

13. Agricultural Economics, Marketing and Statistics

The principles of economics as applied to production of crops and livestock are mainly focused on maximizing yields while maintaining a good ecosystem. The application of the principles lies in resource allocation under scarcity, and combine the theory of the firm with marketing and is linked to empirical applications of mathematical statistics to develop econometric methods. The major areas encompassing these are agricultural environment and resources, risk and uncertainty, consumption and food supply chains, prices and incomes and market structures. Accordingly, optimum returns from an agricultural produce is always kept in view to take care of all sorts of variations inherent in production activities. Hence, the need for a reliable statistical procedure is a must to arrive at a precise estimate to employ timely strategy for marketing produce in the interest of ultimate beneficiaries. In this context, weather-based forecast models for productivity as well as growth models for consumption to income involve a database on economical parameters to determine marketing strategy.

Farm size and productivity

Farm size in India is continuously shrinking and fragmenting. This has raised concern about its impact on production, productivity, profitability and farm income. Though the studies during 1970s and 1980s showed that smaller farms were with higher land productivity but it was predicted that over the long-term small farms will lose this advantage. The reasoning given for this is that as per capita income rises, economy diversify and workers leave agriculture and wage rate goes up. It then becomes more efficient to have progressively large and more mechanized farms. This debate has assumed renewed importance in the wake of the changes brought about by technological change, liberalization, commercialization and further divisions of land holdings into smaller size. In this background, the present study revisits the debate on

farm size and agriculture productivity to suggest policy measures to address the twin problem of raising productivity and growth of agriculture and improving income and livelihood of small holders in agriculture who constitute more than 80% of the total farming households, 50% of rural households and 36% of total households in India. The study uses all India level data from Agriculture Census, Input survey and Situation Assessment Survey: 59th Round of NSSO.

Small farm holders do not lag behind from other farm-size holding categories in adoption of improved technologies and use of fertilizer and irrigation. Productivity at small farms in India is much higher than large size holdings. However, due to low per capita land, per capita output and income at small holdings are awfully low and not enough to keep farm family out of poverty despite high productivity.

Therefore urgent steps need to be taken to create employment avenues for smallholders outside agriculture, but within the countryside, so that workforce at small farms gets work and income from rural non-farm activities without leaving farms.

Agricultural growth

The debate on the linkage between agricultural growth and poverty reduction has been going on fiercely in India since the beginning of planned era of development. Some scholars have argued that the agricultural growth process stimulated by the green revolution brought little or no gain to the rural poor, while others have pointed the farm output growth to be the key to rural poverty reduction. Present study uses time series data on poverty, NSDP agriculture and other variables at state level.

Poverty data were derived from NSSO household unit level data, NSDP agriculture data were taken from National accounts Statistic of CSO. Data on other variables like education and agricultural wages were taken from Statistical Abstract of India and

Agricultural output per household, per hectare and per capita on different farm-size categories

Farm size class: hectare	Household size: number	Per capita land: hectare	Output value (₹)		
			Per household	Per capita	Per hectare
0.01–0.4	5	0.04	4,783	965	25,173
0.4–1.00	5	0.12	12,563	2,364	18,921
1.01–2.00	6	0.24	23,292	3,801	16,780
2.01–4.00	6	0.43	40,403	6,734	15,091
4.01–10.00	7	0.82	77,120	10,588	13,564
>10	8	2.20	137,473	16,782	7,722
All	6	0.22	18,858	3,143	15,426

Source: Situation Assessment Survey, NSSO 59th Round, Report No. 497.

from Ministry of Agriculture publication *Agricultural Wages in India* respectively. The study revealed that the significant negative coefficient of Agricultural Net State Domestic Product (AgNSDP) per capita suggests that improvement in agricultural performance is associated with substantial reduction in rural poverty, indicating that benefits of growth in agriculture have trickled down to rural poor and growth has been inclusive. The agricultural productivity has played an important role in poverty reduction. However, agricultural growth alone will not be sufficient to alleviate rural poverty. Wages are the major source of rural households, and improvement in wages can significantly reduce poverty. Therefore, the rural development programmes that have direct or indirect influence on the living conditions of farming and landless labour households should be accorded considerable importance.

