REMOTE SENSING AND AGRICULTURAL STATISTICS: RATIONALE, SCOPE AND AIMS

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Remote Sensing Applications in Agricultural Statistics System: Scope, Potential and Limitations

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I

INTRODUCTION

The indispensable role of sound statistical system to deliver the reliable statistics in desired format at right time has been affirmed by the dependence of planners and policy makers on statistics during their endeavour for social and economic development in the past five decades. If the Indian agriculture has transformed itself from a stage of being vulnerable to vagaries of nature and susceptibility to recurring droughts leading to frequent food shortages faced in the fifties and the sixties to a self-sufficient and food secured country, the credit goes to the pioneering work in the field of crop sciences and to an effective policy mechanism and monitoring device, based on strong agricultural statistics system.

However, the system over the years has come under deeper scrutiny mainly on account of benefits derived and the risks involved in the data based decision-making process. There had been impediments in decision-making due to the absence of advance reliable information on crop conditions, the mechanism for which has not been strengthened on scientific lines. The constraints in environment planning and possible under-estimation of cropped area and that of gross domestic product (GDP) due to the quality of Land Use Statistics (LUS) have invited the attention of various users. In the recent past, these issues have become extremely relevant because of difficulties faced in taking timely decisions on the agricultural scenario of the country.

The effective mechanism of crop forecasts has immense utility in developing stable economic environment, reducing the risk in production, marketing and distribution operations and decisions for exports and imports. The efforts towards improvement in the system of crop forecasting based on research investigations using modern technological advancements in the fields remote sensing applications, agrometerology and information technology therefore needs to be viewed not only to modernise the whole system of crop forecasting but also to strengthen the decision-making process in the long term perspective.

II

SYSTEM OF CROP ESTIMATION – STRENGTHS AND WEAKNESSES

The complexities involved in any statistical system are on account of the diversities prevailing in its domain and the dimensions of its coverage. Both these attributes are abundantly existing in the agrarian economy of India. The redeeming feature of Indian

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agricultural statistics system is its coverage and its ability to modulate itself witn the emerging needs of different periods. The timeliness and the quality of statistics had all along remained the driving force behind the efforts of strengthening the system. The National Commission on Agriculture, 1972 had elaborately emphasised the need for strengthening the system and to incorporate the features emerging over time.

India has one of the best systems in the world to collect, collate and compile official estimates of crop production. These estimates are primarily based on the official feedback of area and production received from the states having their respective systems of collecting these statistics. The final estimates of production of crops based on complete enumeration of area by revenue agencies and yield estimates based on the crop-cutting experiments become available much after the crops are harvested. Production is estimated as a product of estimates of crop area and crop yield. Area under the crops is obtained through complete enumeration of area in respect of land record states. For three permanently settled major states (i.e., non-land record states), namely, Kerala, West Bengal and Orissa, area estimates are obtained through sample surveys. For the remaining states which constitute only 5 per cent of the geographical area and a tiny proportion of gross cropped area, the crop area and yield estimates are based on traditional method. Yield rates of various crops are derived on the basis of crop-cutting experiments conducted on random sampling basis under General Crop Estimation Surveys (GCES). About five lakh crop-cutting experiments are conducted every year on 51 food crops and 15 non-food crops in different states.

The advance estimates consist of pre-harvest forecasts and quick estimates. Pre-harvest forecasts relate to the estimates of likely production of a crop assessed during its growing stage prior to its harvesting. Quick estimates stand for initial post-harvest forecasts of likely production of a crop based on crop area obtained generally from sample survey under Timely Reporting Scheme (TRS) and crop yields obtained from the results based on a partial sample of crop-cutting experiments (CCE) conducted under the General Crop Estimation Surveys (GCES).

