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Impact of weather parameters on rice yield in Karnal district

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Abstract
The analysis was conducted for Haryana district of Karnal for a period of 35 years (1980-81 to 2015-16), based on historical data. Rice yield data were taken from Haryana's Statistical Abstract and corresponding daily weather data from the Central Soil Salinity Research Institute (CSSRI), Karnal were collected. With yield as dependent variable and weather indices (artificial variables created from weekly & fortnightly weather values) both individually and in combinations, were used as predictor variables in stepwise multiple regression technique. The data for the period 1981-82 to 2012-13 were used for model development, and the remaining three years of data, i.e. from 2013-14 to 2015-16, were used for validation. Depending on the Root Mean Square Error (RMSE) and the adjusted R^2, the model is chosen among all models based on the number of rainy days (24 weeks) relying on individual weather variables. The model based on the cumulative effects of maximum temperature and relative humidity morning (22 weeks) predicted rice yields that were very similar to real yields as a per-cent relative deviation from 1.15% to 7.6%.

Keywords: coefficient of determination, forecasting, rice, root mean square error, standard error.

Introduction
Rice (*Oryza sativa* L.) is one of the three most important food grain crops in the world. In India, the total area under rice crop was 44.11 million hectare and production 105.48 million tons in 2014-15. This is also one of the most important crops grown in the state of Haryana. The area under rice cultivation has multiplied since 1980 and in 2015-16 was registered at 1.35 million hectares. In the same year the production and productivity were 4.14 million tonnes and 3061 kg per hectare (Economic Survey of Haryana 2016-17) respectively.
There is significant role of weather parameters in deciding growth and development of the crop, so it can be considered as an indicator in crop yield modelling. It is commonly recognized that the major determinants of crop yield are meteorological parameters such as temperature (maximum & minimum), bright sun shine hours, relative humidity (evening), rainfall, amount of rainy / wet days, etc. The different weather parameters have differential effects on crop yield in different, time periods. Growth indices are the weighted accumulations of various weather parameters in different cycles with weights being their respective yield correlation coefficients. Such indices of growth can be used as determinants of crop yields.
Kandiannan *et al.* (2002) [12] developed a yield forecasting model developed and implemented jointly by handling 20-year data set on dry turmeric yield and monthly climatic variables of nine months raising crop season. Aneja and Rai (2013) [4] developed a statistical model for pre-harvest estimation of cotton yield on the basis of growth indices of plant biometrical characters. Pandey *et al.* (2017) [18] observed the individual response of minimum temperature on wheat yield of Faizabad in Uttar Pradesh. It was found that first week of crop period has been found as most important week i.e. 61% followed by 60% in terms of coefficient of determination (R2).

Methodology
The analysis was focused upon secondary rice crop data. Rice yield data from Karnal district were collected from Statistical Abstracts of Haryana released by the Department of Economic and Statistical Analysis (DESA) for a period of 35 years from 1980-81 until 2015-16. The weekly weather data for the same period were also obtained from Central Soil Salinity Research Institute (CSSRI), Karnal. The daily weather data covering the full crop season around fortnight before sowing and harvesting (April 30 to October 14) was used to research the impact on yield of weather variables. Such daily forecast data have been translated into data on weekdays and fortnightly. The weather parameters considered under the study were;

morning relative humidity (%), evening relative humidity (%), total rainfall(mm), number of rainy days, maximum temperature (°C), minimum temperature (°C) and bright sunshine hours.
The most important variable(s) were discovered using the stepwise regression technique. The multiple regression models were used based on yield as response variable, and variables were developed as regressors for yield prediction. Generated variables were obtained as weighted accumulations of weather variables with weights as coefficient of correlation between weather indices and yield.
The following approaches were made to study the effect of different weather variable on the yield of rice:

Impact of individual weather indices
Yield was defined as a quadratic function of the respective correlation coefficient of weather variables with trend-adjusted yield to test the influence of the individual weather indices on yield in different weeks. The model used can be represented as:

$$Y=a+b_0\sum_{w=1}^{n}X_w+b_1\sum_{w=1}^{n}r_{xy(w)}X_w+b_2\sum_{w=1}^{n}r_{xy(w)}^2X_w+cT+e \quad (1)$$

or

$$Y=a + b0Z0 + b1Z1 + b2Z2+ cT + e$$

Where Z's are generated variables defined as:

$$Z_j=\sum_{w=1}^{n}r_{xy(w)}^2X_w \qquad j = 0, 1, 2$$

Y = Rice yield (kg/ha),
a, bj (j= 0,1,2) and c are constants,
n = total number of weeks up to harvest, w = Identification number of the week, Xw = value of weather variable under study in wth week (w = 1, 2… n), rxy(w) = Coefficient of correlation between yield (Y) and variable weather (X) within wth week, and T = the year number, representing trend.

