INFORMATION TECHNOLOGY RESEARCH ACADEMY

A Division of Media Lab Asia

A Report on the

STRATEGY FORMULATION MEETING

Conducted Jointly with

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

On

INFORMATION TECHNOLOGY

IN

AGRICULTURE AND FOOD

March 15-16, 2013

ICARNASC Complex, New Delhi

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PREFACE

This report summarizes the proceedings and outcomes of a meeting conducted by Information Technology Research Academy (ITRA) in collaboration with the Indian Council of Agricultural Research (ICAR). The meeting is another in a series of Strategy Formulation Meetings (SFMs) being conducted by ITRA, each aimed at developing a research and development program in a chosen area. The focus of this meeting was on the use of Information Technology for addressing problems of Agriculture and Food in India. The intent of the meeting, and of the future work that is to follow the SFM, is to treat the two components of agriculture and food together, since they are interrelated. Solving related problems jointly would yield more realisticsolutions. Such an integrated treatment is, however, not very pronounced in this report, mostly because it is still not commonplace in the thinking of scientists and most presentations and discussions, therefore, did not address the food component to the same degree as the agriculture part.

Belowwe firstintroduce ITRA to put the purpose of the SFM in perspective and review the activities leading up to the SFM.

1. ITRA

ITRA is a National Programme to build a national resource for advancing the quality and quantity of R&D in Information and Communications Technologies and Electronics ('IT' for brevity) while institutionalizing an academic culture of IT based problem solving and societal development by closely collaborating teams of researchers and institutions having expertise in the different aspects of the chosen research or application problems. ITRA focuses on strengthening the nation's competitiveness by expanding the R&D base in IT, especially by leveraging the large IT education sector and IT users such as government, industry and other organizations. Initially, ITRA is operating as a Division of Media Lab Asia (MLAsia) which is a not for profit organization of Department of Electronics and Information Technology, Ministry of Communications and Information Technology, Government of India. For more information about ITRA, visit http://medialabasia.in/itra/itra/.

ITRA has been designed to promote problem oriented, team based R&D, by forming and funding problem-responsive teams. The member organizations of a team work collaboratively on solving sub-problems, so their individual solutions come together at the end to constitute the total solution to the original large problem. The teams form centers of excellence in the problem areas. ITRA funds the teams, and then works with them while rewarding performance along the way to continuously enhance the research quality and strengthen the research culture. In addition to the intrinsic quality of the research itself, other measures of performance include the impact the research makes on the quality of teaching programs, development of programs to enhance the societal sensitivity of the team members (i.e. the depth of their sense of connectedness with the society around and the urge to impact it positively), and the extent to which the technologies developed get transferred to actual products and services. These measures are meant tohelp build connectivity of the academic researchers with collaborators in industry, government and NGOs, and promote entrepreneurship and start-ups. The progress made in these areas is to be gauged byspecificmetrics, including the familiar ones such as number of publications, intellectual property developed and patents filed, transfer of technology to industry, joint work with industry, number of PhDs granted, number of faculty/student fellowships, awards and other professional honors, and the numbers of new faculty added.

To ensure that teams work to perform at their best, ITRA is designed to remain engaged with the teams after funding them. This engagement includes devising and employing a range of mechanisms such as fellowships, awards, travel support, etc. to continuously reward performance, help with hiring of faculty, facilitating and supporting collaborations with world-class experts engaged as adjunct faculty, and supporting programs to attract students to PhD. ITRA is aimed at being a long-term

partner of the funded teams, to help with conducting the work itself after the formulation and initiation of the research activities.

ITRA selects large scale problemsthat have large societal impact as well as whose solutions would lead to significant advances in core IT. ITRA fills in the gaps, particularly in the interdisciplinary space, while synergizing with existing other national/other programs. The centers of excellence may have team members from academic institutions, research laboratories, industry, government, research laboratories, NGO's and individual experts both from India and abroad. To reach out to the very large number of IT and related institutions in the country, and in the process also scaling up, ITRA forms a pyramid of academic/research institutions and, through them, their collaborators. The pyramid deepens by adding a new bottom layer of institutions every two-year cycle,thus achieving an exponential growth. ITRA is building the pyramid as a composition of multiple sub-pyramids, each engaged in the work on a separate focus area in IT or IT-in-X (IT applied to the problem domain X).An important role ITRA plays is to provide trained manpower (PhD's, PGs, etc.) at large scale to government, industry and other institutions.

ITRA has initiated two focus areas to date. These are *Mobile Computing, Networking and Applications* (an IT area) and *IT Based Innovations in Water Resources Sustainability* (an IT-in-X area). Information about the associated SFMs is available on the ITRA web site. This current SFM is the third in the series.Its focus area X, Agriculture and Food,is considered as one with a critical need because it represents two major and closely related sectors of the Indian economy and life in general;the performance of these sectors stands to benefit significantly from the incorporation of IT. This focus area is also consistent with the mandate of MLAsia which has been entrusted with bringing the benefits of ICTs and other advanced technologies to the common man.

2. ICAR

As mentioned above, the SFM was conducted jointly with ICAR, headquartered in New Delhi. Central to all IT-in-X focus areas is the expertise in the domain X into which the use of IT is to be integrated. The domain of Agriculture and Food is an old and established discipline, huge and diverse in scope, and already being pursued in India at a commensurately large scale, in a structured manner, under the aegis of ICAR. ICAR is an autonomous organization under the Department of Agricultural Research and Education, Ministry of Agriculture, Government of India. It is the apex body for coordinating, guiding, and managing research and education in agriculture including horticulture, fisheries, and animal sciences in the entire country. With 99 ICAR institutes and 53 agricultural universities spread across the country, this is one of the largest national agricultural systems in the world.Visit http://www.icar.org.in/ for more details.ICAR's participation in ITRA activities in this focus area serves the need for access to domain expertise well. The SFM was conducted with participation of a large number of ICAR scientists.

3. Planning the SFM

As the first step towards exploring the focus area, it was necessary to analyse the area of Agriculture and Food and establish a clear need for an ITRA effort. This was achieved by preparing a white paper that discusses the challenges in Indian Agricultural and Food production systems, how IT can help, state of the art of IT in Agriculture and Food in India andhow that compares with more advanced countries, what steps are neededtowards addressing this need in India, and the potential impact of taking these steps.The paper assesses the extent and criticality of the need for an ITRA effort. It also establishes some parameters that are needed to maximize the effectiveness of the effort, and thus to plan an SFM on IT in Agriculture and Food.

To establish these broad parameters as a preparation for the SFM,a ½-day brainstorming meeting between ITRA and ICAR was organized at ICAR on January 15, 2013. Scientists from ITRA, ICAR, IIIT Hyderabad, the University of Illinois at Urbana-Champaign (UIUC) and Ministry of Agriculture participated. Following is a list of the participants:

ICAR: Director General (DG) Dr. S. Ayyappan. Deputy DGs: Drs. M. M. Pandey, Arvind Kumar, K. D. Kokate and B. Meena Kumari. Assistant DG Dr. Umesh Shrivastava. Director Dr. V. K. Bhatia. Project Director Dr. Rameshwar Singh. Principal Scientists Drs: V. P. Chahal, D. Ramarao.

ITRA/MediaLabAsia/DeitY:ITRA Program Coordinator Prof. Narendra Ahuja, Scientists Shri Gaurav Sharma and Dr. Anurag Kumar.

Academia: Prof. P. Krishna Reddy. UIUC President Prof. RobertA. Easter and Associate Chancellor Pradeep Khanna.

This larger group of scientists did indeed confirm that the Agriculture and Food area has an immense and unfulfilledfor IT based holistic solutions, and that an ITRA SFM would be a good venue to systematically enumerate the major challenges and possible approaches to solving them. Towards identifying the parameters: sevensubareas of Agriculture and Food and nine sub-areasof IT were identified;a number of stakeholder organizations and individuals from them were listed, aimed at ensuring that all efforts across the country get represented, and the roadmap emerging from the SFM is comprehensive and adds to the ongoing and past efforts; and possible members of the SFM organizing committee were named; etc.Annexure 1 presents these outcomes.

A survey template was prepared based on the results of this meeting to solicit the inputs about the parameters identified of the wider community. The survey (Annexure 2)was sent to about 70scientists from IT, and Agriculture and Food subareas for completion and return before the SFM. Among other questions, the survey asked for a list of the highest priority problems thatneed to be addressed in the different Agriculture and Food subareas, thosethat are also IT-amenable, and the types of information technologies(ITs) that are most pertinent to obtaining these solutions. A total of 28 surveys were received, from 12IT and 16 Agriculture and Food scientists.These inputs were used to prepare a final list of parameters to base the SFM on.Annexure 3 lists the five Agriculture and Food subareas used to plan the SFM.

4. SFM Overview

The ultimate objective of the SFM was to develop a work plan, by organizing discussions among Agriculture and Food researchers, preferably those who have investigated the use of IT for solving their problems, and IT researchers, preferably those who have experience with IT interventions in Agriculture and Food problems.The SFM outcomeswill be used to prepare a Request for Proposals to form ITRA teams working on the identified short-term, medium-term and long-term objectives.

The inaugural session presented the context, objectives and the planned follow-ups of the SFM. Following the welcome address by Dr. G. V. Ramaraju, Prof. Narendra Ahuja presented an overview of the ITRA and how the current SFM fits in, and Dr. M. M. Pande reviewed the organization of ICAR and examples of the role of IT in its activities.

In his address, Shri J Satyanarayana, Secretary, Department of Electronics and Information Technology, began with notingthat the demand for annual grain production is expected to increase from 250 MT to 400 MT (with water and land constraints). For that target to be realized, there is need for a Green+IT revolution, like the white and blue revolutions of the previous years. The broadband connectivity now available to about 2,50,000 Gram Panchayats through the National Knowledge Network will go a long way towards using IT not only for agriculture and food, but also forother important areas such as education and healthcare. Additional value will accrue from other ongoing and planned developments, includingDigital Knowledge Centers to be established; a Big Data crunching facility already established in Pune; Data acquisition using sensors; and the emergence of the many field level SMEs in the area who deserve to be supported. Ensuring sustainability of the IT

in Agriculture and Food systems, he said, would require that they be demand driven, providea compelling value propositionbased on a self-service approach, and be locally managed and locally supported.

Dr. S. Ayyappan, Director General ICAR and Secretary Agriculture, welcomed the coming together of IT, and Agriculture and Food researchers, particularly inclusion of food within the scope of deliberations. Hesaid that such teaming and cross-fertilization would help trigger solutions of many vexing problems being faced by agriculture sector in India today. Indeed, this initiative would provide a new opportunity for those in the 65 agriculture universities, including theirfaculty and about 30,000 students, by helping align the powers of youth and information and targeting them on agriculture and food. He expressed the hope that such efforts would make a big difference in the quality of agriculture through better input,technologiesand marketing aids, and even help impart to the farmers the 50 skills they require. He pointed topossible synergy with a new institution being planned onIT in Agriculture, called Indian Institute of Extension Research in Agriculture. He noted that the largest private sector in the country, which is in agriculture and food, would be ready to run with any outputs of these efforts.

Both secretaries said they would look to the recommendations made in this report, and find ways to implement them. They said that they would plan to meet regularly to sustain the cross-disciplinary activities initiated following this report. The main sessions of the meeting began after a vote of thanks by Dr. Rameshwar Singh.

The sessions of the SFM focused on the different objectives of the SFM.About 100 scientists, from academia, industry, government and NGOs, and covering all identified the subareas were invited to the SFM. Agriculture and Food scientists made presentations on the major Agriculture and Food problems in their specific subareas, and their ideas about IT solutions to these problems. To help ensure that the presentations contained all required information, a template was created and sent to them ahead of time (Annexure 4). IT scientists were also given an analogous template (Annexure 5) which they used to present possible IT solutions to the already identified problems and any others.Fortyparticipants represented Agriculture and Food (34 from India and 6 from USA), and represented IT (20 from India and one from USA). Presentations were also made on the specific activities of the presenters and their organizations, including one on the state of the art of IT in Agriculture and Food in the USA. Community opinions were exchanged and the outcomes of the debates recorded in the breakout sessions.The fociiand the organization of the breakout sessions can be seen in the agenda. Following is a summary of the organization of these sessions.

1. As the agenda shows, four breakout sessions were organized, each devoted to one of the four performance/quality measures ITRA uses. Specifically, Sessions 1-4 considered, respectively: intrinsic quality of research, impact of the research performed on curricula, outreach and technology transfer, and development of societal sensitivity.
2. Eachbreakout session was conductedwith five groups of scientists meeting in parallel. The groups were created by having the Agriculture and Food scientistschoose one of the five, already identified Agriculture and Food subareas. In addition, each group also had IT scientists who had chosen to participate in discussions of the group's subarea. A group's discussions were aimed at developing a plan for their subarea so as to maximize progress with respect to the specific quality measure being focused on.
3. Thus, there were a total of 4*5=20 breakout sessions conducted. Each group was moderated by two scientists acting as co-chairs, one each from IT and Agriculture and Food.
4. To initiate the discussions, a separate list of questions was given to participants in each of the four sessions, concerned with what needed to be done to enhance performance with respect to that quality. The groups were expected to explorethe issues related to these questions at the minimum, in addition to any issues they would come up with on their own. These four sets of questions are included in Annexure6.
5. The SFM ended with concluding remarks by the Principal Scientific Advisor to Govt. of India, Dr. R. Chidambaram. He discussed the significance of the subject of the meeting and expressed

his enthusiasm about the possible follow ups. He recalled his meeting with Prof. Robert Easter, President of UIUC - a precursor to the first brainstorming meeting to the current, ITRA-Agriculture and Food initiative. He noted that India needs increased production and farmers need increased income, and that technologies targeted in this initiative address these issues. He gave examples of such technologies aimed at: food processing of surplus produce; radiation sterilization after packaging fruits and vegetables for greater effectiveness; detection and prediction of shortages and excesses; and modeling. He observed that the National Knowledge Network should be of significant value. This network is connected to Euronet, and is expected to be connected to US universities. He emphasized the need for E-Classrooms to meet the shortage of facultyby offering live on-line courses or at least by providing access to archived courses. He mentioned that integration of IT and Agriculture and Food will more likely be achieved by introducing IT at agricultural institutions, rather than vice versa. He gave some examples of IT areas of particular relevance to the initiative, including acquisition and intelligent analysis of large amounts of high quality data, Uttarakhand's Gravity Ropeway and TIFAC's milking machine. He said he favors a slow, evolutionary approach, by first testing technologies in the field and only then transferring them to farmers, since the risk taking ability of farmers is low. The cost of technology and intellectually property should be well matched with the benefits farmers see in them.

The contents of the pre-SFM surveys, the presentations in the main SFM sessions, and the deliberations and recommendations of the breakout groups were obtained from the presenters and the group co-chairs, and compiled and organized for this report. To present these contents, in the following sections, is the main purpose of this report.

New Delhi *Narendra Ahuja*
Monday, September 21, 2013 *(On behalf of SFM Chairs)*

EXECUTIVE SUMMARY

IT is vital to the development, management, and success of businesses and economy. It is also critical to sustainable agriculture – production, planning, marketing, management, and other social agenda items must be carefully thought through. Given the vast nature of agricultural production systems across India, IT can help the average Indian farmer obtain relevant information on markets, inputs, technologies and financing; IT can help in bridging the knowledge gap as it permits geographically distributed organizations to work together more effectively, allowing them to provide mutual mentorship and support; IT can link agricultural producers to increasingly globalized production chains and help develop trade opportunities; and IT can support taking the long-term view, with tools for understanding and planning the future effects of today's economic and land use decisions. Ultimately, IT provides an opportunity to bring qualitative improvement in rural life and thus to India as a whole.

The main objective of this report is to develop a plan of research and development towards realizing large scale field use of IT in agriculture and food (A&F) in India. The intent of the Strategy Formulation Meeting (SFM), and of the future work that is to follow the SFM, is to treat the two components of agriculture and food together, since they are interrelated. Solving related problems jointly would yield more realistic solutions. Such an integrated treatment is, however, not very pronounced in this report, mostly because it is still not commonplace in the thinking of scientists, and most presentations and discussions, therefore, did not address the food component to the same degree as the agriculture part.

The report begins with a general paradigm for using IT in agriculture, and lists classes of some established and immediately usable ITs (Information and Communications Technologies). With reference to this taxonomy of IT, the report then summarizes the state of the art of the use of IT in A&F in India. To illustrate the major advances already made using IT in other countries it provides some examples of IT in A&F common in the US, how they are relevant, adaptable and therefore implementable in the Indian conditions, and how their demonstrated feasibility motivates their widespread use with significant assurance of major returns. The report then presents some example categories of research topics on which an initial effort on IT in A&F may focus. These categories present effectively a partition of the research workspace. For best results, any effort needs to be apportioned so that all categories receive simultaneous attention, to relative degrees that would in general depend on various parameters of the specific application environment. Next, some other directions,complementary to mainstream research, in which work is necessary to enable and enhance the research and development activities and to ensure their sustainability, are presented. Theyare complementary in that together the twosets are intended to form an ecosystem that may be stable in sustaining all of the activities. The various R&D problems listed are shown to correlate well with those mentioned in the 11th Five-Year Plan document put out by the Planning Commission and in ICAR's Vision 2030 document. The R&D problems and the related enabling and enhancement activities are planned as the basis of a Request for Proposals to be issued by ITRA in the second half of 2013. The proposing teams could select a set of problems and activities from those given above, as well as from elsewhere. The number and specific choices of these would determine the coherence and overall thrust of the team's effort.

The categories of agriculture and food problems identified by the SFMfrom which an initial effort may construct its plan are: crop production; soil, water and weather; agriculture education and extension; marketing and agri-business; and livestock and fisheries. The major areas identified under these five categories with high potential for impact are presented below are given below:

3.1. Research and Development Topics in Crop Production

i. Lack of Centralized Data Repositories

ii. Lack of Integrated Crop/Climate/Economic Models for Reducing Yield Gaps and Realizing Yield Optimization
iii. Absence of Country Wide Soil Maps (Physical and Chemical)
iv. Dearth of Expert Systems, Modeling, and Forecasting for Pests/Diseases
v. Poor farm Mechanization, Automation Technologies
vi. Poor Pest and Disease Surveillance
vii. Lack of Innovative Tools/Gadgets for Precision Farming
viii. Lack of Innovative Tools/Gadgets for Harvesting, Grading, Storage, etc.
ix. Poor Food Processing, Quality and Safety
x. Poor Agro-Information Delivery Mechanisms
xi. Other Issues
   (a) Inadequate development and supplies of improved and agro-climatic-zone specific seeds.
   (b) Crop improvement and yield enhancement. This includes prediction, identification and selection of better yielding cultivars.
   (c) Realization of inherent crop yield potential and loss prevention from flood, drought, heat, salinity, climate variability, pathogens, pests, and diseases.
   (d) Acreage data for crops throughout India, to help understand crop requirements.
   (e) Crop specific import/export data on seeds.
   (f) Obtaining an isolated area for seed production.
   (g) Growers' database.
   (h) Dose-response data for each of the nutrients used for each of the tested cultivars (whether released or unreleased) for all major crops, especially rice.
   (i) Ranking of all tested cultivars/varieties by efficiency of nutrient use.
   (j) Phenomics for nitrogen use efficiency in rice/other major cereals/crops.
   (k) Crop yield modeling.
   (l) Variable rate technology.
   (m) Approaches to reduce high level of drudgery involved in agricultural operation.
   (n) Development of specialized machinery for specialized field crops and horticultural crops.
   (o) Declining farm profitability
   (p) Selection of Appropriate Crops/Cropping Systems/Farming Systems
   (q) Farm Mechanization (Shortage of agriculture labor and reluctance of youth to work in the farms.)
   (r) Precision farming (Personalized advice is required as against general advice)

3.2. Research and Development Topics Related to Soil, Water and Weather
i. Weather-Based Agriculture Management
ii. Water Management
iii. Soil Nutrient Management
iv. Saline, Sodic and Acidic Soil Management
v. Water Logging and Drainage
vi. Soil Erosion and Land Degradation
vii. Climate Change
viii. Other Issues
   (a) Low organic carbon
   (b) Quantification of nutrient losses (especially reactive nitrogen and phosphorus) from agricultural fields as pollutants in air, soil, and water.
   (c) Quantification of recoverable nutrients from environment back to agriculture.
   (d) Efficient watershed management.

(e) Accurate climate/rainfall predictions at the village/Taluqa level.
(f) Declining water availability and water quality

3.3. Research and Development Topics in Agriculture Education and Extension

i. Lack of Skills
ii. Lack of Cross-Trained Professionals
iii. Multi-Lingual Content Preparation and Delivery
iv. Coordination Between Research, Extension and Industry
v. Domain Specific IT Tools & Techniques
vi. Research & Development Laboratory Facilities
vii. Other Issues

(a) Right Information Availability: Research on making the right data available at the right time through the right channel.
(b) Ensure technology innovation and development is also usable by women.
(c) Develop a common e-course material (unified syllabus) across the country. Protocol development for standardized e-content and delivery.
(d) Involvement of farmers in the research process, and development of best practices for the required two-way communication. Get students trained in this practice.
(e) Development of content and practices for enabling the rural youth to be exposed to entrepreneurship.
(f) Lack of and/or coordination of IT and agriculture resources: The new professional, i.e. e-kisan, needs new capacity building including in IT and agricultural training resources, materials, etc. Additionally we need professorships, fellowships, and other incentives for promoting R&D and education.
(g) Lack of skilled para-professionals for providing IT-enabled solutions to farmers: Offering diploma/certificate courses with tailor-made curriculum. Need to be skilled in eliciting needs from the farmers whom the solutions are meant to help.
(h) Lack of sufficient distance learning capacity, both in terms of reach and content.
(i) Making the KVK mechanism IT-enabled to increase its effectiveness and reach to a much larger group of farmers, with current human resources.
(j) Lack of Optimum Fertilization and Plant Protection Knowledge. No advice available to a farmer for the specific crop in his field. No soil and leaf analysis data available in most cases.
(k) Farm-specific advice on agronomy, fertilization, crop protection, price discovery, access to credit, seed varieties, etc. can be made easily available on mobile devices.
(l) Building of pest and decease surveillance systems.
(m) Weather-based agro-advisory service.
(n) Crop simulation models for climate change impact and Natural Resource Management (NRM.)
(o) Extension, knowledge dissemination
(p) Pest and disease management
(q) Information management/integration
(r) Networking of experts/institutes
(s) Lack of IT exposure to experts and farmers
(t) Enhancing practical skills of agriculture students to diagnose crop problems
(u) Lack of availability of the right technical (production, protection, etc.) inputs at the right time.

3.4. Research and Development Topics Related to Marketing and Agri-business

i. Easy Access to Market to get Best Price
ii. Product (Crop) Strategy
iii. Developing Affordable Equipment for Quality Assessment and Preservation of Produce
iv. Development of DSS
v. Predicting Right Price and Right Market for the Commodity
vi. Design a System to Empower Agri-Entrepreneurs
vii. Huge Post Harvest Losses (PHL)
viii. Cost of Certification for Traceability (Global GAP – Good Agriculture Practices)
ix. Other Issues
   (a) International crop status, stock levels, price-movement, etc., can be sourced through IT-Tools and accessed via the internet. This information will first need to be analyzed and recommendations subsequently made, since it could be dangerous to provide raw data as most people/organizations may not have the competence to analyze the data, monitor trends, and make correct predictions for the future.
   (b) Risk spreading through co-operatives and other forms of collectives.
   (c) Lack of standards for many food imports.
   (d) Risk management system for food imports clearance.
   (e) Imported food recall.
   (f) Food imports profiling.
   (g) Marketing of perishable agriculture products
   (h) High transaction costs
   (i) Post-harvest management
   (j) Lack of reliable and authentic baseline horticultural data
   (k) Poor marketing infrastructure
   (l) Poor awareness about existing and emerging opportunities in domestic and export markets

3.5. Research and Development Topics in Livestock and Fisheries

i. Efficient Livestock Farming Systems
ii. Automation of Livestock, Poultry, and Aquaculture
iii. Integrated Agri-Animal-Aqua Farming Systems
iv. National Livestock Identification System
v. Animal Identification and Growth Management
vi. Information Delivery and Marketing
vii. Decision Support System for Livestock
viii. Improving Production and Post-Production Quality
ix. Capacity Building of Stakeholders
x. Management of Livestock Under under Climate and Environmental Variations
xi. Other Issues:
   (a) Shortage of animal performance data recording system for health management and breed improvement through selective breeding
   (b) Shortage of feed and fodder resources to feed vast population of livestock and to enhance the productivity of livestock
   (c) Greenhouse gas emission from ruminants of India due to the feeding of poor quality roughages (lack of eco-friendly animal production systems)

(d) Lack of foolproof methods in animal identification techniques resulting in poor record keeping, difficulty in the creation of a database of gene pool and disease onset patterns at the national level, problems in settlement of animal insurance and other related problems.

