"Technologies for Transformation of Indian Agriculture" held on January 10, 2022 - Workshop Report

Executive Summary

The executive summary first presents the background, objectives, and structure of the workshop. This is followed by the key observations made by the experts during the workshop and key recommendations made in the various sessions. Details of the observations and recommendations are available in Sections 1-6.

Background and Objectives

The agriculture sector contributes to 16% of India's GDP employing almost 50% of the total work-force. 85% of the farmers are small and marginal, holding less than 5 acres of land and they do not have access to technology that is accessible to the more prosperous farmers. Agriculture in India is largely dependent on nature; variable climate and more recently global warming make farming both challenging and volatile. Despite significant improvement in food grain production and innovations in agricultural technologies spurring a transformation in agricultural practices and helping increase farmer income, Indian farming continues to be plagued by several complex challenges: soil degradation, 63% of farm-land being rain-fed, low productivity, high levels of water usage, environmental damage, unaffordable farm machinery, lack of skills, lack of knowledge, suboptimal usage of information, etc. The cumulative impact is that farmers continue to be trapped in a vicious circle of low growth, low income, and high debt.

To initiate a scholarly discussion on addressing these challenges, the Indian National Academy for Engineering (INAE), in collaboration with the Indian Institute of Science (IISc), the University of Agricultural Sciences (UAS), and the Indian Institute of Horticultural Research (IIHR), organized an intense, one-day agri-technology workshop with active participation from leading academics, scientists, industry practitioners, entrepreneurs, and agriculturists working and interested in different aspects of agricultural technologies.

Technology, especially with the advent of digital technology and data analysis tools, has the potential to transform agricultural practices to achieve high levels of productivity, efficiency, and wealth creation for farmers and the nation. The objective of this workshop is to gain a deep understanding of the role of modern technology, survey the current state-of-the-art in India and abroad, identify implementable solutions, understand the challenges of implementation, and recommend future strategies and policies. In particular, with around 85% of farmers in India being small and marginal, cumulatively holding 50% of the farm-land, and with high operational costs, there is a pressing need to focus on customized and suitable technologies for this demographic.

Workshop Structure

The workshop commenced with welcome addresses by Prof. K. B. Umesh, UAS, Bangalore and Prof. Indranil Manna, President, INAE. This was followed by addresses by guests of honour: Prof. S. Rajendra Prasad, Vice-Chancellor, UAS, Bangalore; Prof. Usha Vijayraghavan, Dean, Division of Biological Sciences, IISc, Bangalore; and Dr. B N Srinivasa Murthy, Director, ICAR-IIHR, Bangalore.

The workshop expectations and outcomes were then outlined by Prof. V. K. Aatre, Chairman, INAE, Bangalore Chapter. This was followed by a plenary talk by the chief guest, Prof. S. Ayyappan, former Director General, ICAR and Chairman, Karnataka Science and Technology Association. Following this, there were five keynote talks:

1. Precision Agriculture: Prof. M.S. Sheshshayee, UAS, Bangalore
2. Farm Mechanization: Dr. C.R. Mehta, Director, ICAR- CIAE, Bhopal

3. Secondary Agriculture: Prof. Chindi Vasudevappa, Vice Chancellor, NIFTEM, Kundli, Haryana
4. Artificial Intelligence and Machine Learning (AIML) in Agriculture: Prof. Y. Narahari, IISc, Bangalore
5. Industry and Academia Interface: Mr. S. Sivakumar, Group-Head, Agri and IT Businesses, ITC Limited

The above sessions were moderated by Dr. Nipun Mehrotra, Founder and CEO, The Agri Collaboratory.

In the afternoon, four parallel panel sessions were organised:

1. Precision Agriculture: Moderated by Prof. Jaywant Arakeri, Professor, Mechanical Engineering, IISc, Bangalore
2. Farm Mechanization: Moderated by Dr. G. Senthil Kumaran, Principal Scientist, IIHR, Bangalore
3. Secondary Agriculture: Moderated by Dr. C.T. Ramachandra, Associate Professor, University of Agricultural Sciences, Bangalore
4. AIML in Agriculture: Moderated by Mr. Ravi Trivedi, Officer on Special Duty, Agriculture, Indian Administrative Fellowship, Government of Karnataka

This was followed by the valedictory session where the four panel moderators summarized the deliberations in the respective panel sessions. This was followed by the address by the Chief Guest, Mr. Shivaraju Boraiah, Additional Director of Agriculture, Govt. of Karnataka. After the concluding remarks by Prof. V.K. Aatre, Mr. V.V.R. Sastry proposed a vote of thanks.

Key Observations

Many key observations were made by the invited speakers, panelists, and participants on all aspects of technology enabled transformation of Indian agriculture. The important ones are summarised below.

Focus on the technologies needed by the farmers: Technology should transform Indian farmers to agri-preneurs. They should become the stakeholders in a digital platform that provides a variety of services including access to credit and insurance and to agri advisories. Although there are roadblocks to integrating digital technology with agriculture in terms of accessibility and adaptability, farmer-centric solutions are important and hence using social sciences within the scope of technology is much needed.

Address the pain points: We should not come up with great technology and push it onto the farmer; instead, we should identify the pain points of the farmer and then build the AI based algorithms and technology that will help alleviate the pain. AI is not a silver bullet. It should only be used to solve realistic problems where it can add value.

The Government has not been able to convince farmers about MSP in Punjab. Many tall claims are made but realising actual material benefits and convincing the farmers are most important. Simple material improvements like cheaper/better fertilizer, better water management, and better nutrients go a long way and improve the trust of the farmer in technology. China does not use AI but does much better with lower fertilizer than India even though it has less arable land. Use whatever AI technology that is appropriate, concentrate on the important issues like water, credit, and market access.

Enable easy access to technology: It is a mission failure if farmers do not get direct access to the technology benefits. Solutions need to be at scale. Any technology that is produced should be as inexpensive as possible to penetrate deep into the market and especially to small and marginal farmers. Barriers to entry should be zero or negative. The real moonshot is transform technology advances to services that are simple, explainable, and farmer-friendly.

Need for a Multidisciplinary and Partnership Approach: Encourage the engineering and scientific communities to come together to help agriculture. Co-hosting and co-locating several disciplines to enhance partnerships and multi stakeholder collaboration between domain research, industries, academia, and agri start-up ecosystems provide the key to improving innovation. Successful examples include: co-location of multiple streams within the campuses at Cornell University, Australian National University, and University of California, Davis. In the Bangalore context, the Bangalore Science Cluster and the proximally located IISc, IIHR, UAS could come together to set up a centre of excellence to catalyse multidisciplinary interactions.

In order to contribute influentially to the agriculture ecosystem, academics should blend blue sky research coupled with start-up type enthusiasm and innovation. Start-ups could help in engineering solutions partnering with domain players.

Need for Systems Thinking: There is a need for a systems level thinking and multi-stake holder collaboration between policy makers, academia, research scientists, industry and startups to accelerate transformation. A leaf can be taken out of the success of ITC which has partnered with 24 academic and research institutions; 83 government entities across centre, state and district levels; 82 NGOs for execution; and 45 industry enterprises including 13 Agritech start-ups.

