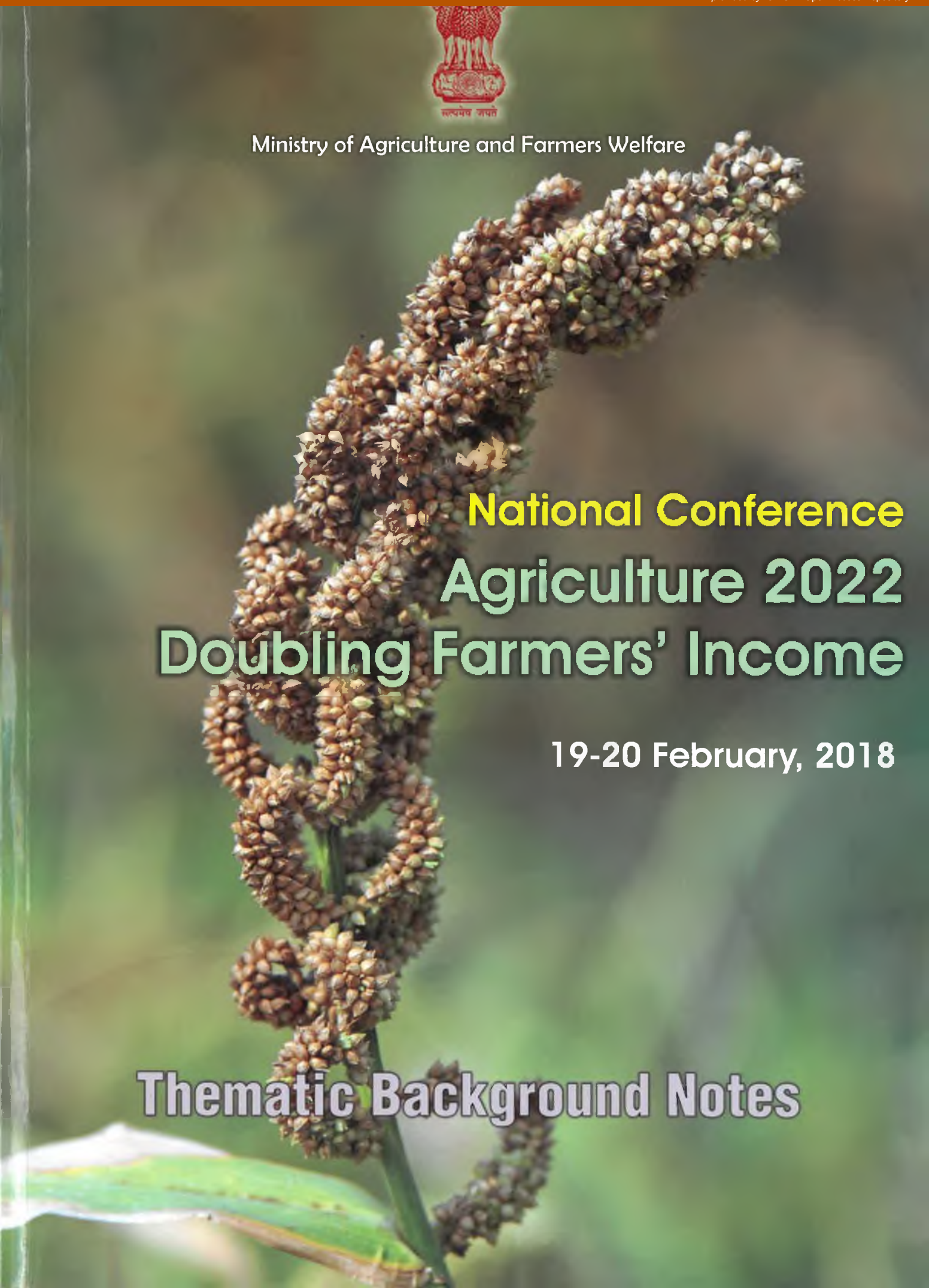


Ministry of Agriculture and Farmers Welfare

National Conference

Agriculture 2022

Doubling Farmers' Income

19-20 February, 2018

Thematic Background Notes

Science & Technology and Startups in Agriculture

Executive Summary

The Indian economy is largely agrarian, with around 55%of the population dependent for their livelihoods on agriculture and allied sectors that generate 15% Gross Value Added (GVA) (GoI 2017a). Indian farmers are vulnerable to impacts of climate change, water scarcity and land degradation. In addition, increasing fragmentation of holdings, extreme weather events, rising input costs and post-harvest losses pose an enormous challenge to sustaining agricultural growth. There has been considerable expansion and change in the research and extension system but the key questions remain: *'Is this sufficient to Double Farmers' Incomes by 2022? Is there a need for a different mindset to ensure agriculture science empowers farmers to reach their full economic potential? Can such be achieved while delivering nutrition to the nation as well as within the ecological boundaries of India's natural resources?'*.

This chapter draws on practical experiences onashift in thinking at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), developedwhileworking with a broad range of partners across thespectrum of **Science of Discovery to Science of Delivery**. Core to this modern approach is **Demand-Driven Innovation** that leverages participatory research to engage farmers and key value chain actors to design, develop and deliver relevant solutions –all with a sense of urgency. This approach has enabled the compression of time to deliver technology and knowledge at scale.

We **partner with the private sectorand support agri-entrepreneurs** to provide modern value addition, delivery of inputs and provision of extension services by bringing together agriculture sciences, Information and Communication Technology (ICT), and allied sectors to deliver sustainable and scalable solutions.

Modernization of research systems draws strongly on**Spatial Data Integration** (SDI), especiallycloud computing capabilities to integrate data assets across organizations. This will help support modern breeding programs, model priorities and track progress using geospatial analytics and apply machine-learning to distill complex data into actionable and relevant recommendations for farmers.

ICRISAT has engaged with the leadership at national and state levels in India to provide technical support and draw on innovation and best practices from around the globe. This led to the production of the MITrA brief (ICRISAT, 2016) that summarized key interventions to realize Pulse Self-sufficiency, *Pradhan Mantri Krishi SinchaiYojana* (PMSKY), Soil Health, National Marketing Platform, Weather Indexed Insurance and Digital Agriculture. ICRISAT has engaged with several state governments to help build a consortium where partners and government ministries convergeto take a systems approach to sustainable rural growth, especially for rainfed production systems that face the most challenges, but offer the greatest growth potential to double farmers' incomes. Given the complexity of convergence and the data-intense nature of agriculture, astrong recommendation is to put in place SDI and incentives for their adoption by research organizations, government ministries and progressive private sector partners in order to enable the delivery of timely, targeted and tailored solutions for farmers to double their incomes by 2022.

A focused effort is required on the "Science of Delivery" to increase rural incomes. Each state needs to take ownership, create robust implementation plans along withadequate budget and leverageAadhaarIndiaStack and SDI to provide the technology backbone. Given the past success of the National e-Governance Division (NeGD) in supporting e-Governance reforms, the NeGD should now pivot its focus to DFI in collaboration with State e-Mission Teams. While agriculture will be the engine for rural growth, it must be seen in the context of agrifood systems to deliver better incomes, nutrition and health. To this end, coordination of schemes that bring together Agriculture, Health and Education will be key for long-term growth and reaping the youth dividend of India to translate Innovation into Impact.

4.1 Science & Technology in Agriculture

Indian economy is largely agrarian with nearly 54.6% of the population dependent on agriculture and allied sectors for their livelihoods while it contributes only 15.4% to the nation's GVA. Marginal and small land holdings (under 2 ha) comprise 85% of the total operational land holdings both in terms of number and area. Of 193.7 million ha, around 45% (87.7 million ha) is irrigated while the rest is rainfed. Groundwater and surface water sources irrigate about 31% and 68% of the irrigated area respectively (GoI 2017a). In addition to water scarcity and increasing land degradation, Indian farmers are vulnerable to impacts of climate change as their livelihood largely depends on monsoon, markets and intermediaries who are integral part of their lives but are unpredictable and play havoc on rural livelihoods. With the agricultural growth rate hovering around 3% annually, farmers have felt severe economic distress and hence the clarion call by the Prime Minister to Double Farmers' Incomes by 2022.

However, this will be a challenge given increasing

fragmentation of holdings, extreme weather events, rising input costs and post-harvest losses. It is where challenges are greatest that we require the very best that human innovation can offer. The government has already placed a clear focus on farmers' welfare with policies to enhance water availability(*HarKhetkoPani*), increased water use efficiency (more crop per drop), better farm practices, improving soil heath, increasing investment in agriculture research, extension and support prices, creating rural infrastructure, ensuring timely delivery of credit and technology, encouraging market reform (e-NAM) and reducing risk in agriculture through the introduction of a new insurance scheme (*Pradhan MantriFasalBimaYojana*).A draft strategy paper released by the Ministry of Agriculture and Farmer Welfare targeted to raise the average annual income of a farmer household in India toRs.2,19,724 by 2022-23, fromRs. 96,703 in 2015-16, with the help of additional public and private investment of Rs. 6.4 lakh crore (GoI, 2017b). Research and technology with the support of pragmatic policies, targeted budget allocations and convergence of schemes based on agro-ecologically focused growth engines will be key to realizing this vision.

4.1.1 Change in the Composition of Household Income

Analysis of National Sample Survey Office (NSSO) data on household income revealed that income obtained from agricultural households increased at an annual growth rate of about 12%at current prices and 3.9% at constant prices (Table 1) (GoI, 2005 and 2013). It is important to note that livestock has been the major growth engine. Non-farm incomes and wagesandsalary of farm households have grown at a much slower rate than cultivation.

4.2 Agricultural Research and Development in India[1]

There have been significant advancements in science, its discovery, management and transfer of technology to end users. NIAP-ICAR reviewed all aspects of agricultural research and development (R&D) in India that covered research, extension, commercialization of technology, intellectual property rights, regulatory reforms, and impact of technology (Pal, 2017). It also looked at trends in public investment and organizational development and evolving roles of federal, state and private sectors in translating innovation into impact. With the growth of Indian R&D system, there was a realization that public funding need not be exclusive for public organizations and that private sector could be an important ally in addressing national R&D needs. In view of this, public funds were made available to private organizations either through sponsored research or competitive funding. Such programs grew over time, both, under externally-funded projects of the World Bank as well as ICAR's Plan budget programs. Nearly 10% of ICAR budget is now spent on demonstration of new technology and skill development of farmers, in partnership with private and civil society organizations. Such initiatives have put India among the few countries having public-private partnership in R&D (Pal, 2017).

The rapid evolution of molecular biology and information technology to integrate across disciplines and sectors will play a critical role in India to unlock innovation and realize impact in farmers' fields. While the agricultural research and development system in India hasresponded to these developments, more can and must be realized by using modern tools (cloud computing, artificial intelligence, mobile, remote sensing, and systems research) to support agrarian reforms to make agriculture a commercially attractive and sustainable enterprise for current and future generations.