A significant negative association between poverty and literacy suggests that the education plays an instrumental role in rural poverty reduction; asserting for greater investment on human resource development in the rural areas for inclusive growth.

Adoption of food safety practices in milk production

This study was undertaken to: (i) assess the status, (ii) estimate the cost, and (iii) identify the determinants of compliance with food safety measures in milk production. This study is based on the primary data collected at the farm-level in three states of India, Bihar, Punjab and Uttar Pradesh for 2007–08. The adoption intensity of safety practices at farm-level plays an important role in ensuring quality and safety of food commodity. To measure the extent of adoption of food safety practices, food safety indices were developed for each milk-producing household.

The adoption intensity of food safety practices varied from 0.42 in Bihar to 0.57 in Punjab implying that farmers are adopting only 42 to 57% of the food safety measures. The value of food safety index was observed

Ordered logistic regression coefficients for compliance with milk safety measures

Dependent variable: Food Safety Measures index

Explanatory variable	Coefficient	Standard error
Education of household-head (years)	0.087*	0.025
Herd-size (no.)	0.180*	0.035
Milk sold to formal buyers (formal=1, otherwise=0)	0.953*	0.236
Experience of household-head (years)	-0.008	0.009
Cut-off point 1	-1.414	0.326
Cut-off point 2	3.124	0.362
Number of observations	422	
log likelihood	-278.438	
Likelihood Ratio $\chi^2(4)$	70.100	
Pseudo R ²	0.100	

*Significance at 1% level.

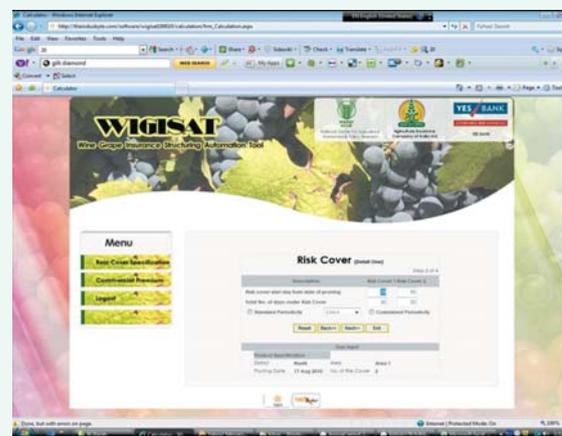
to be marginally higher in Punjab (0.57) than in Uttar Pradesh (0.45) and Bihar (0.42). The compliance with hygiene and other sanitary measures for ensuring quality and safety of milk requires some additional expenditure. On an average, cost of milk production would increase by ₹ 0.50/litre. A difference was observed in cost of compliance across different states, which was significantly higher in Bihar than in Uttar Pradesh or Punjab. These regional differences in cost of compliance may be partly attributed to the difference in the levels of infrastructural status and productivity of animals in different states.

Determinants of compliance with food safety measures in milk production: The empirical results are based on a field survey covering about 225 dairy farmers each in Punjab, Bihar and Uttar Pradesh. The survey was conducted during 2007–08. Ordered Logistic regression was used to estimate the probability of adoption of food safety practices. These estimated coefficients provide the qualitative effect of the independent variables and showed the direction of change.

