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Agricultural Statistics Research in India

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SUMMARY

The paper reviews the research work in Agricultural Statistics in India during the last six decades, changing scenario and future needs. The origin of Agricultural Statistics has been discussed along with early research efforts made in this direction. The role played by the Indian Agricultural Statistics Research Institute (IASRI) and other institutions in the development of Agricultural Statistics has been discussed. The major advances (basic and applied) made in Sample Survey Methodology, Design of Experiments, Statistical Genetics, Forecasting Techniques and Computer Application in agricultural statistics research have been highlighted. Some points related to changing scenario and the future research needs have also been discussed in the paper.

Key Words: Sample survey methodology, Design of experiments, Statistical genetics, Computer application, Forecasting technology, Agricultural statistics system is India.

1. Introduction

1.1 It is an honor to write an article in the memory of Prof. P.V. Sukhatme. The authors are fortunate to have been associated with Prof. Sukhatme for nearly 3 decades. He started his career as a Statistician. He had the vision and the far sight to see the immense role of statistics in agricultural research and development. This helped in recognizing Agricultural Statistics as an important discipline of agricultural research in addition to being a source of data or tool for planning of agricultural development. He was instrumental in the establishment of the Indian Society of Agricultural Statistics (ISAS) and the Indian Agricultural Statistics Research Institute (IASRI) and is rightly called the father of Agricultural Statistics in India. These two institutions have made remarkable contributions to the growth and development of Agricultural Statistics research in India and the world.

1.2 Prof. Sukhatme's contributions to the theory of sampling and its applications to agriculture in the broad sense of the term have well recognized

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and appreciated worldwide. These had an impact on the improvement of agricultural statistics globally and India became a leading country in the field of Agricultural Statistics. As a statistician working in the Indian Council of Agricultural Research (ICAR) he evolved the objective technique based on modern sampling methods coupled with objective crop yield measurement for estimation of crop yields and demonstrated what is now known as stratified multistage random sampling technique based on the approach of crop cutting experiments used in crop estimation surveys in India and several other countries of the world.

1.3 While heading the Statistics Division of the Food and Agriculture Organization (FAO) of the United Nations in Rome for two decades and subsequently, he used his statistical genius for elucidating the problems of poverty and nutrition in the world and worked for the betterment of the mankind in general. This paper reviews the research work in Agricultural Statistics in India during the last 6 decades, changing scenario and future needs.

2. Origin

2.1 Collection of agricultural data for administrative purposes has been going on in India since time immemorial. Kautilya's Artha-Sastra (321-296 B.C.) makes references to collection of agricultural statistics as part of the administrative system. In mediaeval period also, importance was given to collection of agricultural statistics. However, organization and systematic collection of agricultural statistics may be said to have begun from the British India time when the Commission of Inquiry on India's Famines in its report in 1928 made reference to the defects in the statistics collected at that time. A fresh impetus to the growth of agricultural statistics in India came from the recommendations of the Royal Commission on Agriculture (RCA) in its Report in 1928. It was, however, in 1943 in the midst of World War II and in the wake of the Bengal famine, that concerted action was taken for development of Agricultural Statistics System in India for which research efforts had to be initiated.

2.2 Agricultural Statistics Research in India has basically revolved around the extensive and sustained efforts made in this field in the Indian Council of Agricultural Research, earlier known as Imperial Council of Agricultural Research (ICAR). Thus the history of development of modern Agricultural Statistics System in India dates back to 1929 when, realizing the fact that statistics plays an important role in the planning and evaluation of agricultural research and development, on the recommendations of the RCA, ICAR set up a statistical section. This section grew into a Statistical Branch (SB) in 1943

which was later designed as Statistical Wing of the Council until the establishment of the Institute of Agricultural Research Statistics (IARS) in 1959 as a separate institute within the Council. The name of the Institute became more or less synonymous with research and training in Agricultural Statistics.

2.3 The principal functions of the statistical section were to assist the agricultural and animal husbandry workers in the provinces in the planning of experiments, analysis of data and interpretation of results. The statistical section was under the charge of a statistician. To derive full benefits from the Section, the Council decided in 1933 that the statistician should scrutinize technical programmes and progress reports of its research schemes. As a result of this and with the appointment of Dr. Sukhatme as statistician to the council in 1940, the activities of the statistical section increased rapidly. It was found that appropriate statistical methodology was not always available for solving practical problems in agricultural research/development and the statistical section had to undertake research in the theory of statistics for developing appropriate methodologies.