Precision agriculture is interdisciplinary: Precision agriculture is highly interdisciplinary, and there is huge scope and need for collaboration and close interaction among agricultural scientists, mechanical, electrical and computer engineers and industry to develop precision agriculture technologies. But India does not have institutes that have experts in all these disciplines in one place, thus requiring collaboration across institutes and labs.

Precision agriculture challenges: Small landholdings; huge diversity in climatic and soil conditions and in cropping patterns; skilled labour shortage.

Focus on India specific precision agriculture: Fundamental research on different aspects (movement of fertilizers, pesticides in soil, absorption of pesticides, drone imaging and spraying, etc); Development of precision agriculture specific sensing systems: temperature, humidity, light, imaging, wireless sensor networks and sampling tools for pest detection and soil health; Development of precision agriculture technologies – water & nutrient delivery systems, mitigating hardwater problems, multispectral image analysis, sensor plant health/stress, nutrition, non-chemical based pest and disease management.

Economically viable precision agriculture: Precision agriculture may be developed for high-value crops and protected agriculture which is more economically viable; there is room for development of new technologies – imaging, sensing, delivery systems, robotic systems – that can be taken to open-field agriculture. Some target commercial crops: Tea, Coffee, Sugarcane, Cotton, Grape. Identify more crops where precision agriculture techniques could act as catalyst for increasing the income of farmers.

Key considerations for farm mechanization: Marginal land holdings and labor shortage imply that affordability, equipment size, and minimal human intervention are important considerations for farm mechanization along with the need to optimize life cycle cost of ownership, down time, drudgery, etc.

Farming as a service: Subscribe to a service at various stages of the farming lifecycle – pest control, optimal fertilizer application, water management, soil health monitoring, planning for harvest, etc. Uberization of precision agriculture technologies for large scale adoption in farming is promising: companies own the high-technology machinery and provide services like spraying, de-weeding, etc.

Educate and train the farmers: Training aspect of farmers is very important for grassroot adoption. Social media will play a big role here. Use of technology and algorithms should be easily explainable to the farmers.

Secondary agriculture presents a big opportunity: The secondary agriculture sector is a sunrise sector for the Indian economy as it has a major role to play in employment generation, poverty alleviation, and product diversification. Secondary agriculture is one of the ways to achieve holistic and inclusive development of the farmers, forest dwellers, and cattle owners. A big opportunity for manifesting science and engineering for agriculture is in food processing with post-harvest losses ~Rs. 90,000 crores, including input water wastage *(3500 litres/kg of rice, 1500 litres/kg of wheat)*, there is a pressing need for better technology for processing, value addition, food safety, and quality assurance.

Attract the Youth towards Agriculture: Initiatives need to be taken to attract fresh talent towards agriculture, highlighting it as an attractive career option for India's youth. The start-up ecosystem which is crucial to technology enabled agriculture could become an attractive avenue in this context.

Famer Cooperatives: Amul has set a benchmark for cooperatives. FPOs (Farmer Producer Organisations) have been started to realise the vision of cooperative transformation. To scale up and create cooperatives like Amul, we need funds, social mobilisation, organising and coordinating the farmers and empowering them with the ability to do business and earn money. A seamless technology platform owned by the farmers and all other stakeholders may be the right approach.

Government is a key player: The governments both, state and central, need to enable technology enabled transformation of Indian agriculture. These include formalising the activities related to education, research and development. A clear roadmap with adequate and sustained funding, government and private, and institutional support for development of India specific technologies, bringing them to the market and implementation at farm level. Making clean data accessible to all stakeholders is an important enabler. Enabling industry and start-ups is crucial, with provisions for close interaction with academia, scientists and farming community.

AIML can potentially influence decision making in the entire agriculture cycle: There is a potential for AIML to aid decision making across the entire Agri lifecycle, viz., planning *(what to sow)*, input decisions like fertilizers *(when and how much to apply)* and credit, crop management *(pest control and grading)*, and harvesting *(when to harvest and where to sell)*, etc. National grand challenges using AIML techniques can be proposed for (1) crop recommendation, (2) yield estimation and crop price prediction, and (3) seamless access to markets. Great potential exists as well for using AI for pest prediction and prevention, for grading and yield estimation, credit assessment and leveraging game theory to design markets attractive to both farmers and consumers. Proactively provide the right quantity of nutrients (micronutrients) at the right time.

Data Governance and Management: There is a need for one main directory as there are too many variations and types even in a single crop. Standardizing all these varieties and documenting them is key. Data exists but it is all siloed out in multiple organisations and entities. Data is not high quality so collecting itself is a problem. The key is data quality, data collection training, and data sources.

Responsible Algorithms: Addressing inequality should be factored into how the model is built. Technology should optimise for all, not farmers alone. There is a need for responsible AI algorithms with fairness, transparency, accountability, and full cognizance of ethical considerations. The algorithms should be explainable.

Key Recommendations

Education and Research: Launch joint research programs between agricultural and engineering institutes; Start academic programs (M.Tech., Ph.D.) programs across institutes to bring together students from agricultural and engineering disciplines; Introduce internship programs in agri-industries and agri-startups for students to get exposure and hands-on experience.

Set up centres of excellence in precision agriculture on the lines of CISTUP (Centre for Infrastructure, Sustainable Transportation, and Urban Planning, IISc set up by the Karnataka Government). In order to promote seamless collaboration among academic institutions, research labs, industry, and startups, set up an interdisciplinary technology innovation hub in digital agriculture on the lines of *Technology Innovation Hubs* set up under the DST initiative in inter-disciplinary cyber physical systems.

Set up precision agriculture test beds where technologies can be developed and tested – sensor networks, imaging systems, pest control strategies, delivery systems (robotics, drones, etc). To begin with, the following can be set up: two farms – a farmer's field, and a field in an university; two protected agriculture units (polyhouses, green houses) – one in an academic institute and another in an industry.

Recommendations for Farm Mechanization: In the short term, (1) the curriculum of agricultural engineering be enhanced with increased focus on making the outgoing agricultural engineers industry-ready; (2) conduct frequent academia and industry meets to exchange the ideas and develop need-based machinery to increase the level of mechanization; (3) Increase the number of reserved posts for agricultural engineers in the Departments of agriculture from the present level to 30% (4) custom hiring centres may be established at Taluk level along with heavy / special machinery to help farmers; and (5) a national level test certificate for the newly developed machinery may be issued and all the state departments may honour the same for their empanelment of the machinery under subsidy schemes.

In the long-term, (1) establish a separate Department/ Directorate of Agricultural Engineering in every state wherever it is not established so far; (2) data on soil types/ properties in the state may be made available to help the manufacturers to develop machinery suitable to the various soil types; (3) develop crop-specific and multifunctional machinery for different agricultural operations; (4) more assistance and encouragement to be given to the start-ups to attract the young / fresh engineers into the area of agricultural mechanization; and (5) develop energy efficient, autonomous and sensor-based machinery using the latest technological innovations.