The relationship between adoption intensity of food safety measures and herd-size was positive. The formal milk buyers (dairy-cooperatives, private dairy, etc.) as compared to informal milk buyers (milk-vendors, shopkeepers, etc.) affect the compliance with food

Wine Grape Insurance Structuring Automation Tool (WIGISAT)

WIGISAT encompasses broad structure of the wine grape insurance worked out by the insurance company as per the range of pruning dates, risk periods and historical weather parameters; values of different ratemaking parameters for computing commercial



premium finalized as per consultation with the grape growers; individual grape-grower empowered to structure wine grape insurance policy themselves. This on-line interface helps eliminate delays in data movement and reduces data-entry and tabulation errors. It also maintain MIS of wine grape insurance portfolio, on-line policy issuance through insurance channel partners, notification of claim event occurrence through policy holders and channel partners, and collection of farmers feedback on grape insurance policy aspects including the services of insurance channel partners.

safety measures positively. The association with modern milk supply chain enhances the prospects of higher compliance with food safety measures due to easy transfer of innovative knowledge and skills, reduction in transaction cost and a premium price to the farmers, based on the quality of milk. The greater sensitization, awareness generation and capacity upgradation of milk farmers would further result in improved compliance with food safety measures at the farm-level. The findings suggest that farmers' characteristics play a major role in determining the relative importance of various incentives and in turn, the intensity of adoption of food safety practices by milk farmers.

Risk assessment and insurance products for agriculture

Proper designing and implementing specific crop insurance products will protect the numerous vulnerable farmers from hardship, bringing stability in farm income. Under this study, a new insurance product for Wine grape was designed named as Modified Draksha Bima Yojana for grapes. It was implemented by using on-line IT platform 'Wine Grape Insurance Structuring Automation Tool (WIGISAT)'. It provides cover for unseasonal rain and downy mildew. On-line decision support system has been firmed up for the farmers to know about the insurance products to be used for their specific crops by on-line registration login into the system, submission of personal particulars and providing information on household characteristics, land attributes, farm assets and financial parameters.

Food demand

Data on household consumer expenditure collected by the NSSO show that per capita direct consumption of cereals in the country has been declining, and intake of horticultural and livestock products has been increasing. Demand for food towards the end of XII five year plan and towards 2026 has been estimated using four approaches.

Demand for cereals is projected to grow at 1.3% per year in the next 15 years. In contrast, demand for pulses and edible oils is projected to increase by 3–3.5%.

Demand for food commodities in India

Commodity	Quantity: million tonnes			Compound growth rate (%)
	2011–12	2016–17	2026–27	2011–2026
Rice	103.48	110.21	122.01	1.10
Wheat	80.79	89.06	107.18	1.90
Coarse cereals	34.60	36.40	36.05	0.27
Maize	16.86	19.27	24.16	2.43
Total cereals	218.86	235.67	265.24	1.29
Pulses	18.84	21.68	29.73	3.09
Chickpea	7.02	8.22	11.70	3.47
Pigeonpea	4.48	5.10	6.84	2.86
Foodgrains	237.71	257.34	294.97	1.45
Edible oils	14.23	16.64	23.98	3.54
Rapeseed and mustard	4.48	5.19	7.32	3.32
Groundnut	2.12	2.48	3.55	3.48
Sugar	23.70	26.50	32.95	2.22
Vegetables	139.17	161.01	226.39	3.30
Potato	35.76	41.19	56.91	3.15
Onion	15.00	17.42	24.74	3.39
Fruits	77.83	96.86	164.00	5.09
Milk	117.83	141.14	217.50	4.17
Meat, fish and eggs	12.47	15.75	29.36	5.87

Total factor productivity and role of public sector research and education in agricultural growth

This study analyzed role of agricultural research in output growth and has estimated the contribution of agricultural research to India's economy and attainment of food self-sufficiency in the country.