3. Early Research Efforts

3.1 The activities of the statistical section entered a new phase towards the end of 1943, after the Bengal famine. No objective sampling methods were available for collecting reliable data on yields of crops and other commodities such as livestock products and fish production etc. As desired by the Government of India and the ICAR the statistical section undertook research in the methods of collection of yield statistics of crops by developing survey technique for yield estimation based on methods of random sampling. In this connection special mention may be made of the long scientific debate which look place between Prof. Sukhatme [17] and Prof. PC Mahalanobis [4] on the use of large square/rectangular versus small circular plots for estimation of crop yields during forties and early fifties. Finally, it was found that large plots, 5m $\times$ 5m or 5m $\times$ 10m, suggested by Prof. Sukhatme were more suitable.

A critical statistical review of ten year's data collected in a goat breeding project at Etah in UP State by Dr. Sukhatme [15] became the landmark in focussing attention of animal breeders on the need for a continued statistical appraisal of the results of breeding. In the Etah project, it was shown that year to year improvement recorded in the herd was not due to genetic improvement of the stock through selection but to non-genetic factors.

Indian statisticians, under the leadership of Prof. R.C. Bose, have also made notable contributions to the theory of experimental designs following the work of Yates and Finney. They developed in 1940 the powerful tool of Galois

fields and finite geometries. These have been found to be extremely useful in the construction of many improved designs such as confounded plans for symmetrical and asymmetrical factorial experiments, balanced incomplete block (BIB) and partially balanced incomplete block (PBIB) designs etc. for agricultural and other experiments.

3.2 The period between 1945-49 was one of the intensive activities in the Statistical Branch when under its technical guidance yield estimation surveys using random sampling methods were carried out in almost all States of the country on wheat and rice crops. The results of the surveys were also used for official forecasts. Gradually, other crops such as jowar, bajra, maize and cotton were also covered. The work of the section also involved scrutiny, editing, compilation and analysis of massive data collected through the crop cutting surveys. In view of this the statistical section had to be reorganized into Statistical Branch with substantial expansion in staff strength and headed by a Statistical Advisor. The advisory work relating to agriculture and animal husbandry was separated into two units each under the charge of a statistician. It is relevant to mention these developments because these research efforts would not have been successful without the importance and financial support received from the Council.

3.3 An important development was the introduction of two regular training courses viz. Junior Certificate Course (JCC) of 6 months duration and Senior Certificate Course (SCC) of one-year duration respectively in 1945. Subsequently, a Diploma Course involving a research project of one year, in addition to the Professional Statistician's Certificate Course (PSCC) of one-year course work in advanced statistics was also introduced. The purpose of introducing these courses was to provide adequate trained manpower for strengthening Agricultural Statistics activities in the country. The Statistical Branch received international recognition in 1949 when under the auspices of the ICAR and in collaboration with FAO and the Statistical Office of the United Nations, it organized a 14-week International Training Course. The purpose was to help member governments in developing appropriate census and sampling techniques as applied to population and agriculture and to disseminate information on international level regarding World Agricultural and Population Census of 1951. In addition to participants from India, 35 participants from Burma, Ceylon, Indo-China, Indonesia, Korea, Nepal, Pakistan and Thailand participated in the training.

3.4 The period between 1951-55 was marked by multi-pronged activities for development as well as application of sample survey techniques in a number of fields. The Statistical Branch successfully undertook the assessment of Grow

More Food Campaign, initiated by the Government of India in 1947. Fisheries and livestock surveys for estimation of cost of production of crops and milk were initiated. In January, 1953, the work of crop cutting surveys on food crops and some other surveys was transferred to the National Sample Survey Organisation (NSSO) as the methodology for undertaking these surveys had been sufficiently developed. Crop cutting experiments on randomly selected fields became the basis of estimates of yield of all major crops.

