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ORIGINAL ARTICLE

Pre -Harvest Forecast Models Based On Weather Variable And Weather Indices For Eastern U.P.

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ABSTRACT
In the present study, attempts have been made to develop models for forecasting rice yield at district level on the basis of weather variables. Weekly data (of 19 meteorological weeks) on seven weather variables over a span of 21 years period (1989-90 to 2009-10) has been used along with the annual rice production data for Faizabad district (eastern UP). Stepwise regression was used to screen out the important weather variables and multiple regression approach was subsequently employed to estimate model parameters. The model –I was evolved as best for yield forecasting out of five model evaluated, R^2 and RMSE of this model comes out to be 71.2%, 0.733 respectively followed by model V with R^2 and RMSE 51.25% 1.2524 respectively.
***Key words**: R^2, Rice crop, RMSE, Step wise regression, Weather indices, Weather variables.*

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INTRODUCTION

Rice (*Oryza sativa*), one of the three most important food grain crops in world, forms the staple diet of 2.7 billon people. Rice is intimately involved in culture as well as the food ways and economy of Indians. In the past four decades, our country has made a spectacular progress in rice production and productivity. The impressive growth is mainly owing to wide adoption of high yielding, semi-dwarf varieties, and increased use of chemical fertilizers and improved package of cultural practices. With growing economic prosperity and urbanization, per capita rice consumption has started declining.
Climate directly influences the physiological process that affects the rice plants growth, development and grain formation.
Weather parameters like low light, extreme temperature, oscillation in rainfall, cloudiness etc. affected rice yield from establishment to harvest. Crop growth model is an effective tool for evaluating the consequence of different management strategies on its response to the environment leading to better crop production. Pre-harvest forecast of crop yield is very useful for Government and Planners in taking various policy decisions relating to procurement, storage, distribution, marketing, price, export-import, etc. [2]. A scientifically prepared yield prediction equation with weather variables will be very much helpful in assessing the rice productivity. As on date no such published equation could be traced on rice yield forecasting for Faizabad district.
Moreover, rice is the major crop of Uttar Pradesh which covers about 36.5 percent area of total gross-cropped area in eastern Uttar Pradesh. In Faizabad district Rice is generally sown from the second week of June when average daily temperature falls around 41^0C. All these factors depress the crop yield. The different crop growth phases are discussed below. Accordingly, the present study was carried out to develop the best fitting crop yield forecast model based on weather variables, using stepwise regression approach.

MATERIAL AND METHODS

The study has been conducted for Faizabad district of Eastern Uttar Pradesh, which is situated between 26^0 47' N latitude and 82^0 12' E longitudes. It lies in the Eastern Plain Zone (EPZ) of Uttar Pradesh. It has an annual rainfall of about 1002 mm and is liberally sourced by the Sarju (Ghaghra) river and its tributaries. Soils are deep alluvial, medium to medium heavy textured but are easily ploughable.

The secondary time series data of 21 years (1989-90 to 2009-10) on yield for rice crop, fertilizer consumption (NPK in kg/ha) and percent irrigated area under rice of Faizabad district, Uttar Pradesh have been collected from Directorate of Agricultural Statistics and Crop Insurance Government of Uttar Pradesh.

Weekly data of weather variables have been procured from Agro meteorology, N.D. University of Agriculture & Technology Kumarganj, Faizabad pertaining to the period from 1989-90 to 2009-10. The crop cultivation data had been collected up to the first 19 weeks, which includes 23rd standard meteorological week (SMW) to 42th SMW. The data on three weather variables viz. Rainfall, Wind-velocity and Sun-shine hours had been used in the study.

Statistical methodology

Let m denotes the week (w = 1, 2…, m) at which pre-harvest forecast of crop-yield need to be released. Using the weekly data on m weeks of p weather variables (p= 7 here), new weather variables and interaction components have been generated with respect to each weather variable following the procedures laid down. Forecast model has been developed by considering all generated variables simultaneously including time trend (T). The model used is similar to one described in section which can be written as

Individual effect of weather variables

In order to study the effect of individual weather variable, two new variables from each weather variable are generated as follows

Let X_{iw} be the value of ith (i = 1,2,…p) weather variable at wth week(w = 1,2,…..n). In this study n are 19.