(e) Animal management, precision dairy farming and performance recording system

(f) Animal disease surveillance system

The other activities,toenable and enhance the proposed R&D are: making an impact on Curriculum and instruction, technology transfer/entrepreneurship and outreach, and development of societal sensitivity. Finally, the relationship of the proposed topics with planning Commission's 11th Five Year Plan on Agriculture and ICAR's Vision 2030 are also discussed.

ORGANIZING COMMITTEE

General Co-Chairs:
Prof. Narendra Ahuja, ITRA, and Dr. M. M. Pandey ICAR

Program Chairs:
Profs. Narendra Ahuja, ITRA; Prasanta Kalita (UIUC); P. Krishna Reddy (IIIT, Hyderabad); and Dr. Rameshwar Singh, ICAR

Arrangements:
ICAR:Drs. Rameshwar Singh and M. M. Pandey and Shri Himanshu Varshneya
ITRA/Media Lab Asia:Sarva-ShriGeorge Arakal, Gaurav Sharma and Omveer Chaudhury

Synthesis of Individual Presentations/Reports from Participants:
Prof. Krishna Reddy; Dr. Arun Pande (ITIM); and Prof. Prasanta Kalita

ITRA-ICAR STRATEGY FORMULATION MEETING IT IN AGRICULTURE AND FOOD
NATIONAL AGRICULTURAL SCIENCE COMPLEX, ICAR, DPS MARG, NEW DELHI

ITRA Agri SFM Agenda		
Friday, March 15, 2013		
8:30		Registration
9:00	10:45	Welcome - Dr. G. V. Ramaraju, MD&CEO, Media Lab Asia
		ITRA Overview - Prof. Narendra Ahuja, Coordinator (PSIG), ITRA
		ICAR Overview - Dr. M. M. Pandey, DDG (Engg), ICAR
		Address - Shri J. Satyanarayana, IAS, Secretary, DeitY
		Address - Dr. S. Ayyappan, Secretary DARE & Director General, ICAR
		Vote of Thanks - Dr. Rameshwar Singh, Project Director, DKMA, ICAR
10:45	11:15	Break
11:15	11:25	SFM Program Overview - Prof. Narendra Ahuja
11:25	13:25	Presentations on Problems by Agriculture and Food experts - Dr. Santosh J Epan, IISR Calicut; - Dr. P.S. Tiwari, CIAE Bhopal; - Dr. P.K. Sahoo, IARI Delhi; - Dr. B.N.S. Murthy, IIHR Bnglr - Dr. V.U.M. Rao, CRIDA Hyd; - Dr. K.N. Singh, IASRI, Delhi; - Dr. A.K. Singh, ZPD Kanpur; - Dr. R.C. Goyal, IASRI Delhi; - Dr. Sanjeev Saxena, Agrinnovative, Delhi; - Dr. V.C. Mathur, IARI Delhi; - Dr. S.K. Singh, CIRG Mathura; - Dr. T.K. Mohanty, NDRI Karnal;
13:25	14:15	Lunch
14:15	14:25	IT in Agriculture and Food Activities in Media Lab Asia - Dr. T.S. Anurag, Sr. Research Scientist, MLAsia
14:25	14:45	IT in Agriculture and Food in the US - - Prof. Prasanta Kalita, UIUC, USA
14:45	15:35	Presentations on Solutions by IT experts - Dr. J Adinarayana, IIT Bombay - Dr. Guntuku Dileepkumar, ICRISAT Hyd - Dr. Naveen Kalra, Tata Chemicals, Delhi - Mr Sanjay Chaudhary, DAIICT Gandhinagar - Dr. Arun Pande, ITIM
15:35	16:15	Summary of Problems/Topics presented, Results of Pre-SFM Survey, and Objectives and Structure for Breakout Groups
16:15	16:45	Break

16:45	19:15	Breakout Sessions A – Research & Development				
		Group 1 Co-Chairs: Profs. Santhosh J Epan; G. Dileepkumar	Group 2 Co-Chairs: Profs. V.M.U Rao; K.K Singh	Group 3 Co-Chairs: Profs. A.K. Singh; Jaideep Shrivastava	Group 4 Co-Chairs: Profs. Sanjeev Saxena; Arun Pande	Group 5 Co-Chairs: Profs. T. K. Mohanty; K. Sarjan Reddy
19:15		Networking Dinner				
		Saturday, March 16, 2013				
9:00	9:45	Presentations by the Breakout Session A Co-Chairs				
9:45	11:45	Breakout Sessions B – Curriculum and Capacity Development (With Tea Break)				
		Group 1 Co-Chairs: Profs. Raghuram; P. S. Tiwari	Group 2Co-Chairs: Profs. J. Adinarayana; H.Chandrasekharan	Group 3 Co-Chairs: Profs. Sanjay Chaudhary; G.R.K. Murthy	Group 4 Co-Chairs: Profs. K.C. Ting; V.C. Mathur	Group 5 Co-Chairs: Profs. Neal Merchen; Nila Rekha
11:45	13:45	Breakout Sessions C - Technology Transfer and Outreach				
		Group 1 Co-Chairs: Profs. Bhaskar Gaikwad; Hariharan Iyer	Group 2Co-Chairs: Profs. K.N. Singh; Naveen Kalra	Group 3 Co-Chairs: Profs. A.K.Chaubey; Joseph Kokini	Group 4 Co-Chairs: Profs. P.S. Pandey; Santanu Chaudhury	Group 5 Co-Chairs: Profs. S.K. Singh; Suresh Purini
13:45	14:30	Lunch				
14:30	16:30	Breakout Sessions D - Societal Sensitivity Development (With Tea Break)				
		Group 1 Co-Chairs: Profs. German Bollero; P Krishna Reddy	Group 2Co-Chairs: Profs. S. D. Samantaray; Narendra Ahuja;	Group 3 Co-Chairs: Profs. Nancy Anabel; Gurdeep Singh;	Group 4 Co-Chairs: Profs. Srinivas Josyula; Suresh Pal;	Group 5 Co-Chairs: Profs. N. Sai Bhaskar; Prasanta Kalita
16:30	18:30	Presentations by the Breakout Sessions B, C and D Co-Chairs				
18:30	19:00	Concluding Remarks by Dr. R. Chidambaram, PSA, GoI				

GLOSSARY

AFS: Agriculture and Food System
APEDA: Agricultural and Processed Food Products Export Development Authority
APMC: Agricultural Produce Marketing Committee
ATMA: Agricultural Technology Management Agency
BMPs: Best Management Practices
CDAC: Center for Development of Advanced Computing
CEWIT: Center for Excellence in Wireless and Information Technology
CFTRI: Central Food Technological Research Institute
CIAE: Central Institute of Agricultural Engineering
CIFT: Central Institute of Fisheries Technology
CIPHET: Central Institute of Post-Harvest Engineering and Technology
CIMMYT: International Maize and Wheat Improvement Center
DSS: Decision Support System
ERP:Enterprise Resource Management
GIS/GPS:Geographic Information System/Global Positioning System
GAP: Good Agricultural Practices
HTML: Hyper Text Markup Language
HRD: Human Resource Development
HYV: High Yielding Varieties
IARI: Indian Agricultural Research Institute
IASRI: Indian Agricultural Statistics Research Institute
ICAR: Indian Council of Agricultural Research
IKSL: IFFCO KIsan Sanchar Limited
IT: Information Technology
ICTs: Information and communication technologies
IISR: Indian Institute of Spices Research
IIITH: International Institute of Information Technology-Hyderabad
IITB: Indian Institute of Technology Mumbai
IIT-Kgp: IIT Kharagpur
IIM: Indian Institute of Management
IMD: India Mateorological Department
IPCC: Intergovernmental Panel on Climate Change
IPM: Integrated Pest Management
INM: Integrated Nutrient Management
ITRA: Information Technology Research Academy
KVK: Krishi Vignan Kendra
MANAGE:National Institute of Agricultural Extension Management
NAARM:National Academy of Agricultural Research Management
NARS: National Agricultural Research System
NAIM: National Institute of Agricultural Marketing
NBAGR: National Bauru of Animal Genetic Resources
NCAP: National Center for Agricultural Technology and Policy
NCCF: National Cooperative Consumers' Federation of India Limited
NDRI: National Dairy Research Institute
NGO: Non-Governmental Organization
NIRS: Near-infrared spectroscopy
NRC on Meat: National Research Center on Meat
NRSA:National Remote Sensing Agency
PC: Planning Commission
PhD: Doctor of Philosophy
PHL: Post Harvest Losses
POP: Persistent Organic Pollutants
POP: Package of practices
PPP: Public-Private Partnership
RCT: Resource Conserving Technologies
RFID: Radio Frequency Identification
RML: Reuters Market Light
SMD: Subject Matter Division
SME: Small and Medium Enterprise
ROI: Return On Investment
TDIL: Technology Development for Language Programme
TIFAC: Technology Information, Forecasting and Assessment Council
TNAU: Tamilnadu Agricultural University
UAS-Raichur: Univrsity of Agricultural Sciences-Raichur
UIUC: University of Illinois at Urbana-Champaign
VC: Vice-Chancellor
WSN: Wireless Sensor Network
XML: Extended Markup Language

SFM REPORT
INFORMATION TECHNOLOGY IN AGRICULTURE AND FOOD
March 2013

India, the second most populous country in the world, represents ~17.4% of the world's population with 1.22 billion people. With a population growth rate of 1.58%, India is estimated to grow to 1.53 billion people by 2030, which would make it the most populous country in the world. This expected increase in population will significantly add to the demand on food production and increase the pressure on the agriculture sector and its prerequisites. The Green Revolution has significantly increased food production in India in the last 60 years (grain production increased from 51 million tons in 1951-52 to 250 million tons in 2012). In recent years, India has had the White Revolution (milk production), Yellow Revolution (Pulses), and Blue Revolution (Fish and aquatic productions), but they are not enough.

Agriculture is an integral part of the Indian economy. Two-thirds of the Indian population lives in rural areas, many of whom depend on agriculture for living. In fact, agriculture employs 53% of the total workforce. The share of agriculture and allied sectors in the gross domestic product (GDP) has declined steadily, from 38.8% in 1980-81 down to 14.2% in 2010-11. There is a growing divergence between overall economic growth and agricultural growth, which carries serious implications. 27% of farmers are not satisfied with farming as a source of livelihood because it is not always profitable; 40% would quit farming if they had a choice.

We must ask ourselves one critical question: can agricultural productivity in India keep up with the rate of population growth? Will we be able to feed the estimated 310 million additional people in 2030? This is a serious challenge for policy makers, agricultural producers, scientists, and economists alike. The goal of the 12^{th} five-year plan is to attain more inclusive, faster, and sustainable growth. It is not possible to attain such a goal without focusing on growth in the agriculture sector. Even in some of the progressive states like Punjab and Gujarat, farmers are facing problems as water tables are receding and cultivable land is becoming less productive. A different but major set of problems must be addressed relating to climate change/global warming (unpredictable cold waves, heat waves, droughts, floods, and exceptionally intense downpours). Environmental problems are increasing in severity and are predicted to have a major impact on agricultural production systems. Farmers require improved technology to combat these and other risks. The government plans to pass the Right to Food Act, which would serve as a viable safety net for the vulnerable population groups among whom malnutrition is particularly high. Good nutrition requires a balanced diet through multiple food sources. With economic growth and changing dietary habits, the demand for fruits and vegetables, milk and milk products, meat, and fish is steadily increasing. Diversification of agricultural efforts to improve the productivity of non-cereal crops such as pulses, fruits, vegetables, milk, and meat is a major challenge. Factors that further compound these problems include limited or diminishing additional land available for crop production, limited and degraded natural resources (soil and water), declining in farm labor availability, and the energy crisis.

Across the country as a whole, 58% of cultivated area is rain-fed, accounting for 40% of the food production. The rest of the cultivated area would not receive enough water even with proper irrigation, which would itself require a massive effort. Rain-fed regions are home to ~40% of the human population and 60% of livestock. The performance of rain-fed agriculture, as well as overall water management, is critical to achieve and sustain higher growth in agriculture.

In view of these conditions, and how other parts of the world have addressed similar problems with success, it is widely felt that there must be a strong emphasis on improving technology to match the increasing demands on agriculture. Agricultural and allied production systems must be made more efficient. A greater focus must be placed on sustainable technology with improved conservation practices to increase production while protecting natural resources. More emphasis is needed on improving land and water management, agricultural trade and markets, and new technologies

tocombat production losses due to crop diseases, draughts, nutrient deficiencies, and other factors. A prominent place among the promising new technologies is held by Information and Communication Technology (IT).

1. Why IT in Agriculture and Food

IT is vital to the development, management, and success of businesses and economy. It is also critical to sustainable agriculture – production, planning, marketing, management, and other social agenda items must be carefully thought through. Given the vast nature of agricultural production systems across India, IT can facilitate improvements in efficiency and productivity of agriculture and related activities. By exploiting IT, it is possible to provide timely and quality information for decision making by stakeholders and farmers during the life cycle of agricultural/livestock production systems and corresponding supply chains. Ultimately, IT provides an opportunity to bring qualitative improvement in rural life and thus to India as a whole.

However, while IT has been successfully deployed in other industries such as banking, insurance, telecom, its potential for the agriculture sector is far from having been realized. For example, the Enterprise Resource Planning (ERP) software which has been widely implemented in agriculture input companies does not cover activities of small retailers and farmers. The supply chain of these companies does not respond to the dynamic nature of agri-input demand of the farmers. Similarly, procurement companies do not have good idea of the dynamic position of the supply of produce in different parts of the country at different times. With widespread expansion of cellular wireless networks and availability of affordable handsets, several companies have started to disseminate point information such as market rates, weather, and plant disease alerts. Other companies and government institutions have built agricultural databases and provided facility to query the databases using WEB technology. Though these simple IT systems are of some value to farmers, IT has a much greater potential to impact agriculture. In fact, IT could become a core technology in all phases of agriculture, starting with seed research ad reaching all the way to marketing of the produce. Following are some examples of solutions and services that represent the untapped potential of IT in agriculture research, education, extension, and marketing.

i. Electronic sensors can send environmental, water, soil, and crop data at specific intervals to an IT platform. This data can be integrated with crop models to predict plant disease. Such an IT-based test bed or platform is useful for agriculture research where electronic sensor-based field data and human observation can be observed remotely and combined to obtain desired results. Through collecting, arranging, analyzing, and processing such data, it would be possible to assess the impact of lab research in the field and use field information to influence research direction.

ii. Tracking and tracing food in the supply chain is quite possible through use of an IT system. Crops can be tracked at the farm level using observations such as the amount of fertilizer and pesticide application through mobile-based local language applications. The information on location, farm, and the farmer who supplies produce can be captured in the form of bar codes on shipment cartons. The bar codes can be integrated with a tracking and tracing application, and hence, food purchased by a consumer can be tracked and traced to a farm.

iii. IT has the potential to enable the transition of breakthrough science to large scale adoption. The package of practice (PoP) for new varieties can be embedded into an IT platform and can be disseminated using IVR and/or SMS technology. The IT platform can pass on the names of non-compliant farmers to village workers who can schedule farm visits in a planned way and contact those farmers to ensure proper implementation ofPoP.

iv. Bio-technology research for developing pest resistant and drought resistant crops could be supported through IT techniques. A combinatorial approach is used to identify novel genes which produce crops with specific trait. Large scale trials are conducted to determine the most viable candidates. This process generates huge amounts of data which needs to be processed. Various data mining techniques could be used on terabytes of data to come up with an effective option for selecting the gene.

The main objective of this report is to develop a plan of research and development towards realizing large scale field use of IT in agriculture and food in India. The intent of the meeting, and of the future work that is to follow the SFM, is to treat the two components of agriculture and food together, since they are interrelated. Solving related problems jointly would yield more realisticsolutions. Such an integrated treatment is, however, not very pronounced in this report, mostly because it is still not commonplace in the thinking of scientists, and most presentations and discussions, therefore, did not address the food component to the same degree as the agriculture part.

In Sec. 2, we first present a general paradigm for using IT in agriculture, and list classes of some established and immediately usable ITs (Information and Communications Technologies). With reference to this taxonomy of IT, Sec. 3 summarizes the state of the art of the use of IT in A&F in India. To illustrate the major advances already made using IT in other countries, Sec. 4 provides some examples of IT in A&F common in the US, how they are relevant, adaptable and therefore implementable in the Indian conditions, and how their demonstratedfeasibility motivates their widespread use with significant assurance of major returns. Sec. 5 then presents some categories of research topics on which an initial effort on IT in A&F may focus. These categories represent a partition of the research workspace. For best results, any effort needs to be apportioned so that *all* categories receive *simultaneous* attention, to relative degrees that would in general depend on various parameters of the specific application environment. Without such an integrated effort, isolated applications may deceptively underperform. Sec. 6 presents other, non-research directions in which work is necessary to ensure sustainability of research activities proposed in Sec. 5. The activities presented in Sec. 5 and 6 are complementary, in that they enable and enhance the R&D activities, and together they are all intended to form an ecosystem that may be stable in sustaining all of the activities. Details of the need for such four-pronged systems in different problem areas are the central objective of ITRA, and can be found at www.medialabasia.in/itra/itra. Sec. 7 shows that various research problems listed in ourresearch and development roadmap in Sec. 6 correlate well with those mentioned in the 11th Five-Year Plan document put out by the Planning Commission (PC) and in ICAR's Vision 2030 document. The contents of Sec. 5 and Sec. 6 are planned as the basis of a Request for Proposals to be issued by ITRA in the second half of 2013. Finally, Sec. 8 presents concluding remarks.

2. Types of IT-Based Decision Support Systems for Agriculture and Food andCorresponding Information Technologies

A decision support system (DSS) is a computer-based program that assists with the decision making process. The program can be quantitative, qualitative, or a combination of both. These programs are important because agricultural production andprocessing systems are complex due to the many biological, chemical, and physicalprocesses involved, and therefore require a great dealof information to be processed for proper management.Information technologies can be used to extract and present the information related to a particular problem in a unified manner and thus speed up decision making. Decision support systems may support agricultural scientists and agro-meteorologists in providing extension services such as expert advice on agronomy, pest or decease problems, risk management for unpredictable weather conditions, efficient marketing of agriculture produce, etc. Decision support systems may also be built to help plan optimal resource distribution or meet emergencies. Hence, it is possible to improve the performance of agriculture by building efficient decision support systems for stakeholders in agriculture and food.

Examples of decision support systems related to agriculture and food problems are as follows:

(i) Pest surveillance systems
(ii) Online disease diagnosis
(iii) Online monitoring of pesticide sales/usage
(iv) Service delivery platform to deliver personalized advice and customized agriculture
(v) Location and time specific plant disease forecasting using Wireless Sensor Network (WSN) and with farmer's participation

(vi) Potential fishing zoneand weather alert services to fisherman
(vii) Characterization of soils with Gamma Radiation detection (Sensor based soil nutrient scanning)
(viii) ICT platform based end-to-end Procurement Services
(ix) ICT Platform to introduce good global agriculture practicesin Indian agriculture
(x) Intelligent agriculture ontology tools
(xi) Use of ICT to improve agriculture supply chain efficiency
(xii) Use of ICT platform to improve efficiency of artificial insemination operation and, offer veterinary and nutrient services
(xiii) Animal management in the Indian production system with different breeds of animals, based on the analysis of data from different animal production systems
(xiv) Diseases diagnosis for animals under different management conditions
(xv) Developing market intelligence systems
(xvi) IT-enabled logistics and supply chain management
(xvii) DSSto supportmarketing and production decisions
(xviii) Interactive DSS (expert systems) to know theavailability of inputs
(xix) Interactive DSS on source and technical details of available hybrids, HYV, seed and planting material
(xx) Development of artificially intelligent agricultural machines, to help reduce drudgery and improve health and safety. This may attract rural youth to work with agricultural machines.

Below we give the details of different kinds of information technologies and corresponding Ag&Food problems each type may be able to impact.Theinformation technologies are grouped under four categories: (i) Environment sensing, location sensing, and communication; (ii) Data management; (iii) Modeling and simulation; and (iv) Data mining and knowledge discovery.

2.1 Environment, Location Sensing, and Communication

The IT technologies included in this category are embedded systems, GIS/GPS, and the Internet of Things: (i) Dedicated hardware and software components can be realized as embedded systems, while incorporating the growing number of sensors that are becoming available. These may be reconfigured into different instruments, e.g., for the purpose of measuring a range of physical parameters such as soil temperature and humidity, and to analyze micro-level impact of such variables on plant growth.(ii) Information systems that integrate, store, edit, analyze, share, and display geographic information for decision making. GIS/GPS technologies provide data sets with spatial and temporal information.They can be combined with other technologies for estimating crop production, draught and change in the farming patterns. In conjunction with sensors, GIS/GPS technologies can be used for developing precision agriculture/horticulture/livestock farming systems. (iii) The Internet of Things consists of devices attached to objects and communication ports, providing data on the internet that can be analyzed and used as feedback, for automatic monitoring and control, or to initiate automatic responses. For example, crop production processes in green houses can be automated by building a system with the Internet of Things.

Types of agriculture and food problems:
(i) Developing soil maps
(ii) Distributed knowledge sharing system by networkingKVKs
(iii) Precision farming bio-indicators, plant cams, wireless networking, and telemetric operations can be used through collaboration among plant scientists, engineers and IT professionals.
(iv) Mechanization with IT-based high technology machines
(v) Automation of agricultural machines would help in reducing drudgery and improving health and safety.
(vi) Development of soil and crop specific agricultural machines and DSS for better soil, crop, and machinery management, sugarcane harvesting, tools for searching and updating databases of equipment manufacturers

(vii) Sensor-based, on-the-go machines for spatial and temporal mapping of soil and crop variability
(viii) Microprocessor, controller, and DSS based machines for site-specific application of agricultural inputs.
(ix) Sensor based animal behaviour recording.
(x) Mobile-based agricultureadvisory services to farmers
(xi) Pest and disease surveillance systems
(xii) Reduction in cost of handsets and delivery charges for farmers
(xiii) Availability of handsets with farmer friendly applications and tools
(xiv) Making access and sharing of information easy for farmers
(xv) Video conferencing (at low cost)
(xvi) Interactive DSS for accessing sources and technical details about storage and processing
(xvii) Animal identification systems
(xviii) Wireless data collection under field conditions
(xix) Livestock disease surveillance systems
(xx) Milking automation
(xxi) Feeding automation
(xxii) Reproduction management systems by maintaining an artificial insemination network
(xxiii) Tracking nomadic herds for health management using GIS, GPS, mobile phones, etc.
(xxiv) Wireless sensor based systems for animal management (heat detection, lameness detection, mastitis detection, climate control, feeding)

2.2 Data Management

Database and data warehousing technologies enable the development of huge integrated databases (text, image, audio and video). Several new conceptual modeling concepts such as object oriented models, ontology, semantic models, XML and HTML have been developed that can be used to design information systems. This may also significantly help the existing processes of agricultural education and practical training by virtually capturing and providing information about diverse agricultural problems. Virtual Laboratories can also be built to enhance skills of students in agricultural colleges.These measures would accelerate research and development.

Ontologies are used for domain specific knowledge representation. On top of ontology, a semantic web based information system can be developed for query processing for better accuracy. Input or query text submitted by a user can be used to perform ontology reasoning to extract knowledge from the ontology. For example, from a text input, describing the symptoms observed by a farmer on a specific crop, ontology reasoning can extract knowledge or provide recommendations on appropriate measures to improve crop production or handle adverse effects of such symptoms on the crop. Such systems can be used by agricultural extension workers to resolve farmers' queries.

Types of agriculture and food problems:
(i) Expert system on soil analysis
(ii) Crop modeling
(iii) A database on HYV (released by ICAR)
(iv) A national portal on seed production systems/nurseries
(v) Developing integrated plant breeding and genetics data
(vi) Virtual learning environments
(vii) Developing e-courses
(viii) Developing content to enhance practical agriculture education
(ix) Developing a database of teaching and extension materials
(x) Strengthening digital library under NARS
(xi) Developing a repository of PhD theses involving Indian agriculture and food
(xii) Developing authenticated content
(xiii) A national bioinformatics grid
(xiv) Crop-specific knowledge management portals

(xv) Creation of a complete database of the transportation machineries, manufacturers, service providersand inventory
(xvi) Soil nutrient mapping, creation of digital maps for use in variable rate applicators
(xvii) Animal management database
(xviii) A horticultural information system on the area, production, productivity, prices and arrivals
(xix) A dedicated plant genetics information system on a single platform for agriculture
(xx) A database system for recording performance of recognized breeds
(xxi) An information management system for livestock genetic resources

2.3 Modeling and Simulation

Modeling and simulation technologies can be used to model a system and to understand its behavior under varying input conditions and component behaviors. It can be used for efficient natural resource utilization, developing efficient crop production systems, studying the impact of unpredictable weather and climate change, predicting pest/decease occurrence, and predicting crop productivity, or market behavior/demand, risks, etc.