4. Indian Agricultural Statistics Research Institute

4.1 In 1952, FAO experts, Dr. D.J. Finney of the Oxford University and Dr. F. Yates of the Rothamsted Experimental Station, England were invited by the Government of India to advise the ICAR on the research and training activities in the field of Agricultural Statistics. In accordance with their recommendations the Statistical Branch was further strengthened and became the Statistical Wing (SW) of the Council. In 1955, it moved to its present campus near the IARI. A mechanical data processing unit was also added in 1957. The Statistical Wing was finally named as the Institute of Agricultural Research Statistics (IARS) in June 1959. This was the birth of a full-fledged research institute for undertaking research, training and teaching activities in the discipline of Agricultural Statistics. The Institute was finally renamed as **Indian Agricultural Statistics Research Institute (IASRI) in 1973,** in line with the names given to most other institutes in ICAR.

4.2 Consequent to becoming a full fledged institute the research and training activities were organized into a number of divisions with the main objective of formulation of research projects in the specific fields such as Sample Survey Methodology, Design and Analysis of Experiments, Bio-statistics and Statistical Genetics and Crop Forecasting etc. These research programmes were undertaken in partnership with agricultural research and development or what may be called as research in Statistics applied to Agriculture. Several central and state organisations participated and supported these programmes.

4.3 Another important development was its collaboration with the Indian Agricultural Research Institute, a deemed university, to introduce training courses at master and doctorate level in Agricultural Statistics, in early sixties. This gave a further impetus to research and training in Agricultural Statistics. This was for the first time that M.Sc. and Ph.D. degrees in this discipline were introduced in India. This was yet another step for strengthening research partnership between Agriculture and Statistics, which helped in the development of Agricultural Statistics Research.

4.4 Importance of applications of computers in Agricultural Research was recognized quite early and the first IBM 1620 computer in the Agricultural Research System was installed at IASRI in 1964. A number of Agricultural Statisticians were trained in computer programming. These statisticians in turn helped agricultural research workers all over India in the analysis of data collected by them. A large number of them were also trained in the use of the computer software. A more powerful computer system Burroughs B-4700 was subsequently acquired and installed at IASRI. Pioneering work was done at IASRI in computer applications to agricultural research and development. Keeping this in view a master's degree programme in Computer Application to Agriculture was introduced in the curriculum of IARI alongwith other disciplines in collaboration with IASRI.

5. Role of Other Institutions

5.1 IASRI played a key role in research efforts for methodological developments in Agricultural Statistics, demonstrating these methodologies to State governments and imparting training to personnel involved in collecting the much-needed data for agricultural development. The responsibility of implementing these methodologies and coordination of the relevant statistics for strengthening the Agricultural Statistics System in the country has rested with a number of other organisations in the State and the Centre.

5.2 The Central Organisations which need special mention are the Directorate of Economics and Statistics (DES) and Animal Husbandry Statistics section, Ministry of Agriculture, the NSSO, the Central Statistical Organisation (CSO), and Planning Commission in the Ministry of Planning and Programme Implementation. These organisation have played a very important role in the improvement and strengthening of database for agriculture in the country. In addition the various crops, commodity or subject specific research institutes under ICAR have also contributed to the development of Agricultural Statistics system in the country and research efforts in Agricultural Statistics.

5.3 In the States, the State departments of agriculture, animal husbandry, fisheries and bureaus of statistics and economics are responsible for implementing the statistical methodologies at the state level. Besides, the various state agricultural universities under the National Agricultural Research System which started coming up in early sixties have also played their part in improving agricultural statistics system in the country. Most of these universities have a statistical department, section or unit to help the research workers in planning their experiments, analysis of the data collected and interpretation of the results. They also participate in teaching statistical courses to students majoring in

Agriculture. Thus the establishment of these universities has contributed a lot in training the manpower and also the growth of the discipline of Agricultural Statistics.

5.4 **Indian Society of Agricultural Statistics** has played a key role in the development of Agricultural Statistics in India and abroad for the last five decades. The society aims to promote the research in and study of Statistical Theory in the widest sense of the term and its applications to Agriculture, Animal Husbandry, Fishery, Forestry and allied disciplines. It has a membership of over 800 comprising individual and institutional members in India and abroad. Uninterrupted publication of its journal since its inception has helped in the dissemination of research findings not only in India but also to an international cross section of agricultural statisticians all over the globe. Its annual conference provides a forum for deliberations on important issues in Agricultural Statistics and related areas before a wider audience.