Considering the genuine requirement of crop estimates much before the crops are harvested for various policy purposes, a time schedule of releasing the advance estimates has been evolved. The first official forecast of area and production of *kharif* crop is prepared in the middle of September when the south-west monsoon season is about to be over and *kharif* crops are at advance stage. This coincides with the holding of the National Conference of Agriculture for Rabi Campaign, where the states bring their assessments of the *kharif* crops. The second assessment of crop forecast is prepared sometime in the month of January. The third advance estimate of production is prepared towards the middle of April when the National Conference on Agriculture for *kharif* and *rabi* crops. All these advance estimates are duly validated with the information available with State Agricultural Statistics Authorities (SASAs), the Remote Sensing Data, the reports of Market Intelligence Units (MIU) as well as the model-based yield forecasts of rice and wheat made by Indian Meterological Department (IMD). The final estimates are worked out about six months after the close of the agricultural year.

Limitations of Existing System of Crop Forecasting

Forecasting is a scientific craft involving the methodical use of endogenous and exogenous parameters to facilitate realistic assessment of a future event. This exercise becomes complex when these parameters have varied behaviour and have direct bearing on the event. The crop condition during this period of sowing and harvesting depend significantly on the diverse agroclimatic conditions. An effective mechanism of crop forecasting may not be possible without evolving a design of collation and analysis of data relating to such volatile exogenous parameters.

The results of area based on TRS and complete area enumeration as well as GCES take quite some time. Therefore, the information based on the reports from the states on crop weather conditions, likely area to be covered under various crops and input offtake is utilised for preparing advance estimates. These advance estimates are revised from time to time depending upon weather conditions, crop situation, prevalence of pest and diseases and abiotic factors like flood, drought, etc. However, the present system of assimilation of such date bases for delivering an effective forecasting mechanism has enough scope of improvement.

Towards improving the quality and timeliness of advance estimates of area and production of crops, the entire crop forecasting system including the methodology and assessment techniques was reviewed by an Expert Group constituted by the Government of India.[1] The Group has also suggested to set up a National Centre for Crop Forecasting (NCCF) in the Ministry of Agriculture (MOA) with strong infrastructure of trained manpower, necessary equipment and appropriate hardware and software configuration with two-fold functions: (a) periodic crop forecasting for major crops; and (b) co-ordination and assimilation of various methodologies and technical advancement relating to crop forecasting.

The Expert Group had specifically recommended for "a strong mechanism of crop forecasting having a cohesion and co-ordination among MOA, SASAs, Department of Space (DOS) and other Central and State agencies associated with generating basic agricultural statistics". The advance estimates of area and production of major crops furnished by SASAs may be based on collective wisdom of various experts of agricultural extension, remote sensing, agrometerology, marketing, inputs, etc.

Infirmities in LUS and Area Statistics

Indian is one of the few countries having a well-established system of collection of Land Use Statistics (LUS). It not only provides an exhaustive data base on utilisation of 329 million hectares of land mass of India in standarised classification but also accounts for cropwise utilisation of land as well as net and gross cropped area. These statistics play a crucial role in the macro as well as micro level planning. Of late, an awareness is generating to explore the possible degradation of such natural resource of lands and to take effective measures for preserving environmental balance in the overall exercise of agriculture and of land utilisation for different purposes.

The present nine-fold calssification of land use does not fully meet the requirement of planning. The details of land under various uses particularly in terms of in-habitat areas and also roads and other characteristics of land like alkalinity and salinity are very often required. This is required to examine the potential use of land and also the deteriorating character of land. There is also demand for separate recording of the data on inland water bodies so as to provide frame for estimation of inland fisheries resources.

The main limitation of LUS is the rigid framework of land record instructions due to which a real scenario of crop and non-crop utilisation is not reflected. The forest area as per LUS is about 23 per cent. However, the imageries of remote sensing have revealed that the actual forest cover is of the order of 18 per cent in further break-up of dense and thin forest. Thus the difference between the facts and figures is not reflected in other utilisations. There are doubts that pasture area has also depleted and has been converted into cropped area. Some of the state procedures do not account for the crop utilisation in summer seasons. The findings of Improvement of Crop Statistics (ICS) Scheme corroborate the somewhat underestimation of net are sown and gross cropped area. The underestimation of cropped area may lead to the underestimation of production and resultantly in the contribution of agricultural sector in GDP. The application of remote sensing thus has significant potential to validate the LUS and cropped area statistics and bridge the data gaps.