More than half of the total growth in output of wheat and around one-fourth in other cereals have been contributed by the increase in Total Factor Productivity (TFP). Punjab, Gujarat, and Andhra Pradesh have been found to fall under high TFP growth status with almost 90% or more cropped area experiencing a moderate to high growth in TFP (more than 1%). About 60% area in Rajasthan has witnessed more than 1% growth in TFP. Tamil Nadu, Haryana, Uttar Pradesh, and Maharashtra, have experienced low to high TFP growth, the cropped area being distributed across all TFP growth classes. The other states, namely

Contribution of agricultural research to output of selected crops

Crop	Past experience 1975–2005			Production 2008–09 (million tonnes)	Present situation	
	Output growth (%/year)	Share of research (%)	Growth rate due to research		Research contribution 2009–10 Million tonne	₹ Crore
Paddy	2.321	13.70	0.32	148.5	0.4723	472
Wheat	3.507	23.59	0.83	80.6	0.6668	733
Bajra	1.738	20.65	0.36	8.8	0.0316	27
Maize	2.897	13.06	0.38	19.3	0.0730	61
Gram	0.608	11.00	0.07	7.1	0.0047	8
Groundnut	0.842	9.76	0.08	7.3	0.0060	13
R&M	4.492	8.95	0.40	7.4	0.0297	54
Cotton (<i>kapas</i>)	3.109	26.40	0.82	11.8	0.0971	243
Sum of above						1612
Share of above crop in value of agri output 2008–09:				Per cent	31	
Research contribution in 2009–10 based on average of above crops				₹ Crore	5200	

Madhya Pradesh, West Bengal, Bihar, Odisha, Kerala, Karnataka, and Himachal Pradesh, have shown a relatively low performance in productivity growth and a large share of their cropped area falls under negative, stagnant or poor productivity category.

The overall internal rates of returns to public investment in agricultural research during 1975–2005 turned out to be 29% for rice, 38% for wheat, 28% for maize, 39% for *jowar*, 31% for *bajra*, 34% for gram, 57% for *arhar*, 18% for groundnut, 20% for rapeseed and mustard, and 39% for cotton. The study has suggested that further investments on research will generate significant returns.

The agricultural research carried out during the past three decades has improved self-sufficiency status in wheat by 15% and in rice by 7%. An important contribution of output growth achieved through agricultural research is the reduction in import dependency in meeting food requirement of the country and in improving food self-sufficiency of the nation. In oilseeds, groundnut production would have been lower by 80 thousand tonnes and rapeseed and mustard production would have been turned 5.2 lakh tonnes lower without the contribution of the research. Without the contribution of research, self-sufficiency in wheat would have declined to 83.4%. This implies that India would have been forced to import 9.8 Mt of wheat in the absence of research contribution. Similarly, without research contribution, India would have been forced to import 1.77 Mt of rice, after wiping out export of 4 Mt rice. Contribution of research in attainment of self-sufficiency in chickpea and groundnut has been limited. In the case of rapeseed and mustard, import dependency of India would have increased from 34% to 38% without the contribution of research to output growth of rapeseed and mustard.

STATISTICS

Strengthening statistical computing for NARS

An NAIP Consortium on Strengthening Statistical Computing for NARS (www.iasri.res.in/sscnars) was initiated that targets at providing research guidance in statistical computing and computational statistics and creating sound and healthy statistical computing environment for the benefit of researchers of NARS by way of providing advanced, versatile, and innovative and state-of-the-art high end statistical packages and enable them to draw meaningful and valid inferences from their research. The efforts focus on an interface of statistics, computer science and numerical analysis, involving designing of intelligent algorithms for implementing statistical techniques particularly for analyzing massive data sets, simulation, bootstrap, etc.

A general purpose high-end statistical software package was procured. It is expected that it would also facilitate data sharing over web and creation of analytics for All-India Co-ordinated Research Projects and other Network Projects of NARS.

Installation and configuration

- 180 researchers/nodal officers from all 151 NARS organizations were trained in Software installation.

Capacity Building

- **209 trainers were trained on SAS:** A Comprehensive Overview and SAS Genetics/JMP Genomics and Data Analysis Using SAS across 83 NARS organizations.
- 1,080 researchers of NARS were trained. One of these training programmes was organized for researchers for AICRP on Agroforestry on Data Analysis of Agro-forestry Experiments Using SAS.
- NAARM, Hyderabad has included Data Analysis Using SAS in the course curriculum for Foundation Course for Agricultural Research Services (FOCARS) training.

