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RESEARCH PAPER

Weather based pre-harvest forecasting of wheat at Ghazipur (U.P.)

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Abstract : Wheat yield forecasts provide useful information to farmers, distributors, government agencies and other users. In the present study multiple linear regression (MLR) equations were derived for estimating wheat productivity for the district of Ghazipur in eastern Uttar Pradesh. Weather indices were computed using varied weather parameters for the year 1982-83 to 2005-06. The cross-validation of the developed forecast models were tested their accuracy using the year 2006-07. Based on a forecast error percentage it was found that the forecasting model produced the most accurate forecast for 15^{th} week of the crop growing season. The relationship between actual and forecast wheat yield was highly significant being R^2 varied from 0.72 to 0.89 for the different weeks.

Key Words : MLR techniques, Wheat yield, Weather indices

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INTRODUCTION

Agriculture is backbone of Indian economy, contributing about 40 per cent towards the gross national product (GNP) and provide livelihood to about 70 per cent of the population. Its share in country's GDP is about 17 per cent against 2-4 per cent in developed countries. Wheat (*Triticum aestivum* L.) is the most important food crop of the India, which plays a critical role in food security. Varanasi division comprises of four districts *viz.*, Ghazipur, Varanasi, Chandauli and Jaunpur. Ghazipur has second largest total area (173793 ha) followed by Jaunpur and has productivity is about 26.60 (q/ha).

Forecasting opens menu window on to future. It is a medium guiding towards plans for the development of a better future. Crop yield forecasting based on weather, staff scheduling, business production planning and multistage management decision analysis are among distinctive examples of forecasting areas. Reliable pre-harvest forecast of crop yield is likely to provide valuable information in regard to sale, storage, export, industries and government for advanced planning. The use of statistical models in forecasting food production and prices for agriculture and livestock sectors holds great significance. Although no statistical model can help in forecasting the values exactly but by knowing even the approximate values can help in formulating future plans (Garde, 2009). Understanding the impact of climate variability and change on crop yields is fundamental to the success of such research. It is also an essential step towards the development of key adaptive strategies to scope up with climate change.

Similar work have been done by many scientist *viz.*, Agrawal *et al.* (1980) developed forecasting models for the rice yield in Raipur district based on weekly data of weather parameters. It was found that forecasting of rice yield using weather variables is best possible only two and half months after sowing for a crop of five month duration. Jain *et al.* (1980) found that developed pre harvest model was reliable to forecast rice yield only after about two months of sowing. Agrawal *et al.* (2001) developed forecasting model for wheat in Vindhyanchal Plateue zone of Madhya Pradesh. It was reported that reliable forecasting yield could be obtained when

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the crops were 12 weeks old *i.e.* about 2 month before harvest.

Pre harvest forecasting is extremely useful in formulations of policies regarding stock, distributions and supply of agricultural produce to various part of the country. The main objective of the present study was to develop a simple methodology for forecasting the wheat yield before harvesting using weather parameters.

MATERIALS AND METHODS

The study was carried at Ghazipur district of eastern Uttar Pradesh. It is located in the middle Ganga valley of north India, in the eastern part of the state of Uttar Pradesh. It is stretched between 83° 34' East and 25° 35' North. The district has a humid subtropical climate with large variations between summer and winter temperatures. The study utilized secondary yearly yield data of wheat (q/ha) for 25 years (1982-83 to 2006-07) which were collected from different issues of Uttar Pradesh Ke Krishi Aankre published by Directorate of Agricultural Statistics and Crop Insurance, Uttar Pradesh, Krishi Bhavan, Lucknow and weekly weather data for 25 years which were collected from Indian Meteorological Department (IMD), Pune. Seven weather parameters were included in the study; namely maximum temperature (X_1), minimum temperature (X_2), total rainfall (X_3), pan evaporation (X_4), relative humidity at 7.00 hrs (X_5), relative humidity at 14.00 hrs (X_6), and sunshine hrs (X_7). However, weekly weather data related to *Rabi* crop season starting from a fortnight before sowing up to one month before harvest were utilized for the development of statistical models. Therefore, the weather data for wheat crop (*Rabi* season), from October 15 to March 18 in each year were utilized. Data for last one month of the crop season was excluded so as to forecast crop yield at least one month before harvest. The wheat yield distribution over the year is shown in Fig. A.