Types of agriculture and food problems:

(i) Simulation models for crops/cropping systems (their development, parameterization, validation, and application)
(ii) DSS for site specific inputs management (soil fertility delineation and nutrients' management, on-farm water management, Integrated Pest Management (PM), Resource Conserving technologies (RCT) & Best Management Practices (BMPs)
(iii) Weather-based agro-met advisory service
(iv) Soil health service and Persistent Organic Pollutants (POP)
(v) Climate change and its impact on agriculture
(vi) Yield prediction
(vii) Optimizing fertilizer use
(viii) Weather forecasting

2.4 Data Mining and Knowledge Discovery

Data mining/knowledge discovery can be used to extract knowledge/patterns from large databases. IT experts can apply different approaches to extract the knowledge/regularities hidden in textual data and structured databases. A huge amount of relevant spatial and climatic data is available from different organizations. Spatial data mining can help to study the impact of climate change and generate recommendations for crops affected by climate change.

Types of agriculture and food problems:

(i) Agriculture universities have strong databases regarding research experiments performed on research farms related to different crops. Pattern extraction can help in understandingthe crop behavior.
(ii) Extracting thehidden patterns to generate recommendations regarding various crops.
(iii) Text mining can be used for extracting knowledge from text /unstructured data
(iv) Market intelligencesystems
(v) Weather analysis and pattern recognition
(vi) Weather-based market forecasting

3. State of the Art of IT in Agriculture and Food in India

A number of efforts have been made to use IT to improve the performance of agricultural research, education, and extension. Some of the major ones are summarized below.

(i) As a part of the National Agricultureal Technology Project (NATP), the ICAR Institutes have developed software systems such as those named/outlined below.

(a) Database Management Systems: For Genebank Management, Identification and Management of Nematodes in India, Poultry Disease Diagnostics and Remedies, Animal Genetic Resources of India, Agricultural Pest Information, Pulse Information for Uttar Pradesh, and Potato Pests.
(b) Application Software Systems: For Implementing HACCP by Seafood Processing Plants and Identification of Eggs and Larvae of Parasites.
(c) Expert Systems: For Grape, Cabbage and Mushroom Cultivation, Cotton Insect Pest Management, and Statistical Quality Control of Dairy Plants.
(d) Simulation Systems: A model, RAINSIM, for Rain Water Simulation.

(ii) As a part of National Agriculture Innovation Project (NAIP), ICAR has initiated the research projects outlined below.

a) KrishiPrabha - Indian Agricultural Dissertations Repository (Proponent: Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar)
b) Consortium for e-Resources in Agriculture (CeRA) (Proponent: Indian Agriculture Research Institute, New Delhi).
c) Development of e-Courses for B.Sc. (Agriculture) degree program (Proponent: Tamilnadu Agriculture University (TNAU), Coimbatore, Tamilnadu).
d) Development of e-Courses for Bachelor of Veterinary Science and *Animal Husbandry (*B.V.Sc. & A.H). degree program (Proponent: Tamil Nadu Veterinary and Animal Sciences University (*TANUVAS*), Chennai).
e) Re-designing the Farmer-Extension-Agricultural Research/Education Continuum in India with ICT-mediated Knowledge Management (Proponent: ICRISAT, Hyderabad).
f) AGROWEB – A Digital Dissemination System for Indian Agricultural Research (ADDSIAR) (Proponent: National Bureau of Plant Genetic Resources (*NBPGR*) New Delhi).
g) Development of e-courses for Bachelor of Fisheries Science (*B.F.Sc*) degree programme (Proponent: Karnataka Veterinary Animal & Fisheries Sciences University (*KVAFSU)* Mangalore, Karnataka).
h) Development of e-courses for B.Sc.(Horti.) degree programme (Proponent: University of Agricultural Sciences (UAS), Bangalore).
i) An E-Publishing and Knowledge System in Agricultural Research (Proponent: Directorate of Information & Publication of Agriculture (*DIPA*), ICAR).
j) E-Home Science Courseware Consortium (Proponent: Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad).
k) A Decision Support System for Agricultural Commodity Market Outlook (Proponent: National Centre for Agricultural Economics & Policy Research (*NCAP*), New Delhi).
l) Development and maintenance of a Rice Knowledge Management Portal (Proponent: Directorate of Rice Research (DRR), Hyderabad).
m) Establishing and Networking of Agricultural Market Intelligence Centres in India (Proponent: TNAU, Coimbatore).
n) Strengthening Statistical Computing for National Agricultural Research System (NARS) ((Proponent: IASRI, New Delhi).
o) A DSS for Enhancing Productivity in Irrigated Saline Environment using Remote Sensing, Modeling and GIS (Proponent: CSSRI, Karnal).

p) Strengthening of digital library and information Management under National Agricultural Research System (NARS) (e-GRANTH) (Proponent: Indian Agricultural Research Institute, New Delhi).
q) Mobilizing mass media support for sharing agro-information (Proponent: DIPA, New Delhi).
r) Integrated Information Dissemination System (IIDS)for dissemination of farm and farmer specific advisories / information at user preferred mode (voice, text, image) and time. (Proponent: MediaLab Asia, Acharya N G Ranga Agricultural University, National Institute of Rural Development, Mudra Institute of Communications)

(iii) As a part of MLAsia activities,DeitYhas initiated the research projects outlined below:

a) *eSagu*– An IT-based personalized agricultural advisory system based on the crop images and farm history.Digital photos of crops sent to agricultural scientists & customised advice sent back to coordinator / farmer (Internet and Mobile). Delivered 100,000+ expert advices to 13000+ farmers on 32 different crops covering 200+ villages in 7 districts of Andhra Pradesh.
b) *aAqua* - Web based discussion and advisory forum for farmers. It allows users to create, view and manage content in their native language.Technology is transferred on non exclusive basis for large scale deployment.
c) *AgroSense* - A cost effective Wireless Sensor Network device, which helps in real-time monitoring of the Agro-Metrological parameters like temperature, humidity, rainfall and wetness of soil, electrical conductivity, soil PH.
d) *DEAL* - A Multimedia platform f**o**r creation, sharing and dissemination of agricultural information among farmers and experts.Created an ontology based agricultural vocabulary database in Hindi with more than 28,000 agricultural items
e) *Community Radio*: Community Radio Stations at five SAU were commissioned, namely in Faizabad (UP), Ranchi (Jharkhand), Coimbatore (TN), Hisar (Haryana) and Raipur (CG).
f) Gramin Gyan Kendra - Models for use of ICT to improve social infrastructure and public interaction for the emerging knowledge based society. Nine Gyan Kendras in Vindhya region of U.P is established under the project.
g) Integrated Agri Services Program (IASP) - Model for delivery of a portfolio of agricultural advisory, financial services, input services, output procurement and information services on a single platform, in a commercially sustainable manner.
h) Integrated Information Dissemination System (IIDS) – The consortium led by Media Lab Asia has studied major ICT initiatives in Agriculture in India vis-à-vis information need of the Indian farmers. Based on the field study (1381 farmers from 57 villages across 12 states) and analysis of 26 ICT initiatives, an Interactive Information Dissemination System (IIDS) for farmers has been developed. The IIDS is an integrated system with a combination of IVRS, Mobile Application and Interactive Portal for dissemination of farm and farmer specific advisories / information at user preferred mode (voice, text, image) and time.
i) Mobile Based Agricultural Extension System in North-East India (M4Agri NEI) -To empower the farmers by providing right information at the right time. (Proponent: Central Agricultural University (CAU), Imphal &MediaLab Asia)

(iv) As a part of C-DACactivities,DeitYhas initiated the research projects outlined below:
a) Ubiquitous Agriculture (u-Agri)Application of Wireless Sensor Networks (WSN) in the Agricultural Domain, for micro climate monitoring. (Proponent: C-DAC Hyderabad and Central Research Institute for Dryland Agriculture (CRIDA),
b) Ask an Expert:The Ask an Expert application seeks to connect the experts and users in an authentic, efficient and coordinated manner. (Proponent: C-DAC Hyderabad)

c) Dynamic Market Information -Dynamic Market Information (DMI) seeksto provide accurate market related information to farmers and related stakeholders on daily basis. (Proponent: C-DAC Hyderabad)
d) e-Vyapar - e-Vyapar is a buyer-seller platform which facilitates information exchange between buyers and sellers. (Proponent: C-DAC Hyderabad).
e) Real Time Weather forecast -The service aims at providing 72 hour weather forecast information at mandal/block level. On a pilot basis, the forecasts were made available for over 31,000 stations spread across **six** states (Proponent: C-DAC Hyderabad).
f) Climate Controlled Research Greenhouse -Climate control system for research greenhouse suitable for climate resilient agriculture /transgenic research. (Proponent: C-DAC Mohali)
g) Wireless sensors for field application -Low power wireless sensor motes for easy deployment both in greenhouses as well as in the field. (Proponent: C-DAC Mohali)
h) Low Cost Programmable Irrigation Scheduler :Low cost time based irrigation scheduler as an import substitute which performs user defined functions and controls appropriate actuators (i.e., solenoid valves, and motor) to irrigate the fields. (Proponent: C-DAC Mohali).
i) Tele-veterinary -Telemedicine has now been considered as a parallel healthcare delivery system, so much so that apart from humans, this technology is now being extended to animals. (Proponent: C-DAC Mohali).
j) Hydroponics -It plans to design and develop an automatic hydroponics feeding system to increase agricultural production in the areas of infertile soil as because it does not involve the use of soil. (Proponent: Chaudhary Sarwan Kumar Himachal Pradesh Krishi VishvavidyalayaPalampur (CSK HPKV) and C-DAC Mohali).
k) Development of electronic nose for monitoring industrial obnoxious odorous constituents generated from pulp and paper industries under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: NEERI Nagpur& C-DAC Kolkata)
l) Web Enabled Access of Agricultural Information under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: Birsa Agriculture University, Ranchi& C-DAC Kolkata)
m) Application of Digital Image Processing Technologies in Tasar Sericulture. (Proponent: PRADAN, Jharkhand & C-DAC Kolkata)
n) Exploratory study / scientific investigation / Experimentation to monitor thickness of silk yarn online during spinning / reeling operations under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: PRADAN Jharkhand& C-DAC Kolkata)
o) Investigation of possible technologies for estimation of silk content in a cocoon in non-invasive manner under Application of Electronics for Agriculture & Environment" (eAgriEn) (Proponent: PRADAN Jharkhand& C-DAC Kolkata)
p) Development of Handheld E-Nose employing Embedded systems and indigenous sensors made by Sensor Hub under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: C-DAC Kolkata)
q) Development of Membrane Electrode Array Based Novel Sensing System for Rapid Taste Characterization of Food and Agro Produces under Application of Electronics for Agriculture & Environment" (eAgriEn). (Proponent: IIT Kharagpur& C-DAC Kolkata)
r) Developing tools for a Decision Support System Framework for Tea Production System using a Wireless Sensors Network (WSN) under Application of Electronics for

Agriculture & Environment" (eAgriEn). (Proponent: Tea Research Association, Jorhat& C-DAC Kolkata)

s) Olfaction for Biotechnology with specific Application of (Proponent: C-DAC Kolkata):
   i. Soil quality testing for fertility
   ii. Waste water quality monitoring
   iii. Quality estimation of Cardamom
   iv. Cheese ripening process

t) e-safeT "Temperature Data Logger-The e-SafeT is a compact, ultra-low power data logger consisting of a High resolution temperature sensor, Memory, Visual indicators and Wireless link. (Proponent: C-DAC Noida)

u) Intelligent Advisory System for Farmers (IASF) -To develop an advisory system for farmers of north eastern states which will provide them automatic answers to their farming related queries**.** (Proponent: C-DAC Mumbai). Project aims to develop an Intelligent Advisory System (expert system) for automatic answering queries related to farming activities carried out in North-eastern states of India.

(v) As a part of DeitY, TDIL has initiated the research projects outlined below:

a) Voice based Information Access for Agricultural Commodity Prices (Automatic Speech Recognition in Indian Languages) -Automatic Speech Recognition (ASR) engines for Agricultural Commodity Prices for six Indian Languages namely Hindi, Marathi, Bengali, Assamese, Tamil and Telugu languages have been developed. (Proponent: TDIL)

b) Text to Speech (TTS) in Indian Languages -Text to Speech systems integrated with screen reader for 6 Indian Languages namely Hindi, Bengali , Marathi Tamil , Telugu and Malayalam languages have been developed**.** (Proponent: TDIL)

c) Other Multilingual Technologies-Various Multilingual technologies and Software Tools such as Machine Translation systems, Transliteration , Open Office , Localized Web Browsers and Fonts have been developed. (Proponent: TDIL).

(vi) Other Efforts

(a) Efforts have been made to connect all ICAR labs, KVKs and agricultural universities, and to strengthen e-connectivity within agricultural universities.

(b) A National Agricultural Research Database was developed and bibliographic inputs were provided for inclusion in AGRIS database.

(c) The government of India has decided to launch a central scheme called AGRISNET. The objective of AGRISNET is to provide improved services to the farming community through use of ICT.

(d) A system called Agricultural Knowledge Management Unit (AKMU) is being implemented to bring information management culture to NARS so that agricultural scientists can carry out research more effectively by having systematic access to information available in India as well as in other countries, better project management of agricultural research, and modernization of office tools.

(e) To resolve the crop husbandry related problems, the Ministry of Agriculture, Departments of Agriculture, Ministry of Information and Communications Technology, and Agricultural and Horticultural Universities are making efforts to facilitate the advances in agricultural/horticultural technologies to reach farmers through Web Portals; Kisan Call Centers, etc.

(f) Some other important efforts to disseminate information to farmers are eSagu, agropedia, aaqua, and digitalgreen.

(g) For planning/forecasting purposes, GIS/GPS based systems are being used (National Remote Sensing Center, Hyderabad).
(h) Agricultural Marketing Information System (AGMARKNET) has been developed and operated by Directorate of Marketing and Inspection, Department of Agriculture and Cooperation, Ministry of Agriculture. It is a Mission Mode Project, started under National-Governance Action Plan (NeGAP) 2005.

4. Relevant IT in Agriculture and Food in the US

Crop yield in India is lower as compared to other developed agricultural countries because of limited use of IT in agriculture. Mobile phone technology is a big industry in India. However, the use of this technology to improve agricultural productivity and rural areas in general is limited, while IT applications in industrial sectors have made rapid progress. In contrast, in many developed countries, (including the USA) the application of IT in agricultural research and development has revolutionized the farming system, research, and extension, sustainable agricultural development, and participatory research. Some common IT applications involve the use of geo-spatial technologies, pre-harvest production forecasting of major crops, crop assessment based on soil moisture availability, development of farm and regional scale digital soil maps for assessing land suitability for crop production, short and long range weather forecast, cropping system analysis, site suitability for horticulture development, and wetland inventory and assessment for inland fishery development. IT in agricultural extension has benefitted agricultural extension activities through having location-specific modules of research and extension and promoting market extension.

4.1. Ag & Food Problems Addressed in the US that are Relevant to India but Unaddressed

The agriculture and food system (AFS) is a complex bio-based economic engine. The goal of the AFS is to produce and utilize food, feed, fiber, fuel and furnishing in a sustainable and competitive manner. The top level tasks of the AFS include production, processing and manufacturing, utilization and consumption, and finishing and maintenance. IT provides capabilities of information processing and physical work including perception, reasoning and learning, communication, task planning and execution, and systems integration and decision support. Opportunities exist to create an intelligence-empowered AFS through effective interfaces. The positive driving forces are a higher technology readiness level; building on the past success of agricultural knowledge, mechanization, and modeling capabilities; effective communication systems and computational platforms; improved economic situation; better market acceptance; potential spin-off technologies; facilitating implementation of emerging technologies, etc. The IT resources needed to empower the AFS are informatics, computer modeling, analysis (in the forms of computation, simulation, and optimization), decision support, and effective actions. All of these need to take into consideration the content, audience, delivery, and action.

4.2. Some Examples of IT Solutions in the US

Many institutions in the US are making significant progress employing IT in agriculture, resulting in a significant improvement in agricultural production, processing, and marketing systems. The following are some examples of IT being used successfully in agricultural systems in the US.

(i) Remote and proximity sensing techniques have been developed to monitor pre-harvest crop growth and development to inform site-specific crop management. Sensors and control systems have been used to advance granular application technology and create a smart spreader system, which has been incorporated into all-in-one systems to provide GPS guidance, automatic rate control/monitoring, and GIS. One application is the integration of in-field real-time N stress sensing and sensor-based variable rate application of fertilizer.
(ii) Yield prediction models, based upon soil characteristics, have been produced for use in the determination of bond release for the reclamation of coal mining land.The maps

show similarity between actual and predicted grain yields. Strip cropping of corn and soybean has also shown great promise for the central US.This is now possible because of GPS guidance on equipment and variable rate seeding.

(iii) One prospective application in animal agriculture involves monitoring of activity or other indicators that can be correlated to health or production characteristics, and translating that information into simplified tools for decision making by the farmer. As an example, the activity level of dairy cows has been shown to be related to the development of certain health problems.The IT applications would require collection and analysis of the indicator (activity) data and delivery of the results (prediction of health outcomes) to the farmer in a simplified way – perhaps to a cell phone or other hand-held device.

(iv) A National Science Foundation supported Industry/University Cooperative Research Center (I/UCRC) for Agricultural, Biomedical, and Pharmaceutical Nanotechnology has been in operation at the University of Illinois at Urbana-Champaign. The core themes of the center include: photonic sensors for live organisms, drugs and toxins; microfluidic biochips for cell counting for food safety; imaging of seeds and grains for online quality determination; gene expression analysis enhanced by photonic crystals for plant and animal systems; safety evaluation of bionanomaterials; MECS for integrated monitoring of soil nutrients; SERS determination of nematodes and pests; biodegradable fluidic platforms for handheld sensors (e.g. moisture in soil); 3D biofabrication with stereolitography; bionanoparticles for delivery of bioactives; and nanocomposite intelligent packaging.

(v) A project on engineering solutions and supply chain analysis for biomass crop production has been aimed at facilitating the movement of biomass from the fields to the points of utilization. IT has been applied to four tasks that cover the value chain of pre-harvest crop monitoring, harvesting, transportation, and storage. A fifth task of systems informatics and analysis has been the integration of supply chain materials handling and logistics using database, modeling, simulation, optimization, and decision support methodologies.

(vi) Grain harvesting systems require coordination of the operations of harvesting combines, in-filed grain carts, over-road semi-trucks, and drying/storage elevators. Decision support systems have been developed to enable real-time communication among and issue proper actions to the operators of the equipment and facilities. The purpose is to optimize the resource use.

(vii) As alluded to above, a biomass production and provision ConSEnT (concurrent science, engineering and technology) platform is being developed to provide protocol and management of data collection, storage, processing, and retrieval; computer models of crop production and provision systems; analysis of the impact of technologies, infrastructure, geographic and environmental factors, and agent strategies; and a web-based decision support system.

(viii) Examples of online data sources for agriculture include: WARM program that provides weather, soil temperatures, streamflow, groundwater levels, and growing degree days. NADP collects precipitation samples from around the US and analyzes for contaminants. A floodplain mapping program provides digital flood maps at the watershed scale. A geospatial data clearinghouse provides access to many GIS datasets.

(ix) Elluminate is the online course delivery system for off-campus graduate classes. Polycom and MeetingPlace are used for internet conferences, seminars, and short courses. Distance diagnostics allow extension staff to submit digital pictures for pest identification and to receive control recommendations. Online training sites are available for specialized audiences.A certificate is provided after successful completion of modules. Delivery via smartphones is being investigated.

4.3. Applicability and Adaptability of these Solutions to India

Agricultural operations in India are not taking advantage of the IT tools that exist today. As the agricultural industry continues to evolve, IT utilization is critical to the continued competitiveness/survival of individual operations. IT in agriculture in more advanced countries has facilitated bringing timely and reliable information for making decisions, prevention of crop diseases, timely application of irrigation to prevent production losses, animal health protection, increased market opportunities for all farm products, and better crop yield forecasting. Even though the farm size is often larger and framing systems are different in advanced countries, many of the research advances used there are relevant in the Indian context.Some examples are:

Widespread use of mobile (cell phone) technology in India**:** Develop apps for more efficient irrigation scheduling, plant disease identification and treatment, weather updates, use of satellite images and remote sensing for crop stress monitoring, and soil moisture sensing

(i) Preparation of a nationwide soil database (like USDA-NRCS has done in USA)
   (a) Possible collaboration with experts from USDA-NRCS
   (b) Soil database can be used for irrigation and drainage system design as well as soil fertility and productivity assessment
   (c) Overlay of soil, rainfall and elevation information for land suitability analysis of agricultural crops

(ii) Use of IT from farm to market
   (a) Use of information technology to link farm to the market
   (b) Use of IT to refine the market models

(iii) Managing farmers'crop database: The database includes the kinds of crops, the size of cultivated area, time of harvest and yield. Farmers or the extension personnel transmit those data via the internet to a database server.

(iv) Creating crop information service systems: There are many ways in which IT can be used to exchange information more effectively, such as information kiosks that provide not only basic services like email but also help with education, health services, agriculture, irrigation, online trading, community services, etc.; expert systems that help with determining marketing alternatives and optimal strategies for producers, and integrated crop management for different crops.

5. R&D Topics

IT based interventions are likely to lead to an increase in agriculture and food productivity. Following are some examples: IT can help the average Indian farmer obtain relevant information on markets, inputs, technologies and financing; IT can help in bridging the knowledge gap as it permits geographically distributed organizations to work together more effectively, allowing them to provide mutual mentorship and support; IT can link agricultural producers to increasingly globalized production chains and help develop trade opportunities;andIT can support taking the long-term view, with tools for understanding and planning the future effects of today's economic and land use decisions.

Significant research advances are taking place in IT (data management, information systems, communication, sensor networks, modeling and simulation, data mining, etc.)andagriculture (green house technologies;high yielding, climate resistant and draught resistant varieties; new storage techniques; etc.). IT and agricultural researchers are both making independent and isolated efforts. The current need is to start collaborative projects carried out by interdisciplinary teams consisting of researchers from agricultural and IT sectors.

Succinctly, what is needed is a large number of institutions – faculty and PhD students -collaborating intensely on advanced research and development motivated by specific challenges faced in the field. These teams should simultaneously develop and improve curriculum on a regular basis. For creatively

identifying and formulating problems, the team members need to develop an awareness of them in daily life. Finally, there need to be effective mechanisms to enable transfer of the technologies to real world.

The agriculture and food problems are listed under five categories: crop production; soil, water and weather; agriculture education and extension; marketing and agri-business; and livestock and fisheries. The main objectives of providing this list are the following:

1. To indicate that they are seen as being important by a broad cross section of A&F R&D community.
2. However, each problem is not to be viewed as a standalone undertaking, e.g., to form a proposal from. A good R&D team effort will have a grander goal -a system with a suitably chosen set of topics listed here as coherently interacting, important components of an integrated system, serving an overarching objective of solving a larger problem.
3. Any plan built around these topics is to include a minimal complementary effort in the other three categories of activities, described in subsections 5.2-5.4.

We now provide a brief description of each category and provide a list of corresponding problems.

(i) Crop Production : Under this category we consider production related issues pertaining to cereals, pulses, fruits, vegetables, spices, flowers, oilseeds, etc. The topics under crop production include seed production systems and planting material, crop production systems, protected cultivation, farm mechanization, farm management, precision farming, pest/disease management, biotic stress management, post harvesting management and food processing systems.

(ii) Soil, Water, and Weather: This category covers issues concerning better management of soil, soil mapping, weather forecasting, abiotic stresses, environment management, disaster management, and natural resources management.

(iii) Agriculture Education and Extension: We must cultivate the next generation of students', scientists', and professionals' practical and advanced research skills. Related goals are extending crop technologies to stakeholders (including farmers), reducing the lab to land gap, improving capacity building/training of stakeholders, providing real-time advisory to farmers, and establishing farmer expert connectivity.

(iv) Marketing and Agri-Business: The areas include efficient procurement, storage and supply of quality agricultural produce and processed goods to consumers, sale of produce by farmers, market intelligence, etc.

(v) Livestock and Fisheries: This category is about scientific herd/flock management, management of semen stations and information on availability of semen, milk collection, storage and processing; production and availability of fish seed; marketing of fish and aquaculture produce; marine fishing and logistics; fish processing; and production, protection, education, extension, and marketing of animals and animal products.

The major areas with high potential for impact are presented below, under the preceding five major topics. Examples of IT in agriculture work associated with each of these topics are given in following sections.