Recommendations for Secondary Agriculture: Establish (a) Directorates of Secondary Agriculture in the states (b) rural agro processing industries with high quality and hygienic products (c) an agri-food biotechnology institute similar to the NABI in Karnataka (d) agro processing centers to take up the secondary agriculture activities (e) a quality testing laboratory for value added products (f) food parks, cold storage, etc. Design and develop suitable processing machines for secondary agriculture.

Data Governance and Data Interoperability: The government should take steps to enable seamless translation of agriculture data into valuable Information and to "actionable" insight for being used for various agriculture use cases, requires data-sets to be seamlessly interoperable across data sources and consumers of data (from govt, private sector, startups, research institutes). Currently there is a gap with respect to agriculture data interoperability for seamless integration across applications. Privacy and security issues to be accorded due priority. IUDX (Indian Urban Data Exchange) seems to be a good model to adopt. Data to be made available to AIML researchers to make the algorithms better. A team of experts to be identified for operationalising the policy as soon as possible.

Sandbox and Pilots for High Impact Applications: The Government should facilitate rolling out innovations that leap frog the growth in technology innovations and help solve the key challenges faced by small and marginal farmers. Two important issues to keep in mind are to ensure adoption at farmer level and also to avoid duplication of efforts. There are many use-cases waiting to be taken up: (a) Price and yield prediction for crops (b) Carbon Sequestration - based incentives, possible for sustainable agriculture. (a) Early pest detection (d) crop recommendation (e) seamless access to credit and insurance, etc.

1. Workshop Schedule

Time	Item
9:45-10:00	Networking
10:00-10:05	Welcome and Introduction by Prof. K.B. Umesh, UAS, Bangalore
10:05-10:10	Welcome Address by Prof. Indranil Manna, President, INAE
10:10-10:15	Address by Prof. S. Rajendra Prasad, Vice-Chancellor, UAS, Bangalore
10:15-10:20	Address by Prof. Usha Vijayraghavan, Dean, Division of Biological Sciences, IISc
10:20-10:25	Address by Dr. B N Srinivasa Murthy, Director, ICAR-IIHR, Bangalore
10;25-10.30	Workshop Expectations by Prof. V K Aatre, Chairman, INAE, Bangalore Chapter
10:30 -10:50	Chief Guest’s Address by Dr.S.Ayyappan, Chairman, KSTA Bangalore & Former Director General, ICAR .
10:50-10:55	Plenary Session: Introduction by Dr. Nipun Mehrotra, Founder, The Agri Collaboratory, Bangalore
10:55-11:20	Keynote Talk: Precision Agriculture by Prof. M.S. Sheshshayee, UAS, Bangalore
11:20-11:45	Keynote Talk: Artificial Intelligence and Machine Learning (AIML) in Agriculture by Prof. Y. Narahari, IISc, Bangalore

11:45-12:10	Keynote Talk: Farm Mechanization by Dr. C.R. Mehta, Director, ICAR-CIAE, Bhopal
12:10-12:35	Keynote Talk: Secondary Agriculture by Prof. Chindi Vasudevappa, Vice Chancellor, NIFTEM, Kundli, Haryana.
12:35-13:00	Industry and Academia Interface by Mr. S. Sivakumar, Group-Head, Agri and IT Businesses, ITC Limited
13:00- 14:00	LUNCH BREAK
14:00-15:30	**Parallel Thematic Sessions** Precision Agriculture: Prof. Jaywant Arakeri, Professor, Mechanical Engineering, IISc, Bangalore Farm Mechanization: Dr. G. Senthil Kumaran, Principal Scientist, IIHR, Bangalore Secondary Agriculture: Dr. C.T. Ramachandra, Associate Professor, University of Agricultural Sciences, Bangalore AIML in Agriculture: Mr. Ravi Trivedi, Officer on Special Duty, Agriculture, Indian Administrative Fellowship, Government of Karnataka
15:45-16:15	Presentation by moderators. Discussion and Feedback.
16:15-16:45	Valedictory Session: Plenary Talk by Mr. Shivaraju Boraiah, Additional Director of Agriculture, Govt. of Karnataka
16:45-16:55	Concluding Remarks by Prof. V.K. Aatre, Chairman, INAE Bangalore Chapter
16:55-17:00	Vote of Thanks by Mr. V. V. R. Sastry, Former CMD, BEL, Bangalore

2. Plenary Session, Keynotes Session, Valedictory Session

The day-long workshop was in the form of a series of discussions among experts from academic, research, and government institutes, industry, and start-ups. The workshop began with welcome addresses by Prof. K. B. Umesh, UAS, Bangalore and Prof. Indranil Manna, President, INAE.

The workshop expectations and outcomes were outlined by Prof. V. K. Aatre, Chairman, INAE Bangalore Chapter. The chief guest, Prof. S. Ayyappan, former Director General, ICAR and Chairman, Karnataka Science and Technology Association, spoke about smart farming and the need for repositioning agriculture as everyone's business. Additionally, a diverse range of experts shared experiences and provided action-oriented recommendations in modern agricultural technologies, through panels and keynotes across four streams – Precision Agriculture, Farm Mechanization, Secondary Agriculture, AI-ML in Agriculture, and Industry and Academia Collaboration. The workshop plenary was moderated by Mr. Nipun Mehrotra, Founder and CEO, The Agri Collaboratory.

Precision Agriculture | Farm Mechanization | Secondary Agriculture | AI/ML in Agriculture | Industry and Academia Interface

These five areas were chosen for keynote talks as they are fundamental to accomplish the goals set by our Honourable Prime Minister towards doubling the income of farmers and reaching a state of *AtmaNirbhar Bharat*.

Precision Agriculture: The AAA sectors (Agriculture, Animal Husbandry, and Aquatic) are key drivers for self-sustenance in food production and can benefit from using technology and data precisely to control application of inputs and decision making. As Prof. M.S. Sheshshayee highlighted in his keynote, precision farming allows us to manage availability and usage efficiency of constrained resources (e.g. water) by leveraging sensors and data to identify symptoms.

Farm Mechanization: A shift from "tractorisation to mechanization" is essential as per Dr. C.R. Mehta. Marginal land holdings and labour shortage imply that affordability, equipment size, and minimal human intervention are important considerations for farm mechanization along with the need to optimize life cycle cost of ownership, down time, drudgery, etc. Developing gender neutral implements and increasing mechanization towards the later stages of the crop lifecycle are also important. Innovative co-op models of ownership and customized hiring of high-end equipment are emerging business models that need to be implemented, along with creating hubs for farm equipment.

Secondary Agriculture: Food surplus does not translate to nutrition sufficiency, leading to rampant malnutrition in rural India. Prof. Chindi Vasudevappa pointed out - "India's food wastage was as much as UK's overall consumption" and the need to maintain quality and safety of both raw produce and processed food are critical. At the same time, losses are very high across all stages: production, storage, processing and packing, distribution, etc. Fortification of foods to address malnutrition, aligning with ODOP (one district one product) model for planning food processing units, and leveraging technology like cold chain, blockchain, drones, etc for improved and auditable food processing are important. Village adoption programs and centers of excellence in agricultural production and food processing need to be designed to bolster the agricultural development in India.

