Vision 2050

INDIAN AGRICULTURAL STATISTICS RESEARCH INSTITUTE
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
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Indian Agricultural Statistics Research Institute

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शरद पवार
SHARAD PAWAR

सत्यमेव जयते

कृषि एवं खाद्य प्रसंस्करण उद्योग मंत्री
भारत सरकार
MINISTER OF AGRICULTURE &
FOOD PROCESSING INDUSTRIES
GOVERNMENT OF INDIA

Dated the 13th June, 2013

MESSAGE

The scientific and technological inputs have been major drivers of growth and development in agriculture and allied sectors that have enabled us to achieve self reliant food security with a reasonable degree of resilience even in times of natural calamities, in recent years. In the present times, agricultural development is faced with several challenges relating to state of natural resources, climate change, fragmentation and diversion of agricultural land to non-agricultural uses, factor productivity, global trade and IPR regime. Some of these developments are taking place at much faster pace than ever before. In order to address these changes impacting agriculture and to remain globally competent, it is essential that our R&D institutions are able to foresee the challenges and formulate prioritised research programmes so that our agriculture is not constrained for want of technological interventions.

It is a pleasure to see that Indian Agricultural Statistics Research Institute (IASRI), New Delhi, a constituent institution of the Indian Council of Agricultural Research (ICAR) has prepared Vision-2050 document. The document embodies a pragmatic assessment of the agricultural production and food demand scenario by the year 2050. Taking due cognizance of the rapidly evolving national and international agriculture, the institute, has drawn up its Strategic Framework, clearly identifying Goals and Approach.

I wish IASRI all success in realisation of the Vision-2050.

(SHARAD PAWAR)

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FOREWORD

The Indian Council of Agricultural Research, since inception in the year 1929, is spearheading science and technology led development in agriculture in the country. This is being accomplished through agricultural research, higher education and frontline extension undertaken by a network of research institutes, agricultural universities and Krishi Vigyan Kendras. Besides developing and disseminating new technologies, ICAR has also been developing competent human resources to addess the present and future requirements of agriculture in the country. Committed and dedicated efforts of ICAR have led to appreciable enhancement in productivity and production of different crops and commodities, which has enabled the country to raise food production at a faster rate than the growth in demand. This has enabled the country to become self-sufficient in food and emerge as a net food exporter. However, agriculture is now facing several challenges that are expected to become even more diverse and stiffer. Natural resources (both physical and biological) are deteriorating and getting depleted; risks associated with climate change are rising, new forms of biotic and abiotic stress are emerging, production is becoming more energy intensive, and biosafety concerns are growing, intellectual property rights and trade regulations impacting technology acquisition and transfer, declining preference for farm work, shrinking farm size and changes in dietary preferences are formidable challenges.

These challenges call for a paradigm shift in our research approach to harness the potential of modern science, innovations in technology generation and delivery, and enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy efficiency, agri-incubators and technology dissemination need to be given priority. Multi-disciplinary

and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive.

It is an opportune time that the formulation of 'Vision-2050' by ICAR institutions coincides with the launch of the national 12th Five Year Plan. In this Plan period, the ICAR has proposed to take several new initiatives in research, education and frontline extension. These include creation of consortia research platforms in key areas, wherein besides the ICAR institutions, other science and development organizations would be participating; short term and focused research project through scheme of extramural grants; Agri-Innovation fund; Agri-incubation fund and Agri-tech Foresight Centers (ATFC) for research and technology generation. The innovative programme of the Council, 'Farmer FIRST' (Farmer's farm, Innovations, Resources, Science and Technology) will focus on enriching knowledge and integrating technologies in the farmer's conditions through enhanced farmer-scientist interface. The 'Student READY' (Rural Entrepreneurship and Awareness Development Yojana) and 'ARYA' (Attracting and retaining Youth in Agriculture) are aimed to make agricultural education comprehensive for enhanced entrepreneurial skills of the agricultural graduates.

I am happy to note that the Vision-2050 document of **Indian Agricultural Statistics Research Institute, New Delhi** has been prepared, based on the assessment of present situation, trends in various factors and changes in operating environment around agricultural scenario about 40 years hence and chalk out a demand-driven research agenda for science-led development of agriculture for food, nutrition, livelihood and environmental security, with a human touch.

I am sure that the **'Vision-2050'** would be valuable in guiding our efforts in agricultural R&D to provide food and nutritional security to the billion plus population of the country for all times to come.

(S. Ayyappan)

Dated the 12th June, 2013
New Delhi

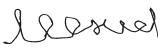
Preface

Indian Agricultural Statistics Research Institute (IASRI) is a pioneer Institute undertaking research, teaching and training in Agricultural Statistics, Computer Application and Bioinformatics. The Institute has used the power of Statistics, as a science, blended judiciously with Information Technology and has contributed significantly in improving the quality of Agricultural Research. In the context of changing national and international scenario, the Institute has to further gear up its research activities to meet the challenges of research and education in Agricultural Statistics along with allied fields and Informatics so as to meet the challenges of agricultural research in newer emerging areas.

The Vision 2050 document of the Institute highlights the achievements made, the gaps in research that could not be undertaken and the research programmes to be undertaken in the coming years, keeping in mind the newer developments taking place, particularly the technological and informatics developments, both at National and International level, till the year 2050. The efforts are to become responsive, vibrant and sensitive to the needs of agricultural researchers, research managers and planners. It is hoped that the Institute would be able to fulfil its mandate, partly generate resources for its research programmes and remain a leader in research and education in Agricultural Statistics and Informatics and exhibit its indispensability in National Agricultural Research System.

I would like to express my gratitude to Hon'ble Secretary, Department of Agricultural Research & Education (DARE) and Director General, Indian Council of Agricultural Research (ICAR) for his invaluable guidance in preparing IASRI Vision 2050. I am grateful to Deputy Director General (Engineering) and Assistant Director General (Engineering) along with their team for providing valuable suggestions in finalising this Document. I appreciate the efforts of all Heads of Divisions of the Institute for their whole-hearted support and cooperation in preparing this Document. I wish to express my sincere thanks to all my colleagues in Prioritization, Monitoring and Evaluation Cell of the Institute in bringing out this Document.

I am hopeful that the readers will find it quite informative and useful. I welcome useful suggestions and comments that would be helpful in undertaking need based research in Agricultural Statistics and Informatics.



(UC Sud)
Director (A)
IASRI, New Delhi

05 July 2013
New Delhi

Contents

Context

Agricultural research is a very complex phenomenon and the elements of uncertainty are most prevalent. Because of the large variability inherent in biological and agricultural data, knowledge of statistical sciences and informatics are necessary for their understanding, interpretation and drawing valid inferences.

Indian Agricultural Statistics Research Institute (IASRI) is a premier Institute of the Indian Council of Agricultural Research (ICAR) with a glorious tradition of carrying out research, teaching and training in the areas of Agricultural Statistics and Informatics. Ever since its inception, IASRI has been mainly responsible for conducting research in Agricultural Statistics to bridge the gaps in the existing knowledge. It has also been providing education/ training in Agricultural Statistics and informatics to develop trained manpower in the country. This research and education has been and will continue to be used in improving the quality of agricultural research and meeting the challenges in newer emerging areas. The functions and activities of the Institute have been re-defined from time to time in the past. The vision of the Institute is to use the power of Statistics with informatics to enhance the quality of agricultural research.

The research, teaching, training and dissemination activities of the Institute are carried out through following broad programmes:

- Development and Analysis of Experimental Designs for Agricultural Systems Research
- Forecasting, Modelling and Simulation Techniques in Biological and Economic Phenomena
- Development of Techniques for Planning and Execution of Surveys and Statistical Applications of GIS in Agricultural Systems
- Development of Statistical Techniques for Genetics/Computational Biology and Applications of Bioinformatics in Agricultural Research
- Development of Informatics in Agricultural Research
- Teaching and Training in Agricultural Statistics and Informatics

The Institute has made its presence felt in the National Agricultural Research System (NARS). The Institute is also becoming progressively a repository of information on agricultural research data and has taken a lead in the development of Financial Management System/ Management Information System for ICAR. The Institute has

established linkages with all NARS organizations for strengthening statistical computing. A National Agricultural Bioinformatics Grid (NABG) has been established with high performance computing facilities. The Institute also occupies a place of pride in the National Agricultural Statistics System (NASS) and has made several important contributions in strengthening NASS, which has a direct impact on the national policies.

The Institute has made some outstanding and useful contributions to the research in Agricultural Statistics in the fields like Design of Experiments, Statistical Genetics, Forecasting Techniques, Statistical Modelling, Sample Surveys, Econometrics, Computer Applications in Agriculture, Software Development, etc. The Institute has conducted basic and original research on many topics of interest and has published number of papers in national and international journals of repute. The Institute has been providing and continues to provide support to the NARS by way of analyzing voluminous data using advanced and appropriate analytical techniques. The Institute has also been very actively pursuing advisory services that have enabled to enrich the quality of agricultural research in the NARS. The Institute works in close collaboration with NARS organizations and many projects are being run in collaboration with All India Co-ordinated Research Projects and ICAR Institutes. Institute has developed linkages with the CGIAR organizations such as CIMMYT, IRRI and ICARDA.