Indian agriculture has many advantages as summarized in the December 2017 report by India Brand Equity Foundation (IBEF), a Trust established by the Department of Commerce, Ministry of Commerce and Industry, Government of India. These advantages include robust demand (domestic and international),

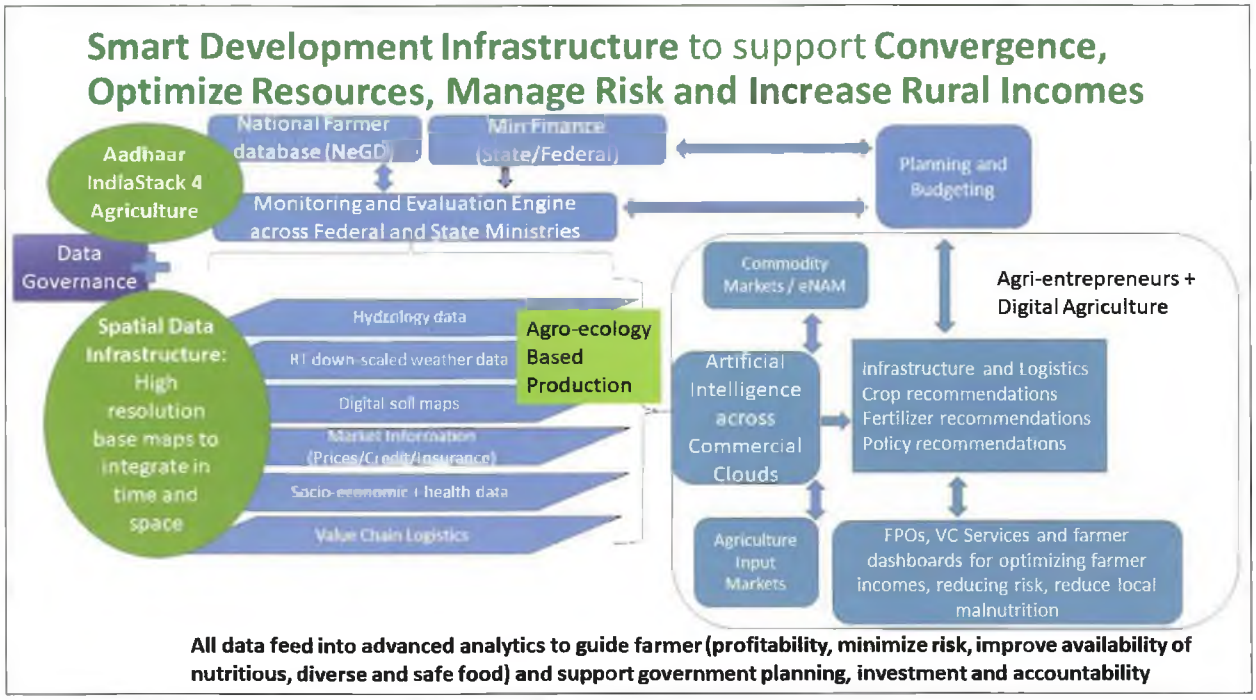
Table 1. Trends in agricultural household income in India

Components of income	Current prices (Rs)		Constant prices: 2011-12 prices (Rs)		Growth rate	
	NSSO 50th round (2002-03)	NSSO 70th round (2012-13)	NSSO 50th round (2002-03)	NSSO 70th round (2012-13)	Current	At 2011-12 prices
Cultivation	11455	36950	21830	33383	12.4	4.3
Livestock	1189	10016	2266	9049	23.8	14.9
Non-farm business	2786	6209	5309	5610	8.3	0.6
Wages and salary	9840	24801	18753	22407	9.7	1.8
Total annual income	25271	77977	48160	70449	11.9	3.9

Source: GoI, 2005 & 2013

[1]This section is largely reproduced from Suresh Pal, 2017 (Ed) 'Agricultural R&D Policy in India'. ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi and India Brand Equity Foundation (IBEF), Ministry of Commerce and Industry, Government of India, December 2017 report on Agriculture and Allied Industries. https://www.ibef.org/industry/agriculture-india.aspx

Fig. 1. Spatial Data Infrastructure (SDI) to support data integration and convergence of sectors and Ministries to increase rural incomes while managing natural resources and risk to deliver on Doubling of Farmers' Incomes and nutritional security.



largest agricultural land (over 157 million ha) with 15 agro-ecologies and 46 out of 60 different global soil types uniquely positions India to design, develop and deliver solutions for smallholder farmers in India that will have global applications (especially Africa) and deliver on global commitments (Paris Agreement on Climate Change and SDGs). The strategic question to ask is: "How can weleverage emerging markets (domestic and export) and value addition opportunities and integrate several Centrally Sponsored Schemes and new policies such as the Contract Farming Law, FDI incentives for seeds, warehousing and storage, and irrigation fund under PMSKY?" The answer to this lies in the convergence using SDI that can be supported with hybrid cloud systems that provide integration with secure cloud services of private service providers.

4.2.1. Emerging Issues

Although the Indian agricultural R&D system has been one of the pioneering systems among developing countries, there are many complexities restricting the system from realizingits full potential (Ramasamy, 2013). The R&D system needs to address multiple development challenges such as efficient and inclusive growth, sustainable natural resource management and environmental safety, food safety, monitoring and management of emerging nutritional security threats – among others.To manage this complexity requires efforts and skill development within the line departments and the move towards modern data management to prioritize and target research (state and federal), coordinate with allied ministries and the private sector.

International research organizations, such as CGIAR institutes, have contributed significantly in terms of crop improvement and natural resource management in India. Overall, 65% of the area of the 10 major food crops (including sorghum and millets) is planted with improved varieties with approximately 60% of this area being sown to varieties with CGIAR ancestry, and half of these are derived from crosses made at a CGIAR Center (i.e., direct releases by national systems). Among regions, impacts have been highest in Asia (both in relative and absolute terms) and lowest in Africa (Renkow and Byerlee, 2010). However, we have only tapped into approximately 1% of the genetic diversity in the development of new varieties (Upadhyaya et al., 2006). As we develop Climate Smart Crops, we will need to apply modern genomic tools, modern crop improvement databases and breeding tools to accelerate the integration of diverse production (pest and disease resistance, drought and flooding tolerance), profitability (machine planting and harvesting, processing quality) and nutritional (amino acid and lipid profiles, micronutrient dense) traits to support modern agrifood systems and economic opportunity for farmers. ICRISAT is working closely with ICAR institutions to migrate breeding programs into the Breeding Management System (BMS) and supported with high throughput genotyping and phenotyping to accelerate genetic gains.

Seed systems research is the next important issue to accelerate replacement of old with new varieties. Innovative models on seed systems that leverage participatory variety selection with farmer producer organizations (FPOs) and state seed corporations have proven to be a very successful model in replacing

Swarna rice variety with a submergence tolerant version called Swarna Sub1. In a similar manner, improved varieties of pulses and groundnuts are being scaled up. In 2002, ICRISAT established the Hybrid Parent Research Consortium (HPRC) for sorghum, pearl millet and pigeonpea that was later replicated for rice and maize. The model offers small and large seed companies access to elite breeding lines and provides public sector breeding programs with feedback on trait prioritization and multi-location testing to increase the confidence that improved varieties will perform in diverse production systems and meet diverse market demands. ICRISAT has captured these different seed production and dissemination models in a recent publication (ICRISAT, 2017)

Difficulty in transition from an intensive pilot level (hundreds) to large scale (millions) adoption of technology by farmers has been referred to as the "Death Valley of development". To bridge this gap, there is a need for a research for development mindset that is focused on demand-driven innovation, that engages a wide range of development actors in the public and private sectors and that consults with farmers and consumers in the design, development and delivery of farmer- and consumer-preferred solutions.

The HPRC offers an example of how the public system can foster partnership with the private sector. In an effort to integrate agriculture and Information Communication Technology (ICT), ICRISAT established the ihub on February 13, 2017 – "i " stands for innovation, integration, inspiration and impact. The platform offers a model to scale science-based solutions through entrepreneurs and works closely with T-Hub, India's largest startup incubator. Some examples of ihub startups include business solutions that use Artificial Intelligence (AI) to identify pests and diseases, market integration, real-time monitoring and evaluation and UAV-supported precision agriculture recommendations. Early indications suggest this is the faster mode of moving from innovation to impact – the theme of the international ICT4D Conference held in Hyderabad (May 16-18, 2017) which was supported by ICRISAT and the state of Telangana.

We refer to these areas of delivering innovation and knowledge at scale as the "**Science of Delivery**".

4.3 Science of Delivery for Impact

4.3.1 Why Science of Delivery?

Science of Delivery is a disruptive concept that will motivatescientists and development practitioners to collaborate beyond their own disciplines and institutions. Popularizing innovative technologies and achieving larger impacts on the ground requires the involvement of majority ofstakeholders.Further, Science of Delivery will require focused funding, institutional incentives, behavior change, and rethinking on the role of public extension systems (World Bank, 2013 http://blogs.worldbank.org/developmenttalk/so-what-exactly-is-the-science-of-delivery). Though development of Agricultural Technology Management Agency (ATMA) has given an institutional identity to extension, it needs to strengthen linkages with other line departments and *Krishi Vigyan Kendras* (KVKs). For strengthening the technology delivery system, KVKs should play a larger role in skill development and participatory technology demonstration to addresslocation-specific constraints. These solutions can then be scaled through targeted dissemination that leverages SDI with IndiaStack which will empower farmers to act on ecologically sound and marketable options to increase their incomes.

4.3.1.1 Anthropology of Adoption

Understanding the decisions of farmers to not adopt new varieties and technologies must be better understood. For most humans, "seeing is believing" and hence the role of lead farmers in demonstrating technologies can be critical in their communities. In this regard, SDI and India Stack can be leveraged to target the testing of improved technologies with lead farmers. Using real-time mobile-based monitoring, the transaction costs and latency of feedback can be dramatically reduced. ICRISAT is now implementing such an approach with the support of an ihub entrepreneur.

4.3.1.2 Formal science recognizes individuals, less so teams or partnerships

Diverse teams focused on outcomes consistently outperform individuals. Despite this common knowledge, incentives in the R&D sector are structured around specialization and not 'convergence' to take on the complex challenges facing society, especially the agriculture sector. This is starting to change with the private sector taking the lead and forming joint ventures to build diverse teams outside their sector. Leadershipis needed to demonstrate and support convergence within and between institutions. Technology can be used to effectively identify and assemble willing and strategic teams, track progress and allocate resources to provide the incentives for behavior and mindset change to unlock innovation and deliver impact at scale. This is not easy but it will be essential for innovation-based economies, especially in the agrifood sector that is arguably the most complex given the current level of farmer access to knowledge, current state of natural resources, and complexity of markets against the backdrop of climate change. Rainfed agriculture holds the most promise for growth but is also at greatest risk which means the very best teams need to be assembled (physically and virtually) to deliver robust innovations.

4.3.1.3 Need to converge institutional cultures, processes and individuals to build successful partnerships

Achieving tangible economic benefits for farmers

will requirere search systems to adopt and operationalize a holistic approach through convergence and collective action (Wani et al., 2003a, 2009). To achieve the goal of DFI, backward and forward linkages in terms of providing necessary inputs (seeds, fertilizers, pesticides, machineries, credit, insurance), local value addition and preservation (primary processing and storage) and market integration supported by grades and standards, pragmatic policies and private sector partnerships is required. The right institutional incentives and partnerships will be required to drive this change at multiple levels and federal and state budgeting will be the key incentive. Based on state priorities and "Labs" that bring critical value chain actors together, research priorities should be set, not only to increase productivity, but also profitability for farmers –reduce production costs while increasing the unit market value of surplus production. Appropriate grades, standards and certification (again a rich space for innovation in India) can increase market value realized by farmers by incentivizing better quality output. With the support of SDI and IndiaStack, these lofty visions can be translated into reality with the commitment of leadership at all levels and to work as a consortium of public and private sector partners to implement with speed and at scale (Wani et al., 2011).

4.3.2 Science of Delivery needs to be undertaken and rewarded

Science of Delivery is focused on HOW to realize large and sustained impact that draws on knowledge management and diverse methods of sharing that include large-scale demonstrations to inform decisions, adapt approaches and changed mindsets that **accelerate the innovation cycle** and ensure local conditions, context and culture are considered in developing and delivering products and services. It also helps compress timelines from discovery to delivery.

