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Effect of weather variables on the yield of rice crop in district Azamgarh of eastern Uttar Pradesh, India

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Abstract
Rice (*Oryza sativa* L.) is the major crop of Uttar Pradesh, which covers about 36.5 per cent area of total gross-cropped area in Uttar Pradesh. The present study mainly deals with to determine the effect of weather variables on the yield of rice crop in Azamgarh district of Eastern Uttar Pradesh, India. On the basis of correlation and regression analysis, we found that rainfall is most important variable which effects the yield of rice crop positively followed by minimum temperature while rest variables show negative effects on the yield of rice crop.

Keywords: Azamgarh, rice, yield, weather variables, correlation, regression, r-square

Introduction

Rice (*Oryza sativa* L.) is the major crop of Uttar Pradesh, which covers about 36.5 per cent area of total gross-cropped area in Uttar Pradesh. In 2015-16, contributing around 41.5 per cent to the total food grain production of the country (DES, 2017). Rice is mostly grown in Kharif (June-October) season. This crop is also studied under the FASAL programme of the Department of Space (Parihar & Oza, 2006) [3]. Due to importance of this crop in the national agricultural scenario, it is important to study the impact of climate change on this crop.

Azamgarh district (Eastern Uttar Pradesh, India) which falls under middle gangetic agro-climatic region and 8th eastern plain agro-climatic zone in the eastern part of Uttar Pradesh at a distance of about 270 km from Lucknow. Azamgarh district lies between latitude 26°03' N and longitude 83°13' E and it is bounded by the districts of Mau in east, Gorakhpur in the north, Ghazipur in south-east, Jaunpur in the south-west, Sultanpur in the west and Ambedkar Nagar in the north-west.

The present study has been undertaken for the yield of rice crop in the district Azamgarh, Eastern Uttar Pradesh, India.

Material and Methods

The time series data on yield for rice crop of Azamgarh district of eastern Uttar Pradesh pertaining for the period from 2000-01 to 2017-18 have been procured from the website http://updes.up.nic.in/spatrika/spatrika.htm by Economics and Statistics Division, Planning Department, Government of Uttar Pradesh.

Weekly weather variables data for rice and wheat crop in the district of Azamgarh, Eastern Uttar Pradesh have been obtained from the National Data Centre, India Meteorological Department, Pune for the study period 2000-01 to 2017-18. The data for rice crop have been collected up to the first 16 weeks of the crop cultivation which include 23rd Standard Meteorological Week (SMW) to 38th SMW of a year. The data on six weather variables *viz.* Maximum Temperature, Minimum Temperature, Rainfall, wind-velocity and Sun-shine hours have been used in the study.

Individual effect of weather variables

The statistical models have been proposed by expressing effect of changes in weather variables on yield in w^{th} week as a linear function of respective correlation coefficients between detrended yield and weekly weather data (Agrawal *et al.*, 1986) [2].

Trend effect on yield is also removed from yield while calculating correlation coefficients of yield with weather variables to be used as weights.

De-trend yield

$$Y = a + bt$$

Where; Y, a, b and t is observed yield, constant, regression coefficient and time trend respectively.

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 i^{th} (i = 1, 2, …, p) weather variable at w^{th} weeks (w = 1, 2, … n). In this study, n is 16.

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

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

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.

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

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

Where, Y is detrended 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 follow normal distribution with mean zero and variance σ^2.

Result and Discussion

Effect of weather variables on the yield of rice crop by correlation analysis

Persual of the table 1, we found that unweighted minimum temperature (Z_{20}) and unweighted rainfall (Z_{30}) are positively correlated as 0.560 and 0.531 respectively with detrended yield of Rice crop at 5% level of significance while unweighted maximum temperature (Z_{10}), unweighted wind velocity (Z_{40}) and unweighted sunshine hour (Z_{50}) found to be negatively correlated with detrended yield of rice crop.

Table 1: Correlation coefficient between detrend yield and generated weather variables

Unweighted variables	Correlation coefficient	Weighted variables	Correlation coefficient
Z_{10}	- 0.259	Z_{11}	- 0.621**
Z_{20}	0.560*	Z_{21}	0.441
Z_{30}	0.531*	Z_{31}	0.738**
Z_{40}	- 0.398	Z_{41}	0.167
Z_{50}	- 0.390	Z_{51}	- 0.641**

Correlation is significant at the 0.01 level (2-tailed) **

Correlation is significant at the 0.05 level (2-tailed) *

Weighted minimum temperature (Z_{21}), weighted rainfall (Z_{31}) and weighted wind velocity (Z_{41}) shows positive while weighted maximum temperature (Z_{11}) and sunshine hour (Z_{51}) shows negative correlation with the yield of rice crop.