5.1 Research and Development Topics in Crop Production

5.1.1 Lack of Centralized Data Repositories

(i) Problem statement: Information on any aspect of agriculture is not readily available in India for researchers, farmers, or policy makers, whether pertaining to valuable germplasm collections, or the simple but basic information on farm holdings, or planting

materials. Likewise, information on high yielding varieties, agri-service providers, best practices, impact stories, land use patterns, research publications, etc., if at all available, is highly segregated. Additionally, this information is often available only in print form. This lack of scientific and authentic information resources is exploited by middlemen. Hence, there is an urgent need to collate all these in one place, in a readily accessible format, and preferably in local languages.

(ii) Challenges and Needs: Highly scattered data, Presence of various agencies, IPR issues , Data integration and warehousing, Crowd sourcing, Ontology/ semantics

(iii) Sources/Areas of Required Expertise: Researchers, IT professionals, and Library professionals.

(iv) Specialized Facilities that would Help Enhance Quality of Work: A centralized knowledge hub, Regional data centres, and Call centres.

(v) Impact and Stakeholders

(a) Impact: Providing authentic and scientific information can revolutionize Indian agriculture. Once such information is made available to Indian farmers, they will greatly increase productivity with improved varieties and genuine agro-inputs. Similarly, a nationwide compilation of research data will immensely benefit our researchers, policy makers and developmental agencies.

(b) Stakeholders: Researchers, students, farmers, development agencies, and policy makers.

(c) Evaluation metrics:Number of databases developed, coverage of databases, content of databases, and accessibility.

(d) Evaluation can be carried out by forming a panel of experts.

5.1.2 Lack of Integrated Crop/Climate/Economic Models for Reducing Yield Gaps and Realizing Yield Optimization

(i) Problem Statement: Simulation models of crop growth help to make projections of productivity based on future climate scenarios, which are essential in view of future food security. In India, some models have been developed for a single crop or part of a crop, often developed independently. Considering the diversity existing in India, we need models that can handle multiple crops in complex rotations and under varied management, weather and soil conditions. We need to link climate, crop, and economic models with cutting-edge information technology to produce improved models capable of projecting climate impact. Such robust crop models will help identify regional vulnerabilities, changes in comparative advantage, price effects, and potential adaptation strategies in the agricultural sector. Finally, multi-model assessments that integrate the range of uncertainty in crop, climate, and economic modeling will improve our understanding of agriculture futures.

(ii) Challenges and Needs: Diverse crops/locations, Need for village level weather data , Crop modeling and simulation, estimation, prediction, Artificial intelligence , Decision support system

(iii) Sources/Areas of Required Expertise: Agricultural scientists, Climate scientists, Mathematicians, Socio-economic scientists, IT professionals.

(iv) Specialized Facilities that would Help Enhance Quality of Work: Supercomputing facility, Automatic weather stations, and Networking.

(v) Impact and Stakeholders

(a) Impact: The development and validation of crop models can improve our understanding of the underlying processes, pinpoint where our understanding is inadequate, and thereby support strategic agricultural research. Decision support systems derived from these models combine the technical knowledge contained in crop growth models with economic considerations and environmental impact evaluations to facilitate economic analysis and risk assessment of farming enterprises. Modeling provides invaluable support for strategic investigations

into the impacts of climate change, land use, and water use. The knowledge-based systems approach offers great potential to expand our ability to make good agricultural management decisions, not only for the current climatic variability, but for the anticipated climatic changes of the future.

(b) Stakeholders: researchers, students, farmers, development agencies, and policy makers.

(c) Evaluation metrics: Number of models developed, number of crops covered, integration of models, and validation.

(d) Evaluation can be carried out by forming a panel of experts.

5.1.3 Absence of Country Wide Soil Maps (Physical and Chemical)

(i) Problem Statement: Soil is a fragile resource and needs to be understood and protected, especially in a country like India which is quite vast and diverse.It is vital for healthy ecosystems, food production, and the economy. Decision-makers need accurate, consistent, and functional information about soil resources to determine the best use of land resources.Soil databases of India, if at all existing, are incomplete in scale, age, and quality. Many maps do not adequately describe the underlying properties of the soil types they represent. We need to develop comprehensive and quantitative soil information to support sustainable agricultural development and scientific modelling.

(ii) Challenges and Needs: Geographic extent of the country, Developing cheaper sensors, and sensor networks, Simple diagnostic kits, Expert systems, DSS, Geo-referencing using GST.

(iii) Sources/Areas of Required Expertise: Soil scientists, Electronics scientists, and IT professionals.

(iv) Specialized Facilities that would Help Enhance Quality of Work: High resolution soil maps, High end computers, Soil testing laboratories, and Networking.

(v) Impact and Stakeholders

(a) A comprehensive soil information system will immensely benefit land evaluation and feasibility studies, soil nutrient management, spatial planning, agricultural extension, environmental protection, etc.

(b) Stakeholders:farmers, and development agencies.

(c) Evaluation metrics: Number of soil maps developed, coverage of maps, and accessibility.

(d) Evaluation can be carried out by forming a panel of experts.

5.1.4 Dearth of Expert Systems, Modeling, and Forecasting for Pests/Diseases

(i) Problem Statement: The dynamics of populations of pests, pathogens, or insect vectors of disease are complex, making the prediction of outbreaks difficult. Mathematical modeling and computer simulation provide ways to help unravel such complex systems and understand how pests and vectors interact with the environment and with other organisms. Modeling approaches are used to ensure efficient use of resources in integrated pest management programmes, to predict the likely impact of new control measures, and to compare economic returns from different control strategies. Linking such models with weather parameters will be useful in disease forecasting.

(ii) Challenges and Needs: Diversity of crops, pests, and diseases, Different climate zones, Lack of basic data on pest incidence/disease prevalence, Artificial intelligence, Lack of diagnostic kits, Expert systems, DSS

(iii) Sources/Areas of Required Expertise: Crop protection scientists and IT professionals.

(iv) Specialized Facilities that would Help Enhance Quality of Work: Digitized pest/disease survey reports, Mobile clinics, and Automatic weather stations.

(v) Impact and Stakeholders

(a) Warning about impending pest/disease outbreaks and their timely identification can help in adopting the right crop protection measures and in preventing the abuse of toxic pesticides, thus minimizing crop losses.

(b) Stakeholders:Researchers, farmers and development agencies.
(c) Evaluation metrics: Number of models/forecast systems developed, number of crops covered, availability in public domain, and usage statistics.
(d) Evaluation can be carried out by forming a panel of experts.

5.1.5 Poor farm Mechanization, Automation Technologies

(i) Problem Statement: Indian agriculture is labour intensive. Because of the improved economic scenario in the country, there is now a continuous decrease in farm labour and rapid rise in rural wages. In order to sustain the crop productivity and to alleviate the labour shortage, agricultural mechanization must be undertaken on a large scale.Hence, research on innovative and affordable, agricultural mechanization models and systems relevant to Indian conditions needs to be emphasized. Applications of computers, controllers, sensors, GIS, GPS, and mechatronics in agricultural machines will make them data-rich, bringing in much needed precision, resolution, and accuracy.
(ii) Challenges and Needs: Intelligent machines, Sensor based controllers and actuators, Cheaper and precise electronics, robotics, Databases, expert systems
(iii) Sources/Areas of Required Expertise: Agricultural scientists, Engineers, Electronics scientists, and IT professionals.
(iv) Specialized Facilities that would Help Enhance Quality of Work: Farm mechanization units, GIS, and GPS.
(v) Impact and Stakeholders
    (a) Farm mechanization and automation can profoundly enhance the efficiency of labor, the timeliness of operations, efficient use of inputs; and sustainability ofproduction systems. Advances in automation will increase crop productivity, increase convenience, and reduce skilled labor requirements for complex tasks.
    (b) Stakeholders: researchers, farmers, and industry.
    (c) Evaluation metrics: Number of gadgets/implements developed, level of automation, ergonomics, savings in labour, and adoption by farmers.
    (d) Evaluation can be carried out by forming a panel of experts.

5.1.6 Poor Pest and Disease Surveillance

(i) Problem Statement: Increased globalization and the changing climate influence disease prevalence, invasive pests, new diseases, etc. Pest surveillance is a survey process which collects and records data on pest occurrence or absence by surveying, monitoring, or other procedures. It involves pest risk analyses, establishment of pest free areas, and the preparation of a pest list. Assessment of changing pest scenarios, mapping of regions vulnerable to pests, and evolving curative and preventive pest management strategies effective under climatic stress conditions are some of the approaches to understanding pest dynamics and creating effective pest management.
(ii) Challenges and Needs: Diversity of crops/pests/diseases, Expertise in pest/disease identification, Trained manpower at field level, Absence of field level diagnostics, Need for handheld devices for disease monitoring, Lack of good databases, expert systems
(iii) Sources/Areas of Required Expertise: Agricultural scientists, Pathologists/entomologists, and IT professionals
(iv) Specialized Facilities that would Help Enhance Quality of Work: Handheld devices and Facilities for keeping records and storing voucher specimens.
(v) Impact and Stakeholders
    (a) An efficient pest surveillance system helps to protect crops by ensuring early detection and identification of harmful or economically significant plant insects, diseases, weeds, or other pests that are naturally occurring or accidentally introduced into the country.
    (b) Stakeholders:researchers, farmers, and traders.

(c) Evaluation metrics: Number of protocols developed, number of crops covered, and number of personnel trained.
(d) Evaluation can be carried out by forming a panel of experts.

5.1.7 Lack of Innovative Tools/Gadgets for Precision Farming

(i) Problem Statement: Traditional farming in India is imprecise, inefficient, and a risky. Many aspects such as the choice of seeds; their spacing; use of inputs such as water, fertilizers, pesticides; and time of harvest are governed by tradition rather than need. On the contrary, precision agriculture focuses on utilizing resources optimally to improve the quality and quantity of crops while lowering the cost of production. It reduces fertilizer and pesticide use, prevents soil degradation, utilizes water optimally, and raises productivity. Globally, precision agriculture is done with the aid of modern, eco-friendly farming practices and technology, including satellite imagery and information technology. Currently, due to prohibitive costs, precision agriculture is only being crudely used in India. Hence, there is a need to devise simple, cheaper devices that can be employed for precision agriculture.
(ii) Challenges and Needs: Intelligent machines, Electronics engineers, Cheaper and precise electronics, Databases, expert systems
(iii) Sources/Areas of Required Expertise: Agricultural scientists, Engineers, Electronics scientists, and IT professionals.
(iv) Impact and Stakeholders
    (a) The primary benefits of precision agriculture, both economic and environmental, result from reduced or targeted placement of crop inputs such as nutrients, pesticides and water. It has the potential to greatly reduce the environmental impact of farming.
    (b) Stakeholders: researchers, farmers and industry.
    (c) Evaluation metrics: Number of devices developed; productivity;savings in labour, water and other inputs;and adoption by farmers.
    (d) Evaluation can be carried out by forming a panel of experts.

5.1.8 Lack of Innovative Tools/Gadgets for Harvesting, Grading, Storage, etc.

(i) Problem Statement: Across all stages of harvesting, sorting, transporting, storing, processing and packaging, there is great need for mechanization and automation. Although India is the 2nd largest vegetable and 3rd largest fruit producer in the world, the reported PHL are enormous. Simply increasing the production and productivity will not be enough. Much more emphasis needs to be placed on post-harvest management of highly perishable crops.
(ii) Challenges and Needs: Intelligent machines, Electronic devices, Databases, expert systems
(iii) Sources/Areas of Required Expertise: Agricultural scientists, Engineers, Electronicsscientists, Food technologists, and IT professionals.
(iv) Specialized Facilities that would Help Enhance Quality of Work: Farm mechanization units, Electronics testing labs,and Cold chains.
(v) Impact and Stakeholders
    (a) A significant amount of labour costs can be saved while, price stability and remunerative prices areensured for the farming community.
    (b) The stakeholders include researchers, farmers, and traders.
    (c) The following evaluation metrics can be employed for measuring impact: Number of gadgets developed, ergonomics, savings on labour, and extent of adoption by farmers.
    (d) Evaluation can be carried out by forming a panel of experts.

5.1.9. Poor Food Processing, Quality and Safety

(i) Problem Statement: To guarantee that food reaches the consumer in a healthy and unspoiled condition, it mustgo through several processes. Through processing, we eliminate and/or reduce the effects of microbes, and prevent food spoilage by deactivating enzymes and preventing oxidation. Hazard Analysis Critical Control Points (HACCP) are identified to handle flaws in the manufacturing process itself and to address any potential contamination risks therein. Strategies are needed for environmentally friendly and sustainable processing methods, recipes,and packaging. Measures to improve food safety should focus on the detection of emerging food pathogens and adulteration, the assessment of available techniques, and an analysis of the risks involved.

(ii) Challenges and Needs: Improved machines, Cheaper and precise electronics,biosensors, Standards, databases, expert systems.

(iii) Sources/Areas of Required Expertise: Agricultural scientists, Engineers, Electronics scientists, IT professionals, and Industry/traders.

(iv) Specialized Facilities that would Help Enhance Quality of Work: Model food processing units and Food testing laboratories.

(v) Impact and Stakeholders
   (a) Ensuring clean and safe food can have a profound impact on the quality of human life and helps to ensures food security for the population.
   (b) Stakeholders: researchers, farmers, and traders.
   (c) Evaluation metrics: Number of food processing units established, protocols developed for detecting adulteration/contamination, and adoption by traders.
   (d) Evaluation can be carried out by forming a panel of experts.

1.1.10 Poor Agro-Information Delivery Mechanisms

(i) Problem Statement: There is much agricultural related information that exists but is unavailable to Indian farmers (weather, local market prices, pest and disease alerts, agro-news, standard agricultural practices, government programmes, etc.). Apart from informal sources, the public-sector agricultural extension has been the traditional formal channel by which farmers have gained access to information related to their farming activities. But small and marginal farmers need relevant, not generic, information in order to improve, sustain, and diversify their farm enterprises. Targeted production and dissemination or delivery of such micro-information can be achieved through digital means and information and communication technologies (IT), mobile devices being ideal tools in the Indian context. However, the content should be highly relevant to the local needs. Context-specific information is more resource intensive, requiring more information at the farm level, which varies spatially and temporally. These complexities in the process of generating and delivering relevant content mean that content management is a major challenge in IT projects.

(ii) Challenges and Needs
   (a) Multi modal content delivery: Mobile devices, Interactive Voice Response Systems (IVRS), SMS, and videos.
   (b) Availability of relevant and localized content in local languages
   (c) Cultural issues

(iii) Sources/Areas of Required Expertise: Agricultural scientists, Communication experts, Media professionals, and IT professionals.

(iv) Specialized Facilities that would Help Enhance Quality of Work: Agri-studios for content development, and an exclusive mobile network for m-agriculture.

(v) Impact and Stakeholders
   (a) IT can enable direct access by farmers to timely and relevant information, as well as empower creation and sharing of knowledge within the farming community.
   (b) Stakeholders: researchers, farmers, and traders.
   (c) Evaluation metrics: Number of contents developed, number of languages supported, number of villages covered, and adoption by farmers.

(d) Evaluation can be carried out by forming a panel of experts.

5.1.11 Other Issues Identified

(i) Inadequate development and supplies of improved and agro-climatic-zone specific seeds.
(ii) Crop improvement and yield enhancement. This includes prediction, identification and selection of better yielding cultivars.
(iii) Realization of inherent crop yield potential and loss prevention from flood, drought, heat, salinity, climate variability, pathogens, pests, and diseases.
(iv) Acreage data for crops throughout India,to help understand crop requirements.
(v) Crop specific import/export data on seeds.
(vi) Obtaining an isolated area for seed production.
(vii) Growers' database.
(viii) Dose-response data for each of the nutrients used for each of the tested cultivars (whether released or unreleased) for all major crops, especially rice.
(ix) Ranking of all tested cultivars/varieties by efficiency of nutrient use.
(x) Phenomics for nitrogen use efficiency in rice/other major cereals/crops.
(xi) Crop yield modeling.
(xii) Variable rate technology.
(xiii) Approaches to reduce high level of drudgery involved in agricultural operation.
(xiv) Development of specialized machinery for specialized field crops and horticultural crops.
(xv) Declining farm profitability
(xvi) Selection of Appropriate Crops/Cropping Systems/Farming Systems
(xvii) Farm Mechanization (Shortage of agriculture labor and reluctance of youth to work in the farms.)
(xviii) Precision farming (Personalized advice is required as against general advice)

5.2 Research and Development Topics Related to Soil, Water and Weather

5.2.1 Weather-Based Agriculture Management

(i) Problem Statement: Information on weather related aspects is not readily available for researchers, farmers, policy makers in India. The unpredictability and uncertainty of weather and rainfall adds to the problem. The weather forecasting and advisories are available at higher resolution and real time information do not reach farmer. Information is mostly available in English and may not be available in local languages.
(ii) Challenges and Needs
    (a) Observation, monitoring and dissemination
    (b) Forecast (short, medium, extended, long)and early warning system
    (c) Weather based agro-advisory and contingency crop planning

(iii) Areas from Which Expertise Is Required : Experts from agriculture (Meteorology, Agro-Meteorology, Soils, Agronomy, Water management, Statistics, Remote Sensing, GIS, Modeling, IT are needed
(iv) Impact: Providing authentic and reliable information on weather can revolutionize Indian agriculture. Once such information is made available to Indian farmers, they can adopt necessary practices which will enhance the productivity and also minimize losses. Similarly a realtime operational weather forecasting and advisories at micro level will greatly benefit our farmers, researchers, policy makers and developmental agencies.
    (a) Stakeholders: Farmers, Researchers, students, development agencies, policy makers, Extension workers, and Planners, industries.

(b) Evaluation metrics: Area covered with forecasting and advisories and crops covered, Dissemination of information

5.2.2 Water Management

(i) Problem Statement:Information on water related aspects, is highly segregated. Information on water harvesting procedures and storage, efficient utilization of harvested water, water requirements at different growth stages of crop, existing government programs their requirements and procedures, is not readily available to farmers. So there is an urgent need to collate all these at one place, in a readily accessible format, preferably in local languages.

(ii) Challenges and Needs: Management of limitedwater, Information and management of water quality, Conjunctive use of poor quality water

(iii) Areas from Which Expertise Is Required: Experts fromwater management,agriculture (Meteorology, Agro-Meteorology, Soil, Agronomy, Statistics, Remote Sensing, GIS, Modeling, IT, etc.) are needed

(iv) Impact

(a) Providing authentic and scientific information can contribute to efficient utilization of water particularly under rainfed conditions. Similarly a nationwide compilation of research data will immensely benefit our researchers, policy makers and developmental agencies.

(b) Stakeholders: Researchers, students, farmers, developmentagencies , policy makers and Planners

(c) Evaluation metrics: Compilation of information and its availability at a single place, Interface for information access

5.2.3 Soil Nutrient Management

(i) Problem Statement: Declining fertility levels of soils, multiple nutrient deficiencies both under the irrigated and rainfed conditions, continuous degradation of land, declining organic carbon levels have contributed to the declining productivity of our soils. Lack of information about the limiting nutrients in a piece of land is a hindrance to realize the maximum yields from a given input use.

(ii) Challenges and Needs: Availability of information on soil fertility status, Integrated Plant Nutrient Management System, Fertilizer availability and management

(iii) Areas from Which Expertise Is Required: Experts from agriculture (soil science, agronomy, Water management, Statistics, Remote Sensing, GIS, Modeling, IT, etc.) are needed

(iv) Specialized Facilities that would Help Enhance Quality of Work: An operational network to analyze the soil fertility statusat the ground level, Data storage and quality check

(v) Impact

(a) Providing authentic and scientific information on the fertility status of soils helps in proper nutrient application strategies for various crops by farmers which will not only enhance the yields from limited sources but also reduces the cost of production and enhances the profitability.

(b) Stakeholders: Farmers, Researchers, developmentagencies , extension workers, policy makers, industries.

(c) Evaluation metrics: Number of soil testing labs established, issuance of soil health cards

5.2.4 Saline, Sodic and Acidic Soil Management

(i) Problem Statement: Significant area in India is being categorized as problematic due to salinity, alkalinity and acidity and the yield levels are low. Technologies for the reclamation of these soils exists and the information on these aspects is not available at a single place.Many a times, this information is available in print form only. So there is an urgent need to collate all these at one place, in a readily accessible format, preferably in local languages.

(ii) Challenges and Needs: Inventory and mapping, Management

(iii) Areas from Which Expertise Is Required : Experts from agriculture (Meteorology, Agro-Meteorology, Soil, Agronomy, Water management, Statistics, Remote Sensing, GIS, Modeling, IT, etc.) are needed

(iv) Impact

(a) Providing authentic and scientific information can help in fast reclamation and helps in developing suitable programmes for their reclamation. A nationwide compilation of research data will immensely benefit our researchers, policy makers and developmental agencies.

(b) Stakeholders: Farmers, Researchers, students, developmentagencies , policy makers and Planners, industries.

(c) Evaluation metrics: Area reclaimed, enhancement of the productivity of these lands

5.2.5 Water Logging and Drainage

(i) Problem Statement: Significant area of the country are being affected with water logging and impaired drainage. Various technological options for their reclamation is available and, is highly segregated. Besides, many a times, this information is available in print form only. So there is an urgent need to collate all these at one place, in a readily accessible format, preferably in local languages.

(ii) Challenges and Needs: Inventory and mapping, Management

(iii) Areas from Which Expertise Is Required: Experts from agriculture (Agro-Meteorology, Soil, Agronomy, Water management, Statistics, Remote Sensing, GIS, Modeling, IT, etc.) are needed

(iv) Impact

(a) Providing authentic and scientific information can revolutionize Indian agriculture. Once such information is made available to Indian farmers, they will do wonders with improved varieties, genuine agro-inputs. Similarly a nationwide compilation of research data will immensely benefit our researchers, policy makers and developmental agencies.

(b) Stakeholders: Farmers, Researchers, students, developmentagencies , policy makers and Planners, industries.

(c) Evaluation metrics: Area reclaimed, enhancement of the productivity from these lands

5.2.6 Soil Erosion and Land Degradation

(i) Problem Statement: Significant area of the country are affected by various forms of land degradation. The information for their reclamation is scattered. Besides, many a times, this information is available in print form only. So there is an urgent need to collate all these at one place, in a readily accessible format, preferably in local languages.

(ii) Challenges and Needs: Inventory and mapping, Management

(iii) Areas from Which Expertise Is Required: Experts from agriculture (Soils, Agronomy,Water management, Statistics, Remote Sensing, GIS, Modeling, IT, etc.) are needed

(iv) Impact

(a) Providing authentic and scientific information can arrest degradation of land and can contribute towards stabilizing the productivity in the long run. A nationwide compilation of research data will immensely benefit our researchers, policy makers and developmental agencies.

(b) Stakeholders: Farmers, Researchers, students, developmentagencies , policy makers and Extension workers, and Planners, industries

(c) Evaluation metrics: Area treated, Extent of reduction in the degradation, Efficacy of these measures

5.2.7 Climate Change

(i) Problem Statement: Information on climate change related aspects is not readily available in India for researchers or farmers or policy makers. Information related to various crops, suitable varieties for different rainfall situations, soil and water conservation practices, critical irrigation, nutrient application, , agri-service providers, marketing opportunities, credit facilities, insurance products, etc. is not available at a single location. Many a times, this information is available in print form only. So there is an urgent need to collate all these at one place, in a readily accessible format, preferably in local languages.

(ii) Challenges and Needs: Scenarios and Extreme weather events, Green house gas emission, Vulnerability, mitigation and adoption strategies

(iii) Areas from Which Expertise Is Required: Experts from agriculture (Meteorology, Agro-Meteorology, Soil, Agronomy, Water management, Statistics, Remote Sensing, GIS, Modeling, IT, etc.) are needed.

(iv) Impact

(a) Providing authentic and scientific information can revolutionize Indian agriculture and helps farmer to manage variable rainfall situations successfully. A nationwide compilation of research data will immensely benefit our researchers, policy makers and developmental agencies.

(b) Stakeholders: Farmers, Policy makers, Students, scientists, Line Department, Extension workers, and Planners, industries.

(c) Evaluation metrics: Store house of information and its accessibility

5.2.8 Other Issues Identified

(i) Low organic carbon

(ii) Quantification of nutrient losses (especially reactive nitrogen and phosphorus) from agricultural fields as pollutants in air, soil, and water.

(iii) Quantification of recoverable nutrients from environment back to agriculture.

(iv) Efficient watershed management.

(a) Accurate climate/rainfall predictions at the village/Taluqa level.

(b) Declining water availability and water quality

5.3 Research and Development Topics in Agriculture Education and Extension

5.3.1 Lack of Skills

(i) Skill types

(a) Analytical and lab skills: Students in agriculture should be exposed to more quantitative methods, modeling and simulation, etc.

(b) Field skills: Skill enhancement through mechanisms like 'virtual crop labs', development of materials for such labs, and development of skills to enable the creation of such materials.

(ii) Likely domain and IT challenges
   (a) How to make acquisition of the above skills interesting to agriculture students ?
   (b) Update/complement curriculum to enablesmooth development of skills.

