



## Development of forecasting model on weather parameters for eastern U.P.

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**Abstract:** The present study has been carried out for the development of pre-harvest forecast model of rice at district level on the basis of weather variables. Weekly data of 14 meteorological weeks on seven weather variables under rice crop season over a span of 21 years period (1989-90 to 2009-10) have been used along with the annual rice production data for Faizabad district of eastern Uttar Pradesh. Generated weather variable (56 weighted, unweighted and joint +1 Time trend) has used under the stepwise regression to screen out the important weather variables and multiple regression approach was subsequently employed to estimate model parameters.  $Q_{140}$  (unweighted interaction between maximum temperature and rainfall and  $Q_{451}$  (Weighted interaction between rainfall and Wind velocity) and time trend comes out to be most significant weather variables for forecasting of rice yield. The proposed model contains combination of weighted and unweighted weather variables and explains 76% (significant at 1% level of significance) of the variability of rice production in terms of  $R^2$ . The model has been developed for 19 years data and validated for 2 years data. Predicted yield for the 2009 is 23.765 and 2010 is 24.31 with deviation 0.021% and -5.69 % respectively, RMSE (1.498) for the model is also calculated for the validation.

**Key words:** Generated weather variables, RMSE, Stepwise regression, Time trend

### Introduction

Rice (*Oryza sativa*), one of the three most important food grain crops in world, forms the staple diet of 2.7 billion people. The effect of weather parameters at different stages of growth of crop may help in understanding their response in term of final yield and also provide a forecast of crop yields in advance before the harvest. Changes in the timing of phenological events are among the most important indicators of global warming (Parmesan and Yohe, 2003; Root *et al.*, 2003). The extent of weather influence on crop yields depends not only on magnitude of weather parameters but also on their frequency distribution. Menzel and Fabian (1999) reported on phenological change due to increasing of temperature. The alternation in global warming has dramatically affected agriculture and its productivity. The increase in temperature has significantly led to change in the agricultural zones and shift in the growing season. Fisher (1936) has been used by biologists to solve the classificatory problems involving multiple measures in different contexts. Models based on weather parameters can provide reliable forecast of crop yield in advance of harvest (Agrawal and Mehta, 2007). The forecasting equations have also been developed for forecasting paddy yield (Shankar and Gupta, 1987), for estimation of sugarcane yield (Singh and Bapat, 1988) and for wheat yield for Kanpur district U.P. (Agarwal *et al.*, 2012). The model on the basis of weather variable has been done by (Hendricks and Scholl, 1943; Jain *et al.*, 1980).

A lot of works have been done for the development of the model with the weather variables but no work has been done in this direction for the eastern Uttar Pradesh for rice crop. In the present study, an attempt has been made to develop suitable statistical models for forecasting of pre-harvest rice yield in faizabad district from the weekly data on weather variables with a few modifications. The estimated yield of the crop can be useful for the planning, pricing, storage, marketing and other policy making as well in two and half months.

### Material and Methods

The study has been conducted for Faizabad district of Eastern Uttar Pradesh, which is situated between 26° 47' N latitude and 82° 12' E longitudes. It lies in the Eastern Plain Zone (EPZ) of Uttar Pradesh. It has an annual rainfall of about 1002 mm. The time series data pertaining for rice crop of Faizabad district of Uttar Pradesh for 21 years (1989-90 to 2009-10) have been procured from Directorate of Agricultural Statistics and Crop Insurance, Govt. of Uttar Pradesh, U.P. Weekly weather data (1989-90 to 2009-10) on respective years on the weather variables of Faizabad district of rice crop have been obtained from the Department of Agrometeorology, N.D. University of Agriculture & Technology Kumarganj, Faizabad. The data have been collected up to the first 19 weeks of the crop cultivation which includes 23rd standard meteorological week (SMW) to 42nd SMW. The data on seven weather variables viz. maximum temperature (maxt) in

(°C), minimum temperature(mint) in (°C), relative humidity(rh) in (%), rainfall(rf) in (mm), wind-velocity(wv) in (km/hr), pan evaporation(evapo) in (mm) and sun-shine(ss) in (hrs) have been used for the study.

**Transformation of weekly weather data into new set of weather variables:** In order to study the effect of individual weather variable, two new variables from each weather variable (consisting of 19 meteorological weeks) have been generated as follows: (Agrawal et al., 1983).

Let  $X_{iw}$  be the value of  $i^{th}$  ( $i = 1, 2, \dots, 7$ ) weather variable at  $w^{th}$  weeks ( $w = 1, 2, \dots, m$ ) in this study  $m$  is 19.

The unweighted generated variables have been generated as follows:  $i=1, 2, \dots, 7$

$$Z_{i(unwt)} = \sum_{w=1}^{19} X_{iw} / 19$$

$i$ - denotes weather variable ( $i=1$  to  $7$ )

$w$ - denotes week number ( $w=1$  to  $19$ ) during the growth of rice crop. The weighted generated variables were computed as follows:

Let  $r_{iw}$  be the simple correlation coefficient between weather variable  $X_{iw}$  at  $w^{th}$  week and crop yield over the period of 21 years. The generated weighted variables have been generated as follows: (Agrawal et al., 1986)

$i=1, 2, \dots, 7$ ;

$$Z_{i(wt)} = \sum_{w=1}^{19} r_{iw} X_{iw} / \sum_{w=1}^{19} r_{iw}$$

Thus we now have a total of 14 weather variables consisting of 7 weighted and 7 unweighted variables.

