality of produce marketed and the loss of output due to wastage. Poor supply chain management is also observed to impact overall availability as well as consumers prices resulting in escalation of food inflation.

5.1 E- Agricultural Markets

In this context, the Government of India launched the National Agricultural Market (NAM) in 2016 with a vision to e connect 585 markets by March 2016 thereby enabling e-trading of agricultural commodities to ensure transparency in market operations, and fair price discovery for the benefit of farmers. Digitizing market operations, and payments will allow weeding out all malpractices and rent seeking activities. E-NAM would also connect farmers directly to the buyers and hence bypass the intermediation in the markets. The states willing to join the e-NAM platform are required to bring about certain policy changes such as i) a single license to be valid across the state, ii) single point levy of market fee and iii) provision for electronic auction as a mode for price discovery through amendments of the existing Act. Till date (April 2017), 13 states have brought about the necessary changes and enrolled under e-NAM thereby connecting 417 markets against a target of 400 markets by March 2017. It is reported that 5.9 million tons of trade has happened thus far across 69 commodity types worth Rs 15,000 crore. According to MoA&FW, 3.95 million farmers, 88,000 traders and 44,000 farmers have joined the e platform (NewsGram Desk 2017).

It is an ambitious program and if delivered on the ground as designed will revolutionize agricultural marketing in India. However, it should be understood that e-NAM will be most impactful i) when farmers directly interface with the buyers and do not have to operate through the long chain of intermediation and ii) when perishables are traded through this platform which is most susceptibility to price fluctuations and have been driving food inflation. Currently, markets are still in the process of setting up the infrastructure and operationalizing the various segments of e-NAM. Farmers still operate through commission agents and have no direct interface with the traders. While bidding is done electronically but still by the same set of traders in a market and inter market bidding is yet to take off, it is not certain if the prices discovered are actually competitive. Payments are done by commission agents to the farmers through a mix of cash, cheque and bank transfers depending on the value of transactions and outstanding loans with the commission agents. Assaying which is critical for the success of e trading of commodities wherein the buyer is guaranteed the quality for which he has bid a price is almost missing in these markets. Currently, assaying is done through physical inspection which is not feasible in inter market trade. For E-NAM to be successful, it is important to ensure that farmers have the bandwidth to undertake cleaning, sorting, grading and packaging at their end, authorized assaying facilities are provided, direct payment to the farmers are made by the traders and not the commission agents. Farmers should have access to warehouse facilities to be able to hold on to their stocks before these are auctioned and finally sold, and there has to be a dispute settlement mechanism to develop an all India market.

5.2 Direct Firm Farm Linkages – Innovative Business Models

High value agriculture in India witnessed several direct firm farm linkages delivering higher incomes to the farmers as observed from innovative business models of Nestle, Amul, Heritage foods, among others in the dairy value chain. In the vegetable value chains, companies like PepsiCo, Mahindra and Mahindra, Desai Fruits and Vegetables, etc. have been working directly with farmers. These ventures have been successful in scaling up their engagement with the farmers, establishing backward integration and facilitating access to key agricultural inputs and services. However there remain issues and concerns around scaling up these and other similar ventures across value chains and geographies and maximize the benefits accruing to the farmers in a sustainable manner.

Nestle reports to now work with over 110,000 farmers delivering over 1.3 million kg of milk per day during the flush season. [8] Given their operations in north India, the farmers are largely medium size and above operating on 2 -10 hectares of land or above. In West Bengal, PepsiCo's potato contract farming program touches 90,000 lives, with assured buyback program for 12,500 farmers and highest ever contract farming procurement of 70,000 metric tons of potato across eight districts, majority of whom are smallholders operating on less than 2 hectares of land (PespsiCo 2011-12). Desai Fruits & Vegetables works with nearly 1,000 farmers under contract arrangement. Mahindra Agri Solutions Ltd, a subsidiary of Mahindra & Mahindra Ltd., part of the USD 17.8 billion Mahindra Group is working with around 800 farmers in Maharashtra dedicated towards improving productivity and quality of grapes. In the 2016 grape export season, MASL retained the position of one of the largest Grape exporter from India. MASL exported 842 containers with 11,000 MT (Mahindra 2017). Innovations in farmer aggregation through Farmer Producer Organizations (FPOs) are emerging in India and have the potential to be an effective means of establishing direct linkages with agribusiness players. FPO model accords greater bargaining power to the farmers, infuses a business spirit and improves access to finance and risk mitigation tools like credit and insurance. Also, front-end players have higher confidence in doing business with a group of farmers rather than individuals as the economies of scale work out better. Mahagrapes in Maharashtra is a classic example of how farmer aggregation into a producer company helped grape growers become part of an export boom by meeting the quality and safety standard requirements right from the fields. Their journey started with massive rejection of export consignments owing to residuals, but over time with setting up a process of quality control, adherence to right farming practices, and continuous efforts to educate and undertake capacity building of the farmers. Mahagrapes was successful in overcoming these challenges and emerged as a major exporter of grapes to the European and UK markets.