Service-oriented computing modules

Service-oriented computing consists of the computing techniques that operate on software-as-a-service. For providing a service oriented computing to Indian NARS users, a portal was established under NAIP Consortium on Strengthening Statistical Computing for NARS which is available to NARS users through IP Authentication at <http://stat.iasri.res.in:8080/sscnarsportal>. Any researcher from Indian NARS may obtain user name and password from Nodal Officers of their respective NARS organizations (list available at www.iasri.res.in/sscnars). There are 1,200 users of this high-end statistical computing facility and 947 data sets have been analyzed.

National Agricultural Bioinformatics Grid (NABG) in ICAR: This will be a national facility to provide computational framework to support biotechnological research in the country. The process of developing supercomputing facilities for undertaking research in the field of agricultural bioinformatics is being initiated at the IASRI along with High Performance Computing (HPC) infrastructural facilities at five Bureaus related to crop science, animal science, fisheries, agriculturally important microbes and insects, namely NBPGR, New Delhi; NBAGR, Karnal; NBFGR, Lucknow; NBAIM, Mau and NBAIL, Bengaluru. All international genomic data bases, i.e. Gene Bank, EMBL and DDBJ, were studied with respect to their coding structure, input and output formats. A comprehensive logical database model was designed to cover all features of these database structures. This database will be used for storage of nucleotide, genes, genome, EST, GSS, SNP, RNA etc. sequences. Web base front end for genomic data submission by the user has been developed.

Web-based SNP database of animal diseases such as foot-and-mouth disease and growth related characters was also developed. Further, attempts were made to develop databases related to salt stress-related genes of the cereal crops, salt tolerance bacteria *Phytophthora*

infestans genome, and late blight disease susceptible genes (available) in potato.

Following four important research studies were initiated in collaboration with partner institutions.

- Identification and characterization of genomic sequences responsible for salinity-stress in cereal crops—rice, sorghum, maize and wheat
- Study of synonymous codon usage and its relation with gene expressivity in genomes of halophilic bacteria
- Analysis/assessment of synonymous codon usage of Cytochrome P450 mono-oxygenase in agriculturally important insects.
- In-silico identification of genes responsible for late blight disease in potato.

Generalized row-column designs: For the experimental situations in which experimental units have two-cross classified sources of heterogeneity and the number of treatments is substantially larger than the number of replicates, row-column designs with each cell corresponding to the intersection of row and column containing more than one treatment can usefully be employed. Generalized incomplete Trojan-type designs were defined for this situation. Some series of generalized incomplete Trojan-type designs with equal/unequal cell sizes were developed. These designs are balanced/partially balanced with respect to variance of estimates of elementary treatment contrasts. There is flexibility in choosing the cell size of these designs depending on the experimental resources available. A catalogue consisting of number of treatments was developed.

An experimenter can use this catalogue as a ready reference while selecting an appropriate design for a given situation. The cell contents of generalized Trojan-type designs can be used to obtain the sample crosses in mating plans, like partial diallel/triallel cross plans. The plans obtained from such designs are uniquely determined as the cell contents are unique and non-repetitive.

Designs for bioequivalence trials: In bioequivalence trials, conducted for evaluation of veterinary medical products, the experimenters are not interested in all pair-wise comparisons among direct effects and among residual effects of formulations, but are interested in test versus reference formulation comparisons of direct as well as residual effects. A class of variance balanced crossover designs with complete sequences was developed for such experimental situations. Besides, a class of partially variance balanced crossover designs with incomplete sequences was also obtained. These designs can be advantageously used in situations wherein the number of available periods is less than the number of formulations.