AI/ML in Agriculture: There is a potential for AI/ML to aid decision making across the entire Agri lifecycle, viz., planning *(what to sow)*, input decisions like fertilizers *(when and how much to apply)* and credit, crop management *(pest control and grading)*, and harvesting *(when to harvest and where to sell)*, etc. Prof. Y. Narahari suggested a governance framework based on FATE (Fairness, Accountability, Transparency, Ethics) and emphasised that data interoperability, standardization, privacy and security guidelines were essential to leverage AI/ML to its full potential. He recommended (1) crop recommendation, (2) yield estimation and crop price prediction, and (3) seamless access to markets using AIML techniques be taken up as national grand challenges.

Industry and Academia Interface: ITC Ltd's Group-Head for Agri and IT Business, Mr. S. Sivakumar highlighted the need for a systems thinking approach and multi-stake holder collaboration between industry and academia to accelerate transformation. Key factors to consider while exploring appropriate technology, and to gain institutional and government support include ensuring:

- relevance at the individual farmer level for easy adoption,
- pragmatic and economic end-to-end solutions that reach farmer, and
- programs need to make at least "business sense or welfare sense."

He emphasized the need for domain expertise, technical knowledge, social sciences, data analytics, and engineering to come together. He highlighted the importance and potential of wide-ranging collaboration using ITC's example of partnering with 24 academic and research institutions; 83

government entities; 82 NGOs for execution; and 45 industry enterprises including 13 Agritech start-ups.

Key Recommendations from Plenary, Keynote, and Valedictory Sessions

The workshop emphasized several holistic, implementable recommendations as next steps in four areas.

Multidisciplinary and Partnership Approach

Most speakers emphasized propagating an approach of co-hosting and co-locating several disciplines to enhance partnerships and multi stakeholder collaboration between domain research, industries, academia, and agri start-up ecosystems which are key to improving innovation. By providing examples of co-location of multiple streams within the campuses at Cornell University, Australian National University, and University of California, Davis, Prof. Usha Vijayraghavan highlighted how Bangalore especially, could catalyse multidisciplinary interactions since the potential partners like IISc, ICAR, IIHR, UAS, are proximally located.

Speakers advised the benefits of this approach, including the ability to examine issues holistically to avoid one policy fix being detrimental to another *(for example free electricity leading to unsustainable water consumption; and working on organic farming or natural farming in combination with issues of climate change and water scarcity).*

As Prof. Y. Narahari stated, collaborators need to have a mindset of blue-sky research coupled with start-up type enthusiasm and innovation. Start-ups could help in engineering solutions partnering with domain players. The future of Indian farming is diversely spread among the areas of horticulture, agroforestry, livestock and field crops. Prof. M.S. Sheshshayee alluded to the premise that management responses need to go beyond biological tasks and be collaborative with engineering and technology for doing the right things at the right place and at the right time. Multidisciplinary courses like M.Tech. in Agricultural Engineering can develop required skills besides integrating engineering domains with agricultural disciplines - for example, a biomedical sciences model could be replicated in agricultural practices.

For developing partnership structures, Mr. S. Sivakumar proposed a “collaboration framework” - advising that “transformation” must benefit everyone and that “innovation, incentives, investments and institutions need to converge”. For partnering to be successful, it is important to complete all the groundwork on scope and get an alignment on the objectives upfront. He proposed a three-dimensional framework for success:

- **Depth** of engagement (degree of immersion and support)
- **Width** (broad engagement across faculty + internships + curriculum development)
- **Length** (alignment duration, conflict resolution)

Moreover, subject knowledge and skill building are critical: early stage and PoC funding are required to encourage innovation and entrepreneurship; incubation infrastructure needs to be developed in PPP mode; and proposals may be made to government agencies to provide incentives and concessions for skill development and entrepreneurship.

Applying Engineering and Scientific Disciplines for the Benefit of Agriculture

Agriculture is often seen only as a societal concern and not an engineering problem and this theme was echoed by several speakers through the workshop. Prof. V. K. Aatre encouraged the engineering and scientific communities to come together to help agriculture. As Prof. Usha Vijayraghavan explained, genome science and genome engineering have the potential to address real problems in the Indian ecosystem which has its own uniqueness with diversity and nature of small holdings.

Technology will be a tremendous facilitator to access markets, inputs, data, advisory, loans and insurance, holistic analytics by integrating agri-data with metrological and soil health data, remote sensing and proximate sensing to evaluate soil indices. The ongoing humanitarian crises with respect to malnutrition and agricultural production needs to be addressed by leveraging 21st century engineering tools. In fact, technology should not just be “used” - instead it should be exploited aggressively for the advantage of the farmer.

Dr. B. N. Srinivasa Murthy suggested using technological solutions like decision support systems, since managing food security with climate change remains a key challenge for science and technology. Smart decision support systems aid farmers with analyzing critical factors: *For example, what should a farmer focus on: Agriculture? Horticulture? Dairy? or Fisheries?*

In Prof. S. Ayyappan’s words, technology should transform Indian farmers to agripreneurs. Additionally, platforms are needed to bring several disparate issues together like the impact of climate change, leveraging data to analyze farming at all stages, stress of abiotic and biotic factors, disaster management and insurance, etc. While innovations are growing at the farmer level, platforms need to help on-board innovation and scale it, develop “farm to fork” systems, integrate learning, usage and adoption of fertilizers, intervene crop-residue burning, and initiate programs for agri-tourism. There is also a need to subsidize the use of technology for agriculture.

A big opportunity for manifesting science and engineering for agriculture is in food processing with post-harvest losses ~Rs. 90,000 crores, including input water wastage *(3500 litres/kg of rice, 1500 litres/kg of wheat)*, there is a pressing need for better technology for processing, value addition, food safety, and quality assurance. Another is increasing mechanization levels - currently inconsistent across crops *(high in staples, low in cash crops)*, and across the crop cycle *(highest in sowing and in the early stages, and low during the later stages)* and addressing land terrain limitations for high power and weight machines, low power availability and spatial variation in cropping systems.

Great potential exists as well for using AI for pest prediction and prevention, for grading and yield estimation, credit assessment and leveraging game theory to design markets attractive to both farmers and consumers. Although there are roadblocks to integrating digital technology with agriculture in terms of accessibility and adaptability, farmer- centric solutions are important and hence using social sciences within the scope of technology is much needed.

Attracting Youth towards Agriculture

Initiatives need to be taken to attract fresh talent towards Agriculture, highlighting it as an attractive career option for India’s youth. Given how younger farmers are receptive to technology, skill development coupled with the energy of the youth can go a long way into scaling the agricultural ecosystem in India.

Prof. S. Ayyappan suggested promoting agri-oriented skill and career development in India can help increase the involvement of youth. Specialized schools and vocational programs in agri-sciences, and capsules of agriculture-related syllabus should be introduced at the high school level, along with distance learning for young farmers. Women student participation should also be encouraged, amidst the rise of regenerative agriculture with the goal of reaching zero waste by 2030, through education and capacity building. Ultimately, energy should be harnessed for community participation, resource recovery centers for waste management, and empowered learning for greater reach and holistic development of the youth.