The Council has recently decided that all the Institutes should revise their perspective plan in the form of Vision 2050 document that brings out the achievements made, the gaps in research that could not be undertaken and clearly spells out the research programmes to be undertaken in the coming years till the year 2050. The programmes have been identified keeping in mind the newer developments taking place, particularly the technological and informatics developments, both at National and International level. Road map for research programmes need to be carried out in the specified time scale and support required for meeting these challenges are clearly spelt out. Accordingly, the Institute has done an exercise to prepare the Vision 2050 document and the efforts are to become responsive, vibrant and sensitive to the needs of agricultural researchers, research managers and planners.

This document provides the mandate to be followed in the coming years. The main emphasis has been on the statistical issues of national interest in various emerging areas of biotechnology, bioinformatics, biodiversity, genomics, market intelligence, risk analysis, technology

forecasting, impact studies particularly of climate change, natural resources accounting and information communication technology.

With a proper planning, review, reporting and evaluation of these programmes, it is hoped that the Institute would be able to fulfil its mandate, generate resources for its research programmes and remain a leader in research and education in Agricultural Statistics and Informatics and exhibit its indispensability in National Agricultural Research System and National Agricultural Statistics System.

Significant Research Achievements and Impact

A brief discussion on the research achievements in different areas of Agricultural Statistics and Informatics has been outlined as follows:

Design of Experiments

The Institute has made many notable contributions in both basic research and innovative applications of the theory of statistical designs and analysis of experimental data. Some of the areas are:

- Designs for single factor experiments which include variance balanced, efficiency balanced, and partially efficiency balanced designs; designs for tests versus control(s) comparisons; designs for multi-response experiments; crossover designs; designs with nested structures; neighbour balanced designs; optimality and robustness aspects of designs.
- Designs for multi-factor experiments which include confounded designs for symmetrical and asymmetrical factorials; block designs with factorial structure; response surface designs, mixture experiments for single and multifactor experiments; Orthogonal main effect plans; orthogonal arrays; supersaturated designs.
- Designs for bioassays; microarray experiments and agroforestry experiments.
- Diagnostics in designed field experiments.
- Computer aided construction of efficient designs for various experimental settings.
- The scientists of the Institute participate actively in planning and designing of experiments in the NARS and have also involved themselves in the analysis of experimental data.
- Basic research work carried out on balanced incomplete block designs, partially balanced incomplete block designs, group divisible designs, α-designs, reinforced α-designs, square and rectangular

designs, nested designs, augmented designs, extended group divisible designs, response surface designs, experiments with mixtures etc. have been adopted widely by the experimenters in NARS.

- Designs for factorial experiments such as response surface designs and experiments with mixtures have been used for food processing and value addition experiments; soil test crop response correlation experiments; experiments with fixed quantity of inputs and ready to serve fruit beverage experiments, etc.
- The analytical techniques based on mixed effects models and biplot developed for the analysis of data generated from Farmers Participatory Trials for resource conservation agriculture have been used by Rice-Wheat consortium for Indo-Gangetic plains for drawing statistically valid conclusions.
- The analytical techniques for the analysis of data from the experiments conducted to study the post harvest storage behaviour of the perishable commodities like fruits and vegetables are being widely used in NARS.
- Planning, designing and analysis of data relating to experiments AICRPs on (i) IFS; (ii) LTFE; (iii) STCR; (iv) Rapeseed and Mustard; (v) Sorghum and (vi) Wheat and barley.
- For dissemination and e-advisory on designed experiments, developed a Design Resources Server (www.iasri.res.in/design) which is being viewed throughout the globe and used extensively in NARS.
- The status of experimentation is now changing and with the support provided in terms of suggesting efficient designs and analyzing the data using modern complicated statistical tools, the research publications of the agricultural scientists are finding a place in high impact factor international journals.

Sample Surveys

The subject of sampling techniques helps in providing the methodology for obtaining precise estimates of parameters of interest. The Institute is involved in evolving suitable sample survey techniques for estimation of various parameters of interest relating to crops, livestock, fishery, forestry and allied fields.

- Significant contributions have been made in theoretical aspects of sample surveys like successive sampling, systematic sampling, cluster sampling, sampling with varying probabilities, controlled

selection, nonsampling errors, analysis of complex surveys, various methods of estimation such as ratio and regression methods of estimation and use of combinatorics in sample surveys.

- The methodology for General Crop Estimation Surveys (GCES), cost of cultivation studies for principal food crops, cash crops and horticultural crops, Integrated Sample Surveys (ISS) for livestock products estimation, fruits and vegetable survey are being adopted throughout the country and many Asian and African countries.
- Methodology based on small area estimation technique for National Agricultural Insurance Scheme, also called Rashtriya Krishi Bima Yojana, suggested by IASRI has been pilot tested in the country.
- The sample survey methodology for imported fertilizer quality assessment, estimation of fish catch from marine and inland resources, flower production estimation, area and production of horticultural crops estimation, etc. has been developed and passed on to the user agencies.
- Integrated methodology for estimation of multiple crop area of different crops in North Eastern Hilly Regions using Remote Sensing data has been developed.
- Sampling methodology for estimation of post harvest losses has been successfully adopted in AICRP on Post Harvest Technology for assessment of post harvest losses of crops/commodities.
- Reappraisal of sampling methodologies, evaluation and impact assessment studies like studies to make an assessment of Integrated Area Development programmes, High Yielding Varieties programmes, Dairy Improvement programmes, Evaluation of cotton production estimation methodology etc. have been undertaken. Most of the methodologies developed are being adopted for estimation of respective commodities by the concerned state departments.
- The Institute is regularly publishing the Agricultural Research Data Book since 1996. It contains information pertaining to agricultural research, education and other related aspects compiled from different sources.
- For providing e-advisory and e-learning in sample surveys, initiated a Sample Survey Resources Server (http://js.iasri.res.in/ssrs/) which also provides calculator for sample size determination for population mean and population proportion among other material.

Statistical Genetics and Genomics

The Institute has made very significant contributions in statistical genetics for improved and precise estimation of genetic parameters, classificatory analysis and genetic divergence, etc.

- Developed procedures for estimation of genetic parameters; construction of selection indices; studying G × E interactions; progeny testing and sire evaluations; detection of QTLs, classification of genotypes using molecular marker data, etc.
- The modification in the procedure of estimation of genetic parameters has been suggested for incorporating the effect of unbalancedness, presence of outliers, aberrant observations and non-normality of data sets.
- Procedures for studying genotype environment and QTL environments interactions have been used for the analysis of data generated from crop improvement programmes.
- The research work on construction of selection indices, progeny testing and sire evaluation have been used for animal improvement programmes.
- The Institute has initiated research in the newer emerging area of statistical genomics such as rice genome functional elements information system; comparative genomics and whole genome association analysis. The establishment of a National Agricultural Bioinformatics Grid (NABG) is a landmark in this direction.
- Supercomputing facility (High Performance Computing System) has been established for biological computing and bioinformatics
- A number of databases and web services have been developed which include pigeonpea microsatellite database, buffalo microsatellite database, genome sequence submission portal, livestock EST database, insect barcode database.

Statistical Modelling for Biological Phenomena

Statistical modeling of biological phenomena is carried out by using linear and non-linear models, non-parametric regression, structural time series, fuzzy regression, neural network and machine learning approaches.

- The Institute has made significant contributions in developing models for pre-harvest forecasting of crop yields using data on weather parameters; agricultural inputs; plant characters and farmers' appraisal.

- The models have been developed using weather and growth indices based regression models, discriminant function approach, markov chain approach, bayesian approach, within year growth models and artificial neural network approach.
- Methodologies for forewarning important pests and diseases of different crops have been developed which can enable the farmers to use plant protection measures judiciously and save cost on unnecessary sprays.
- The methodology developed for forecasting based on weather variables and agricultural inputs was used by Space Application Centre, Ahmedabad, to obtain the forecast of wheat yield at national level with only 3% deviation from the observed one.
- Models developed for forewarning of aphids in mustard crop were used by Directorate of Rapeseed and Mustard Research, Bharatpur to provide forewarning to farmers which enabled them to optimize plant protection measures and save resources on unnecessary sprays consecutively for three years.
- Forecasting of volatile data has been attempted through non-linear time series models. Such models were developed for forecasting onion price, marine products export, lac export, etc. Modelling and forecasting of India's marine fish production was carried out using Wavelet methodology.
- Non-linear statistical models were developed for aphid population growth and plant diseases. Modelling and forecasting of India's marine fish production was carried out using wavelet methodology. The models developed have potential applications in long term projections of food grain production, aphid population, marine fish production, etc. These models were used by Directorate of Rapeseed and Mustard Research, Bharatpur to provide forewarning to farmers which enabled them to optimize plant protection measures.

Econometrics

The Institute has made significant contributions in understanding the complex economic relationship of the factors like transportation, marketing, storage, processing facilities; constraint in the transfer of new farm technology to the farmers field under different agro-climatic conditions of the country.

- Some of the important contributions of the Institute are measurement of indemnity and premium rates under crop revenue insurance, production efficiency and resource use, impact of micro-irrigation,

technological dualism/technological change, return to investment in fisheries research and technical efficiency of fishery farms, the impact of technological interventions, price spread and market integration, price volatility and the dietary pattern of rural households.

Information Communication Technology

IASRI is a pioneer in introducing computer culture in agricultural research and human resource development in information technology in the ICAR. The Institute has the capability of development of Information Systems, Decision Support Systems and Expert Systems. These systems are helpful in taking the technologies developed to the doorsteps of the farmers.