Crossover designs: Experiments with biological entities often involve application of a sequence of treatments to each experimental unit over varying periods of time and are conducted using crossover designs. The distinguishing feature of such an experiment is that any treatment applied to a unit in a certain period influences the responses of the unit

not only in the period of its application but also leaves residual effects in the succeeding periods. These residual effects or carryover effects may be of different magnitudes. Balanced crossover designs are useful for these experimental situations. Linear integer programming approach was developed for generating sequence of treatments to be assigned to the units. Using this approach, cyclic circular balanced and cyclic circular strongly balanced crossover designs were generated and catalogued. The designs obtained are uniform over periods and universally optimal over the class of all connected designs with fixed number of treatments, number of periods and number of sequences.

Supersaturated designs: Supersaturated design (SSD) is useful because of its run size economy. A new method of constructing multi-level SSDs based on the association between the rows of the design was developed. An algorithm was developed for construction of such designs. A catalogue of 11 optimal multi-level supersaturated designs is also prepared. Another method of constructing optimal mixed-level SSDs by juxtaposing mixed orthogonal arrays of strength two with uniform designs was given. Mathematical expression for $E(fNOD)$ and $E(\chi^2)$ criteria and their lower bound have been obtained for these designs by exploiting the combinatorial properties of mixed orthogonal arrays and uniform designs.

A list of many optimal and near optimal, mixed-level supersaturated designs is also provided for $m \leq 60$.

Design resources server: For dissemination of research in design of experiments, design resources server (www.iasri.res.in/design) was further strengthened through adding new link on orthogonal arrays. The details for this link are:

Mixed Orthogonal Arrays and their Usefulness: Orthogonal Arrays (OAs) and Mixed Orthogonal Arrays (MOAs) were used extensively in planning experiments, particularly generating fractional factorial plans for symmetric and asymmetric factorial experiments. A new link on 'Orthogonal Arrays' was initiated on Design Resources Server and is available at <http://www.iasri.res.in/design/Oarray/oa/default.htm>.

Updation of catalogues: Design resources server was also strengthened by updating the catalogues of resolvable block designs with factorial treatment structure in 3-replications for number of levels for any factor at most 12 and that of χ^2 -optimal multi-level supersaturated designs (SSDs) and k -circulant multi-level SSDs.

Usage of the server: The server has a facility of "Ask a Question" through which a lot of questions are being received and answered.

Multiple parallel line and slope ratio assays: Biological assays (bioassays) are a set of techniques relevant to the comparisons between the strength of alternative but similar biological stimuli (a pesticide, a fungicide, a drug, a vitamin, plant extract, etc.) based on the response produced by them on the subjects

(e.g. an animal, a piece of animal tissue, a plant, a bacterial culture, subhuman primates or humans, living tissues, plants or isolated organisms, insects, etc.). In multiple parallel line assays it is indeed possible that several tests have different importance and hence the comparisons of the tests with the standard may be made with different precision. Therefore, weighed A-optimality criterion was developed for multiple parallel line assays. Designs were generated using this criterion. A necessary and sufficient condition was derived for the existence of block designs for two-test preparations slope ratio assay that enable estimation of blank and intersection contrasts free from block effects. Using this condition, a general method of construction of designs was obtained. A catalogue of designs generated was prepared. Further, weighed A-optimality criterion was developed to obtain optimal designs. Some optimal designs were obtained for two test preparations slope ratio assay using this criterion and considering some specific values of the weights.

Weather-based forewarning of mango pests: Models for forewarning time of first appearance of powdery mildew on second flush were developed for Vengrulle. Using these models earliest forecast can be obtained at 50th Standard Meteorological Week (SMW) which can be subsequently revised. Adjusted R^2 of 50th week of forecast was 0.68 which increased to 0.79 in second SMW of the subsequent year. Beyond this week, there was decrease in adjusted R^2 . Therefore, forecasts were obtained based on models with different time of forecasts up to second SMW of subsequent year. Forecasts of different years were obtained from the models based on data of remaining years. The forecasts are, in general, close to the observed ones. It can, therefore, be concluded that reliable forecasts of time of first appearance of powdery mildew can be obtained earliest at 50th SMW and subsequently revised up to second week of subsequent year.