5.3 Cold Chain for High Value Agriculture – Innovative Business Models

In agriculture logistics segment, startups like Tessol in cold chain and Stellapps in dairy farm management are leveraging IoT and cloud technologies to interpret and use information effectively. TESSOL offers cold storage and transportation services through its flagship technology – PLUGnCHILL. It includes end to end solutions for a sustainable agricultural (dairy, seafood, meat, bakery, poultry, ice Cream, vegetables, etc.) and pharmaceutical cold chain (PLUGnCHILL n.d.). Stellapps, India's first IoT dairy company provides end-to-end dairy technology solutions company – SmartMoo™. Both IoT router and in-premise IoT controller acquire data via sensors that are embedded in milking Systems,

[8] https://www.nestle.in/csv/rural-development/milk/home

animal wearables, milk chilling equipment and milk procurement. SmartMoo™ Cloud is capable of supporting data arising out of tens of millions of liters of milk through the milk production, procurement and cold chain flow across millions of farmers (Stellapps n.d.). ecoZen has designed a pioneering and innovative micro solar powered cold storage system. The product primarily designed for the rural segment serves their needs ideally, as it does not depend on grid electricity and after a 2-year breakeven, leads to over 40 percent increase in their profits. This innovative product can be suitably adapted for local conditions across the world (ecoZen n.d.).

Promethean Power Systems founded in the US in 2007, launched a manufacturing and testing facility in India in 2013. It designs and manufactures refrigeration systems for cold-storage and milk chilling applications in off-grid and partially electrified areas of developing countries. Promethean Thermal Storage System (TSS) is the patented technology which enables all of Promethean's refrigeration products. It can store and release large amounts of thermal energy and can be applied to cooling applications as varied as comfort cooling or fermentation control. TSS provides backup cooling power for areas with unreliable grid power; instant cooling power for rapid cooling of fruits, vegetables, milk and other perishable food products; and load shifting from day to night time, which together enables users to reduce energy bills and increase energy efficiency in refrigeration applications. The innovative products include rapid milk chillers, conventional milk chillers, rapid milk chiller premium, solar add-on and customized solutions to help users optimize their capex and opex costs. The goal is to enable village-level chilling that positively impacts quality and costs with dairy processors, better quality products for consumers, and increased opportunities for farmers in villages across India. Rapid chilling technology reduces the temperature of milk from 35 degrees Celsius to 4 degrees Celsius in seconds which in turn saves running and maintenance costs and is environmentally friendly as no diesel generator is required. Since 2013, 502 units have been sold, 25,100 farmers served, 150,600,000 litres of milk chilled and 122,000 litres of diesel saved. Promethean's milk chillers have helped deliver benefits on three fronts: reduction in milk spoilage, improvement in milk quality, and elimination of diesel for power back-up (Coolectrica n.d.)