With 50% of Indian Agri start-ups based in Karnataka, their knowledge and practical experience can help strengthen school programs and motivate the energetic minds of the youth, framing an agri-entrepreneurship mindset early on.

Government Involvement
The Government can help provide a collaborative and interdisciplinary focus across the Agri ecosystem along with consistent data sharing policies. Regular sessions with the Agri start-up ecosystem will help in building deeper partnerships and enable better policy development. A centralized system rather than a state specific system for approval of machinery is a major recommendation. Mr. Shivaraju Boraiah, Additional Director of Agriculture, Govt. of Karnataka explained that Karnataka has established a good balance between private firms and the government, with the open data policy. He mentioned several successful agricultural projects implemented by the Govt. of Karnataka.

- Establishment of a Secondary Agriculture directorate
- Supporting farmers through an integrated farming system: Project worth 76 Cr implemented across gram panchayats
- Data visibility using FRUITS application
- Samrakshane Portal: Completely integrated crop insurance portal of Karnataka
- Kutumba Program: Data on farmer's each family member is being captured
- High transparency: 95% of payments are routed through Direct Benefit Transfer.

Conclusion
There will be a challenge to feed the world in the next 25 years, primarily due to population growth, decrease in arable land, impact of climate change on soil and ecosystem, and demand for water management. Interdisciplinary, cross-disciplinary, trans-disciplinary focus is critical to solve agricultural problems. These problems should be addressed collaboratively to enable India to become self-sustainable and become a provider of Agri-Tech solutions globally. Agriculture is one of the most complex and unique engineering challenges and preservation and post-harvest technology offer a good scope for integrating engineering and agriculture.

As aptly summed up by Prof. S. Rajendra Prasad**,** the acceptance for Agri Technology is growing amongst small and marginal farmers who are adapting to digital modes, thanks to smartphones, access to the internet, and improved digital literacy. Hence, there is a compelling reason to support farmers to switch to smart farming. Issues like digitization, on-line buying, mandi pricing prediction, pre-harvest and post-harvest fertilizer decisions have to be addressed.

Supply chain for agriculture was resilient during COVID-19 - but as agriculture is everyone's business, it is the right time for science, technology, and agriculture to join hands to buttress each other. This workshop established a platform between different disciplines debating integrated issues and it's recommended this be made an annual session. As Mr. Nipun Mehrotra suggested, it is time to put an operational discipline in tracking the several recommendations and implement a few quickly!

3. Panel on Precision Agriculture

Introduction
In precision agriculture, the aim is to use optimum amounts of inputs – water, nutrients, pesticides, etc. – at the optimum times to maximise productivity. The most common and traditional component of precision agriculture is drip irrigation, where water is fed to a plant in the form of drops, typically at a few litres per hour. A variant of drip irrigation is fertigation, where nutrients are mixed with the water. There has been increasing use of sensors to identify deficiencies (e.g., moisture in soils and nutrient levels in plants) and diseases so that appropriate action may be taken. The *sensing* may be from point sensors, to measure soil moisture, temperature, etc., or from imaging, using ground, robot or drone-mounted systems or from satellites to obtain information on plant health, nutrient deficiency,

etc. Targeted delivery of fertilisers and pesticides is increasingly possible using this data and automated or semi-automated delivery systems mounted on tractors or autonomous vehicles. There is a enormous scope to develop new technologies and algorithms for precision agriculture applications that would require close interaction among agricultural scientists, mechanical, electrical and computer engineers, and industry. India has unique challenges for developing these technologies given the small landholdings, and huge diversity in climatic and soil conditions and cropping patterns. The discussion in this session was on various issues related to precision agriculture as applicable to India.

The keynote was given by Prof. M S Sheshshayee of the University of Agricultural Sciences, Bangalore. He presented the various facets of precision agriculture including the latest technologies, and the work that is being done in India.

List of Panelists

1) Prof. Jaywant H Arakeri, (Moderator), Mechanical Engineering, IISc, Bangalore jaywant@iisc.ac.in
2) Dr. Prasanna Bhat, Bayer Crop Sciences, Bangalore: prasanna.bhat@bayer.com
3) Dr. V C Patil, ex-UAS, Dharwad. vcpatilksu@gmail.com
4) Dr. Rabi Sahoo, IARI, New Delhi, rabi.sahoo@icar.gov.in
5) Prof M S Sheshshayee, UAS, Bangalore
6) Prof K R Sreenivas, EMU, JNCASR. krs@jncasr.ac.in,
7) Dr. Kesavan Subaharan, ICAR – NBAIR. subaharan_70@yahoo.com

Summary of Panel Discussion

The moderator briefly introduced the subject of precision agriculture, its different components, the scope of the discussion and the nature of recommendations that are expected from the session. Then he requested each of the moderators to give their remarks.

Dr. Subaharan:

- Now that food sufficiency has been achieved it is important to concentrate on quality, pesticide-free produce.

- Described use of non-pesticide pest control using attractants, repellents and pheromones and establishment of companies in India manufacturing products that use these techniques.

- Understanding of trophic interaction between plants and insects, identification of volatiles necessary to develop these methods.

- Develop sensors for detecting *signals* from plants

- Any technology that is produced should be as inexpensive as possible to penetrate deep into the market.

- Precision agriculture is an assembly line; no individual technology can be a stand-alone component.

Prof Sreenivas:

- Need to look into sensors and engineering technology for both open field and protected agriculture.

- Use sensors to monitor soil health and environmental conditions, including weather stations, imaging technologies, wireless sensor networks for gathering the data and storing it in a way that can be used with Artificial Intelligence and Machine Learning tools.

- Do computational fluid dynamics (CFD) simulations using data from weather stations and satellites for forecasting weather at local level (few kilometers) over short times (days).

- Listed the special circumstances of protected agriculture, for example, in poly houses, that require technologies like micro-climate monitoring and control.

- For high-value crops, for breeding requirements, the cost may not be the main criteria but achieving the required conditions for optimum growth is.
- Technology and sensors that we develop needs to be modular, rugged and it should be scalable; modular in the sense that they can be used for multiple applications: small scale fields, for breeding, for protected agriculture, etc.

- Need expertise from various fields of engineering, like mechanical, computer science, electronics, civil engineering, and satellite image analysis.
- Agricultural and engineering students need to be brought together for masters or doctoral degree programs to foster sustained collaboration between engineering and agricultural sciences.

Dr Bhat:

- In the industry, precision agriculture is being practised currently for breeding, research and design of products.

- Use toolboxes that use data from satellites, drones, and sensors to give information on crop health and advice on interventions like spraying. Satellite imagery data can be used to estimate crop acreages and potential market areas for specific crop seeds and chemicals.

- Development of prescriptive engines that use precision genomics and data science, including Al, ML-based algorithms to predict emergence, germination issues and mitigate crop-related problems. AI/ML is also used in optimizing seed and chemical operations and testing footprints.

- Use farm machinery fitted with sensors to assess soil type and soil health and assess water and nutrients status that indicate current plant needs.

- Cell phone-based prescriptions on the appropriate variety to be grown in a specific area depending on the climatic and soil parameters.