6. Major Research Advances

The achievements made in different areas related to agricultural research and developments in sample survey methodology, design of experiments, statistical genetics and crop forecasting techniques are as given below:

6.1 Sample Survey Methodology

Modern sampling methods are a powerful means of collecting data for monitoring and evaluation of development plans. Estimation of appropriate cost and variance functions have added a new dimension obtaining estimates of various parameters with known precision at the minimum cost. With sampling fractions varying between .001 to 1 percent estimates with accuracy corresponding to sampling errors of 1 to 3 percent can be obtained utilizing these methodologies, Goel [3].

(a) *Applied Research:*

Development of suitable sample survey methodologies for estimation of various parameters in crops, livestock, fisheries production and allied fields has helped in improving agricultural statistics system in the country. The development of the following sample survey methodology in Indian needs special mention.

6.11 Methodology for crop production estimation through crop cutting approach: Sampling methodology for estimation of area and yield of field crops was developed in early 50's and is being extensively used in India and abroad. For 9% of the geographical area of the country,

mostly in permanently settled parts of Orissa, Kerala and West Bengal crop area statistics are also based on sample surveys. Method of crop cutting experiments in randomly selected fields and villages is being largely used for obtaining statistics of crop yields in respect of cereals, pulses and important commercial crops like groundnut, cotton, jute and sugarcane in the entire country.

6.12 Methodology for estimation of livestock numbers, products and attendant practices: Estimation of livestock numbers and products presents different type of problems, on account of the fact that livestock population is very large and highly dynamic and production is spread round the year. Part of the population is migratory and products like milk and eggs are of perishable nature. Moreover the level of production varies considerable not only from year to year but also from season to season and month to month. All these factors have been taken into account in evolving a sampling methodology for collection of data on livestock numbers, livestock products and attendant livestock practices. This is an important application of sampling method in time & space. Sampling techniques for estimation of individual products and also using an integrated approach to cover all principal livestock products are available, Narain *et al* [7].

6.13 Methodology for estimation of extent of cultivation and production of fruits and vegetables: Estimation of area and yield of fruits and vegetables present different type of problems on account of the special features of their cultivation as given below.

- These are short duration crops and the duration varies considerably from vegetable to vegetable.
- Harvesting of vegetable involves a number of pickings and is spread over a long period.
- Vegetable cultivation is a continuous process and operations like sowing and harvesting go on simultaneously.
- They are highly sensitive crops and can be grown under favourable agroclimatic conditions.
- These are perishable commodities and cannot be stored for long.

These problems have been successfully tackled and suitable sampling methodologies are now available for estimation of extent of cultivation and production of important vegetables and fruit crops.

6.14 Methodology for estimation of plantation crops like arecanut, coconut and cashewnut: Keeping in view the perennial nature of the

crops the methodologies have been developed and are being used for the purpose in various states.

6.15 Methodology for estimation of fish catch both from marine and inland resources: The methodologies have been developed for marine resources and some of the inland resources. The problems in case of inland fisheries are entirely different from crops. In this case also sampling in time and space is required to be done for estimation of fish catch.

6.16 Methodology for estimation of cost of production of crops as well as livestock products: Data on cost of production of crops are required for a variety of purposes such as farm planning and agricultural price policies. Basically these surveys involve collection of data on labour and material inputs (fertilizer, pesticides, seed etc.) for a representative sample of agricultural holdings. As the expenditure on various agricultural operations is spread out over a long period starting even before the sowing of crops it becomes necessary to collect data on inputs and outputs with the help of field investigators residing in the sample villages and recording data by day to day contact with the selected cultivators, a method described as the Cost Accounting method.

6.17 Methodology for evaluation studies: Methodologies for assessment of development programmes like IADP, HYVP, dairy improvement programmes, etc. are other important contributions in the development of sample survey methodology. These methodologies have been found to be very effective in monitoring and evaluation of various development programmes.