Understanding how delivery works in agriculture needs to be informed by a broad range of partners across sectors and regions and new tools like social media that aid us immensely in this endeavour. Better understanding of delivery challenges and failures will significantly improve our ability to achieve consistent and transformational impacts in farmers' fields and consumers' plates. We need to recognize that soft skills are required to work effectively in the domain of delivery but these are not taught in agriculture science curricula nor are there incentives within institutions to hone these critical skills.

4.3.2.1 Science of Delivery is a challenging

Science of delivery is a relatively new subject for many scientists, development practitioners and extension agencies. Innovation is happening at an amazing pace but many innovations are not being translated to use. Using all known interventions appropriately could increase grain yield by at least 50% and resource use efficiency from 50-70% and reduction in cost of cultivation by 20% (Wani et al., 2017). However, in India, technology transfer can benefit from changed and improved mindset, infrastructure, institutional support and policy guidelines to translate these innovations into impact.

4.3.2.2 Need to understand the complexities of agricultural systems

Farming is a complex and risky business in the wake of increasing water scarcity, land degradation and climate change. Its success heavily depends on the attributes of the land, weather, markets, knowledge, access to inputs, support services, capital and infrastructure. Hence, solutions need to be flexible in terms of being able to tailor them to local needs and production situations and scaling them through "trust networks" that leverages ICT. Science of Delivery for agriculture development requires strengthened farmer organizations, better functioning service providers and an enabling institutional framework. Demand for high-quality agricultural advisory services will likely emerge from market players who want to compress supply chains to increase quality, integrate traceability, ensure supply and be competitive in the market place. This trend started with high value horticulture and livestock products and is now starting with staple crops.

4.3.2.3 Four ICEs framework for effective delivery of impacts

Past experiences suggest that effective delivery of technology needs an integrated approach to complement different sectors and disciplines on the ground. ICRISAT-led consortia have demonstrated an integrated holistic approach to converge programs and resources to achieve system level outcomes. This approach considers four ICEs which are central to scaling-up of technologies and sustainable intensification.

The framework to **innovate** in an **inclusive** and **integrated** manner to deliver **intensification** (4 "I"s) draws on the principle of **convergence**, **consortium**, **capacity building** and **collective action** (4 "C"s) which are critical in developing strong intermediaries to address the consortium goal through 4 "E"s (**Efficiency, Economic gain, Equity** and **Environmental protection**) which are the important pillars for sustainable intensification and inclusive development (Wani et al, 2011). The framework emphasizes efficient use of land and water resources and, for example, targeted fertilizer blends for sustainable intensification while maintaining the environment. The approach of the consortia programs has been to strengthen input and output value chain linkages to meet the 4 Es through 4 Cs by establishing seed villages, custom hire centers and small-scale businesses to undertake best-bet options for increased agricultural productivity and profitability. Community based organizations (CBOs), service providers and emerging models of Farmer Producer Companies will be

key consortia partners for scaling impact.

4.3.2.4 Science of delivery is neither taught in business schools nor agriculture universities

Agricultural Universities or broader business schools have not emphasized Science of Delivery in their curricula. While specialization is important for the Science of Discovery across biological, engineering, social, economic and environmental sciences, integration across these and other disciplines is limited and practical tools to partner with the private sector and liaise with policy makers are few. It is only in recent years at ICRISAT that we have come to appreciate the importance of "soft systems science" to enable the transition from pilot projects to large-scale implementation and impact. ICRISAT is now training the next generation on these skills that draw heavily on emotional intelligence and partnership engagement and business planning.

4.4 Compressing Science of Discovery to support Science of Delivery

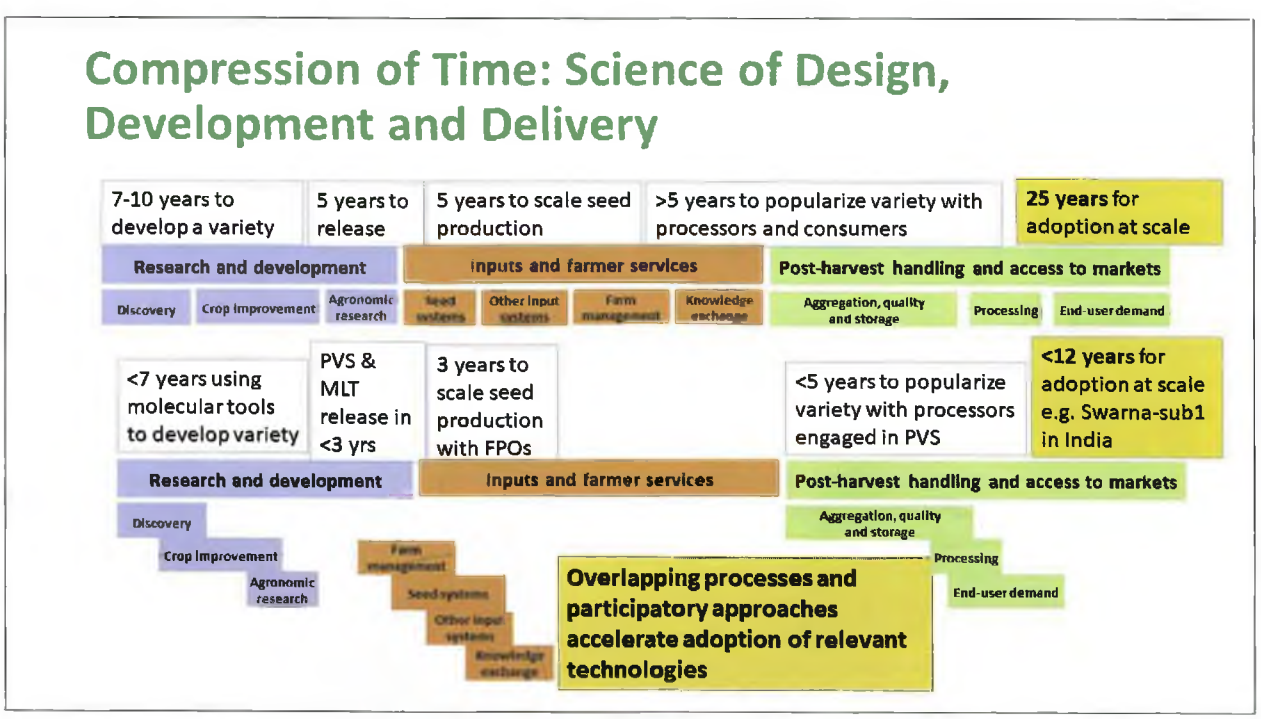
The first mile (discovery) needs to have the last mile (delivery) in mind. In this regard, ICRISAT and its partners are committed to reducing the time for discovery science to reach farmers' fields. Modernization crop improvement programs to accelerate the development and release of new varieties is one such example.

Assessing the status of breeding programs is the entry point for modernization based on best practices used in public and private sector breeding programs. Based on this assessment, prioritized investments were made and implementation of best practices were monitored. New tools included the adoption of a cloud-based breeding management system (BMS), standardized trait ontologies, bar-coding to reduce data error, high throughput genotyping to support marker-assisted breeding, early generation multi-location testing, and crop modeling to target product development and release. Development of the molecular tools to integrate multiple traits is supported through international and national partner networks that are now utilizing genome sequences to resequence a wide diversity of crop germplasm to develop molecular markers in service of developing diverse, robust and nutritious new varieties.

Another area of rapid innovation is in the integration of modeling, remote sensing, advanced geospatial analytics, cloud-computing, internet-of-things and mobile phones. Integration of these tools is providing timely and targeted insights for farmers, agri-business, markets and policy makers. However, the research community is in the early stages realizing the potential of integrating this domain with that of modern crop improvement and farming systems to optimize variety development in the context of farming systems and market demands.

A third important domain for the research community is to look at the compression of time to develop and delivery demand-driven innovation to farmers' fields at a large scale. A few examples of this exist already in India (see examples below for chickpea and rice). The process

Fig. 2. Science of Delivery involves the compression of processes and strategic partnerships to accelerate innovation cycles and compress the time of delivery of farmer- and market-preferred products and services. Example shows how this applied to the replacement of the popular rice variety Swarna with the submergence tolerant Swarna-sub1. (Drawing on lessons from Yamano et al. Agricultural Economics under review).



for how these were realized needs to be adapted for other crops and States in service to realizing economic opportunity and climate smart options for farmers sooner.

4.5 Science of Delivery to double farmers' incomes

4.5.1 Putting in place Spatial Data Infrastructure (SDI)

Spatial Data Infrastructure(SDI) and **institutional incentives to aggregate data** across research organizations (ICAR, SAUs, ISRO, IITs, etc.), industry (fertilizer, seed, processing), Ministries (see MITrA, 2016) can support **agroecological-based agrifood** research, technology targeting and adoption. Leading agriculture nations now use SDI to unlock innovation, track implementation and create accountability for modern agrifood systems. **Aadhaar IndiaStack** can be integrated with SDI by National e-Governance Division (NeGD) ***if focused on DFI*** in partnership with State e-Mission Teams.

Sectors such as finance and IT have been leading the application of advanced analytics to deliver business solutions, while agriculture, which is data-intensive, has made the least use of big data analytics. In large part this is due to the scarcity of structured data and meta-data to drive digital innovation. Two key interventions to address this would be the implementation of Spatial Data Infrastructure that would complement the Aadhaar IndiaStack through cloud storage provided by commercial providers through hybrid (public + private cloud) services. These resources should be opened to the public and private sectors to foster data-driven innovation for agriculture that is now fueling agriculture in advanced economies. The second intervention is to put in place institutional incentives to ensure publicly funded data is stored on such services in a structured manner with clear ontologies and meta data to support integration across institutions. This would support collaboration within the agriculture sector but also with other key allied sectors such as health, development and education.

This will likely involve building on the existing partnership between government (Union and State) and IT sector established by the National e-Governance Division. Key data sets to start with will be soil, hydrology and weather data assets that can be made available to public and private sector researchers and development partners. In the case of hydrology, watersheds could be integrated as meso- and macro-watersheds and further into sub-basins and basin level for the effective planning, management, monitoring to realize sustainable development of rural economies. A research and development unit at the state level needs to be set up to study agro-ecological regions staffed with adequate human and financial resources. Incentives should be in place to promote sectoral convergence at farm level by linking different programs and schemes through SDI and Aadhaar so subsidies are based on needs of the farm and farmer to maximize input use efficiency (irrigation and fertilizer that include micronutrients), support market price stabilization, and eventually offer farmers with simple options in advance of the growing season to reduce risk (production and market), optimize inputs and integrate into structured markets. **Aadhaar offers a unique platform to track the performance of these subsidies and, if designed well, a means to track DFI in real time.**

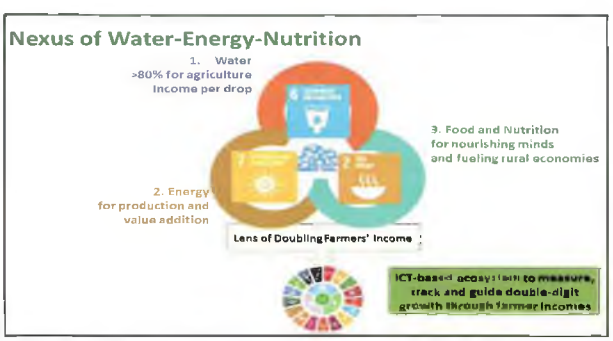
4.5.2 Mindset towards Demand Driven Innovation and Science-led Development

Moving from supply-driven research to a demand-driven research will require a mindset change among the scientific community. A new mindset orientation towards participatory approaches to support bi-directional exchange between farmers and researchers to accelerate the design, development and delivery of farmer-preferred and sustainable farming systems will need to be adopted by public research institutions.