Conjoint effect of two weather indices
In order to research the combined effects of weather variables on rice yield, the model used to research effects of individual weather variables has been expanded by adding words for interaction. The layout changed to take variable' p' is:

$$Y=a_0+\sum_{i=1}^{p}\sum_{j=0}^{1}a_{ij}Z_{ij}+\sum_{i\neq i'=1}^{2}\sum_{j=0}^{1}a_{ii'j}Z_{ii'j}+cT+e \quad (2)$$

p = number of weather variables used, riw/rii′ w for the correlation coefficients of the yield and the ith weather variable (Xi)/ the product of the two weather variables (Xi and Xi′) in wth week.(Here i = 1, 2,…7 corresponding to maximum & minimum temperature, relative humidity morning and evening, bright sunshine hours, rainfall and rainy days respectively. 'n' for the number of weeks up to harvest. Stepwise regression (Draper and Smith 1981) [8] was used to select the significant generated variables.

Comparison and evaluation methods for the different models
Distinct statistics used to compare and validate the Models generated. They are laid out as follows:

Coefficient of Determination (R2) and Adjusted R2
In general, it is used to evaluate the competency of the model. R2 is derived using the following formula

$$R^2=1-\frac{SS_{res}}{SS_t}$$

Where
SSt and SSres are the total sum of squares and the residual sum of squares respectively.

$$R_{adj}^2=1-\frac{SS_{res}/(n-p)}{SS_t/(n-1)}$$

Where
SSt/(n-1) is the total mean square whereas SSres/(n-p) is the residual mean square.

Relative Deviation Percent (RD %)
This measures the forecasted deviation (in percentage) from the actual yield results. The formula for calculating the prediction percent deviation is given below:

RD (%) = {(Actual yield – Forecasted yield)/ Actual yield} *100

Root Mean Square Error (RMSE)
It was used as a measure for comparison between two models and the RMSE formula is described as:

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

Where
Oi and Ei are the actual and predicted rice yield and n' is the number of years that forecasts were made for.

Crop yield prediction
The models were selected based on the maximum value adjusted R2. The selected models were then validated for years 2013-14, 2014-15 and 2015-16. The model having lowest per cent relative deviation and root mean square error were selected for forecasting crop yield for next year.

Results and Discussion
To study the effect of trend on time series data of rice yield for Karnal district, the simple linear equation,

$$\hat{Y}=a+bT$$

with response variable (yield) and T, year number as regressor, was fitted to calculate yield adjusted for trend. The fitted regression of yield on time trend (years) is given by,

$$\hat{Y}=2429.78+18.53\,T \qquad (R^2_{adj}=0.27)$$

Multiple regression models were developed by using seven selected meterological variables *viz.* temperature (maximum and minimum) 0C, relative humidity (morning and evening) percent, bright sunshine hours, total rainfall (mm) and rainy days. For each of these models stepwise regression technique has been used with rice yield as response variable and weather parameters as regressors. Perusal of the results show that models using correlations based on yield adjusted for trend effect were better than the ones using simple correlations.
Table 1 gives a glimpse of the contribution of weather variables in various models towards a common goal to predict

yield. In models 1, 3, 5 & 7 the contributing variable in maximum temperature while for models 2 & 4 no. of rainy days contributes more to yield and for models 6 & 8, the variable is relative humidity (evening). The inference drawn from inter-class comparison (model developed using different time spans of crop i.e. 22, 24 weeks and 11, 12 fortnights) is that models based on weekly weather variables performs better than those built over fortnights on the ground of adjusted R2, percent relative deviation & root mean square error. Table 2 gives a glimpse of comparison between joint effects of two weather indices for weekly (using data for 22 & 24 weeks) and fortnightly (using data for11 & 12 fortnights) based prediction models. It can be easily be seen that the joint weather indices models based on weekly data performs better than those based on fortnightly data. The model 9 (i.e. joint model of maximum temperature & relative humidity morning) performing better than all such models on the basis of statistics adjusted R2 and has a comparable RMSE with the model based on joint indices of minimum temperature & bright sunshine hours (model 10) which shows the lowest RMSE among all models. From Table 3, it can be seen that the individual weather variables have not much effect in the last weeks of crop duration as these are not having much differences in adjusted R2 and root mean square error (the two main measures to compare models) while when it comes to joint interaction of weather variables there is considerably difference in results at pre-harvest forecast (22 weeks or 11 fortnights) & at harvest forecasts (24 weeks or 12 fortnights).

Summary and Conclusions

Models based on the linear function of correlation coefficients and the yield adjusted for trend can be used to forecast the crop yield. The models based on maximum temperature (22 & 24 weeks) and no. of rainy days (22 & 24 weeks) are comparable with each other on the basis of adjusted R2, therefore on the basis of root mean square error the model based on no. of rainy days (24 weeks) having lowest RMSE (=219.14) is chosen among all models based on individual weather variables. The actual forecasts using model based on no. of rainy days (24 weeks) for 2013-14 to 2015-16 years were 3207.11 kg/ha, 3318.09 kg/ha and 3322.61 kg/ha, respectively.