6.18 The methodologies evolved and described above are being used for estimation of extent of cultivation and production of respective crops and commodities by the concerned departments in the various states and this work is being coordinated by the Directorate of Economics and Statistics (DES) and other concerned wings of the Ministry of Agriculture, Government of India. Some of these methodologies have been internationally used.

(b) *Basic Research:*

The significant contributions in many areas of sampling techniques such as successive sampling, systematic sampling, cluster sampling, sampling with varying probabilities, controlled selection, non-sampling errors, various methods of estimation such as ratio and regression

methods, analysis of survey data, etc. have been made in order to solve many problems for which suitable sampling techniques were not available.

6.19 The use of combinatories (or experimental designs) in sample surveys has led to some useful contributions particularly for variance estimation in large scale complex surveys and varying probability selection procedures. Useful contributions have also been made in the categorical data analysis and variance estimation using re-sampling techniques like Jackknife technique and Balanced Repeated Replications (BRR). Studies on small area estimation have helped in local level planning.

6.20 The techniques developed have been found to be quite useful by the Planning Commission, Ministry of Agriculture and various State Departments. These techniques have helped in building up the National Agricultural Statistics System and only because of these contributions the systems of reliable estimation of production of crops, livestock, fishery, forestry etc. are available in the country today.

6.2 Design of Experiments

During the past decades, advanced research in the theory of experimental design is being pursued with vigour and a wide variety of asymmetrical factorials, fractional factorials, response surface designs, mixture designs, PBIB designs, efficiency balanced (EB) designs, partially efficiency balanced (PEB) designs, supplemented block designs etc. have been extensively investigated.

Major achievements in this area are as given below:

(a) *Applied Research*

6.21 A number of applied type studies [Bhargava *et al* [2], Soni *et al* [14]] which contributed a lot in agricultural research include:

- Analysis of long term experiments planned on fixed rotations (the rotation of crop sequence adopted at the time of initiation of the experiment) and conducted at different cooperating centres under All India Coordinated Research Project (AICRP) on Long term fertilizer experiment.
- Planning, designing, analysis and interpretation of data collected from experiments on Cropping System Research (CSR) and cultivator's field trials under the Project Directorate of CSR.

- Analysis of data from experiments on Agroforestry using various statistical techniques and development of suitable models and designs for Agroforestry research experiments.
- Development of yardsticks for major cereal crops for different agroclimatic regions.
- Statistical studies to determine the extent to which nitrogen could be substituted through organic sources.
- Development and identification of suitable models based on soil test values for estimating the optimal fertilizer response and economic gains.
- Quantification of drought threshold (minimum amount of rainfall required for normal growth of a crop) rainfall values for droughts of various durations (e.g. 1-week, 2-weeks, ..., 17-weeks) using rainfall and crop-yield data.
- Assessment of changes in crop production in command areas of river valley projects.
- Analysis of data from uniformity trials on several crops with a view to finding the relationship between the plot and block sizes on the one hand and plotted variation on the other for arriving at the optimum size and shape of plots and blocks.
- Investigation on the use of designs with mixture crops and their analysis in experiments involving split applications of inputs like fertilizer, irrigation, etc. to obtain optimum splits.

(b) *Basic Research:*

6.22 In developing more efficient designs for experiments and their methods of analysis Nigam *et al* [9] the important contributions include:

- Construction of balanced confounded factorial experiments for symmetrical as well as asymmetrical factorial experiments, providing flexibility in the choice of factors and their levels. Procedures of analysing these designs have also been suggested.
- For screening experiments or when the higher order interactions are negligible or the experimental resources are not enough for one complete replication, fractional factorial designs and, particularly, orthogonal resolution plans have been obtained.
- For the experimental designs where it is desired to study the relationship between quantitative level of factors and the response, various types of designs for fitting response surfaces including rotatable, group divisible rotatable have been developed and analytic

procedures have been suggested. These designs can also be used to obtain optimum combination of levels of factors.