Established players like Amul in Maharashtra, Hatsun Agro in Tamil Nadu, Mother Dairy in Uttar Pradesh, Heritage Foods in Vizag and dairies in Andhra Pradesh and Tamil Nadu sourcing milk from farmers are investing in buying the rapid milk chillers which cost Rs 500 000 to 600 000 each, and installing these in their respective village-level collection centres in Tamil Nadu, Maharashtra, Andhra Pradesh, Telangana, Rajasthan, and Uttar Pradesh. Amul has a collection centre at Pahad Dhara, a village in outskirts of Pune outskirts where it has put up an RMC. Earlier, a regular BMC that used to operate most of the time on diesel entailed a monthly expense of Rs 35,000. With the RMC, expenses on electricity has come down to Rs 5,000 procuring an average 600 litres per day of milk from 20 farmers in the village (Mishra 2017). The company has 25 installations in Bangladesh for the world's largest NGO, BRAC. It has also installed a trial unit in Sri Lanka. The company has now sold over 500 milk chilling units to its dairy partners in India, Sri Lanka and Bangladesh - all of them in villages. Promethean has a working solution in the food segment as well. Online retailer Green Tokri uses Promethean's system for refrigerating vegetables and fruits. Promethean is in the process of developing milk chillers of 500 liters/day capacity to enable dairies to go into smaller villages. The company is also working on a monitoring system so that the dairies can track in real time all the critical parameters of the milk chillers installed in remote villages (Jha 2017).

5.3.1 Technology enabled Onion Storage

Onion storage is critical for containing the extreme price fluctuations and deliver higher prices to onion growers preventing them to undertake distress sale. Conventional ventilation storage of onions results in high wastage up to 35 percent depending on the weather conditions. Turnaround of onions is difficult due to shortage of skilled laborers. Due to crop diseases, farmers are forced to sell their onions in shorter time after harvesting. Controlled atmosphere storage reduces the wastage and there is no need of turnaround of onion during storage period resulting huge labor cost. Post storage life is very long, hence the vegetables can be sent to remote locations, and that results in direct saving of material cost and farming cost due to saving in weight / spoilage losses. Good quality, disease free onions need to be stored at constant temperature and constant low relative humidity needs to be maintained. A predefined constant level of carbon dioxide needs to be maintained. Air circulation within the product is very essential. Reheating of onions should be carried out properly in order to avoid condensation.

The bulbs harvested from rabi (winter) season (i.e. October to March) have better storage life than kharif (summer) i.e. July – October and late kharif (late summer) onion. The storage life of onion depends on various parameters like season, variety, bulb dormancy, nutrient and irrigation management, pest and disease incidence, pre-and post-harvest management practices and storage environment. Normally, light red onions varieties such as N-2-4-1, Bhima Kiran, Bhima Shakti, Arka Niketan and Agrifound Light Red have better storage potential than dark red, white and yellow varieties. Field curing is ideally done till the foliage turns yellow and necks become thin followed by a shade curing with adequate ventilation. Shade curing of bulbs protects the bulbs from sun scalding, improves the bulb color and keeps the outer surface scale dry. Excessive exposure to sunlight also causes sloughing of the outer scales (baldness), sunburn and excessive shrinkage of the onion. Medium size bulbs (50-80 mm) free from cuts and bruises are recommended for storage.

Bulbs need to be stored in 40-50 kg jute (hessian) bags, gunny bags, plastic netted bags or plastic and wooden baskets for better storage. After packing, onion bulbs should be stacked in a storage structure up to 5 feet height for easy handling. Bottom and side ventilated two-row storage structure and low-cost bottom ventilated single row storage structure are recommended. Storage of onion bulbs in cold store with optimum relative humidity extends the shelf life of onion bulbs and reduces post-harvest storage losses. Optimal storage temperature in cold storage is 0°C with 65-70% relative humidity. Under these conditions, the storage losses after six months are only about 5% which is mainly due to moisture loss. Regular monitoring of both temperature and relative humidity in the store are necessary to avoid significant fluctuations in environmental conditions. Very low temperature (<-2°C) may lead to freezing injury and high temperature (2- 25°C) coupled with high relative humidity (>75%) may cause rotting. The use of gamma irradiation (cobalt 60) at 60 Gr. controls the sprouting completely. However, gradual decrease in temperature i.e. preconditioning, before taking out the commodity from cold store is essential to reduce microbial decay.

Natural Vegetables & Fruits Storage Pvt. Ltd. started to work on onion storage way back in 2004. After conducting an in-depth research, the company has come out with an effective solution for onion storage. Based on the findings, it has also built a commercially successful storage solution that is being used in Gujarat & Maharashtra. The results are very encouraging for farmers and people involved in onion business (Cooling India 2015). Jaimin Engineering Pvt Ltd, a Rajkot-based company, had set up a cold storage especially for onions in 2011 with an investment of Rs 140 million and a capacity of 3200 metric tons. With ultra Oxazine technology, onion can be stored for one year in a controlled atmosphere and the quality of the onions will not change in it (Dave 2011).