A fundamental shift is required within the science community as society demands more from public institutions charged with delivering solutions to serve society. This is especially true for Indian farmers who require innovations and the knowledge to optimize inputs to reduce production costs and maximize unit price of surplus to increase their incomes. Research and innovation also need to embrace and leverage new technology such as cloud computing, mobile, remote sensing and innovative partnerships with the private sector to deliver timely, targeted and tailored products and services to empower farmers to realize their full economic potential, produce safe and nutritious food for the nation within the ecological boundaries of India's natural resource base. Participatory research that engages farmers, value chain actors and researchers will be key and need to provide feedback to determine priorities, budgets,monitor progress and adjust implementation plans as required to accelerate impact – this is the Science of Delivery.

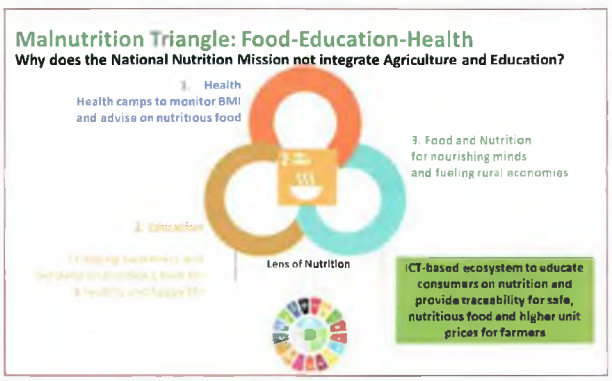
4.5.3 Research from the lens of increasing income and decreasing malnutrition

Agricultural research should be with the lens of increasing incomes and decreasing malnutrition.



Research into improving water-use efficiency, providing clean and sustainable energy to promote value addition at the community level and providing nourishing food at the community level will contribute to increasing incomes. ICT tools can serve as decision support systems while also help guide implementation and monitoring.

Inclusion of education and agriculture domains into the recently-launched National Nutrition Mission can play a crucial role in reducing the burden of malnutrition facing the country. Multi-disciplinary research to address the synergies between health, agriculture and education is vital to tackle malnutrition and ensure that farmers get a premium price for producing nutritious food.



4.5.4 'Systems Approach' toResearch

Research needs to take a **Systems Approach** to diversifying farming systems that includes the optimization of water resources to increase economic opportunity, especially for high value crops, horticulture and livestock (including aquaculture). SDI and mobile-enabled implementation of agro-ecologically appropriate schemes and solutions will be an important step towards a systems approach.

4.5.4.1 Agro-ecological framework for a sustainable agrifood system

Agro-ecological intensification for farmers will be key to increased productivity and profitability by optimizing local resources, maximizing returns from external inputs, improved stability and diversity of nutritious foods, reduced greenhouse gas emissions, enhanced ecological resilience and environmental service provision. Simple interventions such as better seed, nutrients, and water management have yet to reach many parts of India. Moving to knowledge-intensive forms of agriculture will require SDI, integration of ICT coupled with policy and market incentives. In crop production, agro-ecological intensification based on good agronomic management principles for a given context includes:

- Profitable and sustainable crop rotations
- Quality seed of a well-adapted, high-yielding varieties or hybrids that also meets market demands
- Planting at the right time to maximize the attainable yield by capturing water and nutrients
- Maximize water harvesting and efficient utilization of available water
- Integrated soil and nutrient management, including conservation agriculture, balanced and more efficient use of fertilizers
- Integrated pest management, including biological control and the judicious use of pesticides supported by emerging cloud and mobile-based diagnostics
- Optimize recycling and use of biomass and agricultural by-products
- Enhance suitable crop-tree-livestock interactions

4.5.5 Backward integration of value chains

Matching farmers' surpluses with market demand and enabling entrepreneurs to compress value chains that provide primary processing closer to rural communities will reduce losses, increase convenience and diversify diets for better nutrition and resilience.

Most agricultural commodities have long and often inefficient value chains with a host of intermediaries. However, the era of online marketing is now influencing innovation in the agrifood sector to compress value chains and innovative business models are delivering higher prices to farmers and higher quality to consumers. This is an innovation space that is evolving quickly and will bring significant disruption into existing market mechanisms. What is needed to support and accelerate this process is more facilities like ICRISAT's ihub to integrate Science of Delivery with data assets and innovative business models to address past market failures in delivering value to farmers and consumers.

Technology helps farmers get better returns in shorter time

Why (The issue): Banana farmers in Siddipet, Telangana, suffered from a lack of transparency around market demand. Therefore, they sold to intermediaries at rock-bottom prices.

Who (The stakeholders): Agri-preneur Keansa collaborated with Farmer Producer Organizations to map data about the farmers' produce (bananas) to traders in far-off towns interested in buying them.

How (The technology): (i) Traders could access key data – number of farmers, type and amount of produce available, historic price points – on the app and plan their purchases for a sustained period of time. (ii) Ensured of a continued supply, they agreed to pay a premium price for the farmers' produce. (iii) Farmers gained an assured market for their produce and therefore were able to charge higher prices than what they could charge for a distress sale in a local, saturated market.

What (The benefits): 61% increase in farmer income; Time for sale cut down to half;Zero revenue loss due to miscalculations

4.5.6 Research institutions working with rural entrepreneurs

Research institutions need to work with rural entrepreneurs to accelerate the delivery of science-based solutions that can attract youth back into agriculture and treat agriculture as a business. To harness the benefits of scale in value chains, cooperation and collective action through Farmer Producer Organizations (FPOs) is needed. Past experiences point to the success of FPOs to gain bargaining power, as experienced with milk cooperative societies. The opportunity now is how to leverage ICT, IndiaStack and SDI to drive the democratization of markets to empower farmers to realize their full economic potential.

Governments play a key role by providing young people with a favorable investment environment and developing policies that incentivize their participation in agriculture. At present, youth face many challenges to access government and private financing to engage in agribusiness. Training young farmers on best farming practices, post-harvest handling, and packaging is also important as well as developing businesses that provide production, processing and aggregation services to shift more economic opportunity to rural youth. One catalytic opportunity has been realized through ICRISAT's ihub to develop ICT-based business solutions to attract youth back to farming.

4.5.7 Public private funding and partnership as a business model

Public-Private Partnerships (PPPs) enable an optimal policy approach to promote social and economic development, thus bringing together efficiency, flexibility, and competence of the private sector along with the accountability, long-term perspective, and social interest of the public sector. In developing countries, the share of private sector in the total agricultural research investment is only 6.3% against 55.2% in developed countries. There is an urgent need to strengthen public research system in terms of efficiency, evolving technologies to address problems in the order of priority, and strengthening PPP wherever it is more beneficial. (Ramasamy, 2013).

ICRISAT addressed this need by establishing its Agribusiness & Innovation Platform (AIP).Promising intervention models that empowerFPOs (or similar collective models) to adopt value-adding opportunities at the farm level have contributed towards increasing farmer incomes and create rural employment. An emerging area is collection and primary processing centers (PPC) that compress value chains and enable farmers to capture a higher percentage of value.

Development of non-farm entrepreneurship opportunities in food processing, logistics and custom hiring centers, and advisory and testing services are other avenues that can contribute to rural economic development. PPP interventions in such business models by way of additional investments in infrastructure, business support networks and skill development avenues will further augment the investments made by the Government. Value addition based on consumer demand needs to be promoted through business incubation towards creating demand pull and sustainable income for the smallholder farmers.Promotion and establishment of rural agribusiness centers, similar to the Agribusiness Incubator (ABI) of AIP-ICRISAT offers anan important vehicle to support DFI.

In terms of PPP, engagement of a private sector agency for the front-end marketing can be a crucial and successful model wherein the produce from the PPC which is cleaned, sorted and graded is sent to the market in a well-packed and finished form to direct purchase by the last mile customer. This model is successfully being implemented in 10 districts by the Government of Tamil Nadu under their supply chain management project for fruits and vegetables. Similar models can add a higher margin of profits for farmers organized through PPC. These models are likely to be more successful than any efforts put in by any individual stakeholder. A diagrammatic representation is given Fig. 3.

4.5.8 Leverage DFI to drive convergence

DFI candrive convergence across Ministries (State and Union), schemes, local value chain actors and farmers to accelerate the adoption of sustainable (economically, socially, and environmental) options to empower farmers and produce nutrition to a growing nation.

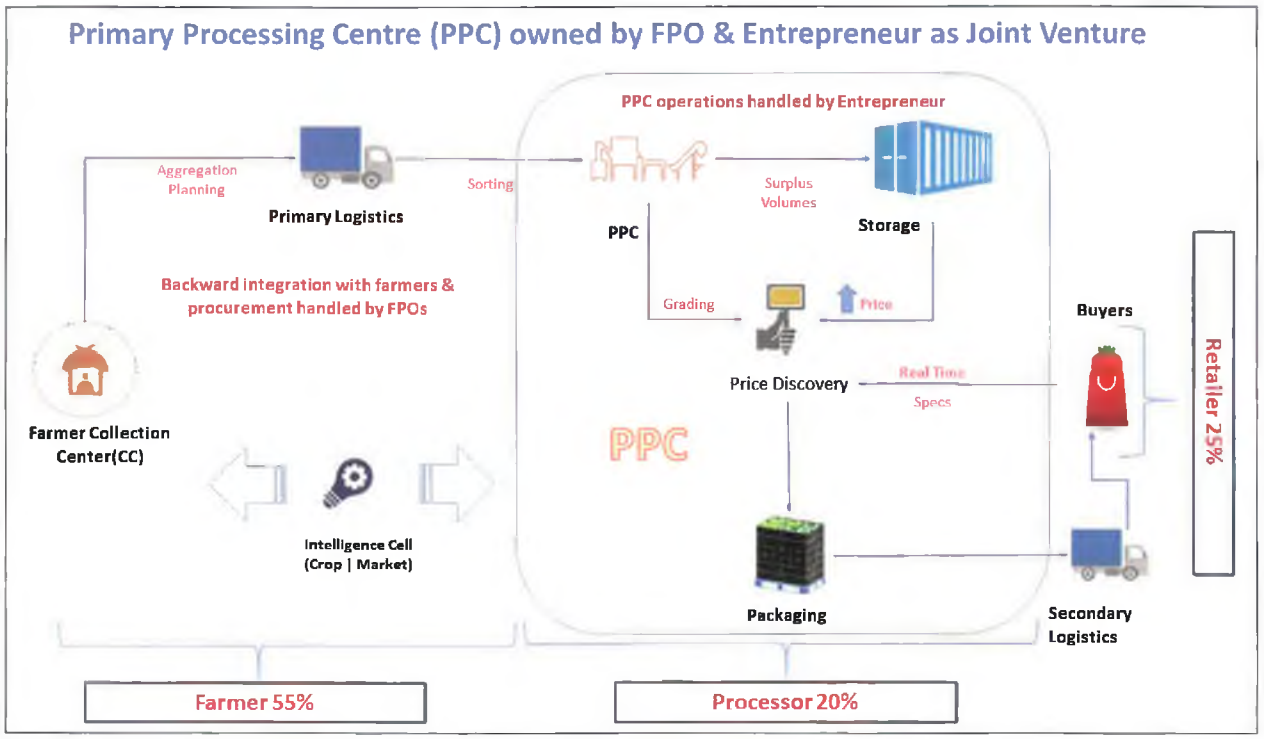
Research and innovation for impact are most important where challenges are greatest and the best solutions are delivered by diverse teams – this is true of Indian agriculture. Fortunately, India has been putting in place the digital infrastructure to deliver personalized interventions to farmers through Aadhaar alongside a wide range of policy support measures to create an enabling environment for farmers and a clear goal to work towards.