Effect of weather variable on the yield of rice crop by regression analysis

Effect of maximum temperature

The multiple regression equation obtained is

$$Y = 70.207 - 1.104\, Z_{10} - 0.545\, Z_{11} - 0.009\, T$$

Table 2: Effect of maximum temperature

Variable	Regression coefficient (Standard error)	*P* value	R^2 (%)	95% Confidence interval	
				Lower B.	Upper B.
Constant	70.207 (21.930)		51.5	23.172	117.242
Z_{10}	- 1.104* (0.613)	0.093		- 2.420	0.211
Z_{11}	- 0.545*** (0.153)	0.003		- 0.873	- 0.217
T	- 0.009 (0.109)	0.937		- 0.243	0.226

From the persual of table 2 maximum temperature is an important weather variable for rice crop. The results indicates that un-weighted & weighted maximum temperature regression coefficients were found to be negatively significant at 10% & 1% level of significant and time trend T was found negatively non-significant. The value of R^2 (%) is 51.5 and F_{Cal} (4.959*) is significant at 5% level of significance.

Effect of minimum temperature

The multiple regression equation obtained is

$$Y = -47.961 + 3.521\, Z_{20} - 1.018 Z_{21} - 0.225\, T$$

Table 3: Effect of minimum temperature

Variable	Regression coefficient (Standard error)	*P* value	R^2 (%)	95% Confidence interval	
				Lower B.	Upper B.
Constant	- 47.961 (19.874)		43	90.588	- 5.335
Z_{20}	3.521** (1.488)	0.033		0.329	6.713
Z_{21}	- 1.018 (1.149)	0.391		- 3.482	1.446
T	- 0.225 (0.135)	0.116		- 0.514	0.063

From the persual of table 3 indicates that un-weighted minimum temperature was significant at 5%, weighted weather variable and time trend T was found negatively non-significant. The value of R^2 (%) is 43, F_{Cal} (3.517*) is significant at 5% level of significance.

Effect of rainfall

The multiple regression equation obtained is

$$Y = 12.715 + 0.003\, Z_{30} + 0.048\, Z_{31} - 0.041\, T$$

Table 4: Effect of rainfall

Variable	Regression coefficient (Standard error)	*P* value	R^2 (%)	95% Confidence interval	
				Lower B.	Upper B.
Constant	12.715 (0.143)		55.1	8.119	17.311
Z_{30}	0.003 (0.045)	0.943		- 0.094	0.101
Z_{31}	0.048* (0.017)	0.014		0.011	0.084
T	- 0.041 (0.107)	0.708		- 0.269	0.188

From the persual of table 4, weighted rainfall regression coefficient was found significant at 5%, un-weighted weather variable and time trend T was found non-significant. The value of R^2 (%) is 55.1 and F_{Cal} (5.735) is non-significant.

Effect of wind velocity

The multiple regression equation obtained is

$$Y = 21.704 - 1.637\, Z_{40} + 0.954\, Z_{41} - 0.004\, T$$

Table 5: Effect of wind velocity

Variable	Regression coefficient (Standard error)	*P* value	R^2 (%)	95% Confidence interval	
				Lower B.	Upper B.
Constant	21.704 (3.457)		44.9	14.290	29.119
Z_{40}	- 1.637*** (0.510)	0.006		- 2.730	- 0.543
Z_{41}	0.954* (0.390)	0.028		0.118	1.790
T	0.004 (0.138)	0.978		- 0.293	0.301

From the persual of table 5, Un-weighted regression coefficient of wind velocity was found to be negatively significant at 1%, weighted variable was found positively significant at 5% and time trend was positively non-significantly. The value of R^2 (%) is 44.9 and F_{Cal} (3.809*) is significant at 5% level of significance.

Effect of sunshine (hr)

The multiple regression equation obtained is

$$Y = 29.362 - 1.213\, Z_{50} - 1.230\, Z_{51} - 0.101\, T$$

Table 6: Individual effect of Sunshine (hr)

Variable	Regression coefficient (Standard error)	*P* value	R^2 (%)	95% Confidence interval	
				Lower B.	Upper B.
Constant	29.362 (4.444)		56.1	19.831	38.893
Z_{50}	- 1.213 (0.846)	0.174		- 3.028	0.602
Z_{51}	- 1.230*** (0.343)	0.003		- 1.966	- 0.495
T	- 0.186 (0.106)	0.101		- 0.414	0.041

From the persual of table 6, weighted regression coefficient of sunshine hour was found negatively significant at 1% level, while regression coefficient of un-weighted sunshine hour and time was found negatively non-significant. The value of R^2 (%) is 56.1 and F_{Cal} (5.957) is non-significant.

Conclusion

All the weather variables which are used in this study is found to be important for the yield of rice crop in district Azamgarh, Eastern Uttar Pradesh, India. Correlation and regression analysis shows that among all these variables two variables *viz*., rainfall and minimum temperature effects positively to the yield of the rice crop while all the rest variables effected negatively.

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