Let r_{iw} be the simple correlation coefficient between weather variable X_i at W-th week and detrended crop yield over a period of K years. The generated variables are then given by

$$Z_{ij} = \sum_{w=1}^{n} r_{iw}^{j} x_{iw} \Big/ \sum_{w=1}^{n} r_{iw}^{j} \qquad ; j = 0,1$$

for j = 0 , we have un weighted generated variable

$$Z_{i0} = \sum_{w=1}^{n} X_{iw} \Big/ n$$

and weighted generated variables

$$Z_{i1} = \sum_{w=1}^{n} r_{iw} X_{iw} \Big/ \sum_{w=1}^{n} r_{iw}$$

for each year [1].

The following model is then fitted to study the effect of individual weather variable

$$Y = a_0 + a_1 z_{i0} + a_2 z_{i1} + cT + \varepsilon \qquad ; i = 1,2,.....p$$

Where Y is untrended yield ; T is variable expressing time effect, a_0, a_1, a_2 and c are parameters of the model to be evaluated for the effect of variables and ε is error term supposed to be normal distribution with mean zero and variance σ^2.

Joint effect of weather variables

For studying the joint effect of two weather variables on crop-yield, the model has been extended in sub section by including interaction term as follows

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

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) [1]

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

the un weighted one.
and

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

the weighted one.
Including these two interaction terms in the model, we have a new model to study the effect of joint weather variables as

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

Where b_{ij} and $b_{ii',j}$ are parameters (regression coefficients) of the model, and other terms have already been explained previous model.
In this study, significant generated variables obtained in the model-I were taken to construct two weather indices. In the first one, correlation coefficients were taken as weights and in the second, standardized regression coefficients were used as weight.

Weather Indices

The first weather index using correlation coefficient has been worked as follows:

$$I_1 = \sum_{i=1}^{k} r_{yi} X_i \Big/ \sum_{i=1}^{k} r_{yi}$$

Where r_{yi} is the correlation coefficient between crop yield Y and significant generated variable X_i.
The second weather index using standardized regression coefficient has been worked as follows

$$I_2 = \sum_{i=1}^{k} b_i X_i \Big/ \sum_{i=1}^{k} b_i$$

where b_i's are standardized regression coefficient of the significant generated variable X_i's. Forecast models using weather indices and time trend have been postulated as follows

Model – II : $Y = a + bI_1 + CT + \varepsilon$

Model – III : $Y = a + bI_2 + CT + \varepsilon$

where I_1 and I_2 are the two weather indices.

RESULTS AND DISCUSSION

1. Joint effect of all weather variables

The stepwise regression analysis, considering rice yield as dependent variable and all generated weather variables (in all 56) and time trend as independent variables, has been carried out. The results obtained by analysis are presented in Table 1.

Model-I

$$Y = 17.968 + 0.008Q_{230} + 0.007Q_{560} + 0.039Q_{561} \quad \text{……(1)}$$

Finally only three variables viz. Q230 (unweighted mean interaction between minimum temperature and relative humidity), Q250 (unweighted mean interaction between wind velocity and pan evaporation), Q251 (weighted mean interaction between wind velocity and pan evaporation), have been included by the step wise regression analysis. This shows that beside other factors including individual weather variables, the interaction effect between these variables as mentioned above are relatively more important for rice yield as they together could explained about 71 percent variation in rice yield.
While studying the joint effects of pair of weather variables on the rice yield, it has been observed that the individual effect of minimum temperature and relative humidity along with their interaction has also shown significant effect.

2. Pre-harvest Forecast Models based on generated weather indices

First weather index (I_1) was constructed by using significant generated weather variables of the fitted model 2 as the procedure laid down in methodology. A simple multiple linear regression model by taking crop yields as regressand, I_1 and time trend T as regressor was fitted. The fitted model is

Model- II

$$Y = 20.5043 - 0.000044_{I_1} + 0.0817T \quad \text{………..(2)}$$

The weather index (I_1) was found to be significant at 1% level and time trend (T) at 10% level. The coefficient of determination R^2 was found to be 46.25 percent which is significant at 1% level. The result is given in Table 2.

The result of Table 3 indicates that the deviation in yield was found to be 2.650% for the year 2008-09; whereas the deviation in the yield was found to be 2.522% for the year 2009-10. It indicated that predicted yield was found almost same as that of actual yield. The value of R^2 was found 46.25 % which is significant at 1% level of significance.