Remote sensing-based methodology for collection of agricultural statistics: An integrated methodology based on remote sensing, GIS and ground survey for estimation of area under major crops in the north-eastern states of the country was taken up. For conducting this study, Meghalaya is chosen as the representative state. Four districts Ri Bhoi, East Khasi Hills, East Garo Hills and West Garo Hills were covered under this study.

In Meghalaya, the total cropped area is also very less (only 10%) and is mostly scattered throughout the state. The results were quite encouraging as area under paddy crop was estimated with percentage standard errors less than 5, ginger 10–12, and maize, potato and pineapple with acceptable standard errors. In future, the use of advanced high resolution data like LISS IV data, CARTOSAT or RADARSAT data may further enhance the efficiency of the estimates.

Distance balanced sampling plans: A family of distance balanced sampling plans (DBSP) with the property that the second order inclusion probabilities are non-decreasing function of distance between the

two consecutive units was introduced as a generalization of $BSA(m)$ plans.

The method is general in nature and two-point, three-point, many other DBSPs, simple random sampling without replacement, balanced sampling plans excluding contiguous units and balanced sampling plans excluding adjacent units fall out as a particular case.

Estimation of meat production in Meghalaya: The study entitled sampling methodology for estimation of meat production in Meghalaya was taken up. The collected data were analyzed as per the estimation procedure for developing species-wise estimates of meat production; and production from sheep, goat, pig, buffalo and cattle in the East Khasi Hills district of Meghalaya was estimated with 13.70% standard error. The villages contributed significantly to the extent of 7.89% of total meat production.

Identification of factors for enhancing productivity in rainfed areas: Linear combination weighed scoring, multi-dimensional scaling and analytical hierarchical process methods were used for envisioning technologies/prioritizing factors in rainfed agriculture from around 50 filled-in questionnaires from subject matter experts. The results revealed that in contrast to yield, input-use efficiency should be taken as an important performance indicator for comparing rainfed vis-à-vis irrigated agriculture. Water harvesting and water saving technologies came out to be best strategies to cope with climate change in the coming years among different technologies considered for rainfed agriculture. Stability of crops should be given highest research priority followed by early maturity, broad adoption, stress resistance and high yield potential in achieving high productivity in rainfed areas.

Impact of global meltdown on Indian agriculture: The production of mentha oil is constantly on the rise and large surplus is available for exports. This statement supports the presumption that rise in price volatility of mentha oil in the recent years may be attributed to the economic and financial disturbances in the global economy. The volatility clusters of high and low variance were more prominent in 2008 in both future and spot price series. This gave an indication that ill-effect of economic turmoil was reflected through higher volatility in 2008 and 2009 as compared to the previous years. The spot price series showed higher level of persistent volatility as compared to future price series. A special mention can be made regarding future trading, which provides an opportunity to lower down the extent of volatility.

Market efficiency in commodity futures: The desirable bi-directional relation between spot and future markets was observed in three contracts of Multi-Commodity Exchange (MCX). The analysis of bivariate relationship between spot and future markets of mentha oil showed that in most of the mentha oil future contracts, secured at MCX platform, better price was discovered mostly in future market. Regarding market dominance in terms of lead lag relationship, strong dominance of future market was observed.

An econometric analysis of groundwater markets in Indo-Gangetic plains: The study suggested that irrigation development in terms of net irrigated area showed meagre growth during the last decade in Indo-Gangetic plains. However, the growth rates differed across the regions. The analysis of groundwater development showed that the groundwater development was in over-exploited category (134%) in Trans-Gangetic plains and in semi-critical and critical categories in Upper-Gangetic plains in 2004. In the Middle and Lower-Gangetic plains, there is an ample scope for further development of this resource as only few blocks were in over-exploited category. These findings gave some clear indications regarding some policy options for more efficient, equitable and sustainable groundwater use in this region. Special attention is needed to monitor further development of the groundwater in Trans-Gangetic and north-west and south-west sub-regions of Upper-Gangetic plains and faster development of groundwater in Middle and Lower-Gangetic plains.