(iii) Mix of expertise required to address challenges: Need Ag&Food core + IT core + field core (core TBD).

(iv) Stakeholders: Universities (Ag + IT), Industry, NGOs, farmers and rural practitioners.

(v) Evaluation metrics and process
   (a) Quality: Measures of reputation of the program, such as student competition to enter, farmers seeking help from institutions, etc.
   (b) Quantity: Number of institutions adopting this program; number of professionals; number of students working on projects in these areas

5.3.2 Lack of Cross-Trained Professionals

(i) Issue: Lack of cross-trained professionals: Creation of joint academic programs, e.g. cross-disciplinary majors, minors, or certificates, to ensure that students have the right skillset needed. Collaborations can also encompass multiple institutions (formal agreements), both national and international.

(ii) Likely domain and IT challenges: Motivation of students to join such a program

(iii) Mix of expertise required to address challenges: Potential collaboration between agriculture discipline and IT discipline for co-development of such curriculum.

(iv) Stakeholders: Ag + IT academia (national + international), Industry, Government

(v) Evaluation metrics and process
   (a) Number of cross-disciplinary collaborations
   (b) Number of students in such programs

5.3.3 Multi-Lingual Content Preparation and Delivery

(i) Issue: How should content be prepared and delivered in multiple languages.

(ii) Likely domain and IT challenges
   (a) Language translation technology geared to agriculture and food
   (b) Agriculture and Food knowledge base
   (c) Professionals trained in these areas

(iii) Mix of expertise required to address challenges: Collaboration among Ag&Food domain experts, linguists and IT experts.

(iv) Stakeholders: Farmers, extension services, government, IT tools suppliers, research labs/universities.

(v) Evaluation metrics and process: Number of products developed, Adoption level of products.

5.3.4 Coordination Between Research, Extension and Industry

(i) Issue: Research capacity needs to coordinate with extension to ensure that the tools reach the stakeholders.

(ii) Likely domain and IT challenges
   (a) Lack of access to end users (infrastructure, solutions, manpower)
   (b) Synchronize the capabilities of research, extension and industry so successful ideas flow smoothly from research to end user

(iii) Mix of expertise required to address challenges: Extension professionals, IT professionals.

(iv) Stakeholders: Extension system, universities, industry.

(v) Evaluation metrics and process: Speed of adoption of ideas by the Ag community; number of ideas adopted yearly; success stories

5.3.5 Domain Specific IT Tools & Techniques

(i) Issue: Development of domain-specific IT tools and techniques needed to (potentially automatically) convert unstructured content into rules for use in agricultural expert systems.

5.3.6 Research & Development Laboratory Facilities

(i) Issue: R&D laboratory needed for assessing emerging technologies in ICT areas, and of relevance to agriculture.
(ii) Likely domain & IT challenges: Budget for creating R&D labs, Trained personnel
(iii) Mix of expertise required to address challenges: Ag research experts trained in IT, IT research experts trained in Ag, Visionary leadership
(iv) Stakeholders: Universities, research labs, government, centers/institutes, industry
(v) Evaluation metrics and process: Standard measures of fundamental and applied research productivity

5.3.7 Other Issues Identified

(i) Right Information Availability:Research on making the right data available at the right time through the right channel.
(ii) Ensure technology innovation and development is also usable by women.
(iii) Develop a common e-course material (unified syllabus) across the country. Protocol development for standardized e-content and delivery.
(iv) Involvement of farmers in the research process, and development of best practices for the required two-way communication. Get students trained in this practice.
(v) Development of content and practices for enabling the rural youth to be exposed to entrepreneurship.
(vi) Lack of and/or coordination of IT and agriculture resources: The new professional, i.e. e-kisan, needs new capacity building including in IT and agricultural training resources, materials, etc. Additionally we need professorships, fellowships, and other incentives for promoting R&D and education.
(vii) Lack of skilled para-professionals for providing IT-enabled solutions to farmers: Offering diploma/certificate courses with tailor-made curriculum. Need to be skilled in eliciting needs from the farmers whom the solutions are meant to help.
(viii) Lack of sufficient distance learning capacity, both in terms of reach and content.
(ix) Making the KVK mechanism IT-enabled to increase its effectiveness and reach to a much larger group of farmers, with current human resources.
(x) Lack of Optimum Fertilization and Plant Protection Knowledge. No advice available to a farmer for the specific crop in his field. No soil and leaf analysis data available in most cases.
(xi) Farm-specific advice on agronomy, fertilization, crop protection, price discovery, access to credit, seed varieties, etc. can be made easily available on mobile devices.
(xii) Building of pest and decease surveillance systems.
(xiii) Weather-based agro-advisory service.
(xiv) Crop simulation models for climate change impact and Natural Resource Management (NRM.)
(xv) Extension, knowledge dissemination
(xvi) Pest and disease management
(xvii) Information management/integration
(xviii) Networking of experts/institutes
(xix) Lack of IT exposure to experts and farmers
(xx) Enhancing practical skills of agriculture students to diagnose crop problems
(xxi) Lack of availability of the right technical (production, protection, etc.) inputs at the right time.

5.4 Research and Development Topics Related to Marketing and Agri-business

5.4.1 Easy Access to Market to get Best Price

(i) Problem Statement: Small and marginal farmers often make distress sales. They sell produce to the agents who visit their villages. Farmers are ignorant about who can give them the best price for the produce. Also, they are unaware how to get the best price. Many farmers negotiate a deal with a local moneylender for financing farm operations in exchange for an agreement to sell produce at throw away prices. The team believes that this is the most urgent problem we should solve to see "quick" impact.

(ii) Challenges and Needs
   (a) How to give latest information on the market for a specific crop?
   (b) How to give latest and reliable pricing information to the farmer?
   (c) How to ensure that the price which farmer gets is the best available?
   (d) How to give the farmer information about a procurement agency that will procure the produce and a specific contact person at the agency?
   (e) How farmers can negotiate and get the best price from a procurement agency?
   (f) How to make sure farmers will not be deceived?
   (g) How to make the procurement agency collect produce from the farm?
   (h) How to ensure the farmer gets payments "immediately" after selling his crop?

(iii) Sources/Areas of Required Expertise: Agribusiness, Agriculture Economics, Market databases, procurement agencies, farmer profiles, Mobile software, Human Computer Interface, IT platform connecting farmers with procurement agencies, Agriculture product price prediction, Knowledge of Kisan Credit Card scheme & Smart Card technology

(iv) Specialized Facilities that would Help Enhance Quality of Work: Agriculture commodity price database with latest pricing updates, Auction platform to discover agriculture commodity prices, Cloud computing and hosting facility to create IT platform, (Mobile)Banking facility to transact business

(v) Impact
   (a) Stakeholders: Farmers and farmer' organizations (Farmer Club, Co-operative society), producers' company, village entrepreneur, gram-panchayat, agriculture produce marketing committee (APMC), procurement agencies, government
   (b) Evaluation metrics: Price which farmer can command, Number of different markets and procurement agencies farmer can contact from mobile phone, Convenience to sell the produce, Speed of payment for the produce, Satisfaction of farmers and stakeholders
   (c) EvaluationMethods: Survey of farmers, Survey of procurement agencies, Comparison of APMC and farmers' prices, Analysis of complaints in Complaint Booking System, Quality of village level support, Audit Report on transactions between farmers and procurement agencies

(vi) Any Other Observations
   (a) R&DProblems
      (i) Price prediction based on number of growers, international market, earlier history of commodity, demand and supply situation, weather prediction, severe climatic events, government policy, etc.
      (ii) Identifying parameters for ranking of markets and developing a ranking methodology
      (iii) Dissemination of farmer-specific market information, as determined by farmer profile
      (iv) Identification of critical factors to ensure farmers have easy access to market
      (v) IT system should be designed to be usable by small and marginal farmers

(vi) A farmer-to-farmer collaboration system using mobile phone, to help exchange ideas

(vii) Methodology: Taking R&D to the field requires proper planning. One may need to define proper methodology to achieve end goals.

(a) Conduct baseline survey of farmers and stakeholders
(b) Hold workshop of farmers, Create awareness
(c) Conduct Participatory Rural Activities (PRAs), such as Chapati diagrams, to assess needs and define intervention accordingly
(d) Create Village Development Committees. Select village volunteers. Involve NGOs
(e) Build consortium of partners, with formal/informal agreement. Highlight value for each stakeholder
(f) Appoint Program/Project manager to create and execute project plan.
(g) Give special attention to handholding of farmers, especially during initial stages, to ensure research/innovation gets a fair chance tosucceed

5.4.2.Product (Crop) Strategy

(i) Problem Statement: The main objective is to determine the strategy that will maximize profit. The majority of farmers choose crops that are traditionally grown in their region. The herd mentality and previous year's prices also influence their decisions about what to grow, resulting in a large supply of commodity, pushing the price downwards. Besides soil, water, and environment considerations, the farmer should consider market linkages when deciding what to grow.

(ii) Challenges

(a) How to determine the crop combination that will fetch maximum ROI, for given soil, water and other environmental parameters without compromising soil and water conservation and environmental preservation?
(b) How to predict price and market behavior, considering that the agriculture industry is also influenced by global phenomena?
(c) How to convince a farmer to take the additional risk of growing a new crop since he is already taking multiple risks?
(d) How to ensure that the best ROI strategy is indeed sound and can be deployed in the field?
(e) How to get historical data on market, prices, national and international events, and government policies?
(f) How to determine the part of any observed income level change that may be ascribed to the product strategy used, as opposed to other coexisting, contributing factors such as weather, or failure of crops in other places due to natural disasters?

(iii) Sources/Areas of Required Expertise: Optimization theory, Non-linear system theory, Crop knowledge, Expert systems, Modeling, Sensor technology and mobile technology to get field data for populating models, Time series analysis, statistics, Data mining (machine learning, genetic algorithms, etc.), Social behavior, Agriculture economics, Agriculture market, International and national commodity trade, Government policies and regulations

(iv) Specialized Facilities that would Help Enhance Quality of Work: Database of trade history, Access to APMC database, Optimization tools, Expert system tools, Membership of national and international commodity exchanges.

(v) Impact

(a) Stakeholders: Agriculture Universities, IT and Computer Science Institutions, Producer Company, Procurement agencies, Commodity Exchanges, APMC, Government
(b) Evaluation Metrics: Better ROI, Better score over traditional approach, Successful Multi -Crop strategy like multi-company portfolio for equity

investment, Successful risk mitigation strategy, Confidence of several experts in multi-crop strategy, Satisfaction of farmers and stakeholders, Ease of execution of the product strategy

(c) Evaluation Methods: Validation of assumptions, Impact of wrong assumptions over ROI, Differences between theoretical and practical results, Surveys, Expert opinions

(vi) Any Other Observations

(a) R&DProblems: Multi-crop product strategy based on sound principles of optimization theory, decision and estimation theory, and non-linear systems

(b) Impact of social behavior issues on multi crop strategy

(c) Use of data mining of historical data to devise the best multi-crop strategy

5.4.3Developing Affordable Equipment for Quality Assessment and Preservation of Produce

(i) Problem Statement: The main objective is to develop affordable instrumentation for quality assessment and preservation. When farmers takes their produce to the Mandi, they do not get the expected price. Often "poor quality" is cited as the reason. In many parts of India, farmers still carry produce (especially cotton) in bullock carts to markets located 15-20 km away. This is a day and night journey and is accompanied with food and family. After standing in a queue for several hours and then reaching the market yard, they are told by purchasing agents that the quality is poor and they will get the lower rate. At that point, farmers have no option but to accept low rates. Instruments taken with the farmers or located at the village which could assess quality would certainly help.

Similarly, affordable equipment which can preserve the produce properly (preventing PHL) would help farmers to sell the produce only when market rates are better.

(ii) Challenges and Needs

(a) What are the quality indicators for each crop, fruit, and vegetables?

(b) How will those be communicated?

(c) How to make instruments to measure the above parameters? How to make them affordable to farmers or groups of farmers?

(d) How to ensure that the instruments are calibrated periodically and maintained properly?

(e) Who will certify the produce? How to ensure such certification is accepted by purchasing agencies?

(f) How to avoid PHL which can run 30% to 40% nationwide?

(g) How to train large number of farmers to pay serious attention to quality and preservation using above instrumentation?

(iii) Sources/Areas of Required Expertise: Global GAP (Good Agriculture Practices), Organic Certification, Electronics and instrumentation, Sensors and wireless sensor networks, Remote maintenance using wireless networks, Remote training using video conferencing, Crop experts, Packing technology experts, Experts who understand issues involved in PHL.

(iv) Specialized Facilities that would Help Enhance Quality of Work

(a) Government to introduce Crop Quality Certification program

(b) KVK/Gram-panchayat to issue instrumentation based certification

(c) Warehouse receipt facility to be extended to micro-warehouses built with the small farmer in mind

(d) Price band to be linked with quality band in ways understood by everybody

(e) Linkage of local engineering colleges with KVK for support for such instrumentation

(f) Bank loans and crop insurance premiums to be linked with the usage of such technologies

(g) Video conferencing facilities at KVKs. Streaming of training videos on mobile phones and tablet computers.

(v) Impact
   (a) Stakeholders: Agriculture Universities, IT and Computer Science Institutions, Producer Company, Procurement agencies, Commodity Exchanges, APMC, Government
   (b) Evaluation: Better ROI, Better score over traditional approach, Successful multi-crop strategy like multi-company portfolio for equity investment, Successful risk mitigation strategy, Confidence of several experts in multi-crop strategy, Satisfaction of farmers and stakeholders, Ease of execution of the product strategy
   (c) Evaluation methods: Validation of assumptions, Impact of wrong assumptions over ROI, Differences between theoretical and practical results, Surveys, Expert opinions

(vi) Any Other Observations
   (a) R&D Problems
      (i) Multi-crop product strategy based on sound principles of optimization theory, decision and estimation theory, and non-linear systems
      (ii) Impact of social behavior issues on multi-crop strategy
      (iii) Use of data mining of historical data to devise the best multi-crop strategy

5.4.4. Development of DSS

(i) Problem Statement:The main objective is to build a DSS that makes decisions based on data coming from various sources, and effectively communicates them to the farmer. Decisions regarding how to access market, which multi-crop patterns to grow, or how to assess quality need to be communicated to farmers pro-actively or based on their queries. Mobile phones and tablet computers offer excellent dissemination mechanisms.

(ii) Challenges and Needs
   (a) What should be the architecture of DSS? Should it be distributed or centralized?
   (b) How can DSS cater to millions of farmers growing different crops, speaking different languages, and having different cultural practices?
   (c) How various technologies such as GIS, GPS, WSN, mobile phones, and mobile payments could be integrated into DSS platform?
   (d) With hundreds of mobile phone models and several languages, what is the best strategy for developing farmer-computer interface?
   (e) How eco partners and stakeholders will interface with the DSS?
   (f) How to address Security and Privacy concerns?
   (g) Can one develop farmer collaboration platform and make it a part of DSS?

(iii) Resources/Areas of Required Expertise: Software development, System architecture,System integration, Designing large systems, Human Computer Interaction, Embedded systems, Deployment of IT systems, Project management, training and application support, IVR technology and Telecom, Agriculture extension

(iv) Specialized Facilities that would Help Enhance Quality of Work
   (a) Access to cloud computing for creating large size production systems
   (b) Data Center with racks, servers, internet bandwidth, and bank of voice boards for IVR
   (c) Software development facility and required tools
   (d) Connectivity to Payment Gateway

(v) Impact
   (a) Stakeholders: IT company/IT University to develop and maintain DSS platform, KVK for extension work, Farmers, Eco-partners, APMC, Government
   (b) Evaluation: Dissemination of information to farmers, Number of farmers benefitted by DSS, Number of transactions on DSS, Functionalities of DSS used by farmers and stakeholders

(c) Evaluation methods: Field trial, Survey of farmers and stakeholders, Third party assessment of ease of use

(vi) Any Other Observations

(a) Building DSS requires mostly software knowledge and the production system has to be robust.Typically, software companies have such an experience.

5.4.5 PredictingRight Price and Right Market for the Commodity

(i) Problem Statement: The main objective is to predict the right price and the right market for the commodity.Most of the farmers do not practice accounting, and hence do not have an idea about the minimum price they should get to recover their costs. They have even less of a sense as to how commodity prices may fluctuate in the near and distant future. They do not know the right Mandi where they should sell their produce.

(ii) Challenges and Needs

(a) How to capture the expenses the farmer incurs on all operations while growing one or more crops, and arrive at a cost per hectare?

(b) How to get yield data and compute per quintal cost of growing particular crop? This will give farmers the minimum price needed to avoid losses.

(c) How to predict the price trend (preferably graphically) to let farmer know likely future price variations and how to arrive at a price that takes into account transportation and other charges incurred in selling the commodity?

(d) How to select the right market from among those available such as: a nearby *mandi*, a local agent, *taluqa* market, district market, metros, and sometimes even the international market?

(e) Besides the right market, farmer should be told the right time and price to sell the product. How can this be done?

(f) How to mitigate the risk of giving such an advice?

(g) How to get training data to validate prediction algorithms?

(iii) Sources/Areas of Required Expertise: Decision and estimation theory, Agri-business, Commodity exchange, future contracts knowledge, Optimization theory, APMC based trading expertise, Trading expertise on agriculture commodity, Deep knowledge of commodity trading, National and export market behavior prediction, Agriculture supply chain expertise, Agriculture product procurement expertise.

(iv) Specialized Facilities that would Help Enhance Quality of Work: Historical data on prices, commodities and market, DSS platform to capture farmer's selling and buying transactions, Accounting services for farmers, Connectivity to APMC database, Data analysis tools

(v) Impact

(a) Stakeholders: Farmers, Producer company, Traders, Eco-partners, APMC, Government, IT experts, Agriculture Business experts

(b) Evaluation metrics: Differences between predicted and actual values of the right price, Differences between the experts' views on the right market and the model output, Model performance on historical data, Farmers' feedback, Farmer profit, Experts' views on parameters describing the right market

(c) Evaluation methods: Field trial, Survey of farmers and stakeholders, Third party assessment of right price and right market

(vi) Any Other Observations

(a) This problem has a significant research component. A model that can predict the right price and right market for a specific commodity available at a specific location would be of great value to the farmer community.

6.4.6 Design a System to Empower Agri-Entrepreneurs

(i) Problem Statement. The main objective is to analyze and design a system (platform) to empower the Agri-Entrepreneur. Various interventions described in this and other group

reports cannot be made unless there is a sustainable business model driven by a Village Entrepreneur/Producer Company. For a Village Entrepreneur/Producer Company to succeed in convincing farmers and stakeholders to pay for services, they should be able to offer various services required by farmers during farming operations. More services are required if farmers have cattle and poultry. Unless the Agri-Entrepreneur/Producer Company is empowered, they cannot offer all the services effectively. Hence, empowering is essential.

(ii) Challenges and Needs
   (a) Identification of all the services required by farmers and stakeholders.
   (b) Finding out what content is required and who will provide the content needed for each service.
   (c) Developing sustainable frameworks between content providers andvillage entrepreneur/Producer Company to provide the service to farmers or their stakeholders.
   (d) Convincing a stakeholder/eco-partner to connect to the IT platform.
   (e) Developing IT platform to connect farmers, eco-partners and the experts.
   (f) Developing business model for village entrepreneur / Producer Company to be ONE STOP SHOP.
   (g) How to come up with a sustainable business model?

(iii) Sources/Areas of Required Expertise: System integration, Deep knowledge of agriculture industry, Agriculture services marketing, Communication skills to convince farmers and stakeholders, Solution architect to build IT platform, Software development, Local language interface, Local language to English translation for farmer transactions from mobile phone, English to local language translation of eco partners' transactions from the web console.

(iv) Specialized Facilities that would Help Enhance Quality of Work: Historical data on prices, commodities and markets, Data center for IT platform, Hosting facility at the data center, ERP interface module, Data analysis tools.

(v) Impact
   (a) Stakeholders: Farmers, Producer company/Village Entrepreneur, Eco-partners, APMC, Government, Computer scientist, IT experts, Agriculture business and marketing experts
   (b) Evaluation Metrics: Transaction efficiency between Village Entrepreneur/Producer Company and eco-partners to provide the required response, Satisfaction to farmers provided by Village Entrepreneur/Producer Company, Number of services offered by VE/Producer Company, Establishment of value for farmers, VE's "healthy" balance sheet, Satisfaction level of Eco-partners connected to IT platform.
   (c) Evaluation methods: Field trial, Survey of farmers and stakeholders, Analysis of services consumed by farmers, Analysis of value provided to eco-partners, Business plan evaluation

(vi) Any Other Observations
   (d) This will be a large system integration project. The project would probably involve IT platform integration with ERP (SAP) system

5.4.7 Huge Post Harvest Losses (PHL)

(i) Problem Statement: The main objective is to reduce the huge PHL in India. The losses are not just limited to fruits and vegetables, but include grains as well. PHL are due to improper or non-storage and also because of improper packing and treatment before transporting the produce. A certain percentage of PHL is due to unexpected rains and the menace of rodents

(ii) Challenges and Needs
   (a) What are the reasons of such high PHL? Are they due to procedural issues, warehouse design issues, or human related issues?
   (b) Who are most affected? Why are they most affected?

(c) How could we prevent PHL? What are the possible solutions?
(d) How farmer can improve storage in his field and at home?
(e) To what extent are untimely events such as flash rains, hurricanes, and high humidity responsible for PHL? What percentage of losses can be reduced by predicting untimely events?
(f) Currently how much do farmers invest in storing their harvest?
(g) Which crops require cold storage? What are the issues in using cold storage? How can one reduce the cost of cold storage?
(h) Which crops require refrigeration during transport?
(i) How much is power shortage affecting cold storage? How to address the power situation in a village? Can one find alternate forms of energy in a village for cold storage?

(iii) Sources/Areas of Required Expertise: Post-harvest knowledge, Supply chain, Warehouse construction technology, Cold storage, Sensors and wireless sensor network, Weather prediction, Alternate energy, Agricultural economics, Crop scientists

(iv) Specialized Facilities that would Help Enhance Quality of Work: Historical data for PHL analysis, Construction of micro-warehouses at farmer's home and field, Assistance from Center of Renewable Energy, Access to technologies used in advanced countries.

(v) Impact
(a) Stakeholders: Producer company/Village Entrepreneur, Eco-partners, Warehouse company, Government, Cold storage company, Procurement agency, IT experts, Agriculture Business and Marketing experts, Agriculture scientist, Universities
(b) Evaluation Metrics: Reduction in PHL, Cost vs. utility, Farmers' preference for new cold storage technology, Deterioration of seed quality after storage, Extent of advantage over traditional methods
(c) Evaluation methods: Field trial, Survey of farmers and stakeholders, Germination quality of seeds after preservation, Analysis of support issues, Business plan evaluation

(vi) Any Other Observations
(a) The analysis of existing PHL data is critical. ITRA may interact with the government departments to get this data.

5.4.8 Cost of Certification for Traceability (Global GAP – Good Agriculture Practices)

(i) Problem Statement: The main objective is to reduce the cost of certification such as Global GAP, Organic, and Traceability using an IT platform. India has more than 100 climatic zones, and hence produces a large variety of fruits and vegetables. Their production is almost equal to grain production. Fruits and vegetables have good export potential, as demonstrated by the grape crop. However, the biggest hurdle in exporting fruits and vegetable is the lack of awareness of quality, cost and complexity of getting certification, and farmers' reluctance to maintain data required for certification.

(ii) Challenges and Needs
(a) How to increase awareness of certification for fruits and vegetables among farmers?
(b) How to make it convenient for farmers to maintain field level data to apply for certification?
(c) How to conduct the training on certification for so many farmers?
(d) How to decrease the cost of certification?
(e) How to give confidence to farmers that quality certification will lead to export and hence a better income?
(f) How to keep the latest list of banned pesticides?
(g) How to make it convenient for farmers to submit samples for residue testing?
(h) How to ensure that the list of banned pesticides overseas is updatedregularly?

(iii) Sources/Areas of Required Expertise: Quality Assurance and Management System, GAP certification, Extension work, IT, Residue testing, Regulatory knowledge

(iv) Specialized Facilities that would Help Enhance Quality of Work: Connectivity to various national and international Residue Testing labs,Government recognition of Certification, Introducing skill building courses on traceability certification, Incentives to farmers who go for GAP or similar other certification for their produce, Portal for submitting samples and getting various certificates for Traceability

(v) Impact
   (a) Stakeholders: Traceability Labs, Producer company/Village Entrepreneur, GAP organization, Auditors, Government, Agri Exporters and Importers, IT experts, Quality experts, Agriculture scientist.
   (b) Evaluation Metrics: Certification cost, Time delay to get certification, Value of certification, Farmer's perception about certification, Importers' and exporters' views on the IT system used for issuing certificates.
   (c) Evaluation methods: Field trial, Survey of farmers and stakeholders, Views of auditors, Usage of IT system by farmers, auditors, and certification labs, Business plan evaluation

(vi) Any Other Observations
   (a) Quality certification SEI-CMM greatly enhanced the IT industry, and exports increased significantly as a result of certification Levels 1, 2, 3, 4 and 5. Now it has become almost mandatory to have such a certification to improve business. Similarly, certification such as GAP or Indian GAP can substantially improve agriculture exports, especially of fruits and vegetables. This will also create employment opportunities for agriculture graduates trained as GAP auditors.