6 Innovations In Agricultural and Food Products

6.1 Innovations in Crop Nutrient

Considering the importance of promoting sustainable agricultural practices, innovations in agricultural inputs that help prevent further deterioration of soil and water health are gaining momentum. For instance, Mycorrhiza, a fungal micro-organism feeding host plant with improved water and nutrients from the soil have the potential to reduce chemical fertilizer use up to 50 percent in certain cases and improve yields by (5-25) percent. The Energy and Resources Institute (TERI) has set up the world's biggest facility for producing mycorrhizae with more than 60 companies selling it as part of bio-fertilizer package.

Mycorrhiza – a fungal micro organism[9]

Another innovation in fertilizers, which helps optimal utilization as well as prevent diversion to non-agricultural uses and hence saves government resources is gaining popularity. Neem Oil spray on Urea slows the release of nitrogen by about 10 to 15 percent, hence reducing consumption of fertiliser. Research claims that neem coated urea increased rice yields by 9.6 per cent and wheat by 6.9 per cent. There is a plan to ensure 100 percent urea used for agricultural purposes is neem coated. Potential gains from savings in urea subsidy and yield improvement about USD 1-2 billion (PTI 2015). Markets for algae based bio stimulants are fast expanding wherein use of chemical pesticides and fertilizers are being rationalized and gradually substituted by more natural and organic products.

Pest management is critical to contain infestation as well as outbreak among crops and minimize crop damage. While pesticides are widely used, prolonged and heavy usage risks contamination of soil and water and damages crop health. Hence, alternatives which are environmentally friendly need to be promoted. In this space, Barrix Agro Sciences Private Limited established in 2011 manufactures pheromone traps for pest management which brings down the use of chemicals significantly. It also provides eco-friendly pest control solutions which in turn support and encourage organic farming. These traps are available for a variety of fruits and vegetable crops and has the potential to significantly improve yields by controlling pre-harvest losses due to outbreak of pest (Barrix n.d.).

[9] Photo source: https://drearth.com/wp-content/uploads/mycorrhizae.png

Vegetable Fly Trap[10]

Innovations in microbial products based on microorganisms such as bacteria and fungi have the potential to contribute positively towards sustainable farming practices and ensuring safe and chemical free food products. Microbes are produced by fermentation in a process similar to brewing beer and the products formulated are applied to seeds before planting, in-furrow or sprayed on crops. This allows effective crop protection and nutrient supply thereby boosting growth and yield as well as enabling optimal utilization of other inputs. In 2014, the market for microbials was estimated to be approximately USD 1.8 billion, while traditional fertilizers and pesticides were USD 240 billion. BioAg Alliance is a strategic partnership between Monsanto and Novozymes in developing microbial technology for agriculture that helps boost productivity and support natural resource management. These new solutions are commercially marketed by Monsanto BioAg (Monsanto BioAg 2016).

6.2 Innovations in Value Added Products

Technology that enables preserve the quality of high value commodities and improve their shelf life will help address the issues related to food losses as well as provide an option to consumers to avail cheaper processed products. Dehydration of fruits and vegetables, which removes the moisture and extends the shelf life without addition of any chemicals has a large potential market in India and beyond. For instance, onions, prices of which fluctuate heavily can be dehydrated and the same used at a much cheaper price when supplies are low and prices escalate. It is estimated that about 9 kg of fresh onions yield 1 kg of dehydrated onions which again turns into 9 kg of onion when put back in the water. To illustrate the point on how dehydrated onions are cheaper than fresh onions, typically a kg of dehydrated onion costs Rs 120 which is equal to 9 kg of fresh onions at the rate of Rs 70-80 (when prices soar). Hence a kg of dehydrated onion actually costs Rs 13 which is much more affordable to the consumers (Dave 2015). It is observed that low prices of fresh onions (around Rs 7 per kg) make dehydration viable for the processors. Jain Irrigation Systems Limited is the largest company in India and the world's third largest player (with 15 percent market share) producing dehydrated onions primarily for export purposes and large businesses in India.