In this context, the agenda of research and development needs to be changed to put greater efforts on integrating research and development through active public-private partnerships that are demand-driven and based on sustainable economic growth engines for rural communities. This will require a framework to prioritize research within each agroecology and state to frame convergence of schemes, institutions (public and private) and disciplines that include new areas such as nutrition, health and education to deliver on both short- and longer-term development goals of India.

4.6 The Way Forward

NeGD can pivot focus to DFI by working with State e-Mission Teams along with SAU, ICAR, CGIAR, private sector and FPOs to define state growth engines for each agro-ecological zone. Focus needs to be on a few leading States that have the full support of their Chief Minister and a direct report supported by the State

Fig. 3. Compressing value chains through rural processing centers enable farmers to capture more value.



e-Mission team that has license to work across Ministries within the State. Key steps that need to be actioned before the next production season:

- Spatial Data Infrastructure is supported by government and commercial cloud services that integrates spatial data assets starting with digital soil maps, hydrology and weather that will drive agroecologically focused innovation systems and stimulate private sector investment, especially entrepreneurs.
- Grades and standards for all major commodities (including horticulture, livestock fisheries) are established that can be graded using mobile-based devices. This will support traceability needed to triple agri-exports by 2022 so farmers can access international markets.
- National Nutrition Mission should integrate with Ministry of Education and Ministry of Agriculture to create consumer awareness of diets for children and young mothers to ensure children reach their full genetic potential and farmers can access local markets.
- Shifting primary processing closer to farmers for value addition, reduced postharvest losses and provide convenience to rural consumers to diversify diets.

Leverage Aadhaar India Stack and SDI to converge schemes with progressive States to deliver targeted and timely subsidies for farmers based on the ecology, soil requirements and forecast market requirements to dampen price volatility and prioritize local investments in processing and storage. Within a year, farmers in participating States could have a mobile-dashboard to optimize farm resources, access service providers and connect to e-NAM clusters, processors or consumers to compress value chains and consolidate logistics – to double their income.

Demand-driven innovation helps farmers cater to markets profitably

Why (The issue): Commercial confectionary groundnut processors are looking for high oleic acid varieties that offer superior taste, long shelf life, and consumer health benefits. Groundnuts from Australia and USA have up to 80% oleic acid, while Indian varieties had only 40-50% oleic acid content.

Who (The stakeholders): ICRISAT groundnut scientists foresaw the increasing demand for high-oleic groundnuts and used innovative technology to breed similar varieties in India.

How (The technology): Cutting-edge molecular research and crop improvement tools helped to quickly and efficiently identify varieties that combine **high-oleic trait that are adapted to growing in Indian agro-ecologies.**

What (The benefits): Advanced technology helped scientists **cut costs and bring down crop selection time** from breeding (first step) to national testing trials (final step) from over 10 years **to just six years**. This means farmers get access to higher value marketable varieties with better nutrition to increase their incomes and deliver in half the time.

4.7 Promoting StartUps in Agriculture

4.7.1 Introduction

Agriculture plays a vital role in India's economy. Over 58% of the rural households depend on agriculture as their principal means of livelihood. As per the 2nd advised estimates by the Central Statistics Office (CSO), the share of agriculture and allied sectors (including agriculture, livestock, forestry and fishery) is estimated to be 17.3% of the Gross Value Added (GVA) during 2016-17 at 2011-12 prices. The GDP of agriculture and allied sectors was recorded at $244.7 Bn in FY '16.

The Indian food and grocery market is the world's sixth largest, with retail contributing 70% of the sales. The Indian food processing industry accounts for 32% of the country's total food market, one of the largest industries in India and is ranked fifth in terms of production, consumption, export and expected growth. It contributes around 8.80 and 8.39% of Gross Value Added (GVA) in Manufacturing and Agriculture respectively, 13% of India's exports and six per cent of total industrial investment.

India holds the record for the second-largest agricultural land in the world, with around 60% rural Indian households making their living from agriculture. The agricultural sector in India employs half of our population and we are greatly dependent on the farmers and agricultural labourers to provide us with a means of sustenance. Yet, this is one of the riskiest sectors to be employed in because it is dependent on uncontrollable factors like weather, market fluctuations and topographical conditions. Efforts are being made to give this sector and its workers a much-needed boost. And the biggest way of doing this is through advancements in agriculture technology. Modern techniques and methods will surely elevate agriculture to the next level and ease the burden on farmers. This therefore creates a huge scope for Agriculture Startups in the country. Transformation of Agriculture to Agri-business is one of the important strategies where enterprising farmers practice profitable agriculture.

Over the last decade, the sector is being streamed with the stream of educated youth, fired by the ideas, passion and innovations to launch newer kinds of technology and business models to lift the face of agriculture from primitive to hi-tech one. Startups are providing missing links in the agri value chain and delivering efficient products, technologies and services to the farmers on one hand and the consumers on the other hand, From ICT apps to farm automation and from weather forecasting to drone use and from inputs retailing and equipment renting to online vegetable marketing, and from smart poultry and dairy ventures to smart agriculture and from protected cultivation to innovative food processing and packaging, its proliferation of all innovations and technology driven powerful startups set to revolutionize the food and agriculture sector.

4.7.2 Market overview

4.7.2.1 Land under Cultivation

At 157.35 million hectares, India holds the second largest agricultural land in the world

4.7.2.2 Varied Climatic Conditions

With 20 agri-climatic regions, all 15 major climates in the world exist in India. The country also possesses 46 of the 60 soil types in the world

4.7.2.3 Record Domestic Production

In FY '16, 253.16 million tonnes of food grain production was recorded in India, up from 252.68 million tonnes in FY '15. India is among the 15 leading exporters of agricultural products in the world

4.7.2.4 Main Products

India is the largest producer of spices, pulses, milk, tea, cashew and jute; and the second largest producer of wheat, rice, fruits & vegetables, sugarcane, cotton and oilseeds

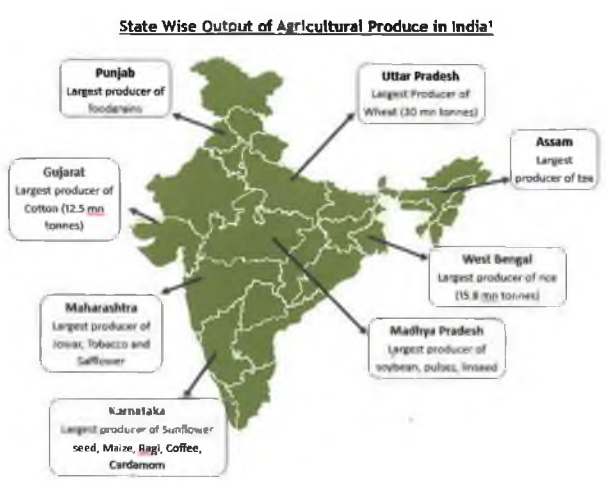
4.7.2.5 Farm Mechanization

India is one of the largest manufacturers of farm equipment such as tractors, harvesters and tillers. India accounts for nearly one-third of the overall tractor production, globally, with the tractor production in the country estimated to increase from 0.57 million units in FY16 and reach to 16 million units by 2030

4.7.3 Challenges in Agri/Opportunities for Startups

4.7.3.1 Inefficient Supply Chain

Powerful incumbents control farming resources such as finance, seeds, chemicals, distribution, and supply chain. These systems have complete access to the distribution networks that supplies to about 8 Mnkiranas across the country too.



4.7.3.2 Middlemen and Agents

The farmer needs on the demand-side are controlled by middlemen and agents who own the fragmented supply chains. They also control the produce pricing. For instance, organized retailers are estimated to source 20% of their produce directly from farmers, the rest of from mandis. But mandis are not ideal farmers' markets, Traders require a license to operate within a mandi but wholesale and retail traders and food processing companies cannot buy produce classified as notified agricultural products (cereals, vegetables etc.) directly from a farmer. Notified products are to be brought to the market committee and auctioned in the farmers' presence. Most of the market committees have failed to provide a competitive platform to farmers and lack transparency and technology intervention to ensure smooth and just trading.

4.7.3.3 Lack of financing

Distributors usually double up as lenders and most farm-debt is created because of using chemicals and seeds that are not pest-resistant. Additionally, domestic subsidies and investments announced in policies rarely reach the end customer – the farmer.

4.7.3.4 Inadequate Irrigation

Agriculture in India is a fragmented activity spread across 600,000 villages and most of the regions still depend on rainfall for water (~70%). While at the same time, groundwater levels are slowly receding from the 1,000 ft. avg. depth yearly.

4.7.3.5 Farm size vs Productivity

Studies have shown that there is an inverse relationship b/w farm size and productivity. Indian farms are fragmented and small; 70% are less than 1 Hectare, while national average is less than 2 Hectares, resulting in significantly low farm yields. In Europe and US, avg. sizes are 30x and 150x of those in India.

4.7.4 Agri-Tech Startups

4.7.4.1 Agritech Sub Sectors

There are over 250 Agri-Tech startups in India across the value chain, leveraging the use of technology and innovation in business models to impact the large agri sector in India.

Sub-Sector	Startup
Upstream (Input) Marketplace model (Matching Agri-input sellers to farmers)	AgroStar, BigHaat, agrevolution, ninjacart, AGRONXT, agrihub
Downstream (Output) 'Farm-to-Fork' supply chain model (Matching farmers to businesses or retail customers for fresh produce, processed food)	KRISHI STAR, crofarm, SABZIWALA, bharatbazar
Farming-as-a-service	farMart, EM3, Ofbeo
IoT/Big Data led innovation	Cropin, FlyBird Farm Innovations
Engineering led innovation	KAMAL KIS, KHEYTI, drip TECH
Miscellaneous (Innovation in agri products, dairy farming)	Cattle Mettle, SUMA AGRO

4.7.5 Agri-Tech Funding

4.7.5.1 Startups Founded & Funding Rounds, by Year

Year	Companies Created	Funding Amount (USD M)	No. of Rounds
2017	32	176.8	49
2016	171	2736.1	49
2015	193	129.0	35
2014	117	148.6	29
2013	87	86.6	29
2012	76	1069.0	21
2011	63	301.0	18
2010	63	151.5	17
2009	58	9.4	6
2008	41	8.4	7
2007	33	39.7	4

Source: Traxcn

4.7.5.2 Funding Deals in India (2017)

According to AgFunder's AgTech Investing Report for 2016, over $3.23 Bn was invested in agricultural sector worldwide of which, 53 Indian agritech startups raised $313 Mn in venture funding[2]. Some of the major deals in the sector last year are highlighted below,

[2]https://research.agfunder.com/2016/AgFunder-Agtech-Investing-Report-2016.pdf

Startup	Investment	Investor	Date
RML Agtech	$4 Mn (Series B)	Ivycap Ventures	Jan-17
Paalak.in	Undisclosed Seed	Angels	Feb-17
Agrostar	$10 Mn (Series B)	Accel, IDG, Aavishkar	Mar-17
Farmart	Undisclosed Seed	Indian Angel Network (IAN)	Mar-17
Waycool	$2.7 Mn	Aspada Ventures	Apr-17
Ninjacart	$5.5 Mn	Nandan Nilekani	Apr-17
Utkal Tubers	$4.6 Mn	CapAleph, Zephyr Peacock	May-17
Crofarm	$783 K (Pre Series A)	Factor [E] Ventures, Rajan Anandan, Jitendra Gupta, LetsVenture	Aug-17
EM3 Agriservices	$10 Mn (Series B)	Global Innovation Fund, Aspada	Aug-17
Cropin	Undisclosed (Pre Series A)	Beenext, Ankur Capital, BSP Funds	Sep-17
Gold Farm	$2 Mn Seed	Mahindra & Mahindra, Infuse Ventures	Oct-17
Farmtaza	$8 Mn Series A	Epsilon Venture Partners, Tara India Fund	Oct-17
Gobasco	Undisclosed Seed	Matrix Partners	Nov-17
Farmlink	$3 Mn	Pioneering Ventures, Syngenta	Nov-17

Source: News Research

4.7.5.3 Split by Geography

State	No. of Startups
Maharashtra	291
Karnataka	209
Andhra Pradesh	153
NCT	138
Tamil Nadu	130
Gujarat	128
Haryana	71
Uttar Pradesh	64
Kerala	44
Madhya Pradesh	43
Punjab	37
West Bengal	35
Rajasthan	26
Union Territory of Chandigarh	13
Odisha	12
Bihar	8
Chhattisgarh	6
Assam	5
Uttarakhand	5
Himachal Pradesh	3
Goa	2
Jharkhand	2
Daman and Diu	1
Manipur	1
Telangana	1
Union Territory of Puducherry	1

Source: Tracxn

4.7.6 Focus Areas for Agri-Tech Startups

4.7.6.1 Big Data

Data, as we all know, is the new oil and going forward, development of farm specific, data-driven diagnostics to determine soil and crop health will be a big opportunity area. Startups are leveraging drones or tractor-based solutions to get data on field, pertaining to both weather and agricultural data to determine risk. Growing smart phone penetration will enable precision decision-making in farming activity to farmers and help drive increased productivity and revenue while reducing unit-costs.