5.4.9 Other Issues Identified

(i) International crop status, stock levels, price-movement, etc.,can be sourced through IT-Tools and accessed via the internet. This information will first need to be analyzed and recommendations subsequently made, since it could be dangerous to provide raw data as most people/organizations may not have the competence to analyze the data, monitor trends, and make correct predictions for the future.

(ii) Risk spreading through co-operatives and other forms of collectives.

(iii) Lack of standards for many food imports.

(iv) Risk management system for food imports clearance.

(v) Imported food recall.

(vi) Food imports profiling.

(vii) Marketing of perishable agricultureproducts

(viii) High transaction costs

(ix) Post-harvest management

(x) Lack of reliable and authentic baseline horticultural data

(xi) Poor marketing infrastructure

(xii) Poor awareness about existing and emerging opportunities in domestic and export markets

5.5 Research and Development Topics in Livestock and Fisheries

5.5.1 Efficient Livestock Farming Systems

(i) Problem Description: Development of livestock farming systems (for all species: cattle, buffalo, sheep, goat, pig, aqua and poultry), focusing on the following areas:

   (a) Genetic resource conservation and improvement
   (b) Identification of newer feeding resources and enrichment of available feed and fodder resources
   (c) Enhancement of reproduction efficiency and productivity

(d) Development of an effective and continuous 'Disease Reporting System' to record information found in the field into a central repository

(ii) Challenges:

(a) The lower productivity of Indian livestock is mainly attributed to the resource constrained farming systems. Hence, more focus should be given to the systems of how animals are living, reared, and used for production. Although India has great biodiversity and gene variation, efforts to conserve and improve the gene pool are insufficient due to lack of technological interventions.
(b) One half of Indian livestock is underfed. The problems are mostly not due to lack of adequate feed and fodder resources, but instead due to lack of identification and enrichment of newer and alternative (unconventional) resources, which can be used to enhance the productivity of livestock up to their genetic potential.
(c) The present system of disease prevention and control is not ready to counter emerging diseases and effectively control the levels of morbidity and mortality. This is mainly due to lack of an effective disease reporting network and early warning and alerting systems. 60% of the breeding livestock population suffers from anestrous (non-receptivity to reproduction) issues, or their reproduction matters are not paid sufficient attention.
(d) Hence, to better understand the severity of all interrelated problems arising across the entire farming system, more emphasis must be placed on "farming systems research".

(iii) Mix of expertise: To provide the required expertise requires Veterinary Scientists from agricultural and veterinary universities, ICAR institutes, IT researchers, Software and hardware engineers, Scientists working in National Physical laboratories, GIS and GPS facility providers including ISRO-like organizations, Organized farmers, Cooperative dairy and sheep federations and animal husbandry staff, and Animal conservation centres from private and public sectors.

(iv) Stakeholders: Farmers, animal breeders, feed industry, and organizations concerned with ensuring public health and national wealth.

(v) Evaluation
(a) Evaluation Metrics: Management ofLarge Databases, GIS, Sensors, Internet of Things, NIRS
(b) Conductingeffective evaluation: ICAR, university research farms, multidisciplinary approach and economical benefits, productivity enhancement, stakeholders perceptions, etc.

(vi) Specialized facilities
(a) Need to identify focal groups and nodal officers from every region, states, universities and domain areas, and involve them in relevant research.
(b) Infrastructure facilities need to be largely created in the participating organizations.
(c) Continuous two-way interactions and technical support between IT and domain areas are required. For this to happen, facilities have to be improved at all organizations participating in the research.
(d) Additional facilities must be created to enable participation in the research by farmers organizations, NGOs, and other participants.
(e) Incubation centres in the various Ag&Food organizations and IT schools need to be involved in identifying and registering innovative methods and technologies in the domain areas.

5.5.2 Automation ofLivestock, Poultry, and Aquaculture

(i) Problem description: Automation of livestock and poultry farming and aquaculture mainly focusing on the organized and entrepreneurial sectors in the following areas:
   (a) Feeding and watering systems
   (b) Precision farming systems
   (c) Disease prediction systems for effective prevention
   (d) Watershed based resource use efficiency and conservation
   (e) Developmentandvalidation of energy efficient designs and their utility in farming systems

(ii) Challenges: At present, the farm holdings in livestock and aqua farms are changing from small holdings to medium and entrepreneurial (large) scales. The shortage of labor and skills is the major issue for total transformation of labor oriented farming systems into semi-automated and automated farming systems. In many of the instances, Indian livestock and aqua produce are rejected in international markets for not meeting standards. In India, the planning commissions and banking sectors are now encouraging the rural unemployed youth to take up farming systems as they can more easily adapt to the IT based technologies involved in these systems. Hence, efficient IT solutions and automation are required to the support the urban-based, machine-oriented, livestock industry.

(iii) Mix of Expertise:A combination of veterinary scientists, fishery scientists, IT researchers, scientists working in National Physical laboratories, mechanical and electrical and electronics engineers, agricultural scientists (soil science, horticulture and other related subjects), structural engineers, watershed area programme managers, NGOs, organized farmers, cooperative dairy and sheep federations and animal husbandry staff, and animal conservation centers from private and public sector.

(iv) Stakeholders:Farmers, forest resources, feed industry, IT industry, livestock and related industries.

(v) Evaluation:
   (a) Evaluation Metrics: Database evaluation, report based evaluation, modeling based evaluation, intellectual properties and patents, research and case studies, success stories and industry approach towards the technologies developed.
   (b) Conducting effective evaluation: GIS, Remote Sensing, WSNs, Sensors, Data Mining, Modeling, Earnings Per Share (EPS)

5.5.3 Integrated Agri-Animal-Aqua Farming Systems

(i) Problem description: Design and development of high intensity and re-circulatory aquaculture and integrated agri-animal-aqua farming systems

(ii) Challenges: Productivity enhancement is the target of any farm. Optimum resource utilization by integratingvarious farm components can achieve this goal. Effective use ofIT tools to design new models of high intensity, recirculatory integrated systems are of much value given disappearing water bodies and depletion of fertile soils. Hence, the research and development in these areas is important.

(iii) Mix of expertise:A combination of veterinary/aqua scientists from agricultural and veterinary universities, ICAR institutes, IT researchers, Software and hardware engineers, scientists working in National Physical laboratories, Organized farmers, Aqua farmers and industry, Animal conservation centers from private and public.

(iv) Stakeholders: Aqua and livestock farmers, Industry, Marketing agencies, IT and related industry.

(v) Evaluation
   (a) Evaluation metrics: Productive traits, resource use efficiency, technology tools, validation and precision of the tools and industry approach towards the technologies.
   (b) Conducting effective evaluation: WSNs, Embedded System

5.5.4 National Livestock Identification System

(i) Problem Description: Development of a National Livestock Identification System to address needs in the areas of:
   (a) Information about different identification methods
   (b) DNA finger printing techniques for elite national stock
   (c) Development of cost effective Radio Frequency Identification (RFID) Technologies, animal banding tools, etc.

(ii) Challenges: To make progress towards precision livestock farming, an effective livestock identification system is necessary for small holdings as well as large farms, to maintain records of their performance, quantities of feed and fodders needed, and other health related issues. It is essential to identify 'national livestock wealth' from the elite stock of multiple species and tag them with permanent, unique identification numbers to enable tracking. The meat animals which are exported to other countries can be tagged with RFID and other devices to trace their performance during quarantine even before they are exported. It will improve the external/international market potential of the livestock and their produce.

(iii) Mix of expertise: A combination of scientists from National Bauru of Animal Genetic Resources (NBAGR), Veterinary Scientists from agricultural and veterinary universities, ICAR institutes, IT researchers, Software and hardware engineers, Scientists working in National Physical laboratories, Bio engineers, Genetic engineering experts, Organized farmers, National livestock/dairy/sheep grids, Animal conservation centers from private and public sector, Cooperative societies, National livestock and fishery export and marketing agencies.

(iv) Stakeholders: Farmers, forest resources, feed industry, IT industry, livestock and related industries.

(v) Evaluation:
   (a) Evaluation Metrics: Stake holders perceptions, resource persons interactions, location specific validation methods, tool testing etc.
   (b) Conducting effective evaluation: RFID Technology, Management of Large Distributed Databases, Image Processing, Biometrics

5.5.5 Animal Identification and Growth Management

(i) Problem description: Development of tools for identification of animal behavior, comfort, humane approach of livestock keeping and slaughtering, and other animal welfare issues.

(ii) Challenges: India has a wide range of bio-diversity and vast livestock population. Thousands of animals are regularly transported for marketing, slaughtering and other purposes. In most cases, they are loaded/housed in an inhumane way and transported for longer distances. Overcrowding is a major problem in most of the farms, includingGoshalas. The food animals are slaughtered using inhumane slaughter techniques. Animal welfare related problems are becoming concern in India. Aside from a few welfare organizations, no mechanisms exist to solve these problems. Hence, IT based mechanisms integrated with legislation on animal welfare issues are essential for our country.

(iii) Mix of expertise: The combination of veterinary scientists from agricultural and veterinary universities, ICAR institutes, IT researchers, Software and hardware engineers, scientists working in nationallaboratories, zoo personnel/ staff ,animal welfare organizations, organized farmers, slaughteringindustry and agencies, policy makers, animal transport systems in private and public sectorwill achieve the targets.

(iv) Stakeholders: Livestock, farmers, animal welfare organizations and judicial system.

(v) Evaluation:
   (a) Evaluation metrics: Animal behavioural indices, image and video recordings. Assessment of physiological and biological values of animals
   (b) Conducting effective evaluation: WSNs, Image Processing

5.5.6 Information Delivery and Marketing

(i) Problem description: Development of effective mechanism for livestock information delivery and the marketing structures for livestock, poultry, aquaculture, and their products**.**

(ii) Challenges: The lack of viable and adoptable technology, outreach of the technologies to the stakeholders, skepticism to adapt revolutionary changes from he IT sector in agricultural and allied domain areas, and their technology delivery systems are few constraints in extension advisory system. Additionally, most of the technologies are confined to laboratories and in vitro methods. Information delivery systems to stakeholders for livestock and aquaculture should be strengthened in combination with other commercial products and advertisements using IT initiatives. For this purpose, the existing IT delivery systems can beintegrated with advisory systems.

(iii) The marketing system for livestock and livestock products has not yet been structured and regularized. Hence, an IT supported mechanism is required for structuring, forecasting the marketing avenues, and finding strategies for the continuous marketing of livestock products. These mechanisms should be developed with due considerations to the perspectives and demands of both producers and consumers.

(iv) Mix of expertise: For achieving goals and targets, experts from various fields should work collaboratively. Veterinary scientists from agricultural and veterinary universities, experts from fishery research institutions and ICAR institutes, agricultural economists, agri-business scientists, experts from IIMs, IT researchers, software and hardware engineers, experts from state governments, marketing agencies, national organizations, and organized farmers' associations should all be involved.

(v) Stakeholders: Farmers, livestock and product traders, marketing agencies, banking system and other financing agencies.

(vi) Evaluation:

  (a) Evaluation metrics: Stake holders perceptions, resource persons interactions, location specific validation methods, tool testing, asset creation, technology know how, socio economic development studies etc

  (b) Conducting effective evaluation: Internet, Mobile Systems, Operations Research, EPS

5.5.7 Decision Support System for Livestock

(i) Problem description: Development of cost-effective Decision Support Systems to help and improve the following processes:

  (a) Ideal livestock, poultry and aquaculture farm management

  (b) Affordable and cost-effective of feed formulations for better nutrition, health, and reproduction

  (c) Appropriation of inputs for optimal output

  (d) Prevention and control of diseases for lowering morbidity

(ii) Challenges: Intelligent decision making is key for the success of any farming systems. Currently, there is no technology support available for efficient resource utilization. Formulation of low cost feeds, optimization of labor efficiency, and effective recycling of resources are some of the needed focus areas for the resource-constrained farming systems existing in the country. The models developed through IT initiatives should be user friendly and have multiple uses.

(iii) Mix of expertise: Veterinary scientists from agricultural and veterinary universities, experts from fishery research institutions and ICAR institutes, IT researchers, software and hardware engineers, scientists and faculty from agri-business management centers, and experts from IIMs.

(iv) Stakeholders: Livestock entrepreneurs, farmers, marketing agencies, IT industry, livestock products manufacturing industries, etc.

(v) Evaluation:

(a) Evaluation metrics: Development of new softwareandprogrammes and their validation, user friendly approach from the perceptions of the users, continuous testing in large herd and data validation.
(b) Conducting effective evaluation: Artificial Intelligence, Machine Learning, Operations Research, Internet, Mobile

5.5.8 Improving Production and Post-Production Quality

(i) Problem description: Technology to improve quality production, post-production andvalue added processing of livestock, poultry, and aquaculture products.
(ii) Challenges: The use of IT in farming structures for the production, post-production, value-added processing and manufacturing, and storage are the priority areas for the livestock products. Product durability, handling, storage and preservation require particular emphasis. The technologies must be location specific, species specific, problem specific, and should incorporate a "hands on experience approach" during adoption.
(iii) Mix of expertise: The combination of veterinary scientists, fishery scientists, IT researchers, scientists working in national laboratories, engineers with mechanical, electrical, and electronic engineering background, agricultural scientists (soil science, horticulture and other related subjects), structural engineers, watershed area programme managers, NGOs, organized and progressive farmers, cooperative dairy and sheep federations,animal husbandry staff, and experts from animal conservation centres from private and public sectors.
(iv) Stakeholders: Livestock entrepreneurs, farmers, marketing agencies, IT industry, livestock products manufacturing industry, etc.
(v) Evaluation:
    (a) Evaluation metrics: Cost effectiveness, durability and choice for upgradation
    (b) Conducting effective evaluation: Robotics, Artificial Intelligence

5.5.9 Capacity Building of Stakeholders

(i) Problem description: Development of IT tools suitable for capacity building of stakeholders at different strata and their utility through knowledge management systems.
(ii) Mix of expertise: Combination of veterinary scientists, fishery scientists, IT researchers, agricultural scientists (soil science, horticulture and other related subjects), national and state government training centres, extension and education institutes, e-learning experts, extension advisory systems of various government departments, NGOs, organized farmers, cooperative dairy and sheep federations and animal husbandry staff, TV, radio media from private and public sectors.
(iii) Stakeholders: Rural unemployed youth, farmers, IT industry, Livestock industry, HRD sectors, NGOs.
(iv) Evaluation:
    (a) Evaluation metrics: Feedback mechanism, Participatory rural appraisal, validation of the training material, content usage etc.
    (b) Conducting effective evaluation: Internet, Mobile, Local Language Support, Human-Computer Interaction

5.5.10 Management of Livestock under Climate and Environmental Variations

(i) Problem description: Changing climatic and environmental conditions have significant impact on livestock productivity, assessment, and mitigation techniques.
(ii) Challenges: IPCC reports have emphasized the need for control of environmental pollution through reduction of the methanogenesis process. In India, livestock shelter management systems are poor. Proper design of livestock shelters along with proper materials need to be identified by integration and utilization of IT. The integration of IT will help develop mitigating strategies to reduce the impact of climate change and adverse environmental conditions on livestock production, health, and welfare.

(iii) Mix of expertise: The combination of veterinary scientists, fishery scientists, IT researchers, scientists working in environmental sciences and engineering fields, mechanical engineers, meteorologists,electrical and electronic engineers, agricultural scientists (soil science, horticulture and other related subjects), structural engineers, organized farmers, cooperative dairy and sheep federations, and animal husbandry staff..

(iv) Stakeholders: Livestock farmers, environmental professionals, NGOs, livestock industries, IT industry, policy makers involved with maintaining national standards and guidelines of IPCC.

(v) Evaluation:
   (a) Evaluation metrics: Comfortness, behavior and productivity of animals ;effluent composition, micro and macro environment assessment, Green house gas emission level estimation etc.
   (b) Conducting effective evaluation: Modeling and Simulation, Sensors, Remote Sensing, GIS, Hyperspectral Imaging

5.5.11 Other Issues:

(i) Shortage of animal performance data recording system for health management and breed improvement through selective breeding

(ii) Shortage of feed and fodder resources to feed vast population of livestock and to enhance the productivity of livestock

(iii) Greenhouse gas emission from ruminants of India due to the feeding of poor quality roughages (lack of eco-friendly animal production systems)

(iv) Lack of foolproof methods in animal identification techniques resulting in poor record keeping, difficulty in the creation of a database of gene pool and disease onset patterns at the national level, problems in settlement of animal insurance and other related problems.

(v) Animal management, precision dairy farmingand performance recording system

(vi) Animal disease surveillance system

6. Activities to Enable and Enhance R&D

(i) In this section, we present the results of the discussion at the SFM on three other aspects that ITRA has identified as supplementary and complementary to the research part discussed in the previous section. These three, and research, constitute ITRA's four-fold Quality Vector. The three components are about: (i) the strong interdependence that exists between research and teaching programs; (ii) the need for enhancing in the researchers the sense of connectedness and sensitivity to society around, and the urge to impact it positively); and (iii) the extent to which the technologies developed get transferred to actual products and services, which is a strong function of (i), (ii) and (iii). These components may also help build connectivity of the academic researchers with collaborators in industry, government and NGOs, and promote entrepreneurship and start-ups. The following subsections summarize the proceedings of the SFM on (i), (ii) and (iii).

6.1 Impact on Curriculum and Instruction

(i) This section summarizes the SFM discussions and recommendations with respect to Item (i) mentioned at the beginning of this section, Sec. 6. The summary is divided into five parts, each addressing one of the identified five main areas of agriculture and food.

6.1.1 Research Related to Curriculum and Instruction in Crop Production

(i) Both agriculture education for IT students and IT education for agriculture students will be essential for the sustainable and long-term success of any interface area of IT in agriculture/food. In the short-term, this may begin with exchange of research scholars (Ph.D. students/post-docs) from IT into agriculture and vice versa through awareness and training programmes. In the medium to long-term, incorporating courses on IT in

agriculture and vice versa in the Bachelors and Masters programmes in various degrees offered in agriculture and IT teaching institutions would be necessary; this will generate the required body of professionals who can make informed and smart decisions regarding interdisciplinary career options at the interface of IT and agriculture/food.

(ii) Mechanisms

(a) IT training needed for agriculture/food students:

(i) Broad curricular content categories/faculty profiles

(a) Electronics, communication, sensors, embedded systems, mechantronics, etc.

(b) Computer systems, programing, databases, networks, etc.

(c) Analytics, Statistics, modelling, data mining etc.

(ii) Some of the above topics are taught at introductory levels in some of the agri courses, but those could be enriched further without grossly revamping the existing course structures. Making a mandatory course/syllabus revision every 3-4 years in the agri-education system is essential for upgradingcontents and interdisciplinary orientation..

(b) Agri education needed for IT students:

(i) Broad content categories/faculty profiles

(a) Crop science and crop biotechnology/bioinformatics

(b) Livestock and fisheries science and animal biotechnology/bioinformatics

(c) Agri-mechanization/automation, post-harvest processing & management

(d) Environmental science/engineering

(ii) Presently there is insufficient exposure of agri/food science topics in IT education. These topics can be introduced at an introductory level for Bachelors students; advanced topics should be required for Masters/Ph.D. students.

(iii) Content Development templates & capacity building

(i) Some models for consideration are: Department of Electronics and Accreditation of Computer Courses (*DOEACC*), Indira Gandi National Open University (IGNOU), Center for Development of Advanced Computing (C-DAC)

(ii) Virtual learning modules, tools, videos, interactive learning

(iii) Wiki-type moderated collaborative online course content development

(iv) Massive Open Source Online Courseware (MOOC)

(v) Social interface and value education of at least one unit (10%) in every subject

(iv) Engaging IT Departments/Institutions (and agri-institutions)

The current level of interest between IT and agri/food faculty and students towards each other is inadequate, but can be improved through the following initiatives on both sides:

(a) For faculty: Refresher courses, on-job training, train-the-trainer.

(b) For students: Finishing school, diploma/certificate course (1yr PG diploma)

(v) Existing models to build on:

(a) Student internships, dissertation projects (1 semester), at agri/IT schools with MOUs

(b) Sandwich programmes, joint-Ph.Ds, meta-university, MOU between ICAR-ITRA

(c) Faculty exchange/deputation/sabbatical/adjunct faculty (admin:facilitate mobility)
(d) Mandatory curriculum revision every 3-4 yrs to incorporate research outcomes
(e) Course content flexibility at the teacher level of at least 20%, internally evaluated
(f) Elective courses (titles & contents) not to be sealed and kept flexible
(g) Institutional funding earmarked for IT-agri teaching/research faculty

(vi) Attracting MS/PhD Students to IT in Agriculture and Food
(a) PR seminars and media briefings by ITRA-ICAR, industry, others
(b) Develop pamphlets, flyers highlighting the excitement in IT-agri interface
(c) Industry leaders addressing students/media
(d) Consult experts in Communication for Development (C4D)
(e) Highlight need-based innovation/R&D/business
(f) Highlight the job satisfaction quotient in the Agri-IT-Society interface

(vii) Any Other Observations: One can learn a lot from management education in India that is promoted through public seminars, road shows, and a variety of other ways that are rare in most other areas of education. One can also learn from how IT education and Biotechnology education in India were promoted through media hype regarding the growing need for professionals to meet the rising career/business opportunities in these areas. Private sector industry (in both agri and IT) as well as the private institutional investors (big banks, venture capitals) can play a major role in this initially.

6.1.2 Research Related to Curriculum and Instruction in Soil, Water and Weather

(i) Establishment of hydrology, soil and weather informatics labs, and related infrastructure, including sensor-based systems
(ii) Agri-informatics as a mandatory course (from UG onwards) on partnership basis with science, technology, and social science
(iii) Bench mark tools and datasets
(iv) Curriculum enhancement and dissemination (keeping in view the current literature on IT applications in agriculture)
(v) Faculty developmentprogram
(vi) Internships of students
(vii) Encourage student credit seminars
(viii) Offer more elective courses
(ix) Invite researchers for special lectures
(x) Encourage online certificate courses and interaction
(xi) Organize brain storming sessions / seminars/workshops on mentor / mentee partnerships
(xii) Special publications (monographs, bulletins, leaflets, etc.) / workshop proceedings
(xiii) DSS and simulation model tools and skills development
(xiv) Create centres of excellence on IT applications in agriculture

6.1.3 Research Related to Curriculum and Instructionin Agriculture Education and Extension

(i) Lack of sufficient numbers of cross-disciplined trained professionals
(a) Creation of joint academic programs, e.g. cross-disciplinary majors, minors, or certificates, to ensure that students have the right set of skills needed
(b) Collaborations can also encompass multiple institutions (formal agreements), both national and international.

(ii) Expected challenges
(a) How to make acquisition of above skills interesting to agriculture students
(b) Update/complement curriculum to make development of skills smoothly
(c) Synchronize the capabilities of research, extension and industry for successful ideas to flow smoothly from research to end user.