The joint effect of weather variables (taken two at a time) on crop yield were studied. The perusal of the results shows that highest value of adjusted R2= 0.68 and with lowest root mean square error (RMSE= 184.71) was obtained when weather indices based on maximum temperature and relative humidity (morning) taken together for 22 weeks. Hence the model has been used for rice yield forecasting for the years 2013-14 to 2015-16. The model based on joint effect of maximum temperature and relative humidity morning (22 weeks) forecasts rice yield which were very close to the actual yields (per cent relative deviation ranging from 1.1 % to 7.6 %. The actual forecasts using maximum temperature and relative humidity morning for 2013-14 to 2015-16 years were, 3244 kg/ha, 3168.03 kg/ha and 3215.34 kg/ha, respectively.

Table 1: Models based on individual weekly and fortnightly weather indices

Period	Model		Contributing variable	Adjusted R^2	Relative Deviation (%)			RMSE
					2013-14	2014-15	2015-16	
22 weeks	Model 1	$\hat{Y} = 4626.22 + 55.36Z_1 + 21.17T$	Tmax	0.56	11.93	3.91	-2.03	255.66
	Model 2	$\hat{Y} = 2354.69 + 115.46Z_1 + 6.28Z_0 + 29.19T$	RDA	0.56	8.81	-2.66	-8.3	228.31
24 weeks	Model 3	$\hat{Y} = 4757.84 + 55.18Z_1 + 21.37T$	Tmax	0.56	10.62	2.27	-3.49	228.31
	Model 4	$\hat{Y} = 2330.00 + 6.75Z_0 + 117.39Z_1 + 29.60T$	RDA	0.58	6.81	-1.15	-9.52	219.14
11 fortnights	Model 5	$\hat{Y} = 4579.10 + 94.25Z_1 + 20.23T$	Tmax	0.50	11.29	4.81	-1.8	248.25
	Model 6	$\hat{Y} = 3707.45 + 22.96Z_1 + 21.61T$	Rhe	0.50	9.7	2.87	-3.95	215.76
12 fortnights	Model 7	$\hat{Y} = 4686.85 + 93.93Z_1 + 20.28T$	Tmax	0.50	12.88	3.47	-0.31	269.5
	Model 8	$\hat{Y}= 3681.03 + 23.09Z_1 + 21.67T$	Rhe	0.51	10.48	1.02	-3.09	220.54

Note: Tmax = Maximum Temperature, Tmin = Minimum Temperature, RHm = Relative Humidity (morning), RHe = Relative Humidity (evening), RF = Rainfall, RDA No. of Rainy days, SSH = Bright Sunshine Hours

Table 2: Models based on joint effect of weekly and fortnightly weather indices

Period	Model		Contributing variable	Adjusted R^2	Relative Deviation (%)			RMSE
					2013-14	2014-15	2015-16	
22 weeks	Model 9	$\hat{Y} = 4443.41 + 58.24Z_{11} - 17.63Z_{21} + 0.86Z_{121} + 22.74T$	Tmax&RHm	**0.68**	5.74	7.6	1.15	184.71
	Model 10	$\hat{Y} = 4791.45 + 83.71Z_{11} + 2.39Z_{121} + 27.44T$	Tmin&SSH	0.61	7.74	2.0	-4.8	182.42
24 weeks	Model 11	$\hat{Y} = 3294.88 + 40.70Z_{11} + 0.56Z_{121} + 21.38T$	Tmax&RHm	0.66	11.26	-0.37	-1.9	231.17
	Model 12	$\hat{Y} = 5443.38 + 37.61Z_{11} + 0.29Z_{121} + 23.10T$	Tmax&RHe	0.61	8.98	1.59	-2.98	192.15
11 fortnights	Model 13	$\hat{Y} = 3638.34 + 69.03Z_{11} + 0.68Z_{121} + 20.419T$	Tmax&RHm	0.58	33.53	30.05	23.98	978.9
	Model 14	$\hat{Y} = 5383.42 + 61.08Z_{11} + 0.56Z_{121} + 21.225T$	Tmax&RHe	0.56	-10.61	-20.3	-26.11	635.47
12 fortnights	Model 15	$\hat{Y} = 3409.30 + 68.11Z_{11} + 0.90Z_{121} + 19.507T$	Tmax&RHm	0.59	12.27	0.13	1.62	250.79
	Model 16	$\hat{Y} = 1665.73 + 5.56Z_{121} + 26.24T$	Tmin&SSH	0.49	10.14	0.75	-5.51	228.33

Note: Tmax = Maximum Temperature, Tmin = Minimum Temperature, RHm = Relative Humidity (morning), RHe = Relative Humidity (evening), RF = Rainfall, RDA = No. of Rainy days, SSH = Bright Sunshine Hours.

