

**Use of satellite data and farmers eye estimate for crop yield modeling****Randhir Singh**Indian Agricultural Statistics Research Institute  
New Delhi, India**Abstract**

Forecasting of crop production is most important aspect of agricultural statistics system. Yield forecasts in the country at present are based on subjective eye estimate of crop condition and crop yield. The main factors affecting crop yield are agricultural inputs and weather. Use of these factors forms one class of models of forecasting crop yields. Another approach uses crop vigour through remotely sensed satellite data. In this regard several studies have been undertaken to establish relationship between spectral parameters through vegetation indices and the crop yield. Shah (1999) used satellite data and geographical information system (GIS) for developing crop yield models. Verma et al (1988) showed that farmers eye estimates are remarkably close to actual production figures. In the present study farmers eye estimate of crop yield has been used more objectively as an auxiliary variable along with the spectral vegetation indices obtained from satellite data to develop improved crop yield forecasting models. The crop yield data is obtained from general crop estimation surveys (GCES), the farmers eye estimates of the crop yield of the corresponding fields and the satellite data of the corresponding area are obtained at the time of maximum vegetation growth stage of crop.

**1. Introduction**

Agriculture is the backbone of Indian economy, contributing about 40 percent towards the Gross National Product (GNP) and providing livelihood to about 70 percent of the population. So for a primarily agriculture based country like India, reliable accurate and timely information on types of crops grown and their acreages, crop yield and crop growth conditions are vital components for the planners engaged in formulating and implementing appropriate prices of agricultural commodities, strengthening country's food security and distribution system and import/export policies of these commodities from time to time and in efficient management of natural resources. .

India is one of the few countries which has a well established system of collection of agricultural statistics and detailed statistics of land utilization are continuously available since 1884. The agricultural crop production of principal agricultural crops in the country is usually estimated as a product of area under the crop and the average yield per unit area of the crop. The estimates of the crop acreage at a district level are obtained through complete enumeration whereas the average yield is obtained on the basis of crop cutting experiments conducted on a number of randomly selected fields in a sample of villages in the district.

The crop forecasts/advanced estimates of crops are presently developed by Ministry of Agriculture for taking policy decision relating to procurement, marketing, export, import etc. The advance estimates of kharif crops are first prepared in July/August tentatively when behaviour of South West monsoon is clear and reports of coverage of area under crops from the states are available. The advance estimates are reviewed during December/January when estimates of area under kharif crop become available under the Timely Reporting Scheme (TRS) and results of the crop cutting experiments portion from the NSSO (normally 10%) become available. The advance estimates of rabi season are also prepared at this stage. The advance estimates are again reviewed in the month of April based on information obtained from the states giving the final forecast for kharif.

With the advent of Remote Sensing Technology during 1970s, its great potential in the field of agriculture have opened new vistas of improving the agricultural system all over the world. Space borne remotely sensed spectral satellite data has been widely used in the field of agriculture for estimation of area under different major crops like wheat, paddy, groundnut and sugarcane. Studies have also been made to examine the relationship of crop growth parameters like leaf area index (LAI) representing crop vigour and the spectral data in the form of several vegetation indices developed from the spectral data of various bands. Remote sensing satellite data can also be used for improving the crop yield estimation through crop cutting experiments and also for developing models for crop yield using historical data, meteorological data, and remotely sensed satellite data.

During 1990-93 a study was conducted at the Institute to examine the usefulness of satellite spectral data for stratification of crop area based on vegetation indices for improving crop yield estimation based on yield data from crop cutting experiments under crop yield estimation surveys. The study pertained to wheat crop yield for district Sultanpur UP for 1985-86 and the satellite data was used from the USA satellite Land Sat-4. This study showed that the efficiency of crop yield estimation can be increased considerably by using the satellite data along with the survey data. The results of this study are given in Singh et. al.(1992). Another similar study was undertaken during 1996-98 for improved estimation of wheat crop yield in district Rohtak for 1995-1996 using the IRS 1B - LISS II satellite data for Feb. 17, 1996 and the crop yield data from crop yield estimation surveys for Rabi 1996. The results from this study presented in Singh et. al (1999). also showed that satellite data in the form of vegetation indices greatly improves the efficiency of crop yield estimator.

## **2 Use of Satellite data in crop yield modeling.**

Forecasting of crop production is one of the most important aspect of agricultural statistics system. Yield forecasts at present are based on quite subjective estimates and the final crop production estimates based on objective crop cutting surveys become available long after the harvests. This as such calls for the necessity of objectives methods for pre-harvest forecast of crop yields.

The main factors affecting crop yield are inputs and weather. Use of these factors forms one class of models for forecasting crop yields. The other approach uses plant vigour measured through plant characters. It is assumed that plant characters are integrated affects of all the factors affecting yield. Yet another approach is measurement of crop vigour through remotely sensed data. These approaches are being tried by various organizations.