(iii) Expertise required to address challenges
  (a) Trained personnel to teach and supervise projects
  (b) Update curriculum to ensure Ag core + IT core + field core
  (c) Visionary leadership to 'make it all happen'
(iv) Stakeholders: Universities (Ag + IT), Industry, farmers & rural practitioners, Government
(v) Evaluation metrics and process
  (a) Quality: Measures of reputation of the program, e.g. student competition to enroll, farmers contacting institution, measurable benefit, etc.
  (b) Quantity: Number of institutions adopting this program; number of professionals; number of students working on projects in these areas, placement/advancement of graduates, average compensation packages of employment, student enrollment, number of employers conducting on-campus recruitment

6.1.4Research Related to Curriculum and Instruction in Marketing and Agribusiness

(i) Core competencies required: Survey methodology, Analytical skills, Agricultural economics, Agribusiness management, Communication skills, Data science, Strategic planning, Commodity quality analysis, Supply chain/logistics, IT skills
(ii) Placement domains: Government, Risk management companies, Commodity exchange, Financial institutions, Agriculture input industry, Export/import companies, Universities/research institutions, NGOs, Food processing industries, Trading/agribusiness corporations, Entrepreneurs/business incubation.
(iii) Learning objectives and outcomes
  (a) Technical competence in marketing and agribusiness and IT
  (b) IT enabled problem identification/definition/solving in agricultural marketing and business
  (c) Lifelong learning ability
  (d) Communication/teamwork/leadership/management skills
  (e) Quality analysis/assurance skills
(iv) Learning activities: Classroom/laboratory, Independent and team projects, Internship , Industry-linked experience, Research experience, Immersion programs, Interdisciplinary/transdisciplinary experience, Workshops/short courses, Experiential/hands-on learning, Practical/operational skills, Case studies.
(v) Course development
  (a) Existing: Production economics, Marketing and price analysis, Fundamentals of business, Management, Econometrics, Operations research (quantitative techniques), Research methodology, Project management, International trade
  (b) New: IT for marketing and agribusiness – fundamentals (computer architecture/organization, programming, networks, data structure, database management, etc.), IT for marketing and agribusiness – Advanced (data analytics, modeling, simulation, optimization, decision support, etc.), IT for product quality, Game theory in marketing and agribusiness, IT in agricultural policy, Management of food quality and safety, Enterprise resource planning, IT project management
(vi) Curricula: Certificate, Vocational, 4 Year, Advanced (Masters and Ph.D.), Professional, Continuing Education
(vii) Delivery: Residence instruction, Distance learning, Hybrid (on-line and residence) , Dual degree program, Extension/outreach education
(viii) Evaluation metrics and process
  (a) Metrics: Placement/advancement of graduates, average compensation packages of employment, student enrollment, number of employers conducting on-campus recruitment
  (b) Actions: University administration, instructors, students, career counselors employers
(ix) Implementation

(a) Faculty development
(b) New hybrid educational mechanisms
(c) Collaborations among industry, private institutions, universities, government, etc.
(d) New teaching facilities (e.g. smart classrooms, team project laboratories, video conferencing, virtual labs, flipped classrooms, etc.)
(e) Incentivize IT institutions to include agriculture and food contents in their teaching with emerging issues.

6.1.5 Research Related to Curriculum and Instruction in Livestock and Fisheries

(i) Potential for Impact on IT in Agriculture and Food Curriculum and Instruction: There are tremendous opportunities to utilize intelligence and decision-making tools formulated from applications of IT to problems in animal agriculture and aquaculture.There is every reason to embrace IT tools as vectors for evaluating and compressing biological data from animals and animal production systems and translating the data into decision-making support for producers.Integration of IT into educational programs for animal and aquaculture production can lead to significant impacts on curriculum, instruction, and learning by both undergraduate and post-graduate students.

(ii) Examples of impactful opportunities for building capacity in instructional programs include:
   (a) Introduction of new courses (with uniform course syllabi) on information management in animal and aquaculture production in post-graduate programs.
   (b) Integration of newly developed software for decision-making into undergraduate courses on animal and aquaculture production.
   (c) Development of new certificate and diploma programs on applications of IT for both traditional courses and for non-traditional audiences (for example, the production industry – this could also be considered part of session 3 – Technology Transfer and Outreach).
   (d) Development of web-based courses and decision-making tools on IT applications in animal and aquaculture production through the efforts of ITRA, ICAR, and international partners.
   (e) Development of course content that incorporates examples in animal and aquaculture production and utilizes case studies on optimizing decision-making.

(iii) Mechanisms: Several mechanisms were identified that could be used to enable institutions to realize the potential for integration of IT with animal and aquaculture production:
   (a) Leadership and program development by bodies like ITRA, ICAR, VCI, AICTE, and UGC to address and incentivize educational institutions to formulate and introduce new courses.
   (b) It is recommended that organizations like IITs/IIITs collaborate with agricultural programs to introduce new certificate and diploma programs.
   (c) Funding should be provided for scholarship programs for students working on IT applications in this domain – such scholarships can serve as “seeding” to incentivize students to consider the new field.
      (i) In the absence of suitable mechanisms to make building new curricula attractive to prospective institutions:
         (a) ITRA and educational partners (in India and/or with international partners) should support state-of-the-art centers to host exposure visits and short-term training for participants that want to build educational programming that integrates IT applications in teaching animal and aquaculture production.
   (d) Engaging IT Departments/Institutions: There is interest on the part of IT institutions to work with agricultural and food programs, but there have been

limited incentives and communication between the domains to make substantial progress in program development. In consideration of how IT and agricultural institutions can enhance relationships and stimulate greater collaboration on problems of common interest, recommendations include:

(i) Funding opportunities must be provided that emphasize the need for collaboration between agricultural and IT scientists.
(ii) ITRA and ICAR should enhance communication between the two groups to build better mutual understanding of the importance and potential impact of the opportunities that exist.

(e) Attracting MS/PhD Students to IT in Agriculture and Food

(i) Students must be provided with motivating opportunities to enter into an emerging discipline like "IT in Agriculture and Food Systems."However, it is very clear that this field can quickly develop into one of sufficient distinction and depth to create research opportunities that can attract funding and, of greater relevance to prospective students, one that offers abundant employment and career opportunities. Specific avenues to stimulate student entry into this area include:
(ii) Institutions must communicate and work with prospective employers to relay the uniqueness and value of the skills and problem-solving capabilities of students with training in this field.
(iii) Institutions must convey these opportunities to students and utilize in-house capacity (placement services) to work with students to realize careers in the field.
(iv) Research programs in this discipline should involve undergraduate students in their laboratories.
(v) Provide funding as scholarships and research assistantships to students to incentivize and stimulate students to enter the discipline.

6.2 Technology Transfer/Entrepreneurship and Outreach

This section summarizes the SFM discussions and recommendations with respect to Item (ii) mentioned at the beginning of this section, Sec. 6. The summary is divided into five parts, each addressing one of the identified five main areas of agriculture and food.

6.2.1 Activities Required for Technology Transfer/entrepreneurship and outreach in crop production

(i) Software for resources and technical documentation needs to be developed for precise advisory and consultancy services.
(ii) GIS/GPS system can be developed to document the services related to input advisory and diagnostic facilities related to soil, water, pest, and disease.
(iii) Mapping of footprints and response of farmer from different parts to determine extension plan.
(iv) Development of online networking with different NARS, SAU and KVK for technology and services sharing.
(v) Human resource developmentof extension scientists about different ICT tools to improve their efficiency.
(vi) Agri-prunerus, master farmers, and farmer friends should be brought into the IT network.
(vii) Feedback to researcher from farmer and extension functionaries should be strengthened using ICT.
(viii) More ICT tools/gadgets/softwares/multi-media

6.2.2 Activities Required for Technology Transfer/Entrepreneurship and Outreach in Soil, Water, Weather

(i) Identify commercial value technologies
(ii) Value addition in content development (Multimedia, animation, short video clips, etc.)

(iii) E-enabled Patenting and IPR issues
(iv) Strengthen Agriclinic/kisan call centres through ICT tools with supportive documents/database
(v) Technology information and field demonstrationthrough ICT and conventional methods
(vi) Constraints analyses and solutions for effective technology transfer
(vii) Encourage startups for technology knowledge dissemination through IT
(viii) Awareness and sensitization e-Workshops / Webinars
(ix) Web based 'discussion-support' system for dissemination
(x) Dedicated Agro-weather TV-Channels (24x7)
(xi) Disaster and extreme weather alarms and associated advisory through advanced IT tools and social networking
(xii) Encourage producer company run by farmers through public/corporate support (inputs and marketing management through e-methods)
(xiii) Mobile based 2-way communication with farmers (SMS/IVR)
(xiv) Agri-knowledge dissemination to farmers through Bhuvan site
(xv) Skill development of mediators at village level for techno-knowledge transfer
(xvi) Delivery through single window system in PPP mode
(xvii) Fertilizer manufacturing companies, water distribution agencies, agri-insurance companies, policy making bodies, rural development institutions/NGOs, etc.
(xviii) Favorable policies need to be created for bearing the initial risk to encourage thousands of startups.
(xix) There are some effective mechanisms available for incubation of startup companies through some of the Business Planning Development (BPD) Units created under NAIP, which needs further strengthening.

6.2.3 Activities Required for Technology Transfer/Entrepreneurship and Outreach in Agriculture Education and Extension

(i) Farmers like to see 'on farm' real-world demonstrations
(ii) Use of mobile communications to strengthen the link between farmers (who have questions) and experts (who have answers); Kisan Call Center (KCC) is an example.
(iii) Private dealers lack agriculture knowledge, yet freely provide advice (often of questionable quality) to the farmers; there needs to be a certification requirement, and a certification curriculum to fulfill the requirement
(iv) Increasing the capability, and capacity, of an extension agent through IT.
(v) Connectivity and content are both very important

6.2.4 Activities Required forTechnology Transfer/Entrepreneurship and Outreachin Marketing and Agribusiness

(i) There is currently a bottleneck in the transfer process due to lack of adequate personnel and lower priority. ICAR has technologies which are not being transferred to farmers due to these problems. However, this is not true for IT in Agriculture – many IP's are not available
(ii) Appropriate incentives and platform for IP generation and technology transfer is inadequate; gap between ICAR and line departments
(iii) Empower end-users with information about new technologies and potential benefits so that demand is generated for technology transfer
(iv) ICT to empower farmer with knowledge about new developments and technology and educate them to take calculated risks and minimize risk coverage through contract;
(v) Provide incentives for trials of new technologies;
(vi) Propagate benefits via social network
(vii) KVK's strengthened to facilitate introduction of new technologies
(viii) PPP model for technology transfer to be created
(ix) KVK's should be made partners in technology development

6.2.5 Activities Required for Technology Transfer/Entrepreneurship and Outreach in Livestock and Fisheries

(i) Mechanisms that could be used to more effectively get prototype concepts, demonstrations, IP, standards, etc. out to their likely beneficiaries:
   (a) Creation of knowledge base of technologies, Public-private partnerships, Kisan Call Centers/chat lines, e-conferencing systems, Web portals, Television (Doordarshan), Community radio, Village Knowledge Center, Information kiosks, Call centers, Agropedia, SMS alerts, Expert systems, Dedicated TV channel, Social networking sites, Time taken in IP management

(ii) What is the plausibility of such technology transfer? What are the potential/known difficulties?
   (a) Responsibility, Quality service, Local language support, Literacy levels, Human Computer Interaction Issues, Infrastructure, Cost effectiveness of technology dissemination.

(iii) What are some possible agencies, initiatives, industries, etc., that, if they like what they see, could realistically help realize the transfer of IT in Agriculture and Food technologies?
   (a) Make a synergetic relationship among the following organizations: DASDF, ICAR, State Animal Husbandry Departments, State Agricultural Universities, State Dairy Federations, KVKs, NGOs

(iv) Could they be involved in the research and development of work to begin with? How?
   (a) Yes. Reporting the issues at the ground level by the extension education agencies, conducting research and validation of knowledge and dissemination of technology to the stakeholders.

(v) Why is there a lack of startups in an area as vast as Agriculture and Food and out of a catchment area as large as indicated by the size of ICAR?
   (a) Realization of the importance of a new technology, Cost of delivery of the service, Scalability issues, Enabling infrastructure, Business viability

(vi) What, if any, are some available and effective mechanisms for incubation of startup companies that may help with the startup needs of, e.g., physical facilities, access to business expertise; administrative and financial support; etc.?
   (a) Knowledge management centers, Single window delivery system of knowledge, e-seva, mee-seva, Public-Private Partnership Mode, Technology Business Incubator

6.3 Development of Societal Sensitivity

This section summarizes the SFM discussions and recommendations with respect to Item (iii) mentioned at the beginning of this section, Sec. 6. The summary is divided into five parts, each addressing one of the identified five main areas of agriculture and food.

6.3.1 Observations/Challenges/Activities to Create Societal Sensitivity for Research in Crop Production

(i) Technology transfer from lab to land is slow.
(ii) Involvement of researcher in extension of particular technology is poor.
(iii) Tight compartments among research-extension-farmer.
(iv) Attitude toward extension needs to be changed.
(v) Less involvement of IT institute in agriculture extension.
(vi) Non availability of IT tools/software for improving tech. dissemination and to study the outreach of technology.
(vii) Farmers as well as extension scientist are illiterate about IT tools.
(viii) Replication of success stories about IT in agriculture does not commonly occur.
(ix) No responsibility for technology dissemination towards extension function is due to non- availability of monitoring system.
(x) Link is missing between basic and applied science, besides technology transfer.

6.3.2Activities to Create Societal Sensitivity for Research Related to Soil, Water and Weather

(i) Market driven research sensitive to the society
(ii) Students should be exposed to the stories of model developments
(iii) Inculcating values of karma and dharma
(iv) Communication and presentation skills
(v) Rural Orientation Training Programme for students
(vi) Exposure to problems of disadvantaged groups (including farmers)
(vii) Experience sharing by successful alumni
(viii) Encourage competitions to identify problems and possible solutions concerning disadvantaged groups
(ix) Create culture of valuing serious thinkers
(x) Top scientists to be requested to deliver guest lectures in different educational institutions
(xi) Offering of liberal arts/humanities courses

6.3.3 Activities to Create Societal Sensitivity in Agriculture Education and Extension

(i) Need to be put in environments where such experienced can be had
(ii) Need to be primed prior to engagement, so as to be able to 'see better'
(iii) Exploration of the societal impact of every project must be part of the research task
(iv) Trained to effectively empathize with farmers' needs/problems – FSR (farm social responsibility)
(v) Courses on sustainability and ethics, including case studies
(vi) Community service component to education
(vii) have a societal awareness component to their capstone project; this can be done by assigning some weight to this factor, or have a project task specific to this
(viii) have this as a volunteer experience
(ix) incentivize the societal component of a project through special recognitions/awards

6.3.4Activities to Create Societal Sensitivity for Marketing and Agri-Business

(i) Routinely and habitually relating their research and development work in various parts of Agriculture and Food to societal issues, needs and problems.
(ii) Helping with suitable projects of government and NGOs.
(iii) Sensitize the students/researchers to social issues linked to the problem being pursued in the context of agri-marketing and agri-business; student must be part of the value chain and experience the problem.
(iv) Students should be encouraged to apply their ideas to solve practical problems by participation in community movements and/or through NGO's working for the cause.
(v) Facilitation for the students to experiment with research outcome through KVK's and doing impact assessment.
(vi) All of the above should be made part of NSS Service programmes operational in different universitiesas extracurricular activities.
(vii) Participation in these activities should form part of university evaluation scheme.
(viii) Humanities courses, e.g., on the lives, philosophies and works of extraordinary people.
(ix) Literature, Culture (eg. Humanity in Food Web) related, and other Humanities courses should be core component.
(x) Debates and/or seminars on local problems are included as part of student activities.
(xi) Programs for developing self-esteem, through objective evaluation of one's culture, traditions, philosophies, lifestyles, etc.
(xii) Workshops to understand and appreciate diversity inherent in the society
(xiii) Courses on values and value systems.
(xiv) Professional ethics through case studies must be introduced with particular reference to the area of specialization.

(xv) Understanding forces known to shape societies and their relevance to living today. In the present context, issues related to the dynamics offamily structure and land-holding and ethics of business should be understood.

6.3.5 Activities to Create Societal Sensitivity in Livestock and Fisheries

(i) Adaptation programs
(ii) Association between Farmer Families and Students/Faculty
(iii) Internship and exposure in rural areas
(iv) Extending basic amenities to everyone
(v) Gender sensitivity
(vi) Ethical handling of animals
(vii) Sensitivity about biodiversity

7. Relationship withPlanning Commission's 11th Five Year Plan on Agriculture and ICAR's Vision 2030

In this section, we take note of two other major efforts on the topic of improving the state of agriculture and food. One of them is the 11th Five Year Plan on agriculture, and the other is ICAR Vision 2030 document.We outline those recommendations made in these two documents that may involve IT, and explain how these recommendations relate to those made in this report.

7.1Summary of Challenges Identified in11'th Five Year Plan on Agriculture

The planning commission's document for 11th five year plan for agriculture covers entire area of agriculture and allied activities.Several challenges have been identified, in different areas, including agricultural research, extension, price policy, soil health management and fertilizer subsidy, horticulture, plant protection, agricultural credit, co-operatives, risk management, marketing, post-harvest management, agro-processing, mechanization, animal husbandry, dairying and fisheries, and rainfed agriculture.The report is very detailed and also includes administrative and structural issues. Below we summarize the challenges that involve IT and are relevant to this SFM report. For ease of cross-referencing by the reader, we have given each challenge the same paragraph (Para) number under which it appears in the original, 11th planning commission document:

(http://planningcommission.nic.in/plans/planrel/fiveyr/11th/11_v3/11v3_ch1.pdf).

In the sequel, we refer to the contents of the Planning Commission document by the Para numbers.

(i) **Agricultural Research**

(a) **(Para 1.23)**The productivity achieved on farms has fallen short of those in field trials.

(b) **(Para 1.24)**

(i) Production of new seed varieties and identification of new genes with high nutritive value.
(ii) Implications of climate change program should be studied.
(iii) Research should be carried out in the areas of site-specific nutrient upply and efficient water management techniques.
(iv) Integrated pest management (IPM) needs greater emphasis. There is a need for interdisciplinary research in plant protection.
(v) In horticulture, there is a need to survey of indigenous biodiversity for resistance to various biotic and abiotic stresses for improvement in production, productivity and quality of produce.
(vi) In livestock, there is a need to reorient research and assess the genetic potential of indigenous breeds.
(vii) Research should explore technologies to augment feed resources.

(viii) Research should be carried out to invent better processing technologies for animal products.

(ix) Need to identify integrated farming systems in different agro-ecological regions.

(c) **(Para 1.25)**So far, focus was mostly on only increasing the yield potential by intensive use of water and bio-chemical inputs. More attention should be given to the development of methods and practices to carry outsustainable agriculture.

(d) **(Para 1.26)**

(i) Available resources foragriculture research are not efficiently utilized. There is a lack of effective flow of bilateral flow of information among research, extension, and implementation departments.

(ii) There is lack of large-scale on-farm validation of techniques and feedback.

(e) **(Para 1.27)**A major paradigm shift is needed to transform the present commodity-based research to a systems approach to bring a region-specificity in technologies.

(ii) **Extension**

(a) **(Para1.31)** There is a large gap between what can be obtained in farmers' fields with the adoption of improved technology and what is obtained with the existing practices followed by the farmers.

(b) **(Para 1.32)** How to involve resource-poor farmers with holding below 1 hectare to take command of their situation and reduce innovation adoption period.

(iii) **Price Policy**

(a) **(Para 1.37)** Price policy concerns arising from the volatility of international prices need to be addressed.

(iv) **Soil Health Management and Fertilizer Subsidy**

(a) **(Para 1.39)** Soil degradation through use of agro-chemicals is a serious issue that needs to be addressed in a priority basis.

(b) **(Para 1.40)** Lack of knowledge on the part of the farmers about the importance of soil health and information about the status

(v) **Seeds**

(a) **(Para 1.44)** Little focus on hybrid seed production in public sector.Even though private sector has filled the gap for some crops, it remains absent in the production of seeds of self-pollinating varieties.

(vi) **Horticulture**

(a) **(Para 1.50)** In horticulture, linkages are to be establishedin the area of agricultural marketing and processing.

(b) **(Para 1.51)**Linking of farmers with corporate buyers

(c) **(Para 1.52)**Low quality of planting material is a majorissue.Farmers do not have access to genuine and disease-free elite to certified planting material in different crops.

(d) **(Para 1.53)** Development of improved varieties/hybrids of fruits, vegetables, plantation crops, medicinal and aromatic crops, flowers and ornamental crops, spices, cashew, oil palm with high production potential, biotic and abiotic stress resistance is the need of hour.

(e) **(Para 1.54)** Development of appropriate horticultural-based cropping systems for different agro-climatic zones.

(vii) **Plant Protection**

(a) **(Para 1.56)** Implementation of Integrated Pest management (IPM) component is disintegrated as a IPM component in different Plan schemes. These fragmented elements need to be co-ordinated.

(b) **(Para 1.66)** Adequate response mechanisms to climate variability andclimate change such as early warning systems, mapping of agricultural losses through remote sensing technologyand so onshould be put in put in place in a decentralized manner.

(c) **(Para 1.67)** The coverage ofNational Agricultural Insurance System (NAIS) is tardy. The popularity with the farmers is limited due several deficiencies of NAIS. Efforts should be made to increase the scope of NAIS for more crops and farmers.

(d) **(Para 1.68)** Development of suitable insurance products is another issue.

(viii) **Marketing**

(a) **(Para 1.70)** Flexibility should be increased for the buyers and sellers to interact in the markets in an efficient manner.

(ix) **Post-Harvest Management andAgro-Processing**

(a) **(Para 1.75)** The losses are about 20%-30% due to inappropriatepost-harvest management.

(b) **(Para 1.76)** Several technologies have been developed in agro-processing, but its adoption is far below the requirements.

(x) **Animal Husbandry, Dairying and Fisheries**

(a) **(Para 1.78)**The growth in livestock is constrained by the availability and quality of support services such as lending andhealth services.

(b) **(Para 1.80)** The future of fisheries export would be influenced by the consistent compliance with food safety measures.

(xi) **Rainfeed Agriculture**

(a) **(Para 1.82)** In rainfed agriculture, the challenge is to improve livelihoods through watershed development projects, reinforced by an integrated farming system approach that would increase productivity in a sustainable manner and contribute to livelihood security.

(xii) **Access toAgricultural Services**

(a) **(Para 1.115)** Small and marginal farmers often lack access to major agricultural services, such as credit, extension, insurance and markets. The key issue with agricultural credit is utter lack of financial inclusion.

(b) **(Para 1.116)** Small and marginal farmers are also deprived ofMSP because of low surpluses.

7.2 Summary ofICAR's Vision 2030

The ICAR Vision 2030 document(http://www.icar.org.in/files/ICAR-Vision-2030.pdf) discusses thekey challenges and opportunities in the agriculture sector over the next two decades, so as to develop an appropriate strategy and a roadmap for the role of ICAR in defining agricultural research for growth, development and equity. The vision is to ensure food and income security for all, through technological innovations and sustainable agriculture.The vision is to be achieved by harnessing the power of science and education with a human touch for higher and sustainable agricultural production. It aims at continuously transformation of the existing National Agricultural Research System into a vibrant National Agricultural Innovation System. The ICAR

document mentions the following 5-point strategy to realizethe vision. In the original ICAR document, these points are listed as bulleted items. For ease of cross referencing by the reader, we have assigned below these bullets our own numbers, and referred to the page number(s) in the ICAR document on which the bulleted item appears. In the sequel, we refer to the ICAR document contents by our assigned numbers.

(i) Improve efficiency of human and financial resources and effective utilization of infrastructure.
   (a) Formulate consortia-based target-oriented eco-region-wise mega research and technology development programmes cutting-across disciplines and institutions within and outside the NARS (p.17);
   (b) Prioritize demand-driven and resource-based research programme with focus on smallholders and emerging market opportunities; (p.18)
   (c) Focus more on rainfed, backward, marginal and fragile areas; and (p.18)
   (d) Harness synergies of partners and stakeholders in developing improved technologies, systems and information. (p.18)

(ii) Facilitate accelerated dissemination of improved technologies, knowledge and information.
   (a) Develop and pilot effective delivery systems and evolve institutional models to link research and development system with farmers and other stakeholders in the value-chain for accelerated adoption, cost-effective post-harvest management, value-addition and processing and efficient marketing through information and communication technology and e-extension; (p.18)
   (b) Provide state-of-the-art scientific facilities in laboratories and infrastructure; (p.18)
   (c) Establish institutional mechanisms and governance structure for linking technology generation and dissemination system with back-end service providers; and (p.18)
   (d) Link research and development system with society by improving science communication. Awareness and sensitization programmes would be developed addressing benefits of science and food safety concerns of the society. (p.18)

(iii) Enhance quality of human resource in agri-supply chain.
   (a) Regular manpower planning in agriculture sector with focus on research and development system, agri-service providing system, post-harvest processing and preservation system, and agri-business to project demand for future human resource needs; (p.18)
   (b) Improve quality of higher agricultural education and enhance capacity of human resource in research for development through talent management for overcoming new and complex challenges; (p.18)
   (c) Develop an accountable, professional, motivated and intellectual property rights-compatible work-culture; and (p.18)
   (d) Facilitate in strengthening and streamlining higher agricultural education system to meet future challenges. (p.18)

(iv) Commercialization of technologies through organized intellectual property rights and benefit-sharing system.
   (a) In the new era of Intellectual Property Rights regime, a compatible intellectual property and technology management system needs to be strengthened for promoting science and benefiting farmers and the society; and (p.18)
   (b) Facilitate harmonization of intellectual property domain with other parallel laws in and outside the country. (p.18)

(v) Promote effective, efficient and decentralized governance by introducing best management practices in the Indian Council of Agricultural Research.