- The Institute has developed information systems for agricultural field experiments, animal experiments and long term fertilizer experiments conducted in NARS as research data repositories.
- A comprehensive Personnel Management Information System Network (PERMISnet) has been implemented for the ICAR for manpower planning, administrative decision making, and monitoring. A Project Information and Management System Network (PIMSnet) was developed and implemented for concurrent monitoring and evaluation of projects. This is being developed as a Project Information and Management System for all ICAR projects. A National Information System on Agricultural Education Network in India (NISAGENET) has been designed, developed and implemented so as to maintain and update the data regularly on parameters related to agricultural education in India.
- Online Management System for Post Graduate Education has been developed and implemented for PG School, IARI, New Delhi. The Institute has taken a lead in the development of Expert Systems on wheat crop, maize crop and seed spices. AgriDaksh has been developed for facilitating the development of expert systems for other crops.
- Web based software for Half Yearly Progress Monitoring (HYPM) of scientists in ICAR (http://hypm.iasri.res.in) has been developed and implemented from 1st April 2012 for online submission of data regarding the proposed targets and the achievements for the half yearly period. It would be possible to monitor online progress of the scientists, manpower status, research projects, prioritized activities and salient research achievements at institute/SMD/ICAR level.

- Realizing the need of integration of databases to prepare a comprehensive knowledge warehouse that can provide desired information in time to the planners, decision makers and developmental agencies, Integrated National Agricultural Resources Information System (INARIS) has been developed. The data warehouse comprises of databases on agricultural technologies of different sectors of agriculture and related agricultural statistics at districts/state/national levels, population census including village level population data as well as tehsil level household assets and livestock census. Subject-wise data marts have been designed, multi-dimensional data cubes developed and published in the form of on-line decision support system. It is being developed as knowledge data warehouse through the development of Knowledge Management for Agricultural Research and Technologies (KMART). The system also provides facility of spatial analysis of the data through web using functionalities of Geographic Information System (GIS).
- Strengthened Statistical Computing facilities in NARS, helped in capacity building in the usage of high end statistical computing and developed Indian NARS Statistical Computing Portal for providing service oriented computing to the researchers of NARS, which has paved the way for publishing agricultural research in high impact factor journals.
- A number of software and web solutions have been developed for the agricultural research workers: Statistical Package for Agricultural Research (SPAR) 2.0, Statistical Package for Block Designs (SPBD) 1.0, Statistical Package for Factorial Experiments (SPFE) 1.0, Statistical Package for Augmented Designs (SPAD) 1.0, Software for Survey Data Analysis (SSDA) 1.0, Statistical Package for Animal Breeding (SPAB) 2.1, Online Analysis of Block Designs, Web Generation and Analysis of Partial Diallel Crosses, etc.

Human Resource Development

One of the thrust areas of the Institute is to develop trained manpower in the country in the disciplines of Agricultural Statistics and Informatics for meeting the challenges of Agricultural Research in the newer emerging areas.

- The institute conducts the Senior Certificate Course in Agricultural Statistics and Computing. This course is of six months duration and lays more emphasis on statistical computing using statistical software. The course is divided into two modules viz. (i) Statistical

Methods and Official Agricultural Statistics, and (ii) Use of Computers in Agricultural Research, of three months duration each. 80 participants have completed both modules, 31 module-I and 21 module-II since 1997.

- The institute also conducts degree courses leading to M.Sc. and Ph.D. in Agricultural Statistics and M.Sc. in Computer Application in collaboration with Indian Agricultural Research Institute (IARI), New Delhi. The Institute has so far produced 182 Ph.D. and 314 M.Sc. students in Agricultural Statistics and 105 M.Sc. students in Computer Application. A new degree course M.Sc. in Agricultural Bioinformatics has started from academic year 2011-12 in collaboration with IARI, New Delhi; NRCPB, New Delhi and NBPGR, New Delhi. Ph.D. in Computer Applications will be initiated from Academic Year 2013-14.
- The Institute is functioning as a Centre of Advanced Studies in Agricultural Statistics and Computer Application. Under this programme the Institute organizes training programmes on various topics of interest for the benefit of scientists of NARS. These training programmes cover specialized topics of agricultural sciences. The Centre of Advanced Studies (CAS) is renamed as Centre of Advanced Faculty Training (CAFT).
- There is another form of training courses, which are tailor made courses and are demand driven. The coverage in these courses is need based and the courses are organized for specific organizations from where the demand is received. The Institute has conducted such programmes for Indian Council of Forestry Research, Indian Statistical Service probationers and senior officers of Central Statistical Organization and many other organizations.
- The Institute has also conducted several international training programmes on request from FAO, particularly for African, Asian and Latin American countries, CGIAR organisations (CIMMYT and ICARDA).
- The Institute has broadened the horizon of capacity building by opening its doors to the agro-based private sector. One such training programme was organized for research personnel of E.I. DuPont Pvt. Ltd. The Institute has also conducted training programmes for the scientists/research personnel of CGIAR organizations such as ICARDA and Rice-Wheat Consortium for Indo-Gangetic plains.

Challenges

The subject of Agricultural Statistics forms the backbone of the agricultural research. In order to make our research globally competitive, it is important that sound statistical methodologies be developed and used in the collection of data (both under controlled and uncontrolled conditions), analysis of data and interpretation of results. Thus, there is need to devise strategies of data generation based on statistical principles. Data generation; Data analysis; Inferences drawn from the analysis and Knowledge generated from the analysis and interpretation are the integral component of discipline of Statistics and go hand in hand.

The institute is working in this direction with the following mandate:

- To undertake basic, applied, adaptive, strategic and anticipatory research in Agricultural Statistics
- To conduct Post-Graduate teaching and in-service, customized and sponsored training courses in Agricultural Statistics, Computer Applications and Bioinformatics at National and International level
- To lead in development of Agricultural Knowledge Management and Information System for National Agricultural Research System
- To provide advisory and consultancy services for strengthening the National Agricultural Research System
- To provide methodological support in strengthening National Agricultural Statistics System

The research, teaching and training activities in the institute are conducted under following six divisions:

1. Design of Experiments
2. Statistical Genetics
3. Forecasting and Agricultural Systems Modeling
4. Sample Surveys
5. Computer Applications
6. Centre for Agricultural Bioinformatics (CABin)

In an effort to continue the glorious traditions of the Institute, efforts to maintain a judicious balance of basic and innovative applied research and also to expand the horizon of the teaching and training programmes

have been envisaged. The Institute would delve on developing roadmaps on combating the major challenges of depleting natural resources, climate change, uncertainties of economy and marketing, and natural disasters by addressing the statistical issues involved in it. There is an explosion of data in all spheres which is in both structured and unstructured formats. The Institute would take up research activities in developing statistical methodologies and disseminating statistical methods for massive data sets. The aim would be towards originality of the problem identification that could spur significant advances. This would be beneficial in building a bridge between the statisticians, informatics experts and the farm scientists so as to bring prosperity to the farmers. The Institute would undertake research in newer emerging areas with fresh vigour and zeal.

Operating Environment

As the activities of the Institute started expanding in all directions, the infrastructure facilities also started expanding. Two more buildings 'Computer Centre' and 'Training-cum-Administrative Block' were constructed in the campus of the Institute in the years 1976 and 1991, respectively. There are three well furnished hostels, viz. Panse Hostel-cum- Guest House, Sukhatme Hostel and International Training Hostel to cater the residential requirements of the trainees and students. An important landmark in the development of the Institute was the installation of an IBM 1620 Model-II Electronic Computer in 1964. A third generation computer Burroughs B 4700 system was installed in March 1977 and then replaced in 1991 by a Super Mini COSMOS-486 LAN Server with more than hundred nodes consisting of PC/AT's, PC/XT's and dumb terminals all in a LAN environment. Later, COSMOS-486 LAN Server was replaced by a PENTIUM-90 LAN Server having state-of-art technology with UNIX operating system. Computer laboratories equipped with PCs, terminals and printers, etc. had been set up in each of the six Scientific Divisions as well as in the Administrative Wings of the Institute.

For undertaking research in the newer emerging areas, a laboratory on Remote Sensing (RS) and Geographic Information System (GIS) was created in the Institute. The laboratory was equipped with latest state-of-art technologies like computer hardware and peripherals, Global Positioning System (GPS), softwares like ERMapper, PCARC/INFO, Microstation 95, Geomedia Professional, ARC/INFO Workstation and ERDAS Imagine with the funds received through two AP Cess Fund projects. This computing facility has further been strengthened with the procurement of ARC-GIS software under NATP programme.

An Agricultural Bioinformatics Lab (ABL) fully equipped with software and hardware has been created to study crop and animal biology with the latest statistical and computational tools. Business Intelligence Server has also been installed for statistical computing for NARS.

The networking services at IASRI have steadily been strengthened. Currently the internet services are being provided to the scientists, technical & administrative staff and students through Firewall, Content filtering, E-mail filtering, Antivirus, Application control and Data Leak Prevention (DPL). The Institute domain service like Primary and Secondary DNS, Domain (iasri.res.in) Website (http://www.iasri.res.in), Live E-mail services, more than 462 network nodes

and number of various Online Information Systems are being developed and maintained by the Institute.

There are various labs at the Institute for dedicated services like ARIS lab for training, Statistical computing lab, Student lab and Centre for Advanced Study lab. Some of the important available software are SAS 9.2, SAS 9.3, JMP 8.0, JMP Genomics 4.0, 5.1, 6.0 SAS BI Server 4.2, SPSS, SYSTAT, GENSTAT, Data warehouse software – Cognos, SPSS clementine, MS Office 2007, MS Visual Studio.net, MS-SQL Server, Oracle, Macro-Media, E-views, STATISTICA Neural Networks, Gauss Software, Minitab 14, Maple 9.5, Matlab, Web Statistica, Lingo Super, ArcGIS among others.