Public investment in irrigation on foodgrains productivity: The long-term effect of public investment in irrigation projects on foodgrains productivity indicated that there has been a time varying impact across the states. The disparity among the states on the basis of expenditure on per hectare of gross cropped area in each state has marginally increased over plan periods. Haryana, Madhya Pradesh, Tamil Nadu and Uttar Pradesh have no lag structure relationship. In Andhra Pradesh, Karnataka and Odisha, a lag of six years is observed in attaining the 100% effect of public expenditure (in major and medium irrigation) on foodgrains productivity. Bihar indicated a lag of four years, while Gujarat indicated a lag of nine years. In Kerala, a lag of 11 years is observed, while in Maharashtra and Rajasthan a lag of seven years was observed. In Punjab, West Bengal and Assam a lag of 12 years was observed for realizing the 100% effect of public expenditure on foodgrains productivity.

Bioprospecting of genes and allele mining for abiotic stress tolerance: A database on rice germplasm is designed and is being populated. A mini core is being identified from the collected germplasms under study. Genome prediction techniques are identified for associating the phenotype information of the mini-core collection with the whole genome genotypic information. Key residues responsible for reduced oxygen tolerance across species are identified using bioinformatics approaches. A Genome library was created for genes in different species responsible for various abiotic stresses under the study. A centralized Statistical and Computational Genomics Lab (SCGL) Facility was created.

Web solutions for partially balanced incomplete block (PBIB) designs: PBIB designs are an important class of incomplete block designs. A web-based solution for cataloguing, generation and analysis of PBIB designs

was developed using client server architecture. Also e-learning material on these designs was prepared that can be used as reference material by researchers and students working in this area. This web-based software is designed for multipurpose use, to meet the needs of students and teachers for demonstrating PBIB designs also to meet the requirements of research workers in agricultural and allied sciences.

e-Learning solution for agricultural education: An eLearning solution, "e-Learn Agriculture" was designed, developed and implemented at the IASRI, New Delhi. This platform was developed to fulfill the increasing demand of online interactive PG courses in Agriculture Sciences, and is available at <http://elearnagri.iasri.res.in/home>. Presently, it has been enriched with the fundamental courses under the disciplines of Agricultural Statistics and Computer Application. The system provides online courses, free email-based registration, enrollment key-based entry in a course, course search facility and online help to its users.

AgriDaksh: AgriDaksh, a Knowledge Management (KM) tool for building online expert system for crops was developed. AgriDaksh has modules on knowledge model creation, knowledge acquisition, problem identification, knowledge retrieval, ask questions to experts and administration. AgriDaksh enables domain experts to build online expert system in their crops with minimal intervention of knowledge engineers and programmers. It is possible to build online expert system for each and every crop in shorter time and resources with its use. Online expert systems have the capability to transfer location-specific technology and advice to the farmers efficiently and effectively. This in turn will reduce losses due to diseases and pests infestation, improve productivity with proper variety selection and increase in income of the farmer. Maize AgriDaksh is the first system that provides ICT-based advisories on maize crop and allows interaction with experts using internet. Maize AgriDaksh is available online at <http://expert.iasri.res.in/agridaksh>.

Expert system on seed spices (EXPSS): This expert system extends large amount of research work done by the NRC for Seed Spices and SAU's pertaining to crop management on four major and six minor seed spices to the farmers in a scientific way. It provides expert advice to farmers on variety selection, field preparation, fertilizer application, schedule of irrigation, plant protection from pests/diseases/nematodes. It also provides solution to the problems faced by the farmers through online queries. It helps in identifying insect/pest attack and suggests remedial measures. This system will help in transfer of technology for the enhancement of production level of seed spices. It is an integrated system which addresses all aspects of seed spices crop management in India. EXPSS is available online at <http://iasri.res.in/expss>.