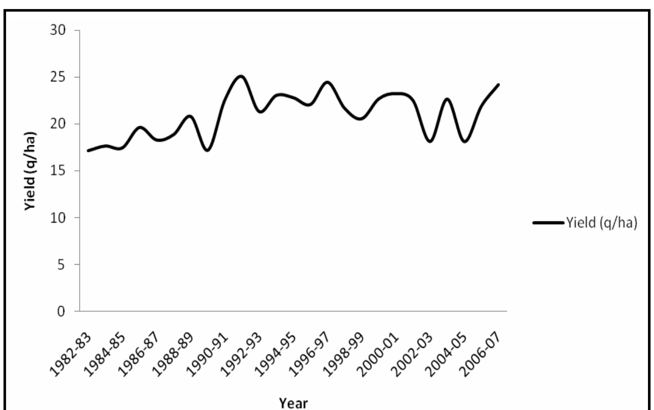

Fig. A : Wheat yield (q/ha) during 1982-83 to 2006-07

Weather indices:

The pre-harvest forecast model was developed by using weather indices as predictors. Weather indices were computed using varied weather parameters for the year 1982-83 to 2005-06. The cross-validation of the developed forecast models were tested their accuracy using the year 2006-07. The weather indices were computed as un-weighted indices and weighted indices, where weight being correlation coefficient between yearly crop yields (de-trended) and weather parameters with respective weeks. The forms of weather indices were given as below:

$$Z_{i,j} = \sum_{w=1}^{m} r_{ij}^{j} X_{iw} \quad \text{and} \quad Z_{i,i',j} = \sum_{w=1}^{m} r_{ii'j}^{j} X_{iw} X_{i'w}$$

where

i, i' = 1, 2, ...p

p = number of weather variables under study

j = 0, 1 (where, '0' represents un-weighed indices and '1' represents weighed indices)

m = week up to forecast (m<n)

w = week number (1, 2, ..., m)

r_{iw} = correlation coefficient between yield (de-trended) and i^{th} weather variable in w^{th} week.

$r_{ii'w}$ = correlation coefficient between yield (de-trended) and the product of i and i'^{th} weather variable in w^{th} week.

Pre-harvest forecast model :

The pre-harvest forecast model were obtained by applying the multiple regression techniques (Stepwise) by taking predictors as appropriate un-weighted indices and weighted weather indices for forecasting wheat yield well in advanced. Thus the model was of the form: (Agrawal *et al.*, 1980, 1986, 2001, Jain *et al.*, 1980; Jha *et al.*, 1981; Agrawal and Jain, 1982; Agarwal and Mehta, 2007).

$$Y = A_0 + \sum_{i=1}^{p} \sum_{j=0}^{1} a_{i,j} Z_{i,j} + \sum_{i \neq i'=1}^{p} \sum_{j=0}^{1} a_{i,i'j} Z_{i,i',j} + cT + e$$

where

Y = District total crop yield (q/ha) adjusted for trend effect

T = Year

A_0, aij, aii'j, c are the constants

e is error term normally distributed with mean zero and variance $\sigma^2_{e.}$

Stepwise regression analysis was used for selecting significant variables. (Draper and Smith, 1981; Gomez and Gomez, 1984)

Simulated pre-harvest forecast models:

The efficiency of the developed forecast models was found by forecast errors percentage for the different weeks (14^{th} to 20^{th} week) of the crop growing season. The expression is given below: (Agrawal *et al.*, 2001).

$$\text{Forecast error (\%)} = \frac{\text{Actual yield} - \text{Forecasted yield}}{\text{Actual yield}} \times 100$$

(Absolute water)

RESULTS AND DISCUSSION

The results obtained from the present investigation have been duscussed below:

Pre-harvest forecast model:

The forecasting models were developed at different periods from the later part of elongation stage to early stage of maturity *i.e.* 14th week onwards at weekly interval up to 20th week of crop growing season. The model was not tried after 20th week of the crop season as the aim of this study was to forecast well in advance of harvest. The coefficient of multiple determination of the models at different weeks of forecast are given in Table 1. The best model was identified on the basis of coefficient of multiple determination, (R^2).