(a) Institutionalize project-based budgeting, management information system (MIS) and priority-setting, monitoring and evaluation (PME); (p.18)
(b) Multi-stakeholder, multi-disciplinary, multi-institutional participatory and consortia-based research; (p.18)
(c) Involvement of social sciences in research prioritization, and technology development, targeting and dissemination; (p.19)
(d) High research priority is to be given to the needs of the rainfed, backward, fragile and marginal ecosystems and vulnerable groups; and provide gender-friendly technologies, machines and management options; (p.18)
(e) Evolve a lean-and-efficient administration by employing information and communication technology; (p.19)
(f) Develop a performance-based work-culture with incentives-and rewards system; and
(g) Develop a futuristic human resource development programme in cutting-edge science and technology. (p.19)

7.3Relationship with 11th Five Year Plan and ICAR's Vision 2031

(i) We now relate the recommendations arrived at by the SFM on IT for Agriculture and Food using the methodology described above, to those already made by the Planning Commission, for agriculture during 11th five year plan, and by ICAR's, as presented in their vision document 2030.
(ii) A major characteristic of the analyses made at the SFM is that we have analyzed and structured the agriculture problems in each of the six areas with respect to what they need by way of IT. Thus, we have identified the variety of ITs needed, and for each type of IT solution, identified all the agriculture subproblems which the IT solution may impact. In contrast, the Planning Commission as well as the ICAR documents naturally enumerate the agriculture problems whose solutions are needed, without, in general and as is to be expected, always discussing specific types of solutions or technologies that may be involved. A solution may be designed by including IT in a small or large part or not at all. Consequently, each IT problem we identify is in general related to multiple agricultural problems listed in the Planning Commission and ICAR documents. Our IT based indexing and enumeration of the IT challenges may help the IT developers choose the ITs they may want to investigate and help them maximize the impact of the solutions they develop.
(iii) For each of the six agriculture areas, the table below lists the IT problems identified at the SFM as important (Column 2), the multiple paragraph numbers in the Planning Commission document (Column 3) as well as the ICAR document (Column 4) that mention important agricultural challenges that need to be addressed and which will be directly impacted by the solution of the IT problem listed in Column 2.It is reassuring to note that each IT identified by the SFM as important is also found to be relevant for at least one challenge listed as important by Planning Commission or ICAR, i.e., not both of Columns 3 and 4 are empty for any row corresponding to an SFM-identified IT.

TABLE: Relationship of the proposed plan with the plans developed by ICAR and the Planning Commission. The components of our plan are on IT in Agriculture and Food, whereas the recommendations made in the latter two are mostly intrinsic to Agriculture and Food.

	Research Problems identified in SFM in IT for Agriculture by ITRA.	Problems identified in11'th five year plan on agriculture, appearing	Bulleted Items from the ICAR's vision2030 document, referenced

		under the Para Numbers indicated below and reproduced in Sec. 7.1	using the Numbers we have assigned to them in Sec. 7.2
1	**Improved Crop Production**		
	Lack of centralized data repositories		
	Lack of integrated crop/climate/economic models for reducing yield gaps and realizing yield optimization	1.24,1.26, 1.54	1.1, 1.2, 2.1, 5.2, 5.4
	Absence of country wide soil maps (physical & chemical)	1.39	1.3, 2.2
	Dearth of expert systems, modeling and forecasting for pests/diseases	1.56	2.1, 5.4
	Poor farm mechanization		5.4
	Poor automation technologies		5.4
	Poor pest & disease surveillance		
	Lack of innovative tools/gadgets for precision farming	1.24	5.2
	Lack of innovative tools/gadgets for harvesting, grading storage etc.,	1.75	3.1, 5.2
	Poor food processing, food quality, issues on food safety	1.76	2.1, 3.1, 5.2
	Poor agro-information delivery mechanisms	1.24 1.31	2.4, 5.3
2	**Soil, Water, Weather**		
	Weather-based agriculture management	1.66	5.4
	Water management	1.82	1.3, 5.4
	Soil nutrient management	1.39, 1.40	5.4
	Saline, sodic and acidic soil management	1.39,1.40	5.4
	Water logging and drainage	1.24	1.3
	Soil erosion and land degradation;	1.39, 1.40	1.3
	Climate change	1.24	5.4
3	**Agriculture Education and Extension**		
	Lack of skills	1.31	3.1, 3.2, 5.7
	Lack of cross-trained professionals	1.31	1.4, 3.1,3.4
	Multi-lingual content preparation & delivery	1.26, 1.27	2.4
	Coordination between research, extension & industry	1.26	2.4
	Domain specific IT tools & techniques		2.4
	Research & development laboratory facilities		2.2, 3.4
4	**Marketing and Agribusiness:**		
	Easy access to market to get best price	1.37, 1.116	2.1
	Product (crop) strategy	1.25, 1.26, 1.50, 1.66, 1.67	2.1
	Developing affordable equipment for quality assessment & preservation of produce	1.32	2.1
	Development of decision support system (DSS)	1.32,1.70, 1.76	2.3, 5.1
	Predicting right price and right market for the commodity	1.32, 1.50	2.1
	Design a system to empower agri-entrepreneur	1.32, 1.67, 1.68	2.3, 4.1. 4.2
	Huge post-harvest losses	1.31	
	Cost of certification for traceability (Global GAP – Good Agriculture Practices).	1.24	4.1, 4.2
5	**Livestock and Fisheries**		

	Efficient live stock farming systems	1.24	2.1
	Automation oflivestock, poultry and aquaculture	1.24	5.2
	Integrated agri-animal-aqua farming systems		5.2
	National livestock Identification System	1.24	5.2
	Information delivery and marketing		2.1
	Decision support system for livestock	1.78	2.1
	Improving production and post-production quality	1.24, 1.78, 1.80	2.1
	Animal identification and growth management	1.24	2.1
	Capacity building of stakeholders		2.3, 2.4, 3.1
	Management of livestock under climate and environmental variations.	1.24	5.4

8. Conclusions

(i) A rapid increase in population adds significantly to the demand on food production, which increases the pressure on agriculture and its prerequisites. This is a serious challenge not only to the policy makers, but also to agricultural producers, scientists, economists, and civil society. A greater focus is needed to increase agricultural production, while also making sustainable use of natural resources and improving conservation practices. Farmers need improved technologies to combat food production challenges and cope with the risks associated with climate change. Many nations have successfully utilized IT applications in agriculture for the use of geo-spatial technologies, pre-harvest production forecasting of major crops, crop assessment based on soil moisture availability, development of farm and regional scale digital soil maps for assessing land suitability on crop production, short and long range weather forecasts, cropping system analysis, site suitability for horticulture development, and wetland inventory and assessment for inland fishery development. Given the vast nature of agricultural production systems in India, IT can facilitate similar improvements in efficiency and productivity of agriculture and related activities; timely and quality information inputs to decision making, and marketing; and bringing about an overall qualitative improvement in rural life.

(ii) The objective of this RFP is to assemble a tightly collaborative group of individuals and institutions working on as many of the relevant aspects of IT in Agriculture and Food identified herein as possible. Any other relevant ideas not included here may be informally discussed with ITRA before any effort is put into proposing them. The best collaborations will likely include agriculture and food researchers who have worked on aspects of IT or are well positioned to do so, and IT researchers who have experience with developing IT systems for agriculture and food.

(iii) It is required that the work proposed in response to this RFP is designed so it would significantly benefit the Indian agriculture and food scenario, using IT, in ways, ranging from education, research, and development to extension. IT would help in mobilizing science and technology by linking agricultural specialists into virtual communities and accelerating agricultural research exchanges among different entities. IT in agriculture will bring direct contribution to agricultural productivity, empower farmers to make informed and quality decisions, and would help develop policies to positively impact rural economies and livelihoods. IT would significantly promote economic development of agricultural producers, facilitate community development, drastically improve research and educational development activities, help develop small and medium enterprises, and promote development of media networks.

(iv) Specifically, IT in agricultural research would enhance development of efficient location-specific crop production systems and best agricultural practices (for example:

integrated pest management and integrated nutrient management). It would result in the invention of high yielding crop varieties (resistant to weather variability, pests, and diseases) along with the corresponding best agricultural practices. IT in agricultural education would facilitate producing high quality agricultural graduates who possess enhanced conceptual, research, and practical skills, to provide innovative solutions to new problems in agriculture. IT in extension would accelerate the processes of dissemination of best agricultural practices to farmers and other stakeholders in a timely manner. Increased productivity and market access would raise farmers' income, which may result in reducing migration from rural India to cities. The living standards of rural population would likewise improve. With timely interventions, the usage of chemical fertilizers and pesticides would be reduced, and there would be significant improvement in the water, soil, crop and ecosystem quality, which would arrest environmental degradation.

(v) IT in Agriculture in India would have a significant impact on agriculture and livelihood globally. India has diverse farming situations due to diversity in the weather and geography.Some of the related issues are similar to those encountered in many other developing countries. For example, any IT-based solutions developed for agriculture in India could be transferred to several countries in South/South East Asia, and Africa.By producing high quality agricultural produce, Indian farmers would be able to compete in the international market.

(vi) This report has enumerated a variety of ITs needed, and for each type of IT solution, identified subproblems in each of the six areas which the IT solution may impact. In contrast, the Planning Commission as well as the ICAR documents naturally enumerate the agriculture problems whose solutions are needed, without, in general and as expected, always discussing specific types of solutions or technologies that may be involved. Each IT problem identified here is in general related to multiple agricultural problems listed in the Planning Commission and ICAR documents. The IT based indexing and enumeration of the IT challenges presented here may help the IT developers choose the ITs they may want to investigate, and help them maximize the impact of the solutions they develop.

ANNEXURE 1

MAJOR POTENTIAL CONTRIBUTORS IN IT IN AGRICULTURE AND FOOD

Agriculture	**Organization / People**	**IT Tools:**	**Organization / People**
HR development / capacity building / Education and training -	PIs of e-courses, Deans / faculty of selected colleges, Researchers, NAARM, IASRI, VCs	a. Sensors / actuators Applicators	IITH; IITB; CDAC
Precision farming (automation) [a - i] - Crop production - Horticulture - Animal husbandry and - Fisheries	SMDs (all) - 2 inst. from each smds (CIAE), 5 Private sector companies	b. Data Collection, Analysis and Estimation; Pattern recognition; Modeling and simulation	UAS Raichur, TNAU, IASRI, IIITH, IIT Kgp.,IARI
E-Extension [a; b; d;j;] - -	3 zonal project directors, 2 private sectors, 3 KVKs, 2-3 NGOs, 3 govt. /state extension departments, 2 ATMA MANAGE	c. Prediction	IMD NCCF NRSA
Marketing	PIs of market research project (TNAU; NCAP;), NIAM, Directorate of Marketing, NIC,IIM – Lucknow,2 private sector, CIMMYT	d. Communication - Sensor networks - Internet / web - Mobile - Mass media	MLAsia CDAC IITs ERNET DD and AIR 2 IT savvy journalists
Processing and food quality	CIPHET, CFTRI, NDRI, CIFT, NRC on Meat, APEDA 2 Private companies, AMUL India, Certification bodies (Agmark)	e. DSS	IFPRI, AI – IITK
		f. Interfaces	IIITH, TDIL CEWIT, IITM, RML, IKSL, NOKIA,AIRTEL, TCS (m-Krishi), IITD
Estimating the Environment parameters	CRIDA, IMD, ICRISAT	g. Visualization	ISRO – Bhuvan, IMD, AI IITD, AI IITB
Data and information knowledge management	IASRI, DKMA, IITB; IITK; IITM; IIITH; MLAsia; IIITK	h. Instrumentation	CIAE, AMIL Manufactures reps
		i. Human knowledge extraction tools	NISCAIR, IITK-AI, IITB – AI

ANNEXURE 2

IT in AGRICULTURE AND FOOD
TEMPLATE FOR PROVIDING INPUT TO THE SFM
To be held on March 15-16, 2013

The information you provide below will be used to more effectively structure the SFM agenda. The SFM output will be used to eventually define, design and initiate multi-institutional, team-based, collaborative IT-in-Agriculture&Food programmes, based in academic institutions and research laboratories, in collaborations with other relevant organizations. The number of institutions involved will double or triple every 2 years until the size of the activity is considered optimum. Faculty, students and other scientists involved will be engaged in research and development, curricular innovations and technology transfer in Agriculture&Food, and in programmes for developing/enhancing workforce sensitivity to societal needs.

1. Your Name: _____

2. Organization_____

3. Your Mobile Number _____

4. Email Address_____

5. List the sub-area (or two sub-areas) of Agriculture, Food and/or IT in which you have yourself made contributions or involved, emphasizing those subareas involving IT. Examples of these sub-areas include , but are not limited to: *Agricultural Extension, Agricultural Research, Agricultural Education, Precision Agriculture, HR Development and Capacity Building, Agricultural CropProduction, Agricultural Crop Protection, Plant Breeding, Seed production, Seed Technologies,Soil Science, Agriculture Engineering, Farm Management, Farm Mechanization, Post-harvest Management, Green House Farming, Horticulture, Sericulture, Apiculture, Animal Husbandry, Livestock Farming, Aqua Culture, Fisheries, Risk Management, Climate Change, Extreme Weather Conditions, Forest Management, Environment, Marketing, Food Processing and Food Quality.*

3.1.
3.2.

6. *For each sub-area you have listed in 3.1 and 3.2 above:* In the Table below, name at most 5 Agriculture/Food problems/issues (irrespective of the role for IT in them) whose solutions will lead to very significant improvements in the state of the art in the sub-area.For each Problem/Issue, also indicate whether it is amenable to IT based solution.

	Problems	IT Amenable? (Say Yes or No)
Sub-area 1	1.	
	2.	
	3.	

	4.	
	5.	
Sub-area 2 (If you have listed it)	1.	
	2.	
	3.	
	4.	
	5.	

7. For the Problems/Issues amenable to IT listed in the Table above, name, or state in a sentence or two, the types of information technologies that would be useful. Examples of information technologies include, but are not limited to: *Data and Information Based Systems, Decision Support System, Data Mining, Pattern Recognition, Prediction, Internet/Web, Mobile Phones, Machine Learning, Artificial Intelligence, Modeling and simulation, Data Science, Embedded Systems, Interfaces, Visualization, Human Knowledge Extraction, Sensors and Sensor Networks, GIS/ GPS, Internet of Things etc.*

5.1
5.2
….
….

ANNEXURE3

GROUPINGS OF TOPICS OF IT RELEVANCE IN AGRICULTURE AND FOOD

Note:

(i) Agriculture: Production of food, fiber, fodder, fruits and vegetables, Agro-forestry, greenhouse farming etc.

(ii) Livestock: Animal husbandry and aqua farming.

Group 1	Crop Production (IT interventions for improved seed, crop production/protected cultivation, farm mechanization, farm management, precision farming, pest management, post-harvesting and food processingprocesses)
Group 2	Soil, Water and Weather (IT interventions for efficient management of soil, weather forecasting, environment, disasters, natural resources, remote sensing, soil mapping)
Group 3	Agriculture Education/Extension (IT interventions for better education/trainingprocesses to produce quality students/scientists/extension professionals with practical and advanced research skills, extending latest crop technologies to stakeholders including farmers,reducing the lab to land gap, and better capacity building/training of stakeholders. real-time advisory to farmers, farmer-expert connectivity)
Group 4	Marketing and Agri-business (IT interventions for efficient procurement, storage, and supply ofquality agricultural produce and processed goods to consumers, sale of produc e by farmers)
Group 5	Livestock (IT interventions for scientific herd management, management of semen stations and information on availability of semen, production, protection, education, extension, and marketing of animals and animal products)

ANNEXURE 4
THE POWER-POINT TEMPLATE USED FOR
PRESENTATIONS BY AGRICULTURE AND FOOD SCIENTISTS

ITRA-ICAR SFM on
IT in Agriculture and Food
An Overview of Problems in
<Insert title of your problem group>

REPLACE THIS AND FOLLOWING LINES WITH YOUR YOUR
NAME
TITLE
ORGANIZATION
EMAIL
PHONE NUMBER

HIGHEST PRIORITY PROBLEMS

Replace this and the following lines with the most important Agri&Food problem in your group whose solutions will make a very major impact on meeting the challenges of your group and on the overall Agri&Food situation:

1. Problem 1: Most Important problem
2. Problem 2: the next important problem,...
3. Problem 3 : the next important problem
4. Problem 4: the next important problem
5. Problem 5: the next important problem

CURRNT SOLUTIONS

Replace this and the following lines with if/what the currently used solution is for the problems mentioned in the previous slides, respectively:

1. Solution for Problem 1, and
2. Solution for Problem 2, and
3. Solution for Problem 3, and
4. Solution for Problem 4, and
5. Solution for Problem 5

IT-AMENABLE?

Replace this and the following lines if/what you feel IT can do for

1. Solution for Problem 1 with IT...
2. Solution for Problem 2 with IT...
3. Solution for Problem 3 with IT...
4. Solution for Problem 4 with IT...
5. Solution for Problem 5 with IT...

AGRICULTURE&FOOD COLLABORATORS

Replace this and the following lines with the names and organizations of Agri&Food scientists who will work with IT experts to develop a solution for

1. Problem 1, and
2. Problem 2,...
3. Problem 3...
4. Problem 4...
5. Problem 5...

ANNEXURE 5
THE POWER-POINT TEMPLATE USED FOR PRESENTATIONS BY IT SCIENTISTS

ITRA-ICAR SFM on
IT in Agriculture and Food

EXAMPLES AND POTENTIAL OF IT SOLUTIONS

REPLACE THIS AND FOLLOWING LINES WITH YOUR
TITLE OF YOUR IT AREA (One of Areas 1-5)

YOUR NAME
TITLE
ORGANIZATION
EMAIL
PHONE NUMBER

EXAMPLES OF IT SOLUTIONS

Replace this and the following lines with

1. IT Based Solution 1: Agri&Food problem(s)/Agri&Food Group number(s) that have been addressed by you/others using technologies mainly from your IT Area, and How?
2. IT Based Solution 2: Another example like 1
3. ...Up to 5 examples
4. That demonstrate that integration with IT can make
5. A very major impact on meeting the challenges of Agri&Food problems from different Groups (1-5), and thus on the overall Agri&Food situation

EXAMPLES OF POTENTIAL IT SOLUTIONS

Replace this and the following lines with any other types of information technologies (from any of Areas 1-5 or others) that you feel have the potential for solving Agri&Foodnn problems

1. Information Technology Type 1: Examples of Specific/Group of Agri&Food Problems that may be solvable using this type of IT, and Why?
2. Information Technology Type 2: Another Example like 1
3. ...
4. ...
5. ...

ENGAGEMENT OF IT EXPERTS

Replace this and the following lines with what, if anything, you feel needs to be done to encourage serious engagement of accomplished IT experts at the required scale in Agri&Food.

1. Required Action 1
2. Required Action 2
3. ...

ANY OTHER COMMENTS

1. Comment 1
2. Comment 2
3. ...
4. ...
5. ...

ANNEXURE6

QUESTIONS POSED TO THE BREAKOUT SESSIONS

The questions posed to the SFM participants are divided into four categories, pertaining to the four ITRA quality measures: Research and Development, Curriculum and Capacity Building,Technology Transfer and Outreach, and Societal Sensitivity Development. Each category was discussed in a separate breakout session, with respect to each of the five IT in Agriculture and Food subareasfinalized before the SFM. The structure and questions suggested to the participants for discussion in the four breakout sessions are as given in Sections A-D below.

A. Research and Development

(i) **Purpose:** The objective of this session is to identify the subareas on which research and development work in IT-in-Agriculture and Food should focus.

(ii) **Examples of Questions to be Addressed:** Following are examples of some questions that would help achieve this objective.

(i) List up to ten IT-amenable Agriculture and Food problems from your group,whose solutions will make the biggest impact on the agriculture and food situation.

(ii) Order these problems (and the related knowledge gaps), starting with the one whose resolution will offer the best combination of feasibility and impact, followed by those with decreasing feasibility and impact.

(iii) What are the challenges represented by each problem?

(iv) What mix of expertise is required to solve each?

(v) Who are the stakeholders in each problem area?

(vi) How to conduct an effective evaluation of a candidate solution:

a. What should be the evaluation metrics?

b. How to conduct effective evaluation?

(vii) Given a fixed supply of resources (human, facilities, financial,…), what percentage should be allocated to each of the (up to ten) problems you have identified?

(viii) Are there any specialized facilities that could be established to enhance the quality and pace of high quality work on the problem?

(ix) Any other observations.

B: Curriculum and Capacity Building

(i) **Purpose:** Having close collaboration and cross-fertilization with teaching programs is a central goal of ITRA Research and Development projects. It would serve as a mechanism for inducting the results of the state of the art in research and development into courses, and thus broaden and deepen the curriculum. In addition to other benefits, this would impact the projects themselves, because the researchers, particularly the students, with richer formal knowledge will be more productive as researchers.

The objective of this session is to identify ways in which the research and development work in IT-in-Agriculture and Food (e.g., on the top problems you have listed in Session A) could be used to impact the contents of the curriculum and instruction in the institutions engaged in education in the area of IT in Agriculture and Food.

(ii) **Examples of Questions to be Addressed:** Following are examples of some questions that would help assess the potential for such impact.

(a) How likely is the work on the problems to positively impact the curriculum and student training, i.e., lead to new courses, seminars, laboratories, interdisciplinary streams, textbooks, databases, faculty, students,etc.?
(b) What mechanisms should an institution have in place to realize this potential, e.g., freedom and agility to introduce new courses, set up labs, etc.?
(c) If any of these mechanisms are missing, what are the major steps, if any, that should be taken to put the missing mechanisms in place in the institutions engaged in education in the area ofIT in Agriculture and Food?
(d) How much interest there is among the IT institutions to introduce IT in Agriculture and Food? What can be done to increase this interest?
(e) How to attract MS/PhD students to this area?
(f) Any other observations.

C. Technology Transfer and Outreach

(i) **Purpose:** Imagine millions of students, faculty and other scientists, who are research savvy (Sessions A), well equipped with the knowledge of IT-in-Agriculture and Food (Sessions B), and societally sensitive (Sessions D), being actively engaged in research and development! What related problems could this possibly leave unsolved?Such an environment can be expected to be a source of numerous ideas, datasets, proofs, prototypes, etc., worthy of being explored for transfer to working systems, products and services, useful to industry, Government, NGOs, other institutions and society at large.

(ii) **Examples of Questions to be Addressed:** Following are examples of some questions to be answered.

(a) In view of what approaches have been tried, and their strengths and shortcomings, identify improvements or new mechanisms that could be used to more effectively get prototype concepts, demonstrations, IP, standards, etc., out to their likely beneficiaries.
(b) What is the plausibility of such technology transfer? What are the potential/known difficulties?
(c) What are some possible agencies, initiatives, industries, etc., that, if they like what they see, could realistically help realize the transfer of IT in Agriculture and Food technologies?
(d) Could they be involved in the research and development of work to begin with? How?
(e) Why is there a lack of startups in an area as vast as Agriculture and Food and out of a catchment area as large as indicated by the size of ICAR?
(f) What, if any, are some available and effective incubation mechanisms that may help meet the needs of startup companies, such as physical facilities, access to business expertise; administrative and financial support; etc.
(g) Any other observations.

D. Societal Sensitivity Development

(i) **Purpose:** This session is about the ways in which we could help researchers, particularly the students, who are not only well versed in a research and development, but who also think of society and its needs.

Unless theresearchers:

(a) notice, register and relate societal problems with formal knowledge;
(b) identify with the problems surrounding them at home, on the road, or in the office, feel for those affected, and derive satisfaction from solving such problems; and
(c) discover the pleasures of giving and sharing vs. endlessly acquiring;

they will see the problems as just those – problems: inconveniences that they must learn to desensitize themselves to, in order to efficiently function. This, instead of seeing the problems as a fountain of opportunities for deriving satisfaction while building and advancing their careers.

ITRA encourages development of programs that would help make *relationships to society* a steady backdrop to the students' thinking and mainstream activities. Among many other positives, this can be expected to motivate students:

(i) to set their objectives not only within their subject area but more holistically,
(ii) judge their accomplishments accordingly, and
(iii) help more pointedly direct the vast pool of student talent and energy towards nation and society building.

Some examples of the mechanisms that could be used to enhance the societal sensitivity of the researchers follow, each to be interpreted in the context of Agriculture and Food:

(i) Routinely and habitually relating their research and development work in various subareas of Agriculture and Food to societal issues, needs and problems.
(ii) Helping with suitable projects of, e.g., Government and NGOs.
(iii) Humanities courses, e.g., on the lives, philosophies and works of people who have left extraordinary impact on society.
(iv) Programs for developing self-esteem, through objective evaluation of one's culture, traditions, philosophies, lifestyles, etc.
(v) Courses on values and value systems.
(vi) Understanding forces known to shape societies and their relevance to living today.

This area, of making people more societally sensitive, is unquestionably very challenging while being equally underserved. The good news, however, that naturally follows from this is that making a huge difference is, as always under such conditions, proportionately easier – growing from 1 to 10 means 1000%, while the same absolute growth,when from 1000 to 1010, amounts to nothing. As the output of this session, identify some ways that could be built into the IT in Agriculture and Food projects to help make progress in this crucial area.