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Effect of weather variables on the yield of rice crop in District Jaunpur, Eastern Uttar Pradesh, India

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Abstract
India is an important centre of rice cultivation. The rice is cultivated on the largest areas in India. Rice 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 the effect on weather variables. The study has been undertaken for rice crop in the district Jaunpur, Eastern Uttar Pradesh, India. The present study is formulated to determine the individual effect of weather variables on rice yield. On the basis of R^2, we found that individually Maximum Temperature is more important with 57.8 followed by sunshine (hr.), rainfall, Minimum Temperature, and wind velocity with 54.2, 52.2, 30.1 and 5.32 respectively.

Keywords: Weather variables, correlation & regression, yield, rice crop, R^2

Introduction
In India rice is grown in 43.86 million ha, the production level is 104.80 million tones and the productivity is about 2390 kg/ha (Agricultural Statistics at a glance- 2015). It is grown under diverse soil and climatic conditions the productivity level of rice is low compared to the productivity levels of many countries in the world. Also, about 90% of the cultivated land belongs to Marginal, Small and Medium farmers which is another constrain in increasing the productivity of rice in the country. It is, therefore, there is ample scope to increase the productivity of rice in the country. The highest productivity is 6710 kg per ha of China followed by Vietnam (5573 kg /ha), Indonesia (5152 kg/ha), Bangladesh (4375 kg/ha) etc There are improved technologies and various interventions which could be adapted to increase the productivity in the country. Cultivation of hybrid rice has potential to increase the productivity and needs to be promoted. A lot of work has been done by IASRI, New Delhi in this direction in different locations of the country. The discriminant function has also been used to forecast Preharvest yield of rice by Agrawal (2002) using weather variables.
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 favorable and suitable climate, vast areas of fertile soils, sunshine and adequate water resources. Te cropping intensity is 153% of the Uttar Pradesh. Uttar Pradesh ranks 3rd in the country in production of rice.
Environment plays an important role in crop production. The eastern U.P. has different environment and ecology as compared to other parts of the state and country. The study has been undertaken for rice crop in the district of Jaunpur, Uttar Pradesh, India.

Material and Methods
The time series data on yield for rice and wheat crop of Jaunpur 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 Jaunpur, 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 five 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) [14]. 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

$Z_{i0} = \sum_{w=1}^{n} X_{iw} / n$ 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 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 follow normal distribution with mean zero and variance σ^2.

Result and Discussion

Effect of weather variables on the yield of rice and wheat 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 0.484 and 0.517 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.

Variables	Correlation Coefficient	Variables	Correlation Coefficient
Z10	- 0.148	Z11	- 0.571*
Z20	0.484*	Z21	0.427
Z30	0.517*	Z31	0.714**
Z40	- 0.221	Z41	- 0.047
Z50	- 0.516	Z51	- 0.272

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

Individual effect of weather variable on rice crop with Regression Coefficient and R^2

2.1 Maximum Temperature

The multiple regression equation obtained is

$$Y = 68.375 - 1.492\, Z_{10} - 0.036\, Z_{11} - 0.059\, T$$

Table 2: Individual effect of Maximum Temperature

Variable	Regression Coefficient (standard Error)	*P value*	R^2	95% Confidence interval	
				Lower	*Upper*