- To study the rate of change of response with respect to factors, in biological populations or chemical experiments, slope rotatable designs have been developed.
- For the experimental situations, where it is desired that total dose of factors is fixed but response depends on various proportions of different factors, designs for experiments with mixture have been developed.
- For single factor experiments incomplete block designs viz. variance balanced, efficiency balanced, partially efficiency balanced and simple partially balanced block designs have been developed.
- Sometimes, within blocking factors, there many be more sources of heterogeneity. To deal with such situations block designs with nested rows and columns have been developed.
- Designs for bio-assays.
- Designs for making test treatments and control treatment(s) comparisons.
- Designs for studying competitive effects of treatments.
- Change-over designs.
- Designs for experiments on cultivators fields.
- Multi-dimensional designs for more than one set of non-interacting treatments.

6.23 The cataloguing of the above designs has also been undertaken. Some further studies on obtaining efficient designs with varying replications and unequal block sizes were undertaken. Besides construction of designs, the optimality and robustness aspects of the designs have been investigated. This includes optimality studies under fixed and mixed effects models under homo and heteroscedastic setups in block designs, row-column designs, designs for making test treatment control comparisons etc., and robustness of designs against loss of data, outliers, interchange and exchange of treatments. In the case of analysis of experimental data the contributions include those for missing data, non-orthogonal data, analysis of covariance, intercrop data, data on diallel crosses, asymmetrical factorial designs, groups of experiments with common treatments, use of non-parametric methods.

6.24 Information on Experiments: The Indian Agricultural Statistics Research Institute (IASRI) in collaboration with the All-India Coordinated Research Projects on Agronomy [Project Directorate of Cropping Systems Research (PDCSR)], Long-term fertilizer experiments, Agroforestry etc. developed Agricultural Field Experiments Information System for storage with provision for selective retrieval of information on the agricultural and animal experimentation in the country. The data from this Information System are being utilised in carrying out a number of methodological studies.

6.3 Statistical Genetics

The significant contributions in this field can be divided broadly into four categories namely basic research Narain *et al* [6], applications to plant breeding, applications to animal breeding and biological modelling Narain *et al* [8].

6.31 Under the first category, the investigations embraced a wide range of topics in population and quantitative genetics as under:

- The effect of linkage between genes on homozygosity and genetic structure of population undergoing different systems of mating was studied.
- Correlations between parent and offspring (P/O) and among full-sibs were worked out separately under different mating systems with both autosomal and x-linked genes. The study inter alia provided a general theory for obtaining the correlation between one parent and several offspring as well as the correlation between both parents and several offspring under a given system of mating.
- The transition probability matrices were used in studying the distribution of gene frequencies and chances of eventual fixation of genes as also the effect of dominance of certain genes on selection limits and duration of response to selection in small populations.

6.32 In the area of quantitative genetics the work included:

- Derivation of components of total genetic variability under full-sib mating; effect of linkage on differential gene frequency, in the two sexes, partitioning of phenotypic variability in the presence of gene interactions and genotype-environment (G×E) interaction, components of variation in non-random mating populations and the estimation of number of effective factors involved in the expression of a specific character.

- Efficient selection indices useful in the selection of promising parents such as the 'phenotypic index' and those appropriate to inbred, equilibrium populations were developed.
- A number of investigators in the recent past considered the chance of obtaining estimates of heritability from intra-sire regression and sib correlations outside the permissible limits as well as derivation of improved and meaningful estimators of this parameter. Heritability estimation and response to selection under non-traditional situations were also considered. All these research achievements have paved the way for further theoretical investigations.

6.33 In the case of application of statistical techniques to plant breeding:

- A number of new partial diallel designs useful for plant breeding trials were developed and techniques for analysis of diallel and triallel crosses were evolved.
- A good amount of research effort was also directed towards studying the differential relative performance of genotypes in different locations/years (G×E interaction) and yield stability as relevant to varietal selection. Plant breeders and policy makers have been making use of the results of these researches at the time of planning for crop improvement.

6.34 The long continued association and experience of the scientists in dealing with animal breeding data has enabled them to make worthwhile contributions useful to animal breeders, State animal husbandry departments and policy makers. Of these the special mention can be made of:

- Optimum breeding plans for systematic improvement of diary herds, efficient sire indices for sire evaluation, prediction of lactation yield from partial yield, use of restricted selection indices in diary cattle, indirect selection for life term performance based on characters measured in the first lactation and study of growth structure of breeding population deserve special mention.
- The extensive study on type of gene action culminated in recommendations regarding the optimum level of exotic blood for better performance and physiological adaptability and the evolution of a new breed of dairy cattle from suitable crossbred bases.
- From a recent investigation on curvilinear response in dairy cows, it has been observed that the curvilinearity is due to the fitness reversal

effect of production genes and G × E interaction has nothing to do with this phenomenon.