Eg.: Agro star, RML Agtech are investing INR 5 Cr ($776 K) each in building ground-breaking image recognition technology that enables farmers to receive real-time data on the pest or disease that has affected a crop.

4.7.6.2 Farming-As-A-Service (FAAS)

Agri equipment renting is another area likely to see market traction. As longer gestation periods are a typical feature for this sector and modern equipment is expensive and unaffordable for the average farmer, renting can take the burden of the input costs away from the farmer.

Eg.: EM3 Agri services offers farming services and machinery rentals to farmers on a pay-for-use basis. Other startups include, Gold farm, Ravgo, Oxen Farm Solutions and Farmart.

4.7.6.3 Market Linkage Models

Innovations to help farmers with timely and accurate estimation of sowing and harvesting in sync with consumer demand patterns.

Eg.: MeraKisan.com helps consumers in India to order fresh food and goods sourced from local farmers.

4.7.6.4 FINTECH for Farmers

Farm income is mostly in cash and it presents an opportunity for Fintech startups to digitize payments for farmers through payment gateways linked to their accounts. Such startups can also create the credit profile environment for funders and lenders.

4.7.6.5 IOT for Farmers

Smart farming in agricultural business including concepts like high-precision crop control, data collection, automated farming techniques will remove inefficiencies and bolster productivity. Information on crop yields, rainfall patterns, pest infestation and soil nutrition can be used to improve farming techniques over time.

Eg: Stellapps leverages cloud computing, data analytics and wear ables to improve agri-supply chain parameters, including milk production, procurement, cold chain, animal insurance and farmer payments.

4.7.7 Government Initiatives

4.7.1 Schemes Initiated By Govt

The Indian Govt. has placed a strong impetus on this sector and aims to double the income of farmers by 2022.

4.7.1.1 Pradhan MantriFasalBimaYojana (PMFBY)

a. Launched in 2016, the scheme provides financial support to farmers and cover their crop losses. The scheme covers rabi, kharif crops as well as annual horticultural and commercial crops.
b. PMFBY is a crop insurance policy and premium payable on the principle amount to the farmers.

4.7.1.2 Pradhan Mantri Krishi SinchayeeYojana (PMKSY)

c. Under the scheme, allocation of USD7.64 billion has been made for investment in irrigation, expanding cultivable area, improve efficiency of on-farm water to reduce wastage, enhance adoption of precision irrigation, etc.

4.7.1.3 Paramparagat Krishi Vikas Yojana (PKVY)

ad. The scheme ensures the promotion of organic farming and balanced use of chemical fertilizers and enhance the quality of farm produce.

4.7.1.4 Agricultural Technology Management Agency (ATMA)

e. This technique facilitates retrieval of data and data entry from the internet-based web portals without having internet by using a simple mobile phone.
f. More than a dozen of services of innovative technology like USSD are being operationalized for farmers and other stakeholders.

4.7.2 Agriculture Grand Challenge

Ministry of Agriculture in partnership with Startup India launched the Agriculture Grand Challenge on 15th December, 2017. The challenge is a unique opportunity for Agri-tech start-ups with a commercially viable solution to solve for innovative challenges in the sector. The objective is to support the technology base by funding/ providing incubation support to the best fundamental concepts while helping talented and creative innovations to pursue promising avenues at the frontier of the technology. It will provide start-ups with access to priority infrastructure, and make Agriculture an attractive sector for the country's best brains.

Under this challenge, 12 problem statements were issued in the following areas

4.7.2.1 Development of simplified, sensor based quick testing method to test nutrients & micronutrients in soil

The 11th five-year plan [2007-2012] acknowledged the importance of proper soil management in agriculture for the first time. For this, Soil Health Management (SHM) scheme was devised to assist State Governments to set up new static Soil Testing Laboratories (STLs) and Mini Soil testing Labs (MSTLs).

However, it is found necessary to further reduce the collection, testing time required for the sample to ensure on the spot results to the farmers. In addition, simplification of soil testing protocols needs to be done.

For this, the challenge is seeking development of simplified, senor based and quick soil testing methods to test the nutrients and micronutrients. A proven technology will be supported under Soil Health Management scheme so that states can procure directly from the developer at fixed price (as has already been done for mini soil health labs).

4.7.2.2 Real time assaying and quick grading solution for eNAM to effectively handle huge lots of agricultural commodities

Electronic National Agriculture Market (eNAM) is a virtual market with a physical market (mandi) at the back end, which networks the existing APMC/mandis to create a unified national market for agricultural commodities for pan-India electronic trading. The assaying of agricultural produce at the market level is of utmost importance to enhance the marketability of the produce and to enable the farmers to realize price commensurate to the quality of their agricultural produce.

Mandis handles huge volumes (lots) of arrival and smaller lots, hence it is essential to provide quick quality assaying solutions (preferably within a minute/ parameter) to promote online trading.

For this, the challenge is seeking development of

quick grading & assaying solution for eNAM which can also be connected to the internet to increase the efficiency of the agricultural chain.

4.7.2.3 Development of e-marketplaces to connect food processors with agripreneur/farmers to bridge the value gap – Farm to Fork model

While self-sufficiency in agriculture has been a priority for the Government and several policy initiatives weave around this objective, the post-harvest management including agricultural marketing has not kept pace with the changes in economy, particularly relating to setting up of an efficient supply chain. The need to unify market both at State and National level is, therefore, important to provide better price to farmers, improve supply chain, reduce wastages and create a unified national market for agricultural produce.

In such a scenario, National Agriculture Market (NAM) would create a win-win situation for both i.e. agripreneurs and processors.

4.7.2.4 Price forecast system for Pulses /Oilseeds / Potato /Onion / Tomato at the time of sowing

In India, price of commodity is dependent on various external factors such as area, yield, production, Household food demand, feed demand, etc.

In this regard, a mechanism may be developed by startups who can use the data of past trends and other mentioned factors and bring up the prices forecast of the particular crop depending upon sowing, taken into consideration the sowing patterns, weather and other factor mentioned.

4.7.2.5 Dissemination of information to the last mile - Agriculture Extension, Scheme information, processes, hand holding support for benefit under different Government schemes

In India, farmers may not be aware of all the schemes that are implemented by Central Government and State Governments for their welfare.

In this regard, the challenge seeks development of an online platform at the Panchayat / Common Service Center / KVK level which will provide information to farmers regarding schemes and benefits that they are entitled to thereunder. Linking with Aadhar, Soil Health Cards and crop as well as health insurance etc. may be considered on this platform for the welfare of farmers.

4.7.2.6 Yield estimation modelling at village or farm level

The success of implementation of Pradhan Mantri Fasal BimaYojana depends upon accurate yield estimates at village/farm level. However, crop yield estimation is a very complex activity, as yield is influenced by many factors, such as crop genotype, soil, weather, management practice and various biotic and abiotic stresses.

In this regard, the challenge seeks to develop a web based spatial decision support system which takes data from high resolution satellite, UAV, satellite based agro-meteorological parameters, sensor networks giving information, etc. to provide estimates of yield at farm level. The solution should be evaluated for 2-3 different types of crops taking a block/tehsil as the minimum implementation unit. The solution should be user friendly, upgradable and expandable to other geographical area and other crops.

4.7.2.7 Use of technology in sorting/ grading/ increasing shelf life of agriculture produce (fruits, vegetables, flowers)

In agriculture, post-harvest handling is the preliminary stage in a crop's lifecycle which immediately follows harvest and is important to extend the marketable life of any produce.

The challenge is seeking technological solutions to increase the efficiency of the agricultural chain and ultimately reduce waste while increase farmers' earnings

4.7.2.8 Use of technology to test adulteration of fresh produce

Food is essential for nourishment & sustenance of life. Adulteration of food cheats the consumer and can pose serious risk to health. Food is adulterated if its quality is lowered or affected by the addition of substances which are injurious to health or by the removal of substances which are nutritious.

The challenge is seeking for technological solutions to give the consumer an opportunity to detect common adulterants in food.

4.7.2.9 Availability of small agricultural implements/ micronutrients/certified quality seeds through online/ call center interface – Custom Hiring Centres

Creation of regional Agri-Kiosk by the respective department to provide a kind of a one-stop shop for all agricultural needs providing services such as soil testing, seed selection, appropriate pesticides, herbicides, and fungicides. Agri-kiosks can also provide the latest agricultural equipment on rent which make it easily accessible for women farmers.

The challenge is looking for solutions to improve the availability of agricultural inputs through Custom Hiring Centre.

4.7.2.10 Alternate usage of paddy straw (left in field after harvesting of paddy) to discourage farmers from burning the same especially in Haryana and Punjab.

Burning of agricultural biomass residue, or Crop Residue Burning (CRB) has been identified as a major health hazard. In addition to causing exposure to extremely high levels of Particulate Matter concentration to people in the immediate vicinity, it is also a major regional source of pollution, contributing between 12 and

60 per cent of PM concentrations as per various source apportionment studies. In addition, it causes loss of vital components such as nitrogen, phosphorus, sulphur and potassium from the topsoil layer, making the land less fertile and unviable for agriculture in the long run.

The challenge is seeking for technological solutions for alternative usage of paddy straw to discourage Crop Residue Burning.

4.7.2.11 Technology to substitute the use of pesticides & insecticides to prevent pre-harvest losses

Insect, plant pathogen, and weed pests destroy more than 40% of all potential food production each year. This loss occurs despite the application of approximately 3 million tons of pesticide per year plus the use of a wide array of non-chemical controls, like crop rotations and biological controls. Due to lack of effective, affordable and eco-friendly technologies to control pests, farmers are left with no choice but to continue spraying harmful and toxic pesticides on crops.

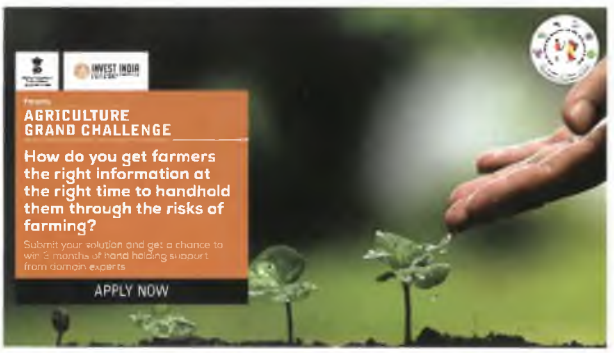
The challenge is looking for technology solutions to substitute the use of pesticides & insecticides to prevent pre-harvest losses.

