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Yield Forecasting Models based on Weather Parameters for Eastern U.P.

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Abstract

In the present study, attempts have been made to development of pre harvest models for pre harvesting forecasting of rice yield at district level on the basis of generated weather variables. Weekly data (14 meteorological weeks) because Time of the pre harvest forecast is 14th week 2½ month before harvesting flowering stage and seven weather variables over a span of 20 years period (1995 to 2014) has been used along with the annual rice production data for respective year for eastern UP. The data of de-trend yield and generated weather variables for 18 years of has been used for generation of the models. (1995-2012). Total five models were validated with 2 year independent data set (2013 and 2014). The (PPE) ranging - 4.32 to 10.56 % from the observed yield for all 5 models. Highest correlation has been found 0.68 between Z_{231} (Weighted interaction between MaxT and MinT). Significance of models are obtained by on the basis of highest R^2 (86%) and by (P-value) (0.08). MBE (Mean Biased Error), RMSE (Root Mean Square Error) and PE (Percent Error) has been used for the Error analysis. On the basis of R2 and other parameter the model IV has been found best.

Keywords

Correlation coefficient; MBE; PE; Rice; RMSE

Introduction

Rice (*Oryza sativa*), one of the three most important food grain crops in world, forms the staple diet of 2.7 billon 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 reported, phonological change due to increasing of temperature. The forecasting equations have also been developed for forecasting paddy yield Shankar and Gupta [1] and for wheat yield for Kanpur district U.P. Agarwal et al. [2].

The majority of the agriculture land is used to grow major cereal crops; rice and wheat. Rice is the major crop in Uttar Pradesh and is grown in about 5.90 Mha which comprises of 13.5% of total rice in India. Uttar Pradesh has favourable and suitable climate, vast areas of fertile soils, sunshine and adequate water resources. The cropping intensity is 153% of the Uttar Pradesh. Uttar Pradesh ranks 3rd in the country in production of rice [3].

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Agriculture is the main source of income for families in the Uttar Pradesh and India as well. It has 11.56 million hectare of cultivated area, constituting 70% of the total geographical area. The irrigated area is over 13.43 million hectare. The small and marginal farmers jointly contribute 19.46% of farming household in eastern region against that of 19.11% of Uttar Pradesh. Agriculture is the most important in the India because about 65% of its population resides in rural areas and 70% of the total workers are involved directly or indirectly in cultivation/farming which accounts for 27% of Uttar Pradesh GDP.

Agriculture is an economic sector which depends highly on climatic conditions. Crop models are frequently used to evaluate the ability of climate forecasts in guiding crop management practices. In statistical model approach, one or several variables (representing weather) are related to crop responses such as yield and yield contributing characters. Crop yield is the integrated effect of a number of physical and physiological processes that occur during the crop-growing period. These processes are influenced by the characteristics of the crop, weather, soil and time management factors [4]. Statistical models provide simple alternative to process- based models. The main advantages of statistical models are their limited reliance on field calibration data and their transparent assessment of model uncertainties [5]. Rice is cultivated during Kharif season (June to October- November) at the area of eastern Uttar Pradesh.

In the present study, an attempt has been made to develop suitable statistical models for forecasting of pre-harvest crop yield in faizabad district from the weekly data on weather variables with a few modifications.

Materials and Methods

Weekly weather data of crop growing season for 20 years (1995-2014) of Faizabad districts (26^0 47' N latitude and 82^0 12'E longitudes and 113 m above mean sea level) has been collected from the Meteorological Station of department of Agro-meteorology N. D. University of Agriculture & Technology, Faizabad Uttar Pradesh, India and 14 week data has been used for pre harvest forecast modelling under the present study. The data on 14 weeks are used because that is flowering stage of the rice crop. The yield data of the rice crop for Faizabad district of Uttar Pradesh for 20 years (1995-2014) have been obtained from Directorate of Agricultural Statistics and Crop Insurance, Government of Uttar Pradesh, U.P. Weekly-data of give weather variables rainfall (mm), maximum temperature (maxT)°C, minimum temperature (minT)°C, morning relative humidity (RH-I) %, afternoon relative humidity (RH-II) % has employed according to growing period of crop. Correlations were worked out between weather parameters (independent variable) with respective year and yield of crop. The yield data was de-trended.

De-trend Yield

$$Y = a + bt$$

Where; Y, a, b and t is observed yield, constant, regression coefficient and time trend respectively. Transformation of weekly weather data into new set. Two new variables from each weather variables (consisting of 14 meteorological weeks) have been generated as follows:

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Let X_{iw} be the value of i^{th} (i = 1, 2,…,5) weather variable at w^{th} weeks (w = 1,2,…..m) in this study m is 14.