[10] Photo source: https://cdn.shopify.com/s/files/1/0722/2059/products/crop-solutions-barrix-catch-vegetable-fly-trap-4_large.jpg?v=1493810976

Dehydrated onion flakes[11]

Micro propagation of tissues for enhancing production of bananas and reducing the crop lifecycle is being adopted in India. JISL played a pioneering effort in banana cultivation by introducing a high-yielding variety, Grand Nain, which has played a major role in improving the productivity and income of Indian farmers. The research and consequent commercialisation of the tissue culture of banana has benefitted farmers by improving production by over 100 per cent and reducing the harvest cycle by 30 percent. JISL is the largest player in this space, with production and sales of about 55 million plantlets, which it sells for Rs 13 each (price that has not been increased in the last decade) (Business India 2015).

Grand Nain (G 9) Banana variety[12]

[11] Photo source: http://www.germanfoods.in/blog/wp-content/uploads/2017/05/onions-282x216-250x216.jpg
[12]Photo source: http://agrifarming.in/wp-content/uploads/2015/03/Harvested-Banana.jpg

7 Innovations In Energy efficient Agricultural Practices

7.1 Vertical Farming Systems – Hydroponics, Aeroponics, and Aquaponics

Innovations in sustainable agricultural practices that allow growers to reduce usage of water, soil, energy and other inputs such as pesticides and fertilizers have added a new dimension to farming. It is no longer about open fields but protected cultivation sites as small as terrace tops, balcony porticos to large tracts of greenhouses, poly-houses, and vertical platforms. Using aeroponics to mist the roots of our greens with nutrients, water, and oxygen, a closed loop system, using 95 percent less water than field farming, 40 percent less than hydroponics, and zero pesticides. LED lights create a specific light recipe for each plant, giving the greens exactly the spectrum, intensity, and frequency they need for photosynthesis in the most energy-efficient way possible. Exactly the same seeds as conventionally used in the field are grown in half the time, leading to 130 times more productivity per square foot than on a commercial field farm. Plant scientists monitor more than 30,000 data points every harvest to improvise practices and minimize typical risks associated with traditional agriculture, and developed a patented, reusable cloth medium for seeding, germinating, growing, and harvesting. AeroFarms is the commercial leader in indoor farming and the growing cloth medium used is made out of BPA-free, post-consumer recycled plastic, each taking 350 (16.9 oz) water bottles out of the waste stream (Aerofarms n.d.).

The vertical farming market is expected to be valued at USD 5.80 billion by 2022, growing at a CAGR of 24.8 percent between 2016 and 2022. Factors such as increasing urbanization, rising demand for high quality, pesticide and chemical free food, and need to adopt sustainable and environmentally benign farming techniques are key drivers of growth in vertical farming. However, the pace of adoption and scalability is somewhat restricted given the high capital investments required, lack of adequate technical knowledge and skilled manpower to set up and maintain these farming units. The Asia Pacific region is leading in vertical farming with Japan, China and Singapore at the forefront. Toshiba (Japan), one of the largest consumer electronics companies converted their old factory into vertical facilities to grow vegetables such as lettuces. The major players in this market include AeroFarms (U.S.), FarmedHere (U.S.), Koninklijke Philips N.V. (Netherlands), Illumitex (U.S.), and Sky Greens (Singapore) (ReportsnReports 2017).

While in India, aeroponics, hydroponics and aquaponics are being field tested and piloted in different regions, there is no commercial model yet. Startups have also ventured into these novel technologies and are still in the stage of building their footprint before they can commercialize and scale up operations.

7.2 Technology Revolutionizing Sustainable Agriculture – LED Energy Source

Future growth in energy requirements in agriculture can be brought down significantly by moving to solar and LED energy sources. LED lighting allows a cooler and more energy-efficient way to optimize conditions than the high-pressure sodium (HPS) lamps traditionally found in greenhouses. Kellner (2014) reports studies that suggest that LED can surpass 50 percent efficiency — converting about half of their energy into plant-usable light — versus just 30 percent for HPS lamps. That translates into significant energy savings: it costs four times more to produce the same amount of fruit with HPS lamps than LEDs. LED technology is being used extensively in greenhouses in Holland with potential enhancement of yield, improvement in quality and taste of the produce and reduction in greenhouse energy costs. Japan is the only country in the world that is using indoor type hydroponic cultivation technology using artificial light. Crop yields and productivity are more than fifty times higher than those under soil cultivation. Lettuce grows two to three times faster than under soil cultivation. These innovations hold immense potential to attain the goal of sustainable agriculture for low income countries with the success already demonstrated in developed countries.