. Box and Jenkins (1976) used time series models for forecasting where the variation in yield during different years is explained using historical data through trend analysis and presented the well-known technique of auto regressive integrated moving averages ARIMA.

The approach using weather parameters is normally based on time series data. The major work in this regard has been attempted at IMD (Sarker, 1977, Sarwade, 1988). Their studies involve identification of significant weather parameters in different periods and utilizing these parameters in the regression model along with trend. At IASRI, studies have been carried out at district level using weekly weather parameters. Various composite weather variables were derived as weighted accumulations of weekly weather parameters/interactions up to the time of forecast and were used as regressors in the model along with trend. Principal components of weather variables were also tried for developing the model (Agarwal et al.1986; Jain et al. 1980). The problem associated with meteorological model is assumption of same weather prevailing in a larger area as observatories are sparsely located. These models also require long series of data, which are not available for most of the locations.

In case of crop yield modeling using satellite data, several studies have been undertaken to establish relationship between spectral parameters through vegetation indices and the crop yield. Sridhar et. al.(1994) presented wheat production forecasting for a predominantly un-irrigated region in Madhya Pradesh. Singh and Ibrahim (1996) examined the use of multi date satellite spectral data for crop yield modeling using Markov Chain Model. Saha (1999) used satellite data and GIS for developing several crop yield models. Crop yield is influenced by a large number of factors related to soil, weather, agro climatic factors, management practices etc. Satellite data is integrated manifestation of effects of all these factors on the crop growth and hence can provide immense potential for use in crop yield modeling.

Several approaches in crop yield modeling using satellite remote sensing data have recently been developed like spectral yield models using spectral vegetation indices or spectral growth profile, meteorological yield models using meteorological data pertaining to some significant crop phenological stages in the form of some indices. Agriculture and climate are closely inter linked in the sense that crop growth development and production are greatly affected by variation in agro-meteorological parameters during crop growth period. In this modeling approach remote sensing derived SVI is coupled with meteorological indices and multiple regression model is developed. A large number of meteorological indices like Growing Degraded Day (GDD), Mean Temperature ( $T_{\text{mean}}$ ), Rainfall index (RI), Crop Water Stress Index (CWSI) etc are being used in agromet spectral yield models. However the

difficulty and delay in availability of weather parameters make this approach less attractive. Studies have also been conducted for developing integrated or combined models incorporating parameters from diverse sources or combining two or more independent forecasting models.

Recently with a view to collect, collate and assimilate large data from different sources, a National Crop Forecasting Centre (NCFC) has been set up under the Ministry of Agriculture during 1998. Deptt. of Space have also recently launched a project – Forecasting Agricultural output using Space, Agro-meteorology and Land based observations (FASAL) envisaging advance reliable assessment of crop acreage and production using remote sensing techniques and also other data. Very recently National Wheat production forecast for (1998-99) using multi date WiFS and meteorological data have been developed under this project.

A study on "Evaluation of crop cut method and farmers reports for estimating crop production"(Verma et al (1988)) was undertaken at Long acre Agricultural Development Centre UK. This study was carried out in 5 countries in Africa during 1987 with the objective of comparing crop estimates based on crop cut methods with estimates obtained by asking farmers directly to state their production. The results of the study showed that farmers eye estimates are remarkably close to actual production figures in all the countries and they also show considerably small variance compared to the estimates based on crop cutting experiments. After the publication of this report considerable interest is again focused on using farmers estimates which are much cheaper to obtain and easier to conduct.

In the present study, therefore an effort is made to use the farmers eye estimate more objectively as a auxiliary variable along with the spectral indices to improve the efficiency of crop yield models for forecasting crop yield. Farmers estimates were obtained for the same fields in which crop cutting experiments were conducted.

### **2.1 Study area and extent of data used in the study**

The study was conducted for district Rohtak of Haryana State which is one of the major wheat growing areas having an acreage of more than 66 percent under wheat crop during Rabi season. Following data were used in the study

#### **(a) General crop yield estimation survey data**

The yield data for the Rabi season for the years 1995-96 and 1997-98 from general crop estimation surveys based on crop cutting experiments for wheat crop for district Rohtak, Haryana has been used.

#### **(b) Satellite data**

The satellite data in the study has been used for 1995-96 from IRS-1B, LISS-II of path 30 and Row 47 of Feb.17, 1996. The total area of Rohtak district is covered in one sub scene

B<sub>2</sub> of 30-47. For 1997-98 IRS-1D data of sensor LISS-III of path 95 and row 51 for Feb.4, 1998 has been used.