Keeping pace with the emerging technologies in the area of Information Technology (IT), the computing infrastructure have been constantly upgraded/replaced with newer platforms and versions. The computing environment in the Institute has latest computing and audio visual equipments i.e. High Performance Computing having 144 cores Intel HPC cluster, rack mount & redundant SMPS servers, workstations, desktops, laptops, netbooks, documents printing & scanning, DVD duplicator, visualiser and wireless multimedia projectors etc. The Institute is also well equipped with 100 MBps bandwidth fiber optics backbone wired and wireless networking campus.

Library of IASRI is considered as a well known and specialized library in terms of its resources in the form of print and electronic format in the field of Agricultural Statistics, Computer Applications, Agricultural Economics and Allied Sciences. It is recognized as one of the regional libraries under NARS with best IT agricultural library under ICAR system. During the XI Plan period, library has undergone ocean of changes in terms of its resources.

- It has strengthened the resource base in terms of core foreign journals.
- With procurement of online and CD-ROM bibliographical data bases the awareness for the use of data bases has increased and users are able to access scientific information in the field of their interest without wasting their time by clicking of a button.
- All house keeping activities of the library have been computerized and bar-coded and all bonafide library users have been issued electronic membership cards and all Ph.D. and M.Sc. Thesis have been digitized and given access to users through LAN. Library of the Institute got associated with CERA in terms of electronic document delivery services.

- The library reading room has been renovated with 5 split air conditioners to provide congenial environment for readers.
- All library users were given training to access on-line services available in the library.

The Institute functioned as a Centre of Advanced Studies in Agricultural Statistics and Computer Application during October 1983 to March 1992 under the aegis of United Nations Development Programme. The purpose of this programme was to develop the Institute as a Centre of Excellence with adequate infrastructure and facilities to undertake advanced training programmes and to carry out research in various emerging areas of Agricultural Statistics and Computer Application. Under this programme, a number of illustrious statisticians and computer scientists from abroad visited the Institute with a view to interact with the scientists, giving seminars/lectures and suggesting gaps in the research programmes of the Institute. Under the programme, a few scientists received trainings in various areas of importance from abroad. Another singular development in the growth of the Institute was the Centre of Advanced Studies (CAS) Programme in Agricultural Statistics and Computer Application established during the VIII Five Year Plan in 1995. Under this programme the Institute organizes training programmes on various topics of interest for the benefit of scientists of NARS. CAS is now renamed as Centre of Advanced Faculty Training (CAFT).

New Opportunities

There are many success stories of the Institute which are fairly spread across all the specialization of Agricultural Statistics and Informatics. The contributions towards research, teaching and training have been monumental. Since scenario of agriculture research is changing at a very fast rate, the Institute has set its future agenda to meet the statistical and informatics needs. The efforts would be to become a lead organization in the world in the field of Agricultural Statistics, Statistical Computing, Informatics including Bioinformatics, and be responsive, vibrant and sensitive to the needs of researchers, research managers and planners. The Institute would undertake research in newer emerging areas in terms of high-dimensional data analysis with the development of new infrastructure with us.

- **Advancement in statistical methodology and its novel applications**
  - Formulate network mode, need based research programmes cutting across disciplines, institutions both within and outside NARS
  - Basic research in newer emerging areas to meet the need of future challenges of agricultural research
  - Develop novel applications of the statistical techniques/models in agricultural research
  - Strengthen collaborations with mainstream statisticians for basic and innovative applied research
  - Network of statisticians working in NARS for pursuing large research agenda of basic, applied and adaptive research in Agricultural Statistics and Informatics
- **Strengthen National Agricultural Bioinformatics Grid (NABG) and provide framework for statistical and computational analytical techniques for high-dimensional genomic data analysis**
- **Strengthen statistical computing for NARS**
  - Provide high-end statistical computing facilities
  - Develop service oriented computing modules
  - Prepare customized modules for online analysis
- **Capacity building and strengthening education in Agricultural Statistics and Informatics through a Centre of Excellence as Deemed University**

- **Strengthen use of Informatics in creation of knowledge management for research data repositories, information systems, decision support systems and expert systems**
- **Continual identification of statistical issues for different subject matter divisions**
  - Close interactions with specialists of different ICAR subject matter divisions
  - Facilitate dissemination of improved statistical techniques, knowledge and information
  - Develop online resources on advances in statistical techniques and informatics
  - Create and strengthen e-training, e-seminars, e-debates and discussions for outreaching the researchers through WebEx and Video Conferencing
  - Organize travel workshops-cum-trainings to outreach scientists
  - Organize customized training programmes
  - Pursue advisory services etc.

Goals / Targets

Since scenario of agriculture research is changing at a very fast rate, the Institute has set its future agenda to meet the statistical and informatics needs. The efforts would be to become a lead organization in the world in the field of Agricultural Statistics, Statistical Computing and Informatics including Bioinformatics and to be vibrant to the needs of researchers, research managers and planners.

The goal of the institute is to conduct research, education and training in Agricultural Statistics and Informatics with a vision of Statistics and Informatics for enriching the quality of agricultural research. The mission is to undertake research, education and training in Agricultural Statistics, Computer Application and Bioinformatics for Agricultural Research which would be carried out in the following broad areas:

Design of Experiments

Design of Experiments has been and continues to be the backbone of agricultural research. As-a-matter-of-fact, designing an experiment is an integral part of agricultural research. It is through proper designing of experiments, analyzing the data and drawing valid inferences that knowledge is generated. Agricultural systems is vibrant and experiments need to be conducted for functional genomics, assessment and mitigation of effects of climate change, resource conservation agriculture, post harvest storage behaviour of perishable commodities etc.

The objectives of the experiments dictate the hypotheses to be tested; this in turn decides the analysis to be performed and therefore, what the data requirements would be and then comes the choice of a proper design. Designing an experiment assumes importance to take care of the variability in the experimental material, which by and large, forms a very large component of the total variability. There can be no thumb rule to decide the choice of a design. With the agricultural research being dynamic in nature and newer vistas of agricultural research opening up from time to time, the data needs change, the analysis changes and consequently the design changes. Therefore, to keep pace with agricultural research, it is pertinent to continue research in design of experiments on a continuous scale, in tune with the requirements of the agricultural research.

IASRI is involved in the planning, designing and analysis of experiments of on-going experiments pertaining to AICRP on

Integrated Farming Systems Research (both on station and on farm trials), Long Term Fertilizer Experiments, Soil Test Crop Response Correlations. Linkages have also been developed with AICRP on Rapeseed and Mustard, All Indian Crop Improvement Programme on Sorghum, etc. These linkages need to be further strengthened. The innovative applications need to be developed as per changing needs of research in agricultural sciences. Indian NARS Statistical Computing Portal developed for providing Service oriented computing needs to be further strengthened by adding new modules for efficient working of AICRPs and network projects.

Research data repository is the lifeline of any research system. Online Agricultural Field Experiments Information System has been developed and data of about 30000 agricultural field experiments is available in this information system. With the availability of online data uploading and retrieval facility, it would be possible to link all the researchers of NARS to upload their experimental data. Further, at present this information system takes care of only single characters. In most of agricultural experiments, data on more than one response variables are generally observed. Therefore, there is need to modify this information system to accommodate multiple character data and also for developing a facility of linking over years and over locations. The scope of the information system needs to widen to include data from different AICRPs. It is also required to develop information systems pertaining to horticulture, agroforestry, laboratory, animal experiments etc. There is also a need to strengthen the provision of value addition in this information through development of indigenous algorithms, as well as linking them with Business Intelligence Server for service oriented computing.

With the dimension of agricultural scientists spread along the length and breadth of the country, it is not possible to reach every scientist of NARS for advisory on this very important subject. Therefore, the creation of strong and efficient web resource is of paramount importance so as to meet the needs of all the scientists in NARS. An effort in this direction has already been made and a Design Resources Server is already available and can be accessed at www.iasri.res.in/design. There is a need of upgrading and strengthening Web resources in this server with efficient designs for spatially correlated observations, designs for functional genomics, response surface designs, efficient designs for estimating indirect effects of treatments, designs for microarray experiments, mating designs, computer experiments, and design of experiments with limited resources and online analysis of

experimental data. The above efforts would result in availability of efficient and robust designs for different experimental situations for improved status of agricultural experimentation in the country for enhancing the visibility and acceptability of agricultural research, use of appropriate and efficient experimental designs, both in terms of cost and precision, and advanced analytical techniques in AICRP to help in drawing statistically valid conclusions, online research data repository of designed experiments, service oriented computing and e-learning and e-advisory services.

Statistical Modelling

It is well recognized that crucial variables in an agricultural system involve complex nonlinear relationships. In order to determine these, the usual practice is to employ nonlinear statistical models formed by adding an additive error term to the deterministic model. However, this type of modelling may not be able to describe the underlying fluctuations in a satisfactory manner. In reality, parameters of a model no longer remain constant but fluctuate randomly. Therefore, it is desirable to study stochastic models in which the parameters, like growth rates are described by appropriate stochastic processes. Another disadvantage of such models is that, unlike nonlinear statistical models, these are applicable for modelling and forecasting in those situations in which the data on response variable can be obtained only on equidistant time-epochs. However, estimation of parameters of these models on unequal time points requires lot of research efforts. Subsequently, relevant computer programs/software packages need to be developed before stochastic models are applied to real data. This would enable development of efficient forecasting techniques based on sound statistical basis. It is not always possible to describe the functional form involving response and explanatory variables. To this end, nonparametric approach is called for.