- Mentioned about a trial near Hyderabad with drone-based insecticide application in a rice farm.

- Precision agriculture especially has an essential role for high-value crops, off-season production, and breeding.

- Interaction required from partners from industry, academia, R&D institutes, and NGOs.

Dr Sahoo:

- Spoke about the role of imaging (visual, IR and hyperspectral), which could be from satellites or from ground level and drone-based systems, in identifying water stress, nutrient deficiencies and disease in plants.

- IARI is using the expertise of the different institutes, organisations working under different domains: soil, crop health, post-harvest analysis, cash crops, climate-change resilient crops

- The knowledge base that is developed can be put on the servers and communication established through the mobile network,

- We have a national-level initiative on network programs and precision agriculture addressing some of these critical issues.

Dr Patil:

- An agriculture scientist, who has become a full-time farmer; he identified ground-level problems, including the uncertainty of markets, the need for availability and use of satellite-based information and weather data and predictions that could help farmers make decisions, for example, whether to spray or irrigate on a particular day.

- Need downscaling of recommendations and high-end technologies to suit local individual farm level requirement. This is a difficult but important task.

- Precision agriculture can be developed for high-value crops and in protected cultivation, to begin with. Once the technology becomes cheap and scalable, we can move to the low-value and food crops.

- To do this integration, we need to fill gaps between engineering and agricultural sciences and find a mechanism for collaboration between experts from engineering sciences, space sciences and agriculture sciences. We cannot develop these technologies in isolation without consulting the farmer; he is the main stakeholder.

- We need to collaborate with space scientists to assess the spatial variability, so once we have together, then we will be able to do an excellent job for the benefit of farmers.

- For farmers, profitability, sustainability, increase in production and income are important. So, the technology needs to be cost-effective.

- Need to build an end-to-end supply chain system, best example being sugar cane. Sugar cane farmers across the country are happy because there is a perfect supply chain system in place; that system is not present for other crops, making them unviable.

Comments from Participants

The important ones are included below.

- Need to think of scale-independent precision agriculture, and for successfully involving farmers as core designers, we must showcase the right technologies.

- Need change of policy so that supply-demand balance is maintained, improve the information flow in our system and improve connectivity.

- SMART farming = “Scientific, Marketable, Acceptable, Reliable and Time-saving technologies”

- Design process needs to be adopted, where specific problems are clearly stated, leading to cost-effective solutions that are likely to be innovative as well.

Technological Challenges and Obstacles to Implement Precision Agriculture in India

- Small landholdings; huge diversity in climatic and soil conditions and in cropping patterns; skilled labour shortage.

- Precision agriculture is highly interdisciplinary, and there is huge scope and need for collaboration and close interaction among agricultural scientists, mechanical, electrical and computer engineers and industry to develop precision agriculture technologies. But India does not have institutes that have experts in all these disciplines in one place, thus requiring collaboration across institutes and labs.

- Very few farmer usable solutions currently available in precision agriculture.

- Even the simplest and most common precision agriculture tool, drip irrigation, has problems of clogging, degradation with time.

Precision Agriculture: Recommendations

Education and Research

1. Joint research programs between agricultural and engineering institutes

2. Start academic programs (M.Tech., Ph.D.) programs across institutes to bring together students from agricultural and engineering disciplines

3. Internship programs in agri-industries, focussing on precision agriculture technologies for Masters/PhD students to get exposure and hands-on experience.

4. Setting up research centres in precision agriculture. An example is CISTUP, set up by the Karnataka Government in IISc for urban infrastructure.

Development

1. Undertake activities in focussed areas of precision agriculture for India specific conditions:

    - Fundamental research on different aspects (movement of fertilizers, pesticides in soil, absorption of pesticides, drone imaging and spraying etc)
    - Development of precision agriculture specific sensing systems: temperature, humidity, light, imaging, wireless sensor networks and sampling tools for pest detection & soil health.
    - Development of precision agriculture technologies – water & nutrient delivery systems, mitigating hardwater problems, AI/ML technologies, multispectral image analysis, sensor plant health/stress, nutrition, non-chemical-based pest and disease management.

2. Precision agriculture may be developed for high-value crops and protected agriculture which is more economically viable; there is room for development of new technologies – imaging, sensing, delivery systems, robotic systems – that can be taken to open-field agriculture. Some target commercial crops: Tea, Coffee, Sugarcane, Cotton, Grape. Identify more crops where precision agriculture techniques could act as catalyst for increasing the income of farmers.

3. Encouraging Public-Private partnering ecosystem for quick scale-up of technologies. Involve established companies and start-ups.

Services for Farmers
Provide information on weather (from satellites, weather stations, forecasts) markets, prices on smart phones.

1. Enable platforms and forums to make available experts' advice on specific problems related to

crops: irrigation scheduling, nutrition management, pest and disease control.

2. Fund farmers to visit learning centres where different aspects of precision agriculture is are being practised.

3. Uberization of precision agriculture technologies for large scale adoption in farming. Companies own the high-technology machinery and provide services like spraying, de-weeding, etc

Setting up of Test Beds

Set up test beds where technologies can be developed and tested – sensor network, imaging systems, pest control strategies, delivery systems (robotic, drone etc). To begin with the following can be set up:

- Select two farms – a farmer's field, and a field in an university

- Select two protected agriculture units (polyhouses, green houses) – one in an academic institute and another in an industry

Role of Government and Industry

The government both, state and central, need to enable some of the activities listed above. These include formalising the activities related to education, research and development. A clear roadmap with adequate and sustained funding, government and private, and institutional support for development of India specific technologies, bringing them to the market and implementation at farm level. Enabling industry and start-ups would be crucial, with provisions for close interaction with academia, scientists and farming community.

4. Panel on Farm Mechanization

Farm mechanization is the use of tools and machinery in different field operations in the production system of agricultural crops. It helps to reduce the drudgery of the agricultural labourers caused by awkward postures, repetitive body movements, and extreme environmental conditions.

Due to the migration of labourers from the villages to cities in search of better life earnings, shortage of labour for agricultural operations in the villages is a major problem. Even the available unemployed youth in the villages are not interested or attracted towards agriculture. So the agricultural operations get delayed in crucial periods such as rainy seasons, during heavy demand situations, and at the critical stage of harvesting.

The availability of tractor power is 16 tractors per 1000 ha in comparison to 19 tractors in the rest of the world. This leads to 2kW of power availability per ha in India and helps in mechanising agricultural operations to the level of only 40 to 50 percent.

The Government of India is trying to improve the mechanization level through subsidies, establishing custom hiring centres under its programmes like Sub-Mission on Agricultural Mechanization. There are indigenous tools and machinery developed under National Agricultural Research System and by the private machinery manufacturers. If needed, machinery can be imported and modified to Indian conditions.

Under these circumstances, it is pertinent to discuss the present status of mechanization in our country, its constraints, issues and provide recommendations to improve the level of mechanization. Hence, the following panelists representing academia, manufacturers, start-ups and state departments were invited to give their views and discuss the problems of various stakeholders. Around 50 different stakeholders attended the session and participated in the discussion. The following important recommendations emerged after the discussion in this session.