6.35 A beginning has also been made in the area of modelling biological phenomena. Single and multi-species stochastic fish population growth models were investigated and optimal fishing effort as well as the optimal expected yield was worked out. These investigations with further follow-up will have their utility in regulating the fishing effort in a manner congenial to sustainable fish production in the country.

Animal breeders and policy makers at the State and Central level have been making use of the results of these investigations for the planning of crop and animal improvement programmes.

6.4 Forecasting Techniques

For developing statistical models for obtaining pre-harvest forecast of crop production on the basis of biometrical characters, weather parameters and agricultural inputs and also to develop forecast models for incidence and intensity of pests and diseases, the researches, mostly undertaken at Indian Agricultural Statistics Research Institute (IASRI) include:

6.41 Crop yield models for pre-harvest forecasting of yield of rice, wheat, jowar, cotton, jute, sugarcane and tobacco, using plant characters like plant height, girth, number of green leaves, tillers/plant, number of curable leaves, number of balls/per plant etc. (depending on the crop) at different stages of crop growth were developed. Studies revealed that making workable forecasts for paddy, wheat, tobacco and cotton crops is possible, about 2 months before harvest using these models. A pre-harvest forecast for sugarcane is feasible at 3 months before harvest. Forecast of hybrid jowar can be made one month before harvest.

6.42 Integrated models using data on plant characters, weather parameters and crop inputs as explanatory variables have been developed for forecasting production of apple and groundnut crops. Results of the studies on apple revealed that the apple yield forecast can be made at full blooming stage at the earliest and later on at the stage of development of fruit size i.e. about 2-months before harvest.

6.43 Yield models for rice and wheat crop using time series data on weather parameters indicated the possibility of obtaining reliable forecasts of their yields two and a half months before harvest.

6.44 Probability model for yield forecasting which is robust against outliers/extreme values and provides non-parametric interval estimates has been developed for forecasting sugarcane yield. Yield forecasts at 7-8 months after planting were found very close to the observed ones.

6.45 A within year growth model for forecasting crop yield using current season data has been developed. Results revealed that logistic growth model can be used to forecast total dry matter at maturity about one month before harvest in wheat and rice whereas forecast of head/panicle weight can be made about 15 days in advance of harvest.

6.46 Appropriate sampling and measurement technique for estimation of incidence of pests and diseases and assessment of consequent loss in crop yield has been developed for local varieties of paddy, maize and wheat and also for high yielding varieties of paddy and wheat.

6.47 Models for forecasting the incidence and intensity of aphid pest in mustard crop have also been developed.

6.48 Model for assessing loss in yield of wheat crop due to weeds has also been developed.

6.5 Computer Application in Agricultural Statistics Research

Development of computer softwares for the analysis of agricultural and animal sciences research data, teaching of computer application in agriculture, training courses on use of computers in agricultural research and support in research data analysis to research workers in agricultural and animal sciences has helped much in Agricultural Statistics research.

6.51 IASRI has been a pioneer in introducing computer culture in agriculture research. It has helped in improving agricultural research by the use of computers.

6.52 The institute catered to the data processing requirements of agricultural research in ICAR institutes, state agricultural universities and departments of agricultural and animal husbandry at the Centre and in the States.

6.53 There are several Computer intensive methods in statistics such as Bootstrap, Monte Carlo & Simulation techniques, Generalized Linear Interactive Modelling etc. which have added new dimension to research in Agriculture Statistics. Their applications in sampling techniques, statistical genetics and design of experiments have been found to be of tremendous use.