Autoregressive integrated moving average (ARIMA) methodology, which is a parametric approach, has virtually dominated analysis of time-series data during the last several decades. Here the role of various explanatory variables enters into the model "implicitly" through response variable observations at past epochs. However, quite often it is not possible to postulate appropriate parametric form for the underlying phenomenon and, in such cases "Nonparametric" approach is called for. Accordingly, in recent years, an extremely powerful methodology of "Wavelet analysis" is rapidly emerging. Although, a number of research papers have been published dealing with various theoretical aspects of wavelets, their application to data is still a difficult

task. The nonparametric approach of wavelet analysis could be applied for modelling and forecasting of time-series data related to agriculture both in time and frequency domains.

In some economic time series, sometimes asymmetric phenomenon arises which tend to behave differently when economy is moving into recession rather than when coming out of it. Many financial time series show periods of stability followed by unstable periods with high volatility. The loss in continuing with age-old ARIMA methodology is that these types of behaviour cannot be explained satisfactorily and nonlinear time-series models are usually needed to describe data sets in which variance changes through time. For these types of volatile data, Generalized Autoregressive Conditional Heteroscedastic (GARCH) model is more appropriate. The combination of Wavelets along with GARCH model can be applied for modelling and forecasting of volatile economic time-series data pertaining to agriculture. Because stochastic volatility models have also environmental applications, these types of models may be useful in modeling climate data as well.

Another important parametric nonlinear time-series model is the Stochastic Volatility (SV) model which is used to model and forecast time-varying volatility. SV models provide a flexible and parsimonious means of modelling the variance and provide a means of tracking and forecasting the variance. SV models are unique in the sense that they treat variance as an unobserved stochastic process. In these models both the mean and volatility equations have separate error terms. The SV models also have some extra flexibility for modelling kurtosis compared to the GARCH family. So this approach of volatility modelling and forecasting may also be taken up.

In time-series, as an alternative approach to non-linear modeling, machine learning techniques such as Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs) have also been advocated for forecasting purposes. These latter techniques are able to adapt non-linearity and approximate complex relationships in a more intuitive way. Nonlinear SVM based on the principles of Statistical learning theory can be employed for classification, density estimation, regression analysis and time-series prediction. There is a need to fine-tune this methodology by carrying out a lot of concerted research efforts. Hybrid modeling of, say, wavelet-GARCH-ANN could be a promising technique for modeling and forecasting of volatile data.

Presence of outliers in the time-series data may give rise to misleading interpretations. So there is a need for detection and study of outliers in

time-series analysis. There are several methods available for detection of outliers in time-series data, the most recent being wavelet analysis which can also be used for robustness studies as well.

Genetic algorithm is one of the recently developed optimization techniques. It can be applied for estimation of GARCH model and other time-series models for improved model fitting. Moreover, identification of periodic time-series model may be done using genetic algorithms. Besides this, Bayesian approach is also a promising technique for estimation of parameters in a model. This approach may be tried for modelling and forecasting time-series. For time-series data having a long memory pattern, Autoregressive fractional integrated moving average (ARFIMA) model which has been found to be appropriate in such cases may be investigated. In order to model volatility, attempts may be made for estimation of long-memory parameters in long-memory stochastic volatility models.

Recently developed optimization techniques, like Particle Swarm Optimization (PSO), Bacterial Foraging Optimization (BFO), Adaptive Bacterial Foraging Optimization (ABFO), Swine Influenza Model Based Optimization (SIMBO) may be used in agricultural field. Hybridization of optimization techniques with machine learning algorithms like ANN and SVM would be one promising area of research in future.

In Statistics, data are usually formatted as single values. However, in reality, data are of functional nature. To deal with these kinds of data, a new area in statistical research, Functional Data Analysis (FDA) was introduced, which have an internal structure unlike classical data. FDA is a set of techniques that allows performing statistical analysis on sets of curves. FDA provides qualitative insight in the form of graphical display of results and quantitative output. Therefore, usual classical statistical methods cannot be readily applied for analyzing functional data. For detecting periodicities in time-series, particularly relating to climate data, nonlinear spectral density estimation may be employed. Climate data is continuous in nature. But whenever a time-series model is applied to climate data it takes care of its discrete nature only. FDA technique can be employed for time-series data which vary continuously. In addition, space-time modelling for detection of trends in climate data may also be employed.

One has to take fresh view towards analysing count time-series data by employing improved models in not only log-linear set up but also explore the possibilities of reorienting the usual logit, probit and tobit models in that framework.

Variable selection plays an important role in model building. To circumvent the inherent limitations and weaknesses of the classical methods applied in such contexts; Bayesian methods for subset selection implemented using stochastic search variable selection (SSVS) algorithms have to be used. Moreover, variable selection by penalised likelihood in the Lasso-based models can also be given importance.

Efforts can be made to use non-parametric and semi-parametric mixtures for density estimation as an alternative to the popular kernel based estimation in order to provide the flexibility and adaptability that a parametric model lacks for an arbitrary data set. For agro-climatic risk analysis and management, wherein the probability of occurrence of event of a particular future time period is of interest, the phenomena can be modeled using Markov models both with fixed and time-varying coefficients.

Data mining in spatio-temporal domain is yet another niche area in this era of information explosion with no dearth for data. Thus, data mining models for geographic knowledge discovery in agricultural and fish ecosystems will be quite useful in not only understanding the underlying phenomena but also to build data driven models with no stringent apriori assumptions. In other words, instead of complex statistical models, one is ultimately supplied with easily comprehensible set of decision rules to predict or classify the future. In contrast to the conventional statistical models, such models have an advantage of handling data sets having very large number of cases and also huge number of variables leading to a multidimensional solution.

The generally accepted method of calculating prediction intervals based on fitting a probability model for which the theoretical variance of forecast errors can be readily evaluated are cumbersome or impossible or inappropriate or not well calibrated to suit the real data situations. In case of time-series data, the dependence between the observations renders the assumptions of large sample theory invalid which are generally based on IID assumptions. A potential alternative to handle such problems is to take recourse to what are called resampling based approaches such as the Jackknife and the Bootstrap. However these resampling methods again require non-trivial modifications in order to produce valid estimators and inference in the context of time-series data relating to which studies should be taken up.

Statistical techniques like survival analysis and sequential testing need to be used in plant protection studies in order to understand dose-response relationships where the doses could be insecticide, fungicide

etc. In addition, these techniques have enough scope in animal sciences whenever censored observations are dealt with.

Forecasting Techniques

The future of Indian agriculture is very much affected by the emerging scenario of population explosion, shifts in dietary pattern, declining size of land holdings, globalization etc. Increasing urbanization and income growth will cause significant changes in the food basket. Recent trends suggest a disproportionate increase in demand for high value horticultural and animal food products as compared to staples. In addition, food system will be governed by stringent food safety and quality regulations. These changes in place give signal for development of a more science-based, demand-driven agriculture. In addition, there are interrelationships between rapid developments occurring in other fields of sciences like nanotechnology, Information and Communication Technology (ICT), Bioinformatics, genomics, biotechnology, remote sensing & Geographical Information System (GIS) etc. vis-à-vis agricultural sciences and technologies. In the past, not enough planned attention has been paid towards maintenance, development of technology capabilities and utilizing resources efficiently for agricultural R&D activities. Increasing competition coupled with increasing constraints on public expenditure requires continuous innovation to achieve ever-higher productivity in relative to economic and social development. It is therefore imperative to articulate technological needs of different segments of agriculture using both bottom-up and top-down approaches and contemplate how developments in science can help address these needs. Use of what is called, Technology Forecasting, can aid in understanding the underlying trends in the key factors of technologies so that they can be influenced to achieve the required needs. Therefore, Technology Forecasting for the task of foreseeing technological trends and needs in agriculture is highly desirable.

Reliable and timely forecasts provide important and useful input for proper, foresighted and informed planning, more so, in agriculture which is full of uncertainties. Agriculture now-a-days has become highly input and cost intensive. Without judicious use of fertilizers and plant protection measures, agriculture no longer remains as profitable as before. Uncertainties of weather, production, policies, prices, etc. are leading to mass suicides by farmers. New pests and diseases are emerging as an added threat to the production. Under the changed scenario today, forecasting of various aspects relating to agriculture is becoming increasingly essential.

With this in view, methodologies have been developed at IASRI for forecasting crop yield in advance of harvest using various statistical techniques based on different types of data for selected crops at selected locations. In the coming years, it is proposed to develop models for crops, pests and diseases not covered so far. Use of some newer techniques will also be explored for improving the models. Statistical software will be developed for obtaining forecasts using different methodologies for different situations. This will be helpful to Crop Science Division for obtaining reliable forecasts of different crops and forewarnings of pests and disease.