Details of Panel Session

Moderator: Dr. G. Senthil Kumaran, Principal Scientist, ICAR-IIHR, Bengaluru

Panelists:

Dr. Veerangouda, Registrar, UAS, Raichur. Professor in Agricultural Engineering having more than 30 years of experience in teaching and research. Guided many M.Tech. and Ph.D students in agricultural Engineering in developing Agricultural Machinery. Received awards for his professional achievements.

Mr. S.V. Raju, Chairman, Agricultural Machinery Manufacturers Association, India: A B.Sc (Ag) graduate from a farming family. He is Director of five agricultural machinery manufacturing companies and apart from using his own designs has successfully adopted designs from research institutes.

Mr. A. Rammohan, Executive Vice President and Business Head, TAFE, Chennai: A mechanical engineer with MBA degree working as Executive Vice President and Business Head (Application Business Unit), TAFE, Chennai. One of the largest tractor manufacturers and most popular brand of tractors in India.

Mr. Manesh Jain, CEO, Flo Mobility, Bangalore: He is founder and CEO of Flo mobility, Bengaluru, a start-up working towards enabling autonomous navigation of vehicles and equipment used in farming. Manesh carries 16+ years of experience working across industries with last 10+ years being involved in running startups. His previous startup was acquired by Reliance Jio. Passionate about green energy.

Mr. N. Unnikrishnan, Superintending Engr, Agricultural Engineering Dept., Coimbatore: He is a member in various technical committees of the department. He has more than 38 years service in different positions in the department handling various development schemes of the state, World Bank schemes to disseminate the agricultural engineering technologies among farmers and entrepreneurs and overall development of the implementing areas.

Recommendations for the Short-Term:

1. The curriculum of agricultural engineering may focus on the need of the industries to make the outgoing Agricultural Engineers industry-ready.
2. Frequent academia and industry meets should be conducted to exchange the ideas and develop need-based machinery to increase the level of mechanization
3. Increase the reservation of posts from 15% to 30% to the Agricultural Engineers in the Department of Agriculture, Govt. of Karnataka
4. Custom hiring centres may be established at Taluk level along with heavy / special machinery to help farmers
5. A national level test certificate for the newly developed machinery may be issued and all the state departments may honour the same for their empanelment of the machinery under subsidy schemes

Recommendations for the Long-Term:

6. Establishment of a separate Department/ Directorate of Agricultural Engineering in every state wherever it is not established so far
7. Data on soil types/ properties of the state may be developed to help the manufacturers to develop machinery suitable for various soil types
8. Develop crop specific and multifunctional machinery for different agricultural operations
9. More assistance and encouragement should be given to the start-ups to attract the young / fresh engineers from different disciplines to contribute to agricultural mechanization
10. Energy efficient, autonomous and sensor-based machinery may be developed to meet future challenges.

5. Panel on Secondary Agriculture

Secondary Agriculture includes *all practices and process which add value to primary agricultural commodities by using efficient technologies, market information, and consumer preference*. The term *secondary* has a bearing on climate change adaptation and its mitigation, small farm viability and profitability, food security, nutrition, sustainable utilisation of natural resources, and optimal usage of produce from primary agriculture and farm incomes. In other words, promoting secondary agriculture has implications for attaining sustainable development goals, which aim to connect primary, secondary and tertiary sectors by using slack/idle factors of production, such as land and labor—contributing to primary agriculture production, capturing *value* in primary agricultural activities, and generating additional income at the enterprise level.

The secondary agriculture sector is regarded as a sunrise sector for the Indian economy as it has a major role to play in employment generation, poverty alleviation, and product diversification. Secondary agriculture is one of the ways to achieve holistic and inclusive development of farmers, forest dwellers, and cattle owners.

Secondary Agriculture plays a very important role after harvesting: it is known by several names such as Post-harvest engineering/technology, value addition, food processing, etc.

Importance of Secondary Agriculture

Secondary agriculture, as is defined, can help drive the growth of primary agriculture, and three avenues have been identified that adequately help utilise capital, human resources, technology, organizational capabilities and risk management:

1. Type A: Value-addition to primary agriculture production systems
2. Type B: Alternative enterprises, but linked to rural off-farm activities
3. Type C: Enterprises that thrive on crop residues and waste materials of primary agriculture

Type A can be achieved by improving livelihood enhancement action plans that are implemented by farmer-based/community-based organizations. Linking farmers with the market through aggregation and assaying/grading of agricultural produce can help them in value enhancement and appropriation. Farmer cooperatives, cluster farming, financial literacy, marketing skills are important to build this avenue.

Type B is based on utilization of alternative enterprises to primary agriculture but is associated with rural off-farm activities. For example, poultry, bee-keeping, duck farming and livestock management are off-farm enterprises that can be promoted as part of integrated farming system. Integrated farming can hedge farm risk in the period of crop failure or ease out the seasonality in the stream of cash flows.

Type C are such enterprises that strive on crop residues, or by-products of primary agriculture. For example, after recovering sugar from the cane, the cane can be used as bagasse for molasses production. Similarly, cotton stalk and seed (after ginning) can be used for de-oiled cake preparation or utilized in the secondary/tertiary sector.

Details of the Panel Session

The objectives of the session were: (1) To share the experiences in modern secondary agricultural technologies and (2) To understand implementation challenges, identify solutions and recommend future strategies in secondary agriculture

Moderator: Dr. C T Ramachandra, Associate Professor and Head, Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, GKVK, Bangalore

Panelists

Dr. V. Palanimuthu, Special Officer, College of Agricultural Engineering, UAS, Bangalore: More than 30 years of experience in the field of Post-Harvest Engineering and Technology and Secondary Agriculture. He has developed several machines and technologies useful to the farming community and food processing industries.

Dr. Ashwani Pareek, Executive Director, NABI, Mohali, Punjab: A prominent plant biologist and educator noted chiefly for his contribution in the area of plant Molecular Biology and Biotechnology. He is currently working as Professor of Plant Molecular Biology and Biotechnology at the School of Life Sciences, JNU, New Delhi, He has keen interest in understanding the physiological and molecular adaptations in xero-halophytic plants and development of transgenic rice plants with enhanced tolerance towards multiple abiotic stresses including salinity and drought.

Dr. Sharanagouda Hiregoudar, Associate Professor and Head, Centre for Nanotechnology, University of Agricultural Sciences, Raichur: He is a prominent scientist in the field of nanotechnology, noted chiefly for his contribution in the area of nano technology applications for secondary agriculture.

Dr. Anil M Naik, Founder, Innovative Food Consultants, Tumkur: He has more than 20 years of experience in food safety systems and quality assurance. He is instrumental in establishing several food processing industries in India and Abroad.

Mr. Prasanna Gudi, Assistant Manager R & D Coffee Processing and Quality at Harley Plantation Research Institute, Sakleshpur: He is an alumnus of Coffee Board of India. He is an innovative researcher in coffee processing and developed several technologies like coffee leaf tea, green coffee, blossom coffee, etc.