LED Technology used for Indoor Farming[13]

Future farms will require precision management enabled by high end automation ranging from irrigation, fertigation, use of seeds determined by soil type and other conditions. Robots and drones will play a larger role in enabling farmers to access information on farm conditions and using this effectively to determine input usage, quality of crop to expect and opportunities related to value addition and marketing. Even for countries which have a large section of the workforce engaged in agriculture, automation will be beneficial to get to the right quality of the produce and the market for it. Apprehensions about people losing their livelihood to drones and robots in agriculture at an impact scale is still quite remote. Rather adoption of such technologies will create an ecosystem for developers; designers; and entrepreneurs in agriculture.

7.3 Technology Revolutionizing Sustainable Agriculture – Solar Energy Source

Use of solar power as an alternative energy source can be a boon for the agricultural sectors and the farmers. Solar power can be used for irrigation, operating cold storages in rural areas where electricity supply is irregular and diesel is the most commonly used. With solar power generation in the farmers' field, they can harvest a third crop which can serve as an insurance against crop damage or failure. Also, farmers can feed the surplus power generated into the grid which can turn out to be an additional source of income and also incentivize farmers against indiscriminate use of solar energy resulting in over exploitation of groundwater and augment farmers' incomes by feeding the surplus power generated into the grid. Experiments are on in Gujarat where solar panels are arranged like a chess board with gaps and at about 15 feet above the field to allow sufficient sunlight for crops. This design known as solar sharing was first adopted in Japan, introduced by Akira Nagashima in 2004. From a fiscal standpoint, replacing electric pump sets with solar pump sets can help bring down the annual agricultural power subsidy bill which can be then used for financing up front capital costs for solar installations. Similar innovative approach of using solar energy to power agriculture in Africa can benefit a large number of smallholders in terms of better access to energy and higher productivity. However, in order to defray the initial installation and maintenance costs for the smallholder farmers, government support and business collaborations can help jumpstart. Germany

[13] Photo source: http://dsg.files.app.content.prod.s3.amazonaws.com/gereports/wp-content/uploads/2014/12/19022700/tumblr_inline_ngsotgZNpJ1qzgziy.jpg

being the global leader in solar power (with largest installed capacity) can offer key lessons and share best practices for regions like India and Africa to look at solar energy as a means of improving agricultural growth as well as augmenting farmers' incomes (Gulati, Manchanda, & Kacker 2016).

Solar energy driven irrigation systems[14]

[14] http://demo.karenergies.com/wp-content/uploads/2016/06/Solution-for-Limited-power-supply-in-Rural-Areas.png

8 The Way Forward

The payoffs from innovations in agriculture are demonstrated in many examples and there is ample scope for further replicating and scaling up the same for achieving a holistic and inclusive growth across regions where agriculture is an important source of income and food security. While we identified promising biological, technical, digital and organizational innovations, that make many aspects of agriculture more efficient (such as cutting transactions costs, increasing returns to scale, offering opportunities for new output and input market functioning, and inclusion of smallholder farmers), a puzzle remains: what is the impact of all these innovations for overall economic growth in Indian agriculture and for equity? More comprehensive impact path way research and implementation research is called for to accelerate design and facilitate access to innovation by the masses of Indian farmers. Enabling policies, institutions and partnerships hold the key to making innovations work and catalyze growth and development. Some key next steps in ensuring that the ongoing efforts gain more pace and deliver greater benefits to the farmers and the other stakeholders in the value chain including the consumer are summarized as follows:

Investing in Innovations: Both public and private sector investments in promoting innovation that have a high potential to solve the common issues facing agriculture will be critical. The Green revolution witnessed a significant surge in public spending in South Asia, which helped bring in the right resources and enable services for the farmers. One of the key factors for the slow progress of the Green Revolution in Africa lies in low public spending, great diversity of agro-ecologies, and limited contract security. Particularly in smallholder economies, the cost of risk mitigation is very high. To achieve the desirable breakthrough in *Brown Revolution* (technologies aimed at improving soil health and fertility) it will be important for both the public and private sectors to step up investments in a big way to encourage impactful innovations (Nkonya, Mirzabaev, von Braun 2016). While large agribusiness companies, individuals, venture financiers and angel investors make up for the large share of investments in advanced technologies, public investments in other related sectors in agriculture (infrastructure, irrigation, advisory services, etc) will play a vital role in creating the right ecosystem for farmers to benefit from these technologies. Also, public spending can be directed towards risk mitigation through credit and insurance mechanisms.

Accelerating commercialization of technologies: It has been a common challenge faced by entrepreneurs. There are several factors – access to finance and capital; fitting of a technology solution to farm level issues; acceptability to the farmers owing to economic and other reasons; lack of skilled resources to service and upgrade the technology, which need to be considered upfront. While an idea can be novel and has the features of solving the issue at hand, testing it for the barriers to adoption can save a lot of financial and other resources. Hence, innovations need to be backed by research and continuous monitoring and evaluation to validate the suitability of a technology in a given geography and value chain. In the context of start-up led innovations, the incidence of going out of business is observed to be rampant.

Regional exchange and knowledge sharing programs: Knowledge sharing about technologies that have worked well and under what conditions offer useful learnings for effective technology transfer across regions and will catalyze the process of innovation led agricultural transformation. To be able to nurture ideas and young talent, students and fellow exchange programs can boost learning on agriculture technologies. Such platforms can be created between India and Africa to help both the regions at the University and college levels to attract youth early on to agriculture entrepreneurship. These programs can be further linked with the agribusiness sector to further strengthen the ideas through piloting and R&D. For instance, India has demonstrated the success of farmer mobilization in the form of farmer producer organizations (FPOs) to overcome the smallholder issue, and accord greater bargaining power to the farmers. Linking the smallest milk producer to markets through an integrated value chain approach is an example. One stop shop models in agribusiness that deliver both backend and frontend inputs and services to the farmers might be demonstrated in Africa too, to help address similar issues.

Strong political will to boost innovations for agricultural prosperity: It is important to develop a sustainable roadmap for attracting and retaining youth in agriculture. Given that these regions have a considerable proportion of young population, and unemployment, working towards an inclusive growth model will require strong political will to mobilize financial resources as well as global collaboration to help countries to adopt technologies for agricultural transformation. For instance, in India, the Government has launched flagship programs like Digital India; Startup India to promote technology adoption in various sectors to promote technology led entrepreneurship. Special incentives are provided to attract young entrepreneurs and enhance ease of doing business for these players.

Strengthening global partnerships: In the field of agricultural innovation, new forms of cooperation between countries should be considered. The traditional technology transfer concepts may be outdated. All can learn from all. Technological innovation can not be pursued separately from organizational innovations, as one depends on the other. Global policy platforms like G-20 can facilitate innovation led agricultural transformation and hence advance the agenda of youth employment and entrepreneurship in the sector. Such platforms could bring together the best practices in agricultural innovations, and customize and adapt them to the needs of low income and emerging economies. Triangular cooperation should be considered too, such as among India, Africa and Germany in this area.

A lot of the technical expertise, capacity building and hand-holding can be provided by the leading institutions and forum already working in this domain. A startup network should be created to pool young talent globally and harness the entrepreneurial zeal that already exists in different parts of the world. This may especially be useful in the field of frugal innovations.

Agriculture is an important source of income and livelihood security for the developing world and the challenges around poverty, health, education and other human development parameters are most profound in these countries. Thus, innovations must strive to achieve success for transformative development that deliver maximum benefit to the smallholder farmers and improve the employability of young people in a remunerative model. Partnerships and policy frameworks that encourage and incentivize developing frugal yet impactful innovations that have the potential to address localized farm issues and concerns of the farmers' needs to be pursued at a global and national level. Innovations in institutions that help deliver, demonstrate and accelerate adoption of technologies should be encouraged.

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