Of late, the area of technology forecasting has come into limelight for predicting the key features of technologies (both tangible ones like machines, devices etc. to intangible ones like methodologies, processes etc.). In addition, in contrast to technology forecasting, a totally new field of technology foresight has sprung up which involves an explicit recognition that the choices made today can shape or create the future. Technology Foresight exercises need to be done to identify key technologies a country needs in particular subdomains of agriculture in order to shape a desired future which emphasizes achieving preferable futures through policy implementation rather than accepting the future obtained from a technological forecast as a given. The Technology Foresight methods such as scenario creation, Delphi survey and cross-impact analysis, technology roadmapping, patent analysis, analytic hierarchy process (AHP), trend impact analysis (TIA) etc. need to be employed in various subdomains of agriculture for envisioning the future technological needs and trends along with actionable policies to make the vision a reality. There is much scope in utilizing soft computing techniques such as neural networks, fuzzy logic, agent based models like cellular automata etc. in combination with the technology forecasting methods such as AHP, TIA etc. In addition, combination of time-series models with diffusion models in order to tap the best of both approaches can be tried. Moreover, systems-dynamics simulation models can be used to estimate how key parameters of technologies are likely to impact the attainment of foresight goals.

Bibliometric analysis represents a relatively new form of meta-analytical research to enhance our understanding of the nature of development in a given research field by measuring and analyzing published materials. In addition to such methods which involve a high degree of objectivity, patent data can also be taken into account as a valuable source of information. Thus the technology foresight approaches which involve more of qualitative information can be supplemented by such scientometric and patent analytical studies. Forecasting the emerging

areas of research which may come into mainstay in the coming years, when such areas are at early stages of development is a difficult but an essential task for the purposes of policy making. However, with only limited data available in such contexts, Bass diffusion model and Bayesian model based on analogy can be attempted to foresee their path and periods when they will come into fruition. Attempts would be made to employ diffusion models for forecasting the future adoption patterns of agricultural technologies and also to foresee emerging areas of research by considering scientific literature published in journals and project reports. Numerous approaches such as patent citation analysis, patent co-citation methods, patent networks etc can be used to assess likely technological impacts based on patent information.

Models would be developed for forecasting marine fish catch and fish production from ponds. These studies will be helpful for obtaining forecasts in fisheries. However, more studies are needed in this area before final methodology is recommended for operational use. Though lot of work has been done in crops and some work in fisheries, no work has been done in the fields of animal sciences, natural resource management, etc. Work will be taken up in these unexplored areas which will be useful for these domains.

Statistical Genetics

Large quantity of qualitative and quantitative high dimensional multivariate data is being generated by the agricultural/animal scientists by high-throughput genotyping and phenotyping of different species in our national agricultural research system. There is need to intensify research in identification and application of Functional Data Analysis techniques, advance multivariate statistical techniques such as classificatory analysis, cluster analysis, dimensionality reduction techniques and diversity analysis, artificial neural network and SVM in high dimensional plant and animal germplasm data with reference to comparative genomics, phenomics and microarray experiments in various situations. Exploring the possible application of computational models for visualization of high dimensional data in biological systems and to apply random regression model in animal breeding data is the need for extracting useful knowledge. It will be of great interest to breeders to develop and identify suitable methods to study the genotype environment interactions in field and perennial crops for varietal selection for both high yield and stability in multi environmental data. Suitable methodology for estimation of important genetic parameters under correlated error structures is not available and need to be developed. Studying precise growth patterns of different animal species

with application of mixed nonlinear models will be quite useful and interesting for the animal researcher and need to be explored. Comparative genome sequence analysis is powerful, but sequencing genomes is expensive. It is desirable to predict how many genomes are needed for comparative genomics, and at what evolutionary distances. There is common problem of identifying conserved sequences. There is need to develop statistical models for identifying conserved sequences using evolutionary distance.

An understanding of phenotypic variation of quantitative traits is of fundamental significance in evolutionary biology, conservation biology, as well as applied genetics. Heritability and genetic correlation are principal genetic parameters for understanding variation of quantitative traits. Such parameters are classically estimated from the degree of phenotypic resemblance between relatives. Advanced estimation approaches that incorporate robustness need to be developed. Bayesian criteria need to be developed and applied to improve the estimation of genetic parameters.

Univariate animal threshold models are quite common. Requirements for successful implementation of multivariate animal threshold models including phenotypic and genotypic information are not yet known. One can use Bayesian mixed linear threshold animal model via Gibbs sampling which is one of the promising areas for estimation of (Co)Variance components.

RNA-Seq technologies are quickly revolutionizing genomic studies, and statistical methods for RNA-seq data are under continuous development. Timely review and comparison of the most recently proposed statistical methods will provide a useful guide for choosing among them for data analysis. Comparison of different recently proposed statistical methods like edgeR, DESeq, baySeq, and a method with a two-stage Poisson model (TSPM), through a variety of simulations based on different distribution models or real data need to be done.

In many applications, for example biology with genome-wide association studies, the number of predictors p can be much larger than the number of observations n. Since the full model is not estimable in this setting, some kind of regularization or selection on the predictor matrix is necessary to find influential predictors. To resolve the issue with $p > n$ or improving the interpretability of the model, it is advisable to try different shrinkage methods like Nonnegative Garrote, Ridge Regression, LASSO and Dantzig.

Genomic selection (GS) uses molecular breeding values (MBV) derived from dense markers across the entire genome for selection of young animals. The accuracy of MBV prediction is important for a successful application of GS. For estimating marker effects one can use Bayesian regression, random regression best linear unbiased prediction (RR-BLUP), partial least squares regression (PLSR) and nonparametric support vector regression (SVR).

Marker-based methods for estimating heritability have been proposed as an effective means to study quantitative traits in long-lived organisms and natural populations. However, only limited studies have been done for evaluating the usefulness and robustness in regression method context. It is required to study and examine the influence of relatedness estimator and population structure on the estimation of heritability and genetic correlation under a regression method.

DNA polymorphisms have been extensively employed as a means of assessing genetic diversity of organisms and have made it possible to study previously inaccessible questions. Efforts should be made to use molecular markers for estimating relatedness among individuals of unknown pedigree.

Researchers consider a multi-test procedure combining the results of individual Mode of Inheritance (MOI) based core tests as a possible statistical method for conducting Genome-Wide Association Studies (GWAS). Combining individual methods and comparing the individual and combined results may help identify the MOI character of the gene. Identification of SNPs, markers and genes associated with complex biotic and abiotic stress traits based on genome wide SNP genotyping data using statistical and algorithmic approaches will address some of the issues related to increasing production of crops, animals and fish products to meet the exponential growth rate of burgeoning population in India.

Fast Statistical Alignment (FSA) program is based on pair hidden Markov models which approximate an insertion/deletion process on a tree and uses a sequence annealing algorithm to combine the posterior probabilities estimated from these models into a multiple alignment. FSA uses its explicit statistical model to produce multiple alignments which are accompanied by estimates of the alignment accuracy and uncertainty for every column and character of the alignment previously available only with alignment programs. FSA uses computationally expensive Markov Chain Monte Carlo approaches that can align thousands of long sequences. Moreover, FSA utilizes an unsupervised query-specific learning procedure for parameter estimation which leads

to improved accuracy on benchmark reference alignments in comparison with existing programs. The centroid alignment approach taken by FSA, in combination with its learning procedure, drastically reduces the amount of false-positive alignment on biological data in comparison to that given by other methods and such methods need to be used in biometrics and bioinformatics.

Prediction through Machine Learning Approaches (MSA) and statistic-algorithmic approaches will help in annotation of important functional elements on genome. Also comparison of prediction accuracies of MSA with traditional regression and other classification approaches will assess the performance of the former over the latter and such studies have to be taken up.

Agricultural Bioinformatics

In order to keep pace with the research and developments in agricultural bioinformatics at global level, country needs expertise and exposure in the area of bioinformatics research in agriculture. In this direction council initiated a project in 2010 for establishment of National Agricultural Bioinformatics Grid (NABG). Under this, development of biological databases, data warehouse, software and tools, algorithms, genome browsers and high-end computational facilities through systematic and integrated approach in the field of agricultural bioinformatics have been initiated. NABG is also aimed for capacity building for research and development and providing platform for inter-disciplinary research in cross-species genomics in agricultural bioinformatics and in turn agricultural biotechnology in National Agricultural Research System (NARS). In order to sustain this activity Council established the Centre for Agricultural Bioinformatics (CABin) with the status of a Division in this institute. The main responsibility of CABin is to integrate number of other institutions/organizations in order to provide computational framework and support to carry out biotechnological research to bridge the gap between genomic information and knowledge, utilizing statistical and computational sciences.

NABG will be further expanded and Centre of Excellence for Computational Biology in the field of Agriculture will be created in the Institute. Strengthening of genomic data warehouse and integrating biological sequences, molecular interactions, homology information, functional annotations of genes, network modelling of gene and biological ontologies will be taken up on priority basis. Further, activities such as development of algorithms and software tools for on-line computational analysis of genomic/proteomics data and web services for dissemination of research in agricultural bioinformatics

need to be further expanded. The research projects will be initiated in the field of sequence analysis, genome annotation, analysis of gene/ protein expression, analysis of regulation, prediction of protein structure, comparative genomics, modelling biological systems, high-throughput image analysis, protein-protein docking and development of computational methods for high throughput biological data analysis. This will help in facilitating new vistas for downstream research in bioinformatics ranging from modelling of cellular function, genetic networks, metabolic pathways, validation of drug targets to understand gene function and culminating in the development of improved varieties and breeds for enhancing agricultural productivity. It is expected that, in due course of time, information and knowledge generated through research on bioinformatics from the genomic knowledge base will start flowing downward and experimentations in different sectors of agriculture will be able to evolve internationally superior competitive varieties/breeds and commodities in agriculture.