The unweighted generated variables have been generated as follows:

$$Z_{i(unwt)} = \sum_{w=1}^{14} X_{iw} \Big/ 14$$

i- denotes weather variable (i=1 to 5)

w- denotes week number (w= 1 to 14) 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 18 years used as a weight. The weighted variables have been generated as follows [6]:

$$Z_{i(w)} = \sum_{w=1}^{14} r_{iw} X_{iw} \Big/ \sum_{w=1}^{14} r_{iw}$$

Thus we now have a total of 10 weather variables consisting of 5 weighted and 5 unweighted variables. The following models are then fitted to study the effect of weather variables:

Effect introduction of weather variables on crop yield

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

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

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

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

the unweighted one.

and

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

the weighted one.

Model fitting

Five models were attempted, one for the set of unweighted generated variables, second for the set of weighted generated weather variables, third for the unweighted + weighted generated variables taken all the 10 variables together simultaneously, fourth for the unweighted interaction weather variables and fifth for the weighted interaction weather variables; used as independent variable and yield as dependent.

Model-I	$Y_i = a + b_i Z_i(\text{unwt}) + \varepsilon_i$	Model-II	$Y_i = a + b_i Z_i(\text{wt}) + \varepsilon_i$
Model-III	$Y_i = a + b_i Z_i(\text{inter unwt}) + \varepsilon_i$	Model-IV	$Y_i = a + b_i Z_i(\text{inter wt}) + \varepsilon_i$
Model-V	$Y_i = a + b_i Z_i(\text{unwt}) + b_i Z_i(\text{wt}) + \varepsilon_i$		i=1,2,……,5

Where Y_i is yield, a is generalized constant a_i's (i=1 to 5) are model parameter associated with unweighted weather variables, b_i's are model parameters associated with weighted weather variables and ε_i is error term supposed to follow normal distribution with mean zero and variance σ^2.

Statistical Analysis of Data

The statistical analysis of data was performed using SPSS-20 and MS Excel used for estimating the model parameters using multiple regression procedures. The validation of the model was also performed using by the Percent Prediction Error (PPE), Mean Bias Error (MBE) and Root Mean Square Error (RMSE) [7].

Percent prediction error (PPE)

$$PPE = \frac{(O - F)}{O} * 100$$

Mean bias error (MBE)

$$\text{MBE} = \sum_{i=1}^{n} [F_i - O_i] / n$$

Root mean square error (RMSE)

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

Result and Discussion

Positive correlation 0.68 found between yield and interaction of Maximum & Minimum Temperature and same result found in yield and weighted Rainfall, minimum and negative correlation -0.47 found between yield & un weighted Minimum Temperature, followed by yield and interaction un weighted Minimum Temperature & Morning Relative humidity (-0.40) (Table 1). Highest R^2 has been found in model IV followed by model III i.e. 86 % and 81 % respectively (Table 2). Model IV found most significant 0.08 followed by model I. Singh et al. [8] reported for similar results on the basis of temperature and rainfall on wheat yield at south western region of Punjab

The observed and forecasted yields for period (2013-2014) have been presented in Table 3 and various error analysis of independent and all data set in Table 4. The regressions models were validated with the two years (2013-2014) of independent data set. The data exposed that the models deviated (PPE) -4.32 to 10.56 % from the observed yield; the error analysis revealed that the MBE, RMSE and PE of models are ranging between -22.81 kg ha^{-1} to – 6.56 kg ha^{-1}, RMSE 175.84 to 205.25 kg ha^{-1}, and 6.81 % to 7.97 % respectively for all data set and 59.07 to 205.32 kg ha^{-1}, 65.57 to 205.40 kg ha^{-1} and 0.49% to 7.40% respectively for independent data set. Similar results have also been reported by Kumar et al. [9] for the rice wheat and sugarcane under the Navsari and Bharuch districts. Pandey et al. [10] also

Table 1: Correlation between generated weather variables and yield.