3. Pre-harvest Forecast Models based on generated weather indices

Second weather index (I_2) was constructed by using significant generated weather variables of the fitted model 3. A simple multiple linear regression model between crop yields and regressor variables I_2 and time trend T was fitted. The fitted model is

Model- III

$$Y = 20.47837 + 0.00008_{I_2} + 0.0819T \qquad \text{……….(3)}$$

The second weather index (I_2) has been found to be significant at 1% level and time trend at 10% level. The coefficient of determination R^2 was found to be 46.53 which was significant at 1% level. The summary of the result is given in Table 4.

The results from Table 5 indicate that the deviation in yield was found 1.9067 % for the year 2008-09; whereas the deviation in the yield was found to be 1.2304% for the year 2009-10. It indicated that predicted yield was found almost same as that of actual yield. The value of R^2 was found 46.53 % which is significant at 1% level of significance. According to [7], rainfall was significantly correlated with annual food grain production. Likewise, yield of groundnut was significantly correlated with growing season rainfall in southern India [4] and temperature, rainfall and relative humidity were found significantly correlated with sugarcane yield according to [9].

Almost similar results, as observed in this study, have been reported by [5] 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 [3].

It is obvious from the results that average of the percent deviation was found to be 0.5. The minimum deviation was -5.69 for 2009-10 for model I and maximum was 2.65 for the year 2008-09 for model II.

According to [8], 89% variation was found due to weather variables and inputs (N+P+K) on 30 year data for Chhattisgarh. Almost similar results, as observed in this study have been reported by [6] Orisa state yield of rice was significantly correlated with rainfall, temperature and fertilizers.

Among the models, the model having highest R^2 and lowest RMSE was selected as best. Table 3 and 5 revels that among the models fitted, the maximum R^2 of 76.2 % and lowest RMSE (0.733) were observed in case of model I which shows comparatively higher and lower, respectively, then that of other models. On the basis of these among the five different models fitted the model I was evolved as a best model.

Table 1. Joint effect of all weather variables

Variable	Regression coefficient (standard error)	Standardized Regression coefficient	P value	Adj. R^2	95% confidence interval	
					Lower	Upper
Constant	17.968(0.497)			71.2	16.919	19.017
Q230	0.008*(0.03)	0.434	0.016		0.002	0.014
Q560	0.007*(0.003)	0.355	0.037		0.0001	0.013
Q561	0.039*(0.012)	0.455	0.004		0.015	0.063

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

Table 2. Pre-harvest Forecast Model based on generated weather index

variable	Regression coefficient (standard error)	P value	Adj. R^2	95% confidence interval	
				Lower	Upper
constant	20.50432(0.5999)	0.00007	46.25*	19.234	21.7647
I_1	0.00004*(0.00013)	0.0046		-0.000073	0.000016
T	0.8173+(.0469)	0.0981		-0.01672	0.180179

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

Table 3. Validation of the model-II

Year	Actual rice yield(Q/ha)	Predicted rice yield(Q/ha)	Adjusted R^2 (%)	Percent deviation	RMSE
2008-09	23.77	21.11944	46.25*	2.650	1.6080
2009-10	23.01	20.48862		2.522	

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

Table 4. Pre-harvest Forecast Model based on generated weather index

variable	Regression coefficient (standard error)	P value	Adj. R^2	95% confidence interval	
				Lower	Upper
constant	20.4783(0.59637)	0.00007	46.53*	19.22545	21.73129
I_2	0.00008*(0.00025)	0.00435		0.00002	0.000134
T	0.819+(.0467)	0.09667		-0.01627	0.18007

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

Table 5. Validation of the model-III

Year	Actual rice yield (q/ha)	Predicted rice yield (q/ha)	Adjusted R^2 (%)	Percent deviation	RMSE
2008-09	23.77	21.8634	46.53*	1.90665	1.3185
2009-10	23.01	21.780		1.23039	

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

Table 6. Estimate of important parameters for the comparison of models.

Model	Adjust R^2 (%)	RMSE
I	76.2	0.733
II	46.25	1.608
III	46.53	1.318

CONCLUSION

The models I, II and III are based on generated weather variables and weather indices. The data on the weekly weather variables starting from 23rdSMW (2nd week of June) to 36thSMW (third week of October) have been utilized to forecast the rice yield before about two months of harvest. Thus, 14 weeks data of weather variables have been used for development of models. Similarly, time series data of rice yield from 1989-90 to 2007-08 have been utilized for development of the model and two years data pertaining to 2008-09 and 2009-10 on rice yield have been used for validation of models. According to R^2 model I is best followed by model III and on the basis of RMSE model I was best followed by model III.

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