III

REMOTE SENSING APPLICATIONS FOR STRENGTHENING THE AGRICULTURAL STATISTICS SYSTEM

The area and crop intensity investigations through Remote Sensing have diverse utility for the agricultural sector as a whole. The activities in this sector are primarily land based. The 328 million hectares geographic space of the country is a vast domain on which these activities are pursued. The data base generated at present involving large human efforts is undoubtedly of great significance to the society and the nation. However, the quality and timeliness of such data base and resultant statistics is a derivative of human endeavour. It is in this background, the incidence of non-sampling errors is also feared in large data generation exercise. Remote Sensing applications have less scope of human bias creeping in data generation.

The RS technology has potential in estimating crop acreage and production at district/group of districts and regional level due to its multi-spectral, synoptic and repetitive coverage. This technology is being used operationally by many advanced nations. The Foreign Agricultural Service (FAS) of United States Department of

Agriculture has been using RS data together with soil moisture and crop yield models to estimate global agricultural production. Similarly, the Directorate General for Agriculture of the European Community is using a range of RS data in estimating the total production of important crops in Europe. In India, the Crop Acreage and Production Estimation project (CAPE) has been in progress ever since the launch of first Indian Remote Sensing Satellite (IRS)-IA in 1988. This project, funded by the Ministry of Agriculture, is being executed jointly by the Department of Space, State Remote Sensing Centres, State Department of Agriculture and Agricultural Universities.

Different approaches of Remote Sensing applications have been studied in the past for providing information about crop production. For example, (a) RS can be used in crop acreage estimation. This could be approached in two ways: either RS can be used in making area sampling frame (crop inventory in this case is done by field survey), or RS is used for making crop inventory. In case the accuracy of inventory with RS data alone is not acceptable, it has to be combined with field surveys..(b) RS data us used for crop yield estimation/forecasting. The approaches in this case are (i) use of RS in pre-harvest yield forecasting (either RS data is used in assessment of crop growing condition and/or crop growth or by developing RS-based crop yield forecasting models), and (ii) use of RS in post-harvest yield estimation. This could be done either through use of RS in the design of crop cutting experiments for yield estimation or by use of RS data for post-stratification for improving precision of CCE yields.

Since 1988, the Department of Space and Ministry of Agriculture have been implementing a joint scheme called Remote Sensing Applications Mission for Agricultural Applications (RSAMAA.) with four major components, viz., Crop Acreage and Production Estimation (CAPE), Drought Monitoring [National Agricultural Drought Assessment and Monitoring System (NADAMS)], Flooded Area Mapping and Marine Fisheries. Considering the valuable information provided by these projects, financial sanction was renewed during the Eighth Plan period.

The Ministry of Agriculture (MOA) had also sponsored research efforts on delineating potential fishing zones using RS data through chlorophyll and/or thermal front mapping. Lately, the utility of RS applications for horticulture development and cropping system analysis have been explored and the proposals thereof have been submitted to MOA.

The recent developments of using remote sensing data with better resolutions have been used to strengthen LUS and crop statistics. The forest cover has been depleting according to the density of trees. Certain procedural limitations of non-spatial LUS data are being reconciled. The interface of space and land-based observations would undoubtedly usher an era of Geographic Information System (GIS) based on LUS for evolving strategies for balanced and optimum use of land resources.

Evaluation of CAPE Project

The CAPE project initiated in 1988 was aimed at providing pre-harvest acreage and production estimates at an accuracy of 90% with 90% confidence (90/90 criterion) for the major crops, viz., wheat, rice, *rabi* sorghum, cotton, mustard, groundnut. As of now, the acreage covered under this project accounts for 90 per cent of wheat, 89 per cent of rice, 83 per cent of *rabi* sorghum, 61 per cent of *kharif* groundnut, 65 per cent of cotton and 55 per cent of rapeseed/mustard. Pilot studies were conducted for sugarcane in Uttar Pradesh and for bajra in Rajasthan. The satellite/sensors available during the early phase of this project permitted production estimation of only a few crops (wheat, rice and sorghum) grown in homogeneous and contiguous areas meeting the 90/90 criterion. Production forecast trials were successful in states like Punjab, Haryana, Uttar Pradesh (wheat), Orissa (rice) and Maharashtra (sorghum). The production forecasts failed to meet the accuracy goals in states like Rajasthan, Madhya Pradesh (wheat), Andhra Pradesh and Tamil Nadu (rice). The forecasts were found fairly reliable at the state level but not at the district level. It is at this stage a review was conducted by an Expert Committee chaired by the Agriculture Commissioner, Government of India. Based on the recommendations of the Committee, research efforts were intensified to improve the sensor capabilities, sampling techniques, analysis algorithms, area coverage of crops and quality of production forecast.