**Joint effect of weather variables on crop yield:** For studying the joint effect of two weather variables on crop-yield, the model has been extended by including interaction terms in the model as follows:

$$Q_{ii',j} = \sum_{w=1}^n r_{ii',w}^j X_{iw} X_{i'w} / \sum_{w=1}^n r_{ii',w}^j \quad ; j=0, 1$$

Where  $r_{ii'w}$  is the correlation coefficient between crop yield (detrended)  $Y$  and product of weather variables  $X_{iw}$  and  $X_{i'w}$  clearly, we have two generated variables(interaction term)

$$Q_{ii',0} = \sum_{w=1}^n X_{iw} X_{i'w} / n,$$

un weighted one and

$$Q_{ii',1} = \sum_{w=1}^n r_{ii',w}^j X_{iw} X_{i'w} / \sum_{w=1}^n r_{ii',w}$$

Weighted.

Including these two interaction terms in the model given below

$$Y = a + \sum_{i=1}^2 \sum_{j=0}^1 b_{ij} Z_{ij} + \sum_{j=0}^1 b_{ii',j} Q_{ii',j} + cT + \epsilon$$

Where  $b_{ij}$  and  $b_{ii',j}$  are parameters (regression coefficients) of the model, and other terms have already been explained previous. Step wise regression method has been used to fit the model with the data.

**Model fitting:** The model for the fitting of the equation is given below: Model  $Y_i = a + b_1 Z_{1(unwt)} + b_2 Z_{2(wt)} + b_3 Q_{1(unwt)} + b_4 Q_{2(intrwt)} + \epsilon_i$

Where  $Y_i$  is yield,  $a$  is generalized constant  $a_i$ 's ( $i=1$  to  $56$ ) are model parameter associated with un weighted weather variables,  $b_i$ 's are model parameters associated with weighted weather variables and  $\epsilon_i$  is error term supposed to follow normal distribution with mean zero and variance  $\sigma^2$ .

**Percent prediction error (PPE):**

PPE = [(Observed yield - Predicted yield) / Observed yield] x 1000

**Results and Discussion**

$$Y = 23.270 + 0.001 Q_{140} - 0.015 Q_{451} + 0.075T$$

Where:  $Q_{140}$  = unweighted interaction between maximum temperature and rainfall;  $Q_{451}$  = Weighted interaction between rainfall and Wind velocity;  $T$  = Time trend (1, 2, ..., 19)

These above two weather indices and time trend have been found most significant variables for forecasting the pre-harvest rice yield at 36th SMW of crop- Production (Ear initiation stage during lay vegetative phase of grand growth phase). In all 3 regressor variables were entered in the model finally, both were interaction variables and. One can see from results of the table 1 that all entered variables have been found to be significant either at 1% or 5% probability level of significance. The coefficient of

**Table-1:** Summary statistics for step wise regression using weighted and unweighted weather variables

Variable	Regression coefficient	Standardized	P value	Adj. R <sup>2</sup>	95% confidence interval	
	(standard error)	Regression coefficient			Lower	Upper
Constant	23.270 (0.688)			76.2*	21.718	24.505
Q140	0.001* (0.001)	0.306	0.027		0.001	0.002
Q451	-0.015** (0.002)	-0.924	0.001		-0.018	-0.010
T	0.075* (0.033)	0.270	0.039		0.001	0.120

\*\*P<0.01, \* P< 0.05, +P<0.1

**Table-2:** Validation of the model

Year	Actual yield	Predicted yield	R2 (Adj)	Percent deviation	RMSE
2008-09	23.77	23.77	76**	0.02	1.498
2009-10	23.01	24.31		-5.69	

\*\*P<0.01, \* P< 0.05, +P<0.1

determination adjusted ( $R^2$ ) has been found to be 76.2 which are significant at 1% level. Our results are in line with Lal *et al.* (1999) also observed that maximum temperature, minimum temperature and moisture stress were crucial weather variables affecting soybean yield. According to Parthasarathy *et al.* (1988), rainfall was significantly correlated with annual food grain production. Likewise, yield of groundnut was significantly correlated with growing season rainfall in southern India (Godgilet *et al.*, 2002) and temperature, rainfall and relative humidity were found significantly correlated with sugarcane yield. (Srivastava *et al.*, 2007). Almost similar results, as observed in this study, have been reported by Kandiannan *et al.* (2002) for Coimbatore in Tamil Nadu, where temperature, rainfall and radiation entered significantly in a stepwise prediction equation of rice yield. In Andhra Pradesh also, rainfall and temperature have been reported to affect rice yield significantly (Barnwal and Kotani, 2010). Substituting the value of 1 in equation, the discriminant scores are obtained, through the discriminant function analysis (Raman *et al.*, 2012). Model for crop yield forecasting of paddy, sugarcane and wheat through linear regression technique for south Gujarat has been proposed by Kumar *et al.* (2014). Weather variable based rice yield forecasting models for faizabad district of Uttar Pradesh proposed by Pandey *et al.* (2014). The proposed model explains well the relationship between weather variables and rice yield. To validate this model, the prediction errors/residuals were computed as difference between predicted and observed yield. Thus the proposed Model has been thoroughly validated using RMSE and Percent deviation thus it can be used for forecasting purposes.

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