The results revealed that all models were appropriate as the coefficient of multiple determination in the different models under the different weeks ranged between 0.72 to 0.89. Based on the value of coefficient of multiple determination and the earliest appropriate time of forecast (Week 15, 16 and 17), it was found that Model A_2, Model A_3 and Model A_4 were appropriate for forecasting the wheat yield.

Simulated pre-harvest forecast models:

In the present study the data for the year 2006-07 were used for validation of the models. The reliability of the models was checkout by the forecast errors percentage which is shown in Table 2.

The comparison of results given in Table 2 showed that for forecasting the wheat yield, the Model A_2 was better with lower forecast error (%) value of 2.98 as compared to all other models. Further, the Model A_2 was also found better as compared to Model A_3, Model A_4 as it provides pre-harvest forecasting in the 15th week of cropping season of wheat *i.e.* about two and half month before harvesting. Comparison of actual yield and forecast yield for the week no. 15, 16 and 17 is shown in the Fig. 1.

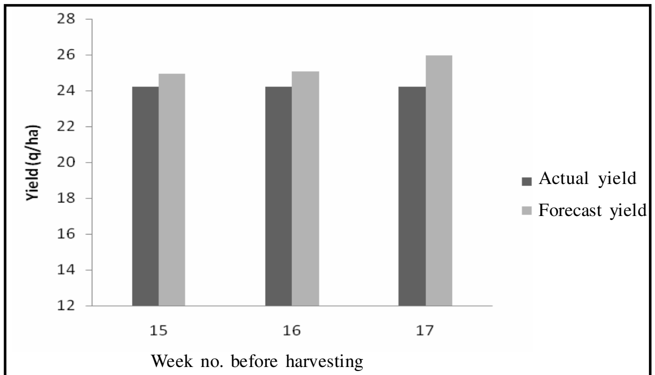

Fig. 1 : Comparison of actual yield and forecast yield

Conclusion:

This study reveals that stepwise multiple linear regression techniques can be successfully used for pre-harvest crop yield forecasting. This model was most consistent and can be apply on zone or state level. The study also shows that use of de-trended yield data in model development gets most appropriate pre-harvest forecast models. It can be concluded from the results that there is a wide scope for using

Table 1 : Wheat yield forecast model equations

Models	Pre-harvest week no.	Model equations	Coefficient of multiple determination (R^2)
A_1	14	$Y=7.436 + 0.291Z_{6,1} + 0.350Z_{3,4,1}$	0.72
A_2	15	$Y=12.944 + 0.161Z_{6,1} + 0.103Z_{2,4,1}+ 0.011Z_{3,7,1}$	0.78
A_3	16	$Y=7.972 + 0.105Z_{6,1} + 0.027Z_{3,4,1}+ 0.080Z_{2,4,1} + 0.005Z_{6,7,1}$	0.88
A_4	17	$Y=7.972 + 0.102Z_{6,1} + 0.028Z_{3,4,1}+ 0.079Z_{2,4,1} + 0.004Z_{6,7,1}$	0.89
A_5	18	$Y=8.645 + 0.100Z_{6,1} + 0.026Z_{3,4,1}+ 0.073Z_{2,4,1} + 0.004Z_{6,7,1}$	0.88
A_6	19	$Y=13.726 + 0.107Z_{6,1} + 0.023Z_{3,4,1}+ 0.073Z_{2,4,1}$	0.82
A_7	20	$Y=8.269 + 0.080Z_{6,1} + 0.019Z_{3,4,1}+ 0.055Z_{2,4,11} + 0.004Z_{6,7,1}$	0.84

Table 2 : Comparison of actual yield and forecast yield

Model No.	Forecasting week no.	Year	Actual yield	Forecast yield	Forecast error (%)
A_1	14			23.26	3.95
A_2	15			24.94	2.98
A_3	16			25.05	3.42
A_4	17	2006-07	24.22	25.95	7.15
A_5	18			25.59	5.65
A_6	19			25.09	3.60
A_7	20			25.27	4.34

alternative approaches to develop predictors that could be used in forecasting models for reliable and dependable forecast. Therefore, it is important to continue research on these aspects for various other crops also on a continuous basis. This methodology can be applicable in many crops *viz.*, rice, pulses, oil seeds, sugarcane etc. to develop pre-harvest forecasting models and these forecasts have significant value in agricultural planning.

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