Table 3: Comparison of selected models based on adjusted R^2 and root mean square error of weekly and fortnightly weather indices

Effect	Individual		Joint	
Duration	**24 weeks**	**12 fortnights**	**22 weeks**	**11fortnights**
Contributing Variable	**Model 2 (RDA)**	**Model 6 (RHe)**	**Model 9 (Tmax & RHm)**	**Model 15 (Tmax & RHm)**
Adjusted R2	0.56	0.51	0.68	0.59
RD % -2013-14	8.81	10.48	5.74	12.27
RD % -2014-15	-2.66	1.02	7.6	0.13
RD %-2015-16	-8.3	-3.09	1.15	1.62
RMSE	236.83	220.54	184.71	250.79

References

1. Agrawal, Ranjana Jain RC, Jha MP. Models for studying rice crop-weather relationship. Mausam 1986;37(1):67-70.
2. Agrawal Ranjana, Mehta SC. Weather based forecasting of crop yields, pests and diseases - IASRI models. Journal of the Indian Society of Agricultural Statistics 2007;61(2):255-463.
3. Agrawal Ranjana, Aditya K. "Use of discriminant function analysis for forecasting crop yield",Mausam 2012;63(3):455-458.
4. Aneja DR, Rai L. Estimation of cotton yield through growth indices of plant biometrical characters, Journal of Cotton Research and Development 2013;27(1):134-137.
5. Aneja DR, Rai L, Grover DR, Batra SD. Pre-harvest forecast models for cotton yield, Journal of Cotton Research and Development 2008;22:129-39.
6. Bannayan M, Crout NMJ. Stochastic modeling approach for real time forecasting of winter wheat yield. Field Crop Research 1999;62:85-95.
7. Chowdhary A, Das HP. Southwest monsoon rains and *kharif* production. Mausam 1993;44(4):381-394.
8. Draper NR, Smith H. "Applied regression analysis". 2nd Edition. New York: Wiley 1981.
9. Gadgil S, Abrol YP, Sheshagiri Rao PR. On growth and fluctuation of Indian food grain production. Current Science 1999;7(6):548-556.
10. Hendrick WA, Scholl JE. Technique in measuring joint relationship the joint effects of temperature and precipitation on crop yield. North Carolina Agric. Exp. Sta. Tech. Bull 1943,74.
11. Jain RC, Agrawal R, Jha MP. Effect of climatic variables on rice yield and its forecast. Mausam 1980;31(4):591-596.
12. Kandiannan K, Chandragiri KK, Sankaran N, Balasubramaniam TN, Kailasam C. Crop weather model for turmeric yield forecasting for Coimbatore district, Tamil Nadu, India, Agricultural and forest meteorology 2002;12(3-4):133-137.
13. Kumar N, Pisal RR, Shukla SP, Pandey KK. Crop yield forecasting of paddy and sugarcane through modified Hendrick and Scholl technique for south Gujarat. Mausam 2016;67(2):405-410.
14. Kumar N, Pisal RR, Shukla SP, Pandey KK. Crop yield forecasting of paddy, sugarcane and wheat through linear regression technique for south Gujarat. Mausam 2014;65(3):361-364.
15. Munu D, Hussain R, Sarma A, Sarmah K, Deka RL. Yield prediction of winter rice employing meteorological variables in central and upper Brahmaputra valley zone of Assam. Journal of Agrometeorology 2013;15(1):162-166.
16. Petr J. "Weather and Yield", Dev. Crop Sci. No. 20, Elsevier, Amsterdam 1991,288.
17. Potgieter AB, Hammer GL, Doherty A, de Voil P. A simple regional-scale model for forecasting sorghum yield across North-Eastern Australia. Agriculture and Forest Meteorology 2005;132:143-153
18. Pandey KK, Chandrakar CK, Singh SK, Maurya D, Gupta G. Identification of most important weeks on minimum temperature for wheat crop, International journal of current microbiology and applied sciences 2017;6(2):788-794.
19. Kandiannan K, Karthikeyan R, Krishnan R, Balasubramanian TN. A Crop–Weather Model for Prediction of Rice (Oryza sativa L.) Yield Using an Empirical-Statistical Technique, Journal of Agronomy and Crop Science 2002;188(1):59-62.
20. Kumar N, Pisal RR, Shukla SP, Pandey KK. Crop yield forecasting of paddy and sugarcane through modified Hendrick and Scholl technique for south Gujarat, Mausam 2016;67(2):405-410.
21. Raj Laxmi Kumar R, Weather based forecasting model for crops yield using neural network approach, Statistics and Applications 2011;9(1-2):55-69.