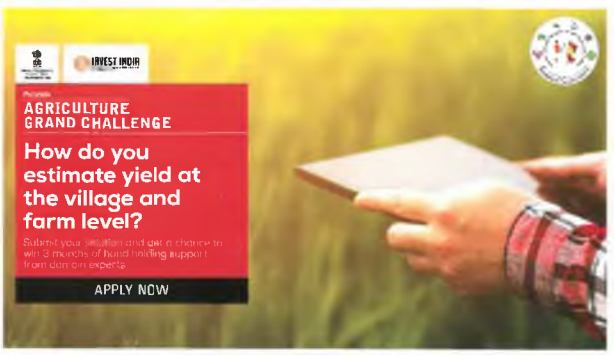
4.7.2.12 Seeking affordable, accessible, easy-to-use technologies, products or services to enhance agricultural productivity in India

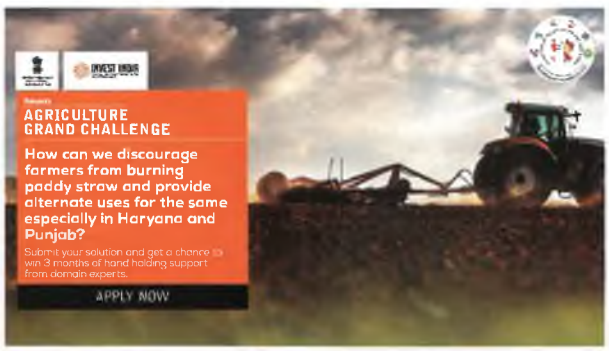
One of the biggest issues facing the agricultural sector in India is low yield: India's farm yield is 30-50% lower than that of developed nations.

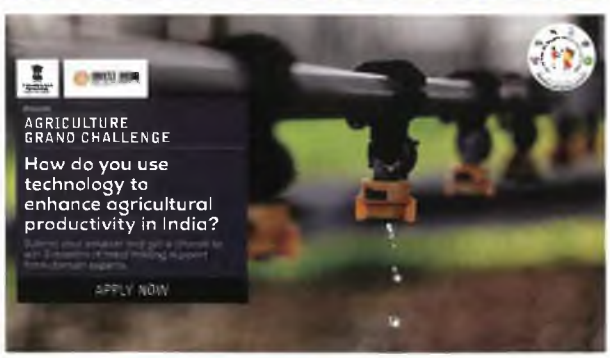
Average farm size, poor infrastructure, low use of farm technologies and best farming techniques, decrease of soil fertility due to over fertilization and sustained pesticide use, are leading contributors to low agricultural productivity. Indian farms are small (70% are less than 1 hectare, the national average is less than 2 hectares) and therefore have limited access to resources such as financial services, credit (or lenders), support expertise, educational services or irrigation solutions.

In the short-term, yield directly impacts a farmer's cash flow and the ability to respond to fluctuations in the market. Long-term, yield limits a farmer's ability to invest into their farm's future to increase productivity and decrease risks associated with their crops (via inputs such as seeds, fertilizer, crop insurance, market/weather









info, livestock health support, etc.) but also to invest into their families in areas such as education, healthcare, training, etc.

The challenge is seeking affordable, accessible, easy-to-use technologies, products or services to enhance agricultural productivity in India.

4.8 Use of ICT in Agriculture

4.8.1 Ministry of Agriculture & Farmers' Welfare aims to improve awareness and knowledge efficiency of farmers. A comprehensive ICT strategy has, therefore, been developed not only to reach out to farmers in an easy and better way but also for planning and monitoring of schemes so that policy decisions can be taken at a faster pace and farmers can be benefited quickly. To empower different sections of rural areas, different ICT strategies have been devised:

- Those who have access to **digital infrastructure** can get the information through websites/web portals.
- Those who have **smart phones** can access the same information through mobile apps.
- Those who have basic phones, can get this information through **SMS advisories** sent by experts.
- To get the personalized information; farmers can call at the toll free number of **Kisan Call Centre** – 18001801551.

4.8.2 Ministry of Agriculture & Farmers' Welfare is implementing **National e-Governance Plan – Agriculture** (NeGP-A) also. Its aim is to achieve rapid development in India through use of Information & Communication Technology (ICT) for timely access to agriculture related information for the farmers. In Agriculture, availability of real time information at the right time is the major miss. Lack of information at proper time causes a huge loss to farmers. NeGP-A aims to bridge this gap in communication by using technology. It provides an integrated approach to the **delivery of services to the farming community** using ICT. Under NeGP-A, around **60 online services** have been developed and launched to provide ease of access and timely information to farmers. Some services are developed for monitoring of schemes so that quick analysis and reporting can be done.

Under Digital India interventions of the Government- **Agriculture 2.0 (Digital Agriculture)** has been given the prominent place for improving overall development of the Country through increasing the agricultural output by ensuring availability of information on various agriculture and allied sectors activities. Agriculture 2.0 (Digital Agriculture) directly falls under **Pillar No. 5 of Digital India**, i.e. eKranti – Electronic Delivery of Services and broadly caters to other pillars as well, like e-Governance: Reforming Government through Technology, Information for All and Early Harvest Programmes. Some of the key thrust areas identified

under Digital India for Ministry of Agriculture & Farmers Welfare are incorporation of space technologies, development of mobile apps, GIS Mapping, citizen-centric services for Cooperation, Fertilizer Testing Labs, Cold Chain availability, identification & development of services for specific sectors of Horticulture and Fisheries, use of crowd sourcing, increasing online transactions, use of innovative technologies like text to speech, image recognition, Big Data Analysis and Data Intelligence, Direct Benefit Transfer etc.

4.8.3 Major ICT Interventions of DAC&FW

Ministry of Agriculture & Farmers' Welfare is implementing some Flagship schemes to provide maximum benefits to the farming community. Deployment of technology is very important in the schemes to make them successful. Some of the ICT interventions are given below:

4.8.3.1 Websites/Portals:

In order to meet the **information needs** of the farmer, Ministry of Agriculture and Farmers' Welfare has developed different websites and web portals that allows farmers to access the information using Internet. Information on Market Price, Soil Health Card, Crop Insurance, Government schemes etc. is available to farmers through websites. These websites also aim at enhancing communication between the research institutions and the farmers and also improves communication and knowledge sharing between researchers and subject-matter experts. **Farmers' Portal, Agmarknet, Soil Health Card Portal, e-NAM, Crop Insurance etc. are the web portals developed for farmers.**

4.8.3.2 Use of Mobile Apps

Spreading agricultural related information to farmers in the poorest communities are made easier by proliferation of mobile phones. Today, mobile apps and services are being designed and released in different parts of the world. Mobile apps help to fulfill the larger objective of farmers' empowerment and facilitates in extension services which can address the global food security issues. Few mobile apps developed for farmers are:

Kisan Suvidha mobile app provides information on five critical parameters—weather, input dealers, market price, plant protection and expert advisories. An additional tab directly connects the farmer with the Kisan Call Centre where agriculture experts answer their queries. Unique features like extreme weather alerts and market prices of commodity in nearest area and the maximum price in state as well as India have been added to empower farmers in the best possible manner.

Pusa Krishi app helps farmers to get information about latest technologies developed in research labs. This app is actually transferring the technologies from "LAB to LAND". **Agrimarket** mobile App can be used to get the market price of crops in market within 50 km of the devices location. This app automatically captures the location of person using mobile **GPS** and fetches the market price. **Crop Insurance** mobile app can be used to calculate the Insurance Premium for notified crops based on area, coverage amount and loan amount in case of loanee farmer.

4.8.3.3 Use of basic mobile telephony

Mobile telephony has transformed the tenor of our lives. In India, increased penetration of mobile handsets, large number of potential users, increased spread of communication, and low cost of usage lead to growth of large number of mobile based information delivery models for the agricultural sector. **SMS, IVRS, OBD, USSD** etc. are the few modes used to meet the information needs of the farmer. In mkisan(mkisan.gov.in), around **2 crore** farmers are registered and experts/scientists of different departments like IMD, ICAR, State Government, State Agriculture Universities send information to farmers.

Weather information about likelihood of rainfall, temperature, etc. enables farmers to make informed decision in choice of seed varieties, decide on timing of sowing and harvesting. Information on occurrence of rainfall and other climatic uncertainties help in organizing better storage facilities. With **market information**, farmers are better informed about markets to sell produce, prevailing market prices and quantity demanded in the market. Thus, they can make informed decisions to sell produce at the **right price and right time**. This helps reducing distress sales by farmers due to market supply fluctuations.

4.8.3.4 Personalized Information through Call Centres

Kisan Call Centres (KCCs) was launched by the Ministry of Agriculture and Farmers' Welfare in **2004** to bridge the gap between farmers and the technology assessment. This initiative was aimed at answering farmer's queries on a telephone call in their own language / dialect.

At present, the KCC services are managed from fourteen locations. All KCC locations are accessible by dialing a single nation-wide **toll free number** 1800-180-1551 through landline as well as mobile numbers of all telecom networks from 6.00 A.M to 10.00 P.M. on all 7 days a week including holidays.

KCC enables farmers to have direct discussions with the **subject matter experts** who are able to analyse the problem effectively and provide the solution directly. For every KCC location, **Level II** experts are also identified from State Agriculture Universities, KVKs etc. In case, Farm Tele Advisor (FTA) is unable to provide answer to the query of farmer, call is being transferred to Level II expert. We receive around **25,000** calls daily in KCC.

It uses a backend data support system, which is inbuilt into the overall MIS (Management Information System). The MIS software captures callers' details and specifications of the query which helps in **analysing area-wise and crop wise details within a time space framework** and provides preventive, advance action solutions.

4.8.3.5 Use of Technology for Data Collection & Monitoring

Use of mobile apps to collect data from the field is indeed a revolutionary change. It definitely avoids human error and increase productivity.

CCE Agri is a mobile app used for data collection and data monitoring in rural areas. Data of crop cutting experiments is digitized using this mobile app which definitely removes chances of human error and reduces the time in data collation. This app significantly improves data speed (from harvesting to insurance loss estimation) and biggest gain is data quality. **Geo- tagging** ensures field visit, photos mitigate the **manipulation risk** and data transfer greatly improves data consolidation/analysis which eventually results in **quick claim settlement.**

In rural areas, there will be no or poor internet connection that is why this app has been designed in such a way that data can be collected **without internet connection** and as and when internet is available, data can be pushed to the server.

4.8.4 Where & how to use ICT effectively

Technologies like precision agriculture aids farmers in tailored and effective water management, helping in production, improving economic efficiency and minimizing waste and environmental impact. Recent progress in Big Data and advanced analytics capabilities and agri-robotics such as aerial imagery, sensors, and sophisticated local weather forecasts can truly transform the agri-scape and thus holds promise for increasing global agricultural productivity over the next few decades. Based on the types of calls received in **Kisan Call Centre** and queries' database, Big-data analytics can help in identifying flu/diseases outbreaks that could ruin a potential harvest.

Sensors on fields and crops can provide granular data points on soil conditions, as well as detailed info on wind, fertilizer requirements, water availability and pest infestations. The use of **granular data and analytical capability** to integrate various sources of information (such as weather, soil, and market prices) can help in increasing crop yield and optimising resource usage thereby lowering cost. Unmanned aerial vehicles, or drones, can patrol fields and alert farmers to crop ripeness or potential problems.

Farming depends on a predictable climate from one year to the next. In addition to hindering farmers, climate change is also suppressing financial investment in agriculture, ranging from small scale producers. Farmers need accurate **weather forecasts**. Since, climate change and extreme weather events will demand proactive measures to adapt or develop resiliency, Big Data can bring in the right information to take informed decisions.