During the execution of the CAPE project in the last few years, timely and reliable crop estimates could not be given for some areas due to inability of the visible and near infrared sensors to penetrate the persistent cloud cover during the *kharif* season. Some preliminary efforts were made to overcome this problem through use of microwave data on R & D basis. The crop yield modeling techniques needed further improvements due to the complex nature of the Indian agricultural system. For example, improvements in the techniques are required to outcome deviations observed at district level between satellite-based forecasts and estimates made by the conventional systems due to heterogeneous nature of cropping patterns. It was also observed that much more experience is required to use RS technology for inventory of cash crops like tobacco, chillies, etc., and horticulture crops like banana, mango, etc. Lack of effective participation of SASAs was also one of the limitations observed during the project.

IV

CONCEPT OF FASAL

The Department of Space has submitted a project proposal – Forecasting Agricultural Output Using Space, Agrometerology and Land Based Observations (FASAL) envisaging advance reliable assessment of crop acreage and production using remote sensing techniques and other data bases available. The FASAL project addresses all important issues related not only to improvement of forecast but also to providing more than one assessment during a crop season and having provision for alternate forecast methodology in case of non-availability of remotely sensed data due to cloud cover, especially in the *kharif* season till the microwave missions become operational. It emerged that RS, weather and field observations provide complementary and supplementary information for making crop forecasts. Thus an approach which integrates inputs from the three types of observations is needed to make forecasts of desired coverage, accuracy, and timeliness.

The concept of FASAL thus strengthens the current capabilities of early season crop estimation capabilities from econometric and weather-based techniques with RS applications. Mid-season assessments can be supplemented with multi-temporal coarse resolution data-based analysis. In the latter half of crop growth period, direct contribution of RS in the form of acreage estimates and yield forecasts is available. However, in this case also, the addition of more extensive field information and weather inputs would increase the forecast accuracy.

Interfacing with Existing Agricultural Statistics System

India is bestowed with a well-established system of estimation of crop production. The Timely Reporting Scheme, and the Scheme for Establishment of an Agency for Reporting Area Statistics initiated in the 1960s and 1970s respectively were oriented to provide area estimates in time. The estimates at the national level are prepared based upon the flow of information from SASAs. The yield estimation is arrived at on the basis of scientifically designed crop estimation surveys in which about 5 lakh crop-cutting experiments are conducted on principal crops in the country. However, the need for the estimates of crop production before the harvest has been felt and it is in this context the focus of FASAL on generating advance estimates is envisaged to strengthen the crop forecasts.

Hence, the primary focus of the FASAL is to provide realistic advance estimates for major crops. However, the remote sensing application can be effectively dovetailed to meet the objectives of cropping system analysis and horticulture development as well.

The FASAL project has scope of providing district estimates in its National-State-District Forecast (NSDF) option. On stabilisation of the project, the same can be expanded to provide districtwise estimates. In addition to it, the estimates emanating from FASAL can be used to validate the final estimates of area and production. The National Remote Sensing Agency in 1988-89 had undertaken the land use and land cover survey as well as the wasteland mapping. Such an exercise can be undertaken once in five or ten years for firming up the existing land use statistics where certain land utilisation may not have proper reflection due to the in-built limitations of land record system.