Statistical Computing

Statistical support to agricultural research workers in their data analysis is a prerequisite so that the research remains globally competitive. Statistical computing methods enable to answer quantitative biological questions from experimental data and help to plan new experiments in a way that the amount of information generated from each experiment is maximized. Proper and appropriate use of statistical methods for agricultural data analysis, in particular, is crucial and serves as a tool to maximize the benefits obtained from investments in agricultural research. A healthy and enabling statistical computing environment has been provided in NARS through NAIP Consortium "Strengthening Statistical Computing for NARS". To make use of this facility to the fullest possible extent, customized modules using macros, stored processes and service oriented computing for commonly used statistical procedures will be developed for AICRPs and other NARS organizations. Further, the benefit of a high-end statistical package can only be realized by proper knowledge of statistical techniques to be used and the accuracy of the statistical software package selected, therefore, training programmes would be organized for the research personnel of NARS. This will benefit the scientists in NARS immensely to enable them draw meaningful and valid inferences from their research.

Sample Surveys

The Institute has developed various sampling methodologies for estimation of important parameters in agriculture. The sampling

methodologies developed in the Institute are being used in the entire country as well as some of the developing countries. However, the agriculture sector has undergone major changes over a period of time. Various development programmes have been launched by the Government to improve the socio-economic conditions of people in the country especially the poor persons. Many survey/census related programmes have been initiated.

Reappraisal and fine tuning of existing methodologies which are, both, easily implementable as well as do not require large manpower are of immense importance. Impact assessment and evaluation studies need to be carried out for proper monitoring. Development of appropriate methodologies for area and production estimation in the horticulture sector will remain a priority area. Besides, activities related to development and validation of models in the farm mechanization sector and surveys for estimation of important farm mechanization related parameters will be vigorously pursued.

Studies, specially on development of new adaptive cluster sampling techniques especially in spatial context and application of these techniques for estimation of population parameter in the field of agriculture, use of Ranked Set Sampling, spatial statistics and Geo-statistics to improve the current methods of crop estimation surveys, Standardization of the newly developed alternative methodology for crop estimation in order to reduce number of crop cutting experiments, validation of the developed alternative sampling methodology for estimation of area and production of horticultural crops and development of sampling methodology for estimation of parameters in high value minor crops are required.

Development and application of new approach of estimation like calibration approach for various agricultural related parameters estimation, computer intensive survey sampling techniques for estimation of important parameters of interest in agriculture and impact assessment/evaluation for proper monitoring need to be studied.

Estimation of crop acreage and production using Hyperspectral satellite data and Methodological studies for developing spectral signature for mixed species based agroforestry systems for estimating area under agroforestry using Hyperspectral satellite data are required. Analysis of complex survey data and basic research in new emerging areas; Model based estimation of various parameters of interests in agricultural surveys will be done. Models in the farm mechanization sector and conducting surveys aimed at estimation of important farm mechanization related parameters will be developed and validated.

Future work in the field of small area estimation will be focussed towards application of model based small area estimation method for discrete data. Small area estimation techniques for estimation of micro level parameters in crop, livestock, fisheries and horticulture including crop insurance will be standardized. Statistical analysis and small group inference under distribution free methods will be done by combining data obtained from multiple sample surveys and other auxiliary sources. Design consistent small area estimates and methods for robust prediction of distributions will be developed.

Appropriate methods will be developed for small sample inference from sample surveys using spatial information. The potential of bootstrap methods for clustered correlated survey data shall be examined. Further, methods for outlier robust estimates for small domains as well as for robust prediction of distributions shall be developed. Research efforts will be directed towards analysis of survey data using M-quantile and Expectile models and design consistent estimates for small area.

Sampling methodologies keeping in view the existing constraints will be reappraised/refined. Methodological studies will be undertaken on filling up of data gaps in crops, livestock, fisheries and horticulture; on assessment and control of various non-sampling errors and to develop spatial sampling techniques in agriculture and allied areas. Geo-spatial ontology for agriculture domain will be developed.

There is a lot of scope of further research in the area of Remote Sensing and GIS applications in agricultural surveys. Studies on development and application of integrated approach using Remote sensing, GIS and Ground survey data in estimation of area and production of horticultural crops and mixed crops in order to get reliable estimates based on significantly reduced number of crop cutting experiments are required. Methodologies for estimation of area under agroforestry, forest cover, tree cover etc. using remote sensing and GIS techniques; spatial modelling of agricultural system including natural resource management will be developed and Application of remotely sensed data and GIS for improvement of area and production statistics and development of yield models for agricultural systems including fisheries and agroforestry in different agro-climatic regions, particularly in hilly regions are required. Small area estimation techniques will be developed for estimation of parameters from agricultural and allied surveys using remotely sensed data and GIS. Remote sensing and GIS based methodology for generation of agricultural intelligence and application of remotely sensed data and GIS in Environmental statistics

are needed. Natural resource accounting and management using remote sensing and GIS will be studied.

Econometrics

Applied work in economics often requires a solid understanding of econometric methods to support decision making. Econometrics is changing dynamically with developments in the economic theory, mathematics and statistics fields. Econometric research in agricultural sciences encompasses several frontier areas of research such as supply and demand, international trade, value addition, market integration, efficiencies in production and marketing, agricultural commodities futures, price discovery, determination and transmission, impact of technological intervention and climate change and equity issues related to gender and categories in farming systems. The outcomes of econometric research in agriculture will be helpful in framing policy prescriptions related to efficiency, equity and sustainability of farming systems. Research work pertaining to the thrust areas impact assessment of technologies/research, study on food security and poverty alleviation, modelling for agricultural marketing, and natural resource management, and technological change, risk and uncertainty in agriculture would be further strengthened.

Information Communication Technology

Information technology has empowered both people and machines with information, which is transformed into knowledge and intelligence. Appropriate use of the knowledge by both people and machines contributes to sustainable development. The Internet, major source of IT exploration has gained immense popularity over the past decade and in this age of information explosion; no country, organization and individual can afford to be ignorant of this emerging technology. It is the easiest way to link the documents and their sections in a nonlinear manner, over the different network paths. A very useful application of the Internet is to design and establish an on-line information system, where anyone around the globe with authorized access permissions can do the data updating and retrieval of useful information. Agriculture has a very wide span of activities spread over crop variety development programs, recommended set of cultural practices, plant protection practices against insects, pest and diseases, water availability and management, soil characterizations, farm implements and tools, livestock species, horticultural crops, plantation crops, agro-forestry, socio-economic characteristics of farmers etc. To meet the requirements of various stake holders in relation to Agricultural Research, number of initiatives will be undertaken in ICT.

Statistical Software for Agricultural Research

The important activity of developing indigenous statistical software packages would be rejuvenated with more vigor and zeal. Need based statistical software will also be developed for new techniques and developed statistical packages would be strengthened with the addition of new modules for newer experimental settings, sample survey data as well as for analysis of data generated in micro-arrays, genome sequencing etc.

Software Solutions for Knowledge Management Systems

With the advances in Internet technologies and mobile computing, there is a need to develop information systems that are Web 3.0 enabled or latest with the features like RSS feed, XML data interchange among applications and web services. The development of knowledge base of crops and technologies using RDF/RDFS and OWL languages will be undertaken that will help in better inference to solve problems through expert systems or multi agent systems. With these new features different crop based systems will be accessible to human users as well as to other applications on the Internet. Crop based information systems will also be made mobile enabled. Value addition to the existing information systems, DSS and expert systems and development of new web enabled DSS and expert systems for important cereals crops, pulses, oilseeds, vegetables and fruits will help in strengthening the extension services and research outputs would reach the stake holders through ICT. A set of web based expert systems for various crops will act as knowledge banks for farmers, extension workers, students and other researchers.

Computational Techniques for Knowledge Extraction and Management

Intelligent analysis of data sets, usually large and non-spatial and spatial, for meaningful and previously unknown insights will be undertaken. This will help the stake holders to transform data into business decisions and policy making. Ontologies are being used as a knowledge representation technique so as to help in better storage of knowledge in a form that can be used by people and other software applications. Development of knowledge base in the form of a set of ontologies will be taken up in important agriculture areas.

Computational techniques, algorithms and software applications will be developed for pattern recognition from large data sets. Focus will be on the use of Machine learning techniques e.g. ANN, Fuzzy, Rough Sets, SVM and hybridized techniques for data mining. Applications of

text mining, web mining and spatial data mining will be taken up for agricultural data sets.

Agricultural research and development requires massive data sets particularly related to agricultural genomics and proteomics, geo-informatics, climate change apart from other data bases related to agricultural statistics and technologies etc. The development of databases, data warehousing for knowledge management, therefore assumes a great importance for future endeavours in agricultural research. This would require a platform for data integration, data sharing and data management. IT Infrastructure is also required for implementation of the e-Governance and other knowledge base systems of ICAR and its Institutes/ Centers/SAUs. An integrated storage and archiving strategy will contribute towards optimization of resources by facilitating intelligent data movement, access to current and historical information, space savings to servers and storage devices, optimize system performance and increase energy efficiency. Many management tasks will get simplified by unification of documents, information systems and MIS leading to paperless office.