A Global Positioning System (GPS) was also used to identify the exact locations of the plots selected for crop cutting experiment for wheat crop in terms of their latitudes/longitudes and also the locations of ground control points(GCP's) which were later used to rectify the raw digital spectral data. A topographic map is the best tool to supply ground truth information for visual interpretation and identification of various features on satellite imageries. From these maps locations of villages along with related features like continuous roads, canals railway tracks etc. can be easily identified on FCC's. Survey of India topographical maps of Rohtak district on 1:50,000 scale were used to identify the location of villages selected for the crop yield estimation surveys.

### **(c) Farmers yield appraisal data**

The farmers eye estimate data has been collected for the years 1995-96 and 1997-98 for wheat crop yield from the same farmers whose fields have been selected for crop cutting experiments in general crop estimation surveys. The data should be collected for eye estimate of yield for only the same fields at the time of maximum crop growth stage where satellite data has highest correlation with yield.

### **3. Integrated yield model using spectral data and farmers eye estimate of crop yield**

Most of the crop yield models developed so far could not be adopted in practice either because of delay in the availability of data on different variables to be used in the model or the high cost in collecting the data and in analysing the results.

For any operational yield model to be successful for adoption it is necessary that data should be available much before the harvest of the crop and it should be cost effective. Spectral data in the form of vegetation indices have proved to be very useful variable for explaining variability of the crop yield which can be early available for use in yield forecasting models. In a recent study for 'evaluation of crop cutting methods and farmers reports for estimating crop production' undertaken at Longacre Agricultural Development Centre UK, it has been shown that farmers eye estimates are remarkably close to actual production figures. But, eye estimates being subjective and amenable to several non-sampling errors, it is desirable that these estimates are not used directly for estimation of crop yield. However, this information can be used as auxiliary variable along with the spectral vegetation indices to improve the efficiency of the crop yield models. An earlier such attempt on using eye appraisal of crop yield of a large number of sample fields as auxiliary information had been made by Panse, Rajgopalan and Pillai (1966).

In the present study, therefore suitable models using spectral vegetation indices in the form of NDVI and farmers eye estimate as explanatory variables in the regression model have been developed for improved crop yield forecasting models. For developing the models, wheat crop yield data for Rabi 1995-96 from GCES and also the farmers eye estimate of crop yield for the corresponding plots for district Rohtak and the corresponding satellite spectral data for Feb. 17, 1996 from IRS IB- LISS II in the form of vegetation indices NDVI and RVI

have been used. For testing the model the respective data has been taken for 1997-98. The results show that the predicted yield is very close to the actual yield in almost all the models. However the most efficient model is achieved when the satellite data in the form of NDVI along with the farmers eye estimate of crop yield are used as independent variables. In this case the value of  $R^2$  is 0.90 with a standard error of 1.02 and the predicted value is very close the actual value with a standard error of approximately 5%.

**Table 1** Wheat crop yield forecasting model using RVI ( $x_1$ ), NDVI ( $x_2$ ) and the farmers eye Estimate ( $x_3$  for forecasting crop yield for district Rohtak for Rabi 1997-98 . (Using the model based on data for Rabi 1995-96).

	$R^2$	a	b	Predicted value(Q/hac.) $\hat{y}$	%S.E.	Percentage of Deviation
$y = a + b_1x_1$	0.451596 (3.102028)	3.3445 (0.5724)	4.251948 (1.998869)	35.86 (4.8568)	13.5434	0.1653
$y = a + b_1x_2$	0.543511 (2.830157)	-6.18267 (2.721178)	44.87417 (5.024239)	35.86 (4.7004)	13.1071	0.1652
$y = a + b_1x_3$	0.867496 (1.124314)	2.036448 (1.52888)	0.216212 (0.021125)	34.85 (2.1200)	6.0828	3.0619
$y = a + b_1x_1 + b_2x_2$	0.59259 (2.03613)	-3.798801 (8.212242)	$b_1 = -2.530032$ (5.094414) $b_2 = 55.993241$ (46.451635)	35.22 (5.2418)	14.8829	1.9872
$y = a + b_1x_1 + b_2x_3$	0.90009 (1.00829)	0.785252 (1.479713)	$b_1 = 1.146923$ (0.510314) $b_2 = 0.179795$ (0.024910)	34.86 (1.8352)	5.2647	3.0424
$y = a + b_1x_2 + b_2x_3$	0.90345 (0.99122)	-1.049277 (1.865161)	$b_1 = 11.219523$ (1.679861) $b_2 = 0.175972$ (0.025054)	34.86 (1.8046)	5.1771	3.0430

$y = a + b_1x_1 + b_2x_2 +$	0.90406 (1.02274)	-2.144346 (4.132285)	$b_1 = -0.770271$ (2.572191) $b_2 = 18.257945$ (23.994514) $b_3 = 0.175182$ (0.025984)	34.86 (1.7992)	5.1613	3.0433
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Actual crop yield for Rabi 1997-98 =35.92 (Q/hac)  
(Figures in braces give the corresponding standard error)

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