National Centre for Crop Forecasting (NCCF)

Precise and up-to-date information on agricultural production is the most important aspect of any system concerning crop production and agricultural statistics. To obtain rapid improvements, while avoiding duplication of work and a diversity of methods, it is necessary to set up a centralised system for planning, co-ordination, execution and quality assurance of the work. Although this system gives emphasis to use of remote sensing data, the techniques will complement the conventional crop survey data. Having a national centre for this purpose stems from the fact that currently a well organised and extensive set-up exists in India for collection of various agricultural statistics. More than one agency is involved in this conventional system. Considering the advance estimation and forecasting of agricultural output as the weak link in the otherwise strong agricultural statistics system, the Expert Group had also recommended the NCCF where the diverse data sets can be effectively integrated.

Advantages of the FASAL Project over Existing Procedure of Crop Forecasts

Against the background of concept, focus and features of FASAL project, the MOA had set up a Task Force to examine the modalities of its implementation.[2] While strongly recommending to adopt the FASAL, the Task Force identified the various counts on which FASAL project was seen to be bringing improvement in the existing system of crop forecasting. These are listed as follows:

(a) Though the existing system of agricultural statistics has a sound design and institutionalised operational framework, has built in a mechanism to commit to the timeliness and quality of data through the schemes of TRS, Establishment of an Agency for Reporting Agricultural Statistics (EARAS) and Improvement of Crop Statistics (ICS) and is enabling the final estimation of area and yield with consistency of aggregation over administrative and geographic hierarchy reasonably well, but for advance estimation and forecasting of crop production, it relies more on conventional impressionistic approach. The FASAL envisages to induct the use of scientific approach and rational analysis of proper databases in the forecasting mechanism.

(b) The existing system of crop forecasting has weak assimilation and application of exogenous parameters and nominal scope of data exchange and networking. The absence of institutionalisation of crop forecasting system is a major hindrance. FASAL focuses on this felt need of the system of agricultural statistics with a concept and mandate of NCCF. In this process, FASAL also consolidates isolated developments taking place in the field of crop forecasting.

(c) The existing system of crop forecasting is not adequately harmonised over the geospace. Further, due to weak technological interface, the existing system has less scope of further development and improvement. FASAL being a technically oriented approach has development and advancement in methodology as its in-built component.

(d) FASAL project integrates itself with the existing system of agricultural statistics envisaging active involvement of SASAs. Hence, it provides a scope of down-the-line technology percolation.

V

CONCLUSION

The potential of remote sensing techniques has been realised to bridge the data gaps in the existing system and to strengthen it for removing the impediments of decision-making and policy formulations. It does not mean that these emerging scientific methods can substitute the existing system which also had been evolved and streamlined over time after the intense methodological debates. The final estimates of area and production emerging from the existing system though can be refined with the help of remote sensing techniques. However, the crop forecasting had been identified as a weak link in the system of agricultural statistics.

The advance estimates and the forecasts are mortals. They die when the final estimates are available. They attempt to foretell the future. However, these forecasts, in spite of their short life-span, have immense value in decision-making, a process which is generally futuristic. The reliability of advance estimates thus strengthens the time-utility of decision process. It is against this background the application of remote sensing in general and the implementation of a project FASAL has great relevance in decisions relating to food security, imports and exports.

The element of human bias in remote sensing techniques is minimum. So are the chances of the incidence of non-sampling errors. In any data-based decision-making exercise, the stake holders for the quality of statistics are the decision-makers. In the federal structure, the stake holders may differ from the data generators whose commitments to quality for the particular statistics may not be in full consonance with the expectations of stake holders. Further, the psyche behind the statistics, when it is linked to financial transactions, such as development fund or relief fund, may tend to hold the information for opportune time. Such factors may dampen not only the spirit of transparency but the spirit of statistical professionalism as well. Application of scientific logic and tools should help in diffusing such aberrations which are likely to dampen the spirit behind the statistical system.

NOTE

1. The Expert Group on Crop Forecasting and Advance Estimates was set up under the Chairmanship of Prof. B.B.P.S. Goel, the then Director, Indian Agricultural Statistics Research Institute, New Delhi, in 1996 and its report was submitted in August 1997.

2. The Task Force to examine the modalities of implementing FASAL was set up under the Chairmanship of Shri J.N.L. Srivastava, the then Additional Secretary in Department of Agriculture and Co-operation and presently Special Secretary in the Department in 1997, which submitted its Report in February 1998.