In schemes like Pradhan Mantri Fasal Bima Yojna, use of Data Analytics can actually help in drawing inferences and making policies. Crop sown area of a state is known. It can be juxtaposed with insured area stats and analysis can be done to find reasons for below or over insurance. Similar other factors can also be examined by putting more layers like Cadastral Maps on top of sown & insured area. Since conducting **crop cutting experiments** is a costly affair and require lot of resources, major challenge is to reduce the number of CCEs so that experiments can be done at selected locations only. Satellite data and weather data can be utilized to cluster groups of IUs by mapping homogeneous IUs expecting similar yield/ vegetative index mapping. On basis of vegetative index, crop areas can be categorized in different groups and for each group, defined number of CCEs can be conducted to arrive at yield of areas. Currently to make sure that CCEs are actually happening, one has to go through each and every picture. Some kind of **Artificial Intelligence** techniques can be used so that images can be recognized and odd one outs can be straight away removed from the lot.

Commodity Price forecasting is another area where Big Data Analytics can help in big way. The prices of the commodities fluctuates significantly in the semi-arid farming zones. The **price forecasting information** can help the farmer to know the price in advance that helps to take appropriate decision whether to sow that particular crop or not. Price Forecasting will also help Government in taking decisions on fixing MSP, Import-Export etc. The prices of the yield is not same across all the local markets. So it is necessary to provide forecasted price information for local market wise, district wise, state wise and nation wise.

Rapid proliferation of mobile technologies in rural areas can allow farmers improve productivity based on the information received after Big Data Analysis. Burgeoning of data offers unprecedented opportunities to understand preferences of farmers, and to deliver customized services to them thereby increasing production with timely and accurate information.

4.8.4.1 Harnessing Big Data Analytics to increase Productivity

With the expected growth in population by 2050, the need to be efficient in providing necessary fiber, medicinal materials, food and water increases by the minute. Further, with growing urbanisation, less of the population is directly linked to agricultural production, while every individual remains intrinsically linked to agricultural output as consumers. This is manifested as demand, which feeds agricultural growth. Growth in demand can lead to unplanned or prejudiced production

which can stress the ecology and in turn lead to less food and water.

Agricultural system therefore, needs to feed the population while remaining ecologically friendly and resource efficient. To address this challenge, it is critical to provide new, digitally-enabled agro services to farmers that will help increase yield while conserving resources, for example, through precision farming. To be successful in this endeavour, or be smart in agriculture, it will be critical to harness intelligent insights from data.

In the first instance, relevant data needs to be identified, get captured and collated, and be analysed for next level application. Today, various organizations are accumulating massive amounts of different data. The major challenge is that the data is available in silos and in different formats. The need of the hour is a comprehensive approach to juxtapose all related data sets in an interoperable manner, so that accurate analysis and predictions can be achieved.

The challenges and opportunities from data analytics is immense in a country like India with 654,000 villages and 130 million farmers speaking around 800 languages under 127 agro climatic regions capable of supporting 3,000 different crops and one million varieties.

Technology has the potential to assess and re-shape past trends for the benefit of society. World is now more inter-connected, spawning massive data and exploration of this data can help to drive decision making that can transform the farm source-to-consumer value chain. There are several touch points along the agri-value chain and each of it holds critical information. Big Data has the potential to add value across each touchpoints starting from selection of right agri-inputs, monitoring the soil moisture, tracking prices of markets, controlling irrigations, finding the right selling point and getting the right price.

4.8.4.2 Use of ICT in Monitoring System

ICT is a blend of technology and communication to transfer information through digital systems. It provides a range of tools for tracking the progress of schemes and efficient use of resources. In Agriculture, various flagship schemes have been launched to help farmers in all possible ways. Due to the federal nature of the Government, success of centrally sponsored schemes depends upon states and ownership level varies from state to state. Real time monitoring helps determine exactly when a scheme is on track and make changes as needed.

Lack of real time information from states often leads to delay in decision making. Thus, it is appropriate to have a Monitoring System in place, which will form the basis for modification of interventions and assessing the quality of activities being conducted. With the rapid spread of mobile phones and network coverage, smart phones that include Global Positioning System (GPS) functions can be used for data collection. Short Message Service (SMS) through mobile phones can also be used as another affordable option for data collection system. ICT solutions can lead to cost & time saving and improve quality of information.

4.8.4.3 Dashboard Monitoring System

Monitoring System within the ambit of Government schemes is an increasingly important phenomenon to track implementation and outputs systematically. Dashboard Monitoring System can enable the tracking of real time progress of Government schemes. The system can capture data of projects including pictures, videos and textual information through ICT enabled devices. Information can be stored in secure format and transmitted from the field in real time to the central server. Information collected through such systems can be used to accurately and clearly assess the situation from the field for decision-making, planning and budget allocation. Policy-makers and government officials can assess and choose the most appropriate option based on the data reported in such monitoring systems.

In Dashboard Monitoring System, field data is originating from the lowest unit and it can be monitored at all the levels in the hierarchy. State/District level monitoring person can monitor the data generated from block level and this way monitoring of schemes not only become easier but also real time and accurate information is made available to all stakeholders. Auto alerts in the form of reports, SMSs or emails can be sent to all concerned so as to enable the mid-course corrections and effectiveness of schemes can be ensured.

Dashboard Monitoring System is a necessary step towards establishing institutionalized mechanisms for achieving transparency and accountability. The adoption of robust and well developed system would certainly improve the implementation and performance of agriculture schemes.

4.8.4.4 Need of Standardisation for effective Interoperability

In current scenario, many applications and datasets exist in silos. To get a holistic view and a standardised solution, there is dire need of interoperability so that information can be exchanged among the systems and seamless integration can happen. Interoperability addresses the open architecture of technologies and allows the software systems to interact with other systems and technologies.

Lack of standards for interoperability can significantly slow down the adoption of emerging technologies. Standardization is critical to allow the production and export of data needed to support quality assessment, decision support, exchange of data. Developing a way to standardize and harmonize data is necessary, especially when working towards data interoperability among many different systems.

Metadata is identified as one of the methods to

manage information by indexing and applying attributes at the "granular" level. An emerging use of metadata is the processing of large amounts of data for analysis and improving quality.

There is need of developing standards that make interoperability possible by providing the protocols of how these data are actually transmitted from one computer system to another. It will support all applications thereby allowing Government to increase the capabilities, flexibility and efficiency of operations.

4.8.4.5 Use of Artificial Intelligence & Precision Farming

In the recent times, with requirements of the better yield of crops, AI has emerged as a tool that empowers farmers in monitoring, forecasting, as well as optimizing the crop growth. Tackling pests, weeds, and diseases, monitoring farm animal along with soil and crop management are some of the thrust areas in agriculture industry **where the use of AI technology can pay rich dividends. AI can be used in following areas:**

4.8.4.5.1 Crop and Soil Management

With the development of AI technology, it is easier to keep a track and predict the right time for planting, irrigation, and harvesting. The advanced sensors and technologies, make the entire task of crop and soil management uncomplicated for the farmers.

4.8.4.5.2 Pest attack prediction

Common pest attacks, such as Jassids, Thrips, Whitefly, and Aphids can pose serious damage to crops and impact crop yield. Use of AI and machine learning can indicate in advance the risk of pest attack. This empowers them to plan in advance, reducing crop loss due to pests and thereby helping them to double the farm income.

4.8.4.5.3 Image recognition

Artificial Intelligence can also be used for recognizing weeds and assessing plant health. Use of AI can differentiate between plants and weeds by leveraging big data, and actively sprays pesticide on the weeds, but ignores the plants.

4.8.4.5.4 Robotics

As the farmers are automating their operation, robots and drones have become an integral part of the agriculture farms and are assisting farmland owners to improve the yield and product quality while addressing the increasing supply needs. With farms as big as they are today, it's almost impossible for a single farmer to go around and tend to all parts of their farm that need watering or a measurement. This is where robots come into play.

4.8.4.5.5 Animal Husbandry

Animal husbandry is an integral branch of agriculture concerned with the care and management of the livestock. It deals with all the tools and technologies involved in managing and ensuring optimum health of farm animals, including genetic qualities and behavior. Generating and leveraging useful information through AI will help farmers to manage their livestock efficiently with minimum supervision. With AI enabled smart sensors, the automated milking units can analyze the milk quality and flag for abnormalities in the product.

The great part about artificial intelligence is that it's always being optimized as it's fed more data. More the data, more the accuracy!!

References

Bantilan, M.C.S. et al. 2014. Short duration chickpea technology: enabling legumes revolution in Andhra Pradesh, India. Research Report No. 23, Patancheru, India, ICRISAT (available at http://www.icrisat.org/what-we-do/mip/SPIA.pdf). This paper was commissioned by the Standing Panel on Impact Assessment (SPIA), CGIAR Independent Science and Partnership Council (ISPC),Rome, Italy.

Government of India. 2005. Situation assessment survey of farmers: Access to modern technology for farming, 59th round (January-December 2003). Report No. 499 (59/33/2). National Sample Survey Organisation, New Delhi: Ministry of Statistics and Programme Implementation.

Government of India. 2013. Situation assessment survey of agricultural households in India (70th round: July 2012-June 2013). National Sample Survey Organisation, New Delhi: Ministry of Statistics and Programme Implementation.

Government of India. 2015. Agricultural statistics at a glance 2014. Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Economics and Statistics.

Government of India. 2017A. Agricultural statistics at a glance 2016. Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Economics and Statistics.

Government of India. 2017B. Report of the Committee on Doubling Farmers' Income. Volume II "Status of Farmers' Income: Strategies for Accelerated Growth" Inter-linkages between Input Costs, Diversification, Capital Formation and Income.

ICRISAT. 2017. Seed Systems: Models & Lessons Learned. Monograph. ICRISAT, Patancheru, Hyderabad.19pp

Pal Suresh (ed). 2017. Agricultural R&D Policy in India: The Funding, Institutions and Impact. ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi.

Ramasamy C. 2013. Indian Agricultural R&D: An Introspection and Way Forward. Agricultural Economics Research Review, 26(1): 1-20.

Renkow M and Byerlee D. 2010. The impacts of CGIAR research: A review of recent evidence. Food Policy, 35: 391-402.

Upadhyaya HD, Gowda CLL, Buhariwalla HK, and JH Crouch. 2006. Efficient use of crop germplasm resources: identification of useful germplasm for crop improvement through core and mini-core collections and molecular markers. Plant Genetic Resources 4: 25-35

Wani SP, J Rockströmand **B Venkateswarlu**. 2011. New Paradigm to Unlock the Potential of Rainfed Agriculture in the Semiarid Tropics. Pages 419-470*in* World Soil Resources and Food Security (Lal R and Steward BA, eds.).

Wani SP, Pathak P, Jangawad LS, Eswaran H and **Singh P**. 2003a. Improved management of Vertisols in the semi-arid tropics for increased productivity and soil carbon sequestration. Soil Use and Management, 19: 217-222.

Wani S.P., Chander G., Anantha K.H. 2017. Enhancing Resource Use Efficiency Through Soil Management for Improving Livelihoods. *In:* Rakshit A., Abhilash P., Singh H., Ghosh S. (eds) Adaptive Soil Management: From Theory to Practices. Springer, Singapore: 413-451.

Wani SP, Bergvinson D, Raju KV, Gaur PM and **Varshney RK.** 2016. Mission India for Transforming Agriculture (MITrA) Research Report IDC-4, ICRISAT, Patancheru, Hyderabad. 15pp

Yamano, T, P Architesh, Ishika G, Prakashan C and **Gumma MK.** Diffusion of Submergence-tolerant Rice in Eastern India: Awareness, Adoption, and an Ex-ante Analysis. Agricultural Economics (Under review)

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