6.54 Computer Net-working and information technology has also helped Agricultural Statistics Research in India.

7. Changing Scenario

7.1 the Agricultural Statistics System in India developed fast until around 1980's on account of a number of favourable factors which include:

- High priority given to improvement of statistics of agriculture by the Govt. of India in the past in view of recurring food shortages.
- High priority given to the research efforts in Agricultural Statistics by the ICAR and Ministry of Agriculture for its role in Agricultural Development.
- Strong linkages between research organisations like IASRI and user organisations like Ministry of Agriculture, ICAR, CSO on the one hand and data producers viz., the Departments of Agriculture, Animal husbandry, Bureaus of Statistics/Economics in the States on the other.
- Concerted action in using and implementing the Agricultural Statistics Methodologies for improving agricultural statistics for agriculture research and development by the concerned organisations.

7.2 Now the scenario has considerably changed. The Agricultural Statistics methodologies developed in 1950's to 1970's still continue to be used for collecting agricultural statistics for development planning without introducing any improvements or refinements. The quality of data on agriculture has diluted and the Agricultural Statistics System is becoming weaker e.g. the quality of crop yield statistics, Rao [11] and forecasts/estimates of production of crops are no longer very reliable, Asthana [1]. Hardly any worthwhile attention has been paid to the improvements required in these methodologies.

7.3 Similarly the linkages between agricultural research and agricultural statistics have weakened over time. Research Statisticians are seldom involved in scrutinizing technical programmes and progress reports of research schemes in agriculture. The post of Statistical Adviser in the Council which facilitated such a linkage was abolished during its reorganization around 1970 without creating a suitable alternate post. A large volume of data gathered in various research schemes of the council remains unutilized for lack of adequate participation by the statisticians within or outside the Council.

7.4 The emphasis on Agricultural Statistics Research has shifted. The agriculture statistician in the IASRI and Agricultural Universities are mostly busy with small research projects, the findings of which are seldom used for

improving the Agricultural Statistics System in the country. To mention a few are methodology for estimating losses due to floods, droughts, pests and diseases etc.

Lack of inspiration and financial support for applied research has driven the research statisticians to take up purely theoretical research in statistics which has hardly any applications to agriculture. Many advanced designs have not been applied in agricultural research on account of lack of participation between the agricultural scientists and statisticians.

7.5 There are several well known data gaps and methodological gaps, existing for many decades and no serious attention has been paid by the concerned authorities as well as researchers to bridge them. A very important example to 'cite ' is appropriate methodology for forecasting crop production.

7.6 For strengthening Agricultural Statistics Research for fast agricultural development and for improving agricultural research this situation needs to be urgently reversed.

8. Future Needs

The future perspective for Agricultural Statistics Research IX Five Year Plan-Department of Agriculture & Cooperation report [12] should take into account the technological trends and need of agricultural data for modernization and globalization of agriculture (Proceedings [10]) on the one hand and development in computer applications information technology on the other.

8.1 The issues requiring concerted efforts in research related to agricultural statistics are to:

- Improve and widen the base of agricultural statistics.
- Efficient planning and designing of experiments on crops, animals and fisheries.
- Study the intricacies of various biological phenomena related to crops, livestock and fisheries through statistical modelling and simulation studies.
- Application of remote sensing and geographical information system (GIS): In these areas the sample survey statisticians and experts in the areas of remote sensing and GIS should work together to arrive at appropriate methodologies.
- The applied research needs to be encouraged and emphasized and should be user oriented.

8.2 Studies for the Integration of statistical methodologies to cover as many agricultural activities as possible should be taken on priority basis.

8.3 The methodologies already developed through pilot studies should be made available in the form of ready to use technologies.

8.4 The Indian Agricultural Statistics Research Institute should be involved in supervising the implementation of the methodologies at the lower level so that there is a mechanism of having a feed back for further improvements and research.

8.5 The existing data available from different sources need to be exploited and there is a strong need to take up some projects involving integration of data sources.

8.6 Due to change in technologies there is an urgent need for reappraisal of methodologies developed so far.

8.7 In certain areas like medicinal plants, floriculture, minor crops, having much economic value, there is a need to develop methodologies for their estimation.

8.8 Networking of agricultural information system all over the country linking districts with State headquarters and in turn with the Centre.

8.9 Small area statistics methodology.

8.10 Workable statistical methodology for making crop forecast/advance estimates by integrating techniques based on field surveys, remote sensing, biometrical models etc., (DES Report [13]).

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