S. No	Variables	Correlation Coefficient	S. No	Variables	Correlation Coefficient
1	Z_{10}	0.52	16	Z_{240}	-0.25
2	Z_{20}	-0.20	17	Z_{250}	-0.15
3	Z_{30}	-0.46	18	Z_{340}	-0.40
4	Z_{40}	-0.21	19	Z_{350}	-0.25
5	Z_{50}	-0.13	20	Z_{450}	-0.16
6	Z_{11}	0.68	21	Z_{121}	0.63
7	Z_{21}	0.54	22	Z_{131}	0.52
8	Z_{31}	0.67	23	Z_{141}	0.60
9	Z_{41}	0.48	24	Z_{151}	0.67
10	Z_{51}	0.34	25	Z_{231}	0.68
11	Z_{120}	0.44	26	Z_{241}	0.53
12	Z_{130}	0.20	27	Z_{251}	0.34
13	Z_{140}	0.42	28	Z_{341}	0.64
14	Z_{150}	0.53	29	Z_{351}	0.46
15	Z_{230}	-0.37	30	Z_{451}	0.35

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Table 2: Statistical models for rice yield forecast at Faizabad district.

Model	Equation	R^2	Significance of the model
I (unwted)	$Y=3998.66+1.43Z_{10}+1.19Z_{20}-3.31Z_{30}-1.15Z_{40}-0.39Z_{50}$ (0.86) (2.41) (4.23) (0.80) (0.32)	0.64	0.15
II (wted)	$Y=2523.77+7.60Z_{11}-3.98Z_{21}-0.98Z_{31}-1.29Z_{41}-0.79Z_{51}$ (8.32) (17.31) (32.25) (7.07) (2.03)	0.41	0.71
III (inter unwted)	$Y=3348.66+0.01Z_{120}+0.57Z_{130}-0.24Z_{140}+0.31Z_{150}-0.17Z_{230}$ (1.17) (1.86) (0.31) (0.43) (1.22) $+0.01Z_{240}+0.04Z_{250}+0.01Z_{340}+0.13Z_{350}-0.03Z_{450}$ (0.12) (0.17) (0.34) (0.35) (0.05)	0.81	0.21
IV (interunwted)	$Y=2196.57-2.17Z_{121}+0.92Z_{131}-0.44Z_{141}+1.79Z_{151}-$ (1.17) (1.86) (0.31) (0.43) $1.23Z_{231}+0.04Z_{241}-0.19Z_{251}-0.30Z_{341}-0.56Z_{351}+0.13Z_{451}$ (1.22) (0.12) (0.17) (0.34) (0.35) (0.05)	0.86	0.08
V (unwted+wted)	$Y=1924.75+3.75Z_{10}-2.80Z_{11}+3.81Z_{20}-16.35Z_{21}-11.37Z_{30}$ (2.45) (12.42) (3.48) (17.97) (8.49) $-37.01Z_{31}-0.72Z_{40}+7.81Z_{41}+0.88Z_{50}+3.96Z_{51}$ (37.82) (1.05) (8.65) (0.76) (4.29)	0.73	0.47

*values in the parenthesis are Standard error of the generated variables.

Table 3: Validation of models.

Model	Years	Observed	Forecast	PPE
I (unwted)	2013	2976	2982.04	-0.20
	2014	2896	2605.68	10.02
II (wted)	2013	2976	2991.39	-0.52
	2014	2896	2590.31	10.56
III (inter unwted)	2013	2976	3104.53	-4.32
	2014	2896	2750.86	5.01
IV (inter wted)	2013	2976	3025.09	-1.65
	2014	2896	2654.89	8.33
IV (unwted+wted)	2013	2976	2893.28	2.78
	2014	2896	2630.57	9.17

Table 4: Error analysis of forecasting models.

Error analysis	Model					
	MBE (kg ha^{-1})		**RMSE (kg ha^{-1})**		**PE (%)**	
	All data set	**Independent data set**	**All data set**	**Independent data set**	**All data set**	**Independent data set**
I (unwted)	-19.05	171.45	198.67	180.01	7.65	6.51
II (wted)	-22.81	205.32	201.47	205.40	7.75	0.49
III (interunwted)	-6.56	59.07	175.84	65.57	6.81	6.11
IV (interwted)	-13.92	125.26	206.44	126.32	7.97	4.49
V (unwted+wted)	-17.84	160.58	205.25	214.56	7.91	7.40

reported the pre harvest forecast models for the rice crop for faizabad district of eastern U.P.

The study is based on the generated weather variables on the collected weather data (raw data) [11]. This is very important not only for the understanding the individual effect of weather variables, joint effect of weather variables and interaction effect of the two variables but also very useful for students to learn about forecast model [12], Pre harvest forecast models for the rice and other crops as well. The work is also very important for researchers, for planners to prepare a plan on two and half months before harvesting of crop yield [13]. The work has importance on pricing and policy making, specially have the importance for implementation of agricultural development at village, block, District, State and country level as well.

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