Recommendations for Secondary Agriculture

1. Establishment of Directorate of Secondary Agriculture in Government of Karnataka
2. Establishment of rural agro-processing industries with high quality and hygiene.
3. Establishment of agri-food biotechnology institute similar to the NABI in Karnataka
4. Establishment of agro processing centers to take up the secondary agriculture activities
5. Establishment of quality testing laboratory for value added products
6. Establishment of food parks, cold storage, etc.
7. Design and development of suitable processing machines for secondary agriculture.

6. **Panel on Artificial Intelligence and Machine Learning for Technology Enabled Transformation in Agriculture**

Moderator (M): Ravi Trivedi, Officer on Special Duty, Agriculture, Indian Administrative Fellowship

Panelists (P):
P1 : Nipun Mehrotra, Founder, Agri Collaboratory
P2 : Sanjiv Kumar Jha, Solution Architect, Amazon
P3: Trilochan Shastry, Founder CCD NGO (working on farmer cooperatives) and Professor, IIM-Bangalore
P4 : Subrat Panda, CTO, Agnext
P5 : Aadith Moorthy, CEO, Boomitra

Opening Remarks by Moderator: Overview of problems that can be solved using AIML and emerging technologies. Examples include: pest control, price and yield prediction of a particular crop, traceability of product and seed.

Given the amount of data being produced by precision farming and digitization trends, we can learn much from supervised as well as unsupervised learning models to uncover interesting trends and connections hitherto not thought of.

How can AI/ML be a game changer and enable a leapfrog of the Agriculture industry?

Panelist Introductions
P1 : Before AI, Collaboration-Innovation and Execution
P2 : Data Science for Social Good : Smart Agriculture, Agri Stack, and Innovation pod
P3 : *There is money in food but no money in agriculture*
P4 : Company mission - *Quality food for billions* : Trifecta of Data, IOT, and AI.
P5 : How to improve farmer's income enabled by AI

DISCUSSION AND QUESTIONS
Q) Is AI just a fad or a silver bullet (simple and magical solution to all problems)?
Prof Narahari in his keynote talk had shared that we are currently at the peak of hype cycle for AI/ML technologies in Agriculture, and, unless we quickly address and resolve the key challenges, we will be end up in a trough of disillusionment. In that context, do you think AI is just a fad or a silver bullet?

P5 : 'We shouldn't come up with great technology and push it onto the farmer; instead, we should identify the pain points of the farmer and then build the AI based algorithms and technology that will help alleviate the 'pain'. AI is not a silver bullet. It should only be used to solve realistic problems where it can add value.

P2 : AI is unavoidable. We have to learn where and how to harness it. It is technology that opens up attractive possibilities. You do not go putting a weather station in every farm to optimise the farm operations. The scale is important.

Q) What are the moonshots of these emerging technologies?

P4 : Detect disease well ahead of time. Proactively provide the right quantity of nutrients (micronutrients) at the right time.

P2 : Farming as a service- this is only possible through AIML. Subscribe to a service to get visibility of farming lifecycle – pest control, optimal fertilizer application, water management, soil health monitoring, planning for harvest, etc.

P1 : AI is a foundation layer and broad technology; it can tackle any problem; sustainability is important. Two critical use-cases are: access to credit (use data to solve the collateral problem) and access to market (fair price).

Q) What does it take for grassroot adoption?

P1: Solution should ultimately target farmers. Institutions like UAS, NABARD and other agri institutions are only the intermediaries. It is a mission failure if farmers do not get direct access to the technology benefits.

P5 : Barriers to entry should be zero or negative. An example is AI for credit in fintech and agri fintech. Even though the farmer does not directly use AI, he uses an AI enabled service. The real moonshot is transform AI advances to services that are simple, explainable, and farmer-friendly.

P3 : The Government has not been able to convince farmers about MSP in Punjab. Many tall claims have been made but actual material benefits and convincing the farmers are most important. Simple material improvements like cheaper/better fertilizer, better water management, and better nutrients go a long way to improve the trust of the farmer in technology. China doesn't use AI but does much better with lower fertilizer than India even though its cultivated land area is lower. Use whatever AI technology that is appropriate, solve simple pain-points like water, credit, and market access.

Q) Challenges, solutions and governance structures for Data?

P4 : Need for one main directory as there are too many variations and types even for a single crop. Standardizing all these varieties and documenting them is key.

P5 : Data exists but it is all siloed out in multiple organisations and entities. Sometimes the names are different. Data is not high quality so collecting itself is a problem. The key is data quality, data collection training, and data sources.

P1 :11 different varieties of Banaganipalli mango. If all are sold at a standardized rate, then the price advantage is lost to many farmers.

P3: Is data for the farmer or farmer for data? Data is important but is not the silver bullet. The simple thing is that people with solutions should get out of the way and let the farmers solve it themselves. Study the AMUL model that is right in front of us. We don’t need to look for AI and data for everything.

Q) Is only maximising utility for farmers the right question? Should we look at only the economic aspect? Is systemic thinking required?

P4 : Moisture is the biggest killer of produce. For a farmer, it may be a small loss but the supply chain loses out, so systemic thinking is necessary.

P5 : Addressing inequality should be factored into how the model is built. AI should optimise for all, not farmers alone. There is a need for responsible AI algorithms with fairness, transparency, and accountability.

OTHER POINTS AND QUESTIONS

- New income routes should be explored - for example carbon sequestration: gateway for farmers to become more sustainable.

- To scale up the cooperatives to be like AMUL we need funds, social mobilization, organising and coordinating the farmers and empowering them with the ability to do business and earn money.

- The math about yield and market price estimation can be done but the most important thing is validation on the ground. Thus, theoretical solutions are not complete unless they are tested against data

- Training of farmers is very important for grassroot adoption. Social media will play a big role here.

Recommendations

Data Governance and Data Interoperability: The government could take steps to enable seamless translation of agriculture data into valuable information and to obtain "actionable" insights that can be used for proposing solutions for various agricultural use cases. This requires datasets to be seamlessly interoperable across data sources and consumers of data (from govt, private sector, startups, research institutes). Currently there is a gap with respect to agriculture data interoperability for seamless integration across applications. Privacy and security issues need to be accorded due priority. IUDX (Indian Urban Data Exchange) seems to be a good model to adopt. Data to be made available to AIML researchers to make the algorithms better. A team of experts needs to be identified for operationalising the policy as soon as possible.

Sandbox and Pilots for High Impact Applications: The Government should facilitate rolling out innovations that leap frog the growth in technology innovations and help solve the key challenges faced by small and marginal farmers. Two important issues to keep in mind are to ensure adoption at farmer level and also to avoid duplication of efforts. There are many use-cases waiting to be taken up: (a) Price and yield prediction for crops (b) Carbon Sequestration - based incentives, possible for sustainable agriculture. (a) Early pest detection (d) crop recommendation (e) seamless access to credit and insurance, etc.

Enable seamless collaboration: The Government should enable intense collaboration between Agri institutions, engineering institutions, start-ups, and industry in developing and deploying the best AIML solutions for problems that make a difference to the farmers and consumers. This could be promoted by an interdisciplinary technology innovation hub in AIML Enabled Digital Agriculture on the lines of *Technology Innovation Hubs* set up under the DST initiative in inter-disciplinary cyber physical systems.