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PRE-HARVEST FORECAST OF PIGEON-PEA YIELD USING REGRESSION ANALYSIS OF WEATHER VARIABLES

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Abstract

In the present paper, an application of regression analysis of weather variables (minimum & maximum temperature, rainfall, rainy days, relative humidity 7 hr & 14 hr, sun shine hour and wind velocity) for developing suitable statistical models to forecast pigeon-pea yield in Faizabad district of Eastern Uttar Pradesh has been demonstrated. Time series data on pigeon-pea yield for 22 years (1990-91 to 2011-12) have been used in the regression mode. The forecast yield of pigeon-pea have been obtained from this model for the year 2009-10, 2010-11 and 2011-12, which were not included in the development of the model. This model has been found to be most appropriate on the basis of R^2adj, percent deviation of forecast, percent root mean square error (%RMSE) and percent standard error (PSE) for the reliable forecast of pigeon-pea yield about two and half months before the crop harvest.

Key words : Weather variables, pigeon-pea yield, regression analysis, forecast models.

Introduction

Forecast of the crop production at suitable stages of crop period before the harvest are vital for rural economy. On the other hand, forecasts of crop yields are important for advance planning formulation and its implementation Forecasting is also vital for crop procurement, distribution, price structure and import export decisions etc. These are useful to farmers to decide in advance their future prospects and course of action. Thus, reliable and timely pre-harvest forecasting of pigeon-pea yield is very important. To meet such needs, crop yield forecasts under the prevalent system of India are being issued by the Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi. These forecasts are however, of a subjective nature since these are based on the judgment of Agricultural officials The final estimates based on objectives crop-cutting experiments, are of limited utility as those become available quite latter after the crop harvest. The statistical techniques employed for forecasting purposes should be able to provide objective, consistent and comprehensible forecasts of crop yield with reasonable precisions well in advance before the harvest.

Therefore, in view of the above consideration there is a need for developing an objective methodology for pre-harvest forecasting. This involves building up suitable pre-harvest statistical model which has certain merits over the traditional forecasting method. These merits include the objective forecast and its ability to provide a measure of degree of prediction, which a traditional forecast method cannot provide. Another merit of forecast through such techniques is their ability to reflect the impact on the components of yield over time due to changes in crop varieties, cultural practices or crop inputs. For the purpose of developing objective methodology of pre-harvest forecast of the crop yield, methods based on the regression approach have found favour among the researchers. Various organizations in India and abroad are engaged in developing methodology for pre harvest forecast of crop yield. Various approaches have been developed, Prominent among them are the pre-harvest forecasting approaches based on models that utilize data on crop biometrical characters, weather variables, farmers eye estimates, agro-meteorological conditions, remotely sensed crop reflectance observations, input of crop-

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production etc.

Crop yield is mostly affected by technological changes and weather variability. It can be visualised that the technological factors will increase yield smoothly through time and, therefore, year or other parameters of time can be used to exhibit the overall effect of technology on crop yield. The variability both within and between seasons is the second and uncontrollable sources of variability in yields weather variables affect the crop differently during different stages of its growth. Thus, the distribution pattern of weather variables over the crop season is an important aspect to be tackled. Pre-harvest forecast statistical models based on weather variables, input factors and biometrical characters have been developed by various workers for different crops (Fisher, 1924; Hendricks & Scholl, 1943; Agrawal *et al.*, 1980, 83, 86; Agrawal and Jain, 1982; Jain *et al*., 1980, 85) etc.

Materials and Statistical Methodology

Area and crop covered

The study has been conducted for Faizabad district of Eastern Uttar Pradesh, India, which is situated between 26^0 47' N latitude and 82^0 12' E longitudes. It lies in the Eastern plain zone of Uttar Pradesh with an annual rainfall of 1002 mm, 90% of which is received during mid-June to mid-October. Pigeon-pea is the principal pulse crop of the kharif season in Faizabad district.

Data

Time series data of pigeon-pea yield of Faizabad district of Uttar Pradesh for 22 years (1990-91 to 2011-12) have been used for development of the models. These data have been collected from the Bulletins of Directorate of Agricultural Statistics and Crop Insurance, Govt. of Uttar Pradesh. Weekly weather data for the same period on eight weather variables *viz*., minimum temperature, maximum temperature, rainfall, number of rainy days, relative humidity at 7 and 14 hrs, sun-shine hours and wind-velocity have been used in the study. The weekly data on these weather variables have been obtained from the Department of Agro-meteorology, N.D. University of Agriculture & Technology Kumarganj, Faizabad, U. P., India.

Crop season

Preparation for sowing of pigeon-pea starts roughly from the first week of June in Faizabad districts and its harvesting starts from the first week of April. The entire crop season has been divided broadly into four phases. Phase I: pre-sowing, sowing, emergence and initial growth phase that includes the period from 28th may to about 22 July. Phase II: vegetative growth phase that includes the period from about 23rd July to 18th November. Phase III: flowering, reproductive and pod formation phase that includes the period from about 19th November to 25th February. Phase IV: ripening, maturity and harvesting period that start roughly from 26th February to 15th a April. Therefore, the weekly data on weather variables have been collected for 46 weeks of the crop production which included 22nd Standard Meteorological Week (SMW) that starts from 28th May to 52nd SMW of a year and 1st SMW to 15th SMW of the next year which ends by the second week of April.