Human Resource Development

Creation of adequate and quality human resources is the basic need of any organization to keep its vibrancy. Therefore, it is of importance to develop quality trained manpower in Agricultural Statistics and Informatics to address emerging challenges of Agricultural research and extension. This would be achieved through

- Preparing text books and teaching material in electronic format for Post-Graduate degree programmes in Agricultural Statistics, Computer Applications and Bioinformatics
- Modernize education system in terms of infrastructure and faculty
- Including problem solving approach in curricula
- Conducting training programmes under Centre of Advanced Faculty Training
- Conducting summer and winter schools
- Conducting customized and ad-hoc National and International training programmes
- On-line training and e-Learning programmes
- Content generation, development, management and dissemination of all informatics and databases

The Institute is conducting Post Graduate degree in Agricultural Statistics, Computer Application and Bioinformatics; Ph.D. in Agricultural Statistics and Senior Certificate Course in Statistics and Computing. This horizon would be further broadened by initiating the Ph.D. programmes in Computer Application and Bioinformatics. These activities would be strengthened by creating a Centre of Excellence in teaching and training as Deemed University.

Targets and Important Activities

The activities to be undertaken by the Institute about 40 years hence under six broad programmes are listed below.

Programme 1: Development and Analysis of Experimental Designs for Agricultural System Research

- Development of efficient need base designs and advanced analytical techniques for Agricultural Systems Research
- Planning, designing and analysis of experiments under AICRPs
- Development of information systems for designed agricultural experiments
- Development and strengthening of web resources on Design of Experiments

Programme 2: Forecasting, Modelling and Simulation Techniques in Biological and Economic Phenomena

- Development of forecasting and forewarning models for agricultural systems
- Statistical modeling for biological phenomena using advanced statistical techniques
- Forewarning pests and diseases in crops
- Modelling of climate change and its impact on agriculture
- Models for estimation and projections of economic parameters
- Methodology for agricultural technology forecasting

Programme 3: Development of Techniques for Planning and Execution of Surveys and Statistical Applications of GIS and Remote Sensing in Agricultural Systems

- Development and application of small area estimation techniques for estimation of parameters relating to crops, livestock, fishery and socio-economic aspects

- Development of methodology for improving area and production estimates, estimation of cost of production, harvest and post harvest losses, and assessment and evaluation of agricultural development programmes
- Application of Remote Sensing and Geographical Information System in improving crop area and production statistics and natural resource management

Programme 4: Development of Statistical Techniques for Genetics/ Computational Biology and Applications of Bioinformatics in Agricultural Research

- Strengthening of Agricultural Bioinformatics Grid and development of statistical and computational analytical techniques for genomic data (in Network Mode)
- Development of advanced statistical techniques applied to plant and animal breeding research particularly estimation of efficient and robust genetic parameters, Genetic analysis of massive data sets

Programme 5: Development of Informatics in Agricultural Research

- Software solutions for knowledge management including decision support systems/ expert systems of various crops/ commodities/ resources in agriculture
- Development of computational techniques and algorithms for knowledge extraction and management
- Strengthening Statistical Computing for NARS
- Development of Statistical software for agricultural research
- Strengthening of Data Centre of ICAR
- Strengthening of FMS/MIS of ICAR

Programme 6: Teaching and Training in Agricultural Statistics and Informatics

- Post-Graduate degree programs in Agricultural Statistics, Computer Application and Bioinformatics in collaboration with IARI, New Delhi
- Senior Certificate Course in Agricultural Statistics and Computing
- Conducting ICAR sponsored and customized training programmes

Way Forward

Goal	Approach	Performance Measures
Improving the status of experimentation in NARS for enhancing the visibility and acceptability of agricultural research	• Develop efficient designs both in terms of cost and precision for agricultural systems research • Develop need based statistical analytical techniques for experimental data • Rigorous advisory and research support to plan, design and analyze experiments conducted in NARS with emphasis on AICRP/network projects	• Availability of efficient and robust designs both in terms of cost and precision, and appropriate analytical techniques for different experimental situations for drawing statistically valid conclusions
Research data repository on designed experiments	• Develop/strengthen information systems with value addition for experiments conducted in NARS • Linking information systems to service oriented computing environment	• Online research data repository of designed experiments with value addition
Web resources on design of experiments	• Strengthening web resources on design of experiments for dissemination of advances in design of experiments through e-advisory and e-learning services • Develop decision support system on design of experiments	• e-learning and e-advisory services on design of experiments

Goal	Approach	Performance Measures
Create super computing framework for bioinformatics	• Establish and strengthen National Agricultural Bioinformatics Grid (NABG) • Integration and implementation of different ICAR institutions in the NABG • Implementation of bio-clustering and bio-simulation services • Develop biological databases and data warehouse • Develop web portal for providing access of computing services in genomics	• Biological computational facilities and framework
Create interdisciplinary groups in the field of computational biology	• Initiation of research programmes with different national organizations	• Number of inter-institutional and inter-disciplinary programmes undertaken
Forecasting and forewarning models for agricultural systems	• Develop forecasting and forewarning methodologies using linear & nonlinear models, simulation techniques, Bayesian approach, machine learning techniques and climatic modelling relevant to agricultural systems • Develop systematic roadmaps of agricultural research pathways using technology forecasting methodologies	• Improved models for reliable forecasts in agricultural systems

Goal	Approach	Performance Measures
Statistical modeling for biological phenomena	• Develop methodology for efficient estimation of parameters of stochastic models • Develop relevant computer programs/ software packages for application of stochastic models to real data for efficient forecasting • Fine tuning of nonlinear SVM for classification, density estimation, regression analysis and time-series prediction • Exploiting data mining techniques on spatio-temporal information for geographic knowledge discovery	• Improved efficiency in forecasting biological phenomena • Software package in statistical modelling for use in agricultural research • Efficient prediction methodology by using nonlinear SVM
Statistical techniques applied to plant and animal breeding research, particularly, estimation of efficient and robust genetic parameters	• Develop and apply new improved statistical models for explaining different agricultural scenario by applying data mining and resampling techniques • Intensify research in application of multivariate statistical techniques for genetic diversity in plant and animal germplasms with reference to microarray experiments • Explore the possible application of computational models for visualization of high dimensional data in biological systems	• Online sharing of knowledge and information for improving research efficiency in plant and animal breeding • New methods for handling and analysing high dimensional data • Reveal actual hazard behaviour of mortality of important insect pests which will in turn help in finding optimum dose of a pesticide

Goal	Approach	Performance Measures
	and to apply random regression model in animal breeding data • Study insect survival patterns and their hazard rates with more precision • Develop sound statistical methods using accelerated failure model and non-proportional hazard models for identification of prognostic factors • Study G × E interactions in perennial crops for varietal selection for both high yield and stability in multi-environmental data	• Suitable methods for studying G × E interaction in perennial crops
Estimation and projections of economic parameters	• Work out supply and demand of agricultural commodities, market efficiency and food security • Work out equity, efficiency and sustainability in natural resource management and gender empowerment in agriculture. • Develop agricultural market intelligence	• Knowledge on extent of sustainability of resource use and women empowerment in agriculture • Methodology for estimation of domestic supply of agricultural commodities
Improve sampling methodologies for estimation of important parameters	• Reappraisal and fine tuning of existing sampling methodologies in crops, livestock and fishery sectors	• Sample survey techniques for reliable estimation of crops, livestock, horticulture, farm mechanization and fishery sectors, etc.

Goal	Approach	Performance Measures
	• Develop appropriate methodologies for improving area and production estimation in the horticulture sector • Develop and validate database in the farm mechanization sector • Impact assessment and evaluation studies for proper monitoring and effectiveness of various schemes • Statistical analysis and inference by combining data obtained from multiple sample surveys and other auxiliary sources • Develop methodology for estimation of parameters in allied areas	
Standardization of small area estimation techniques	• Develop and apply small area estimation techniques for estimation of parameters relating to crops, livestock, fishery and socio-economic aspects	• Reliable micro level estimates in crop, livestock and fisheries sectors
Application of remote sensing and GIS in survey sampling	• Standardization of the methodology for crop acreage estimation of multiple crops using remote sensing and GIS in hilly regions	• Methodology for precise estimation of various parameters of interest in agricultural surveys by using remote sensing and GIS

Goal	Approach	Performance Measures
	• Develop integrated methodology for acreage estimation of horticultural crops using ground survey and remote sensing • Develop geostatistical models for estimation of cloud cover in satellite imagery • Develop spatial prediction models • Develop remote sensing and GIS based methodology for generation of agricultural intelligence • Studies relating to natural resource accounting and management using remote sensing and GIS	• Methodology for estimation of cloud cover in satellite imagery
Enhanced use of ICT and software solutions for knowledge management	• Develop DSS and expert system for transfer of technology • Setup a Data Centre for data integration, data sharing and data management • Develop and implement FMS/MIS for efficient functioning	• DSS and expert systems for sharing knowledge • Sharing of data for research and web services • Unification of documents and services
Improve statistical computing for appropriate research data analysis	• Develop service oriented computing modules for AICRP/Network projects • Develop need based statistical software for new statistical techniques • Customised training for research workers on statistical softwares	• Service oriented computing modules for data analysis • Customized statistical packages for data analysis

Goal	Approach	Performance Measures
Create adequate and quality human resources in Agricultural Statistics and Informatics to address emerging challenges	• Modernize education system in terms of infrastructure and faculty by including problem solving approach in curricula • Capacity strengthening of the faculty through training at national and international level • Conducting post graduate and Ph.D. courses in Agricultural Statistics, Computer Application and Bioinformatics • Ad-hoc national and international training programmes • On-line training and e-learning programmes • Preparing text books and teaching material in electronic format • Content generation, development, management and dissemination of all informatics and databases	• Qualified manpower in Agricultural Statistics and Informatics


हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद
Agrisearch with a human touch