Statistical Methodology

This model is based on the method given by Agrawal *et al*. (1986) for developing forecast model using weather indices. This is not based on regression function analysis. In this Model, the entire 35 weeks data from 22nd SMW week to 52nd SMW of a year and 1st SMW to 4th SMW of the next year have been utilized for constructing weighted and un-weighted weather indices of weather variables along with their interactions following the formula given in equation. In all, 72 indices (36 weighted and 36 un-weighted) consisting of 8 weighted weather indices and 28 weighted interaction indices; 8 un-weighted and 28 un-weighted interaction indices have been obtained. Considering these 72 indices and trend variable (T) as regressors and yield as dependent variable, forecast model has been developed. The model fitted is

$$y=a_0+\sum_{i=1}^{p}\sum_{j=0}^{1} a_{ij} Z_{ij}+\sum_{i\neq i'-1}^{p}\sum_{j=0}^{l} a_{ii'j} z_{II'J} +_c T+\varepsilon$$

$$\text{Where, } Z_{ij}=\sum_{w=1}^{n} r_{iw}^{j} X_{iw} \Big/ \sum_{w=1}^{n} r_{iw}^{j} \quad j = 0, 1$$

$$Z_{ii'j}=\sum_{w=n_1}^{n_2} r_{ii'w}^{j} X_{iw} X_{i'w} \Big/ \sum_{w=n_1}^{n_2} r_{ii'w}^{j}$$

y is the original crop yield, X_{iw} is the value of the ith weather variable in wth week, $r_{iw}/r_{ii'w}$ is correlation coefficient of yield adjusted for trend effect with ith weather variable/product of ith and i'th weather variable in wth week, n is the number of weeks considered in developing the weather indices and p is number of weather variables used. a_0, a_{ij}, $a_{ii'j}$ and c are the model parameters. ε is error term assumed to follow N (0, σ^2).

The step-wise regression analysis was employed to develop the forecast model.

Comparison and validation of forecast models

Different procedures have been used for the comparison and the validation of the models developed. These procedures are given bellow.

(i) R_{adj}^2: The six models were compared on the basis of adjusted coefficient of determination (R_{adj}^2), which is as follows : $R_{adj}^2 = 1 - \frac{ss_{res}/(n-p)}{ss_t/(n-1)}$

Where, $ss_{res}/(n\text{-}p)$ is the residual mean square and $ss_t/(n\text{-}1)$ is the total mean square.

(ii) The percent deviation of forecast from actual have been computed by the following formula

Percentage deviation =

$$\frac{\text{Actual yield - Forecast yield}}{\text{Actual yield}} \times 100$$

(iii) Root Mean Square Error (RMSE)

It is also a measure for comparing two models. The formula of RMSE is given bellow

$$RMSE = \left[\left\{\frac{1}{n}\sum_{i=1}^{n}(O_i - E_i)^2\right\}\right]^{\frac{1}{2}}$$

O_i and the E_i are the observed and forecasted value of the crop yield, respectively and n is the number of years for which forecasting has been done.

(iv) Percent Standard Error of the forecast

Let, $\hat{y}_f$ be forecast value of crop yield and X_0 be the column vector of values of P independent variables at which y is forecasted. Then, variance of $\hat{y}_f$ is given by (Draper and Smith, 1998)

$$V(\hat{y}_f) = \hat{\sigma}^2 X_0'(X'X)^{-1}X_0$$

Where, $X'X$ is the matrix of the sum of square and cross products of regressors (independent variables) and $\hat{\sigma}^2$ is the estimated residual variance of the model. Therefore, the percent standard error (c.v.) of forecast is given by

$$\text{Percent S.E (C.V.)} = \frac{\sqrt{V(\hat{y}_f)}}{\text{forecast v alue}} \text{ x } 100$$

Results and Discussion

Considering the actual pigeon-pea yield as regressand and 72 weather indices generated and time trend (T) as regressor variables, the model was fitted using step-wise regression (forward) analysis. The results are presented in table 1.

Table 1 : Estimate of regression coefficient of finally entered variables along with their standard error.

S. no.	Variables	Regression coefficient	Standard error
1.	(Constant)	5.321	1.07
2.	Z41	2.658**	0.555
3.	Z371	0.005*	0.002
4.	Z480	0.766*	0.23
5.	Z181	-0.008*	0.003

* $P< 0.05$, ** $P<0.1$

Forecast Model

$Y = 5.321 + 2.658Z_{41} + 0.005Z_{371} + 0.766Z_{480} - 0.008Z_{181}$

Where,

Z_{41} = Weighted average of number of rainy days,

Z_{371} = weighted interaction between rainfall and sunshine hour.

Z_{480} = un-weighted interaction between rainy days and wind-velocity, and

Z_{181} = weighted interaction between minimum temperature and wind-velocity.

These four weather indices have been found significant variables for forecasting the pre-harvest pigeon-pea yield at 4^{th} SMW of crop-production at reproductive/pod Phase.

The model is validated by forecasting the pigeon-pea yield for the years 2009-10, 2010-11 and 2011-12. The results of validation are given in table 2. The values of per cent deviation of forecast yield from actual yield, % RMSE and %SE were also computed and are presented in the table 2.

It can be observed from the results of the tables 1 and 2 that finally entered regressor variables were significant. The value of adjusted R^2 is also quite high to

Table 2 : Validation of the Model.

Year	Actual yield	Forecast yield	% Deviation	RMSE	%SE	R^2 (%)	Adj. R^2(%)
2009-10	10.53	9.05	14.01	1.820	5.963	89.2	86.1
2010-11	16.26	13.66	15.99		5.355		
2011-12	11.53	10.53	8.68		4.147		

the extent of 86%. The per cent deviation, %SE and RMSE are also quite low indicating thereby that the model is best fitted and it has high power to pre-harvest forecast pigeon-pea yield at reproductive/pod, about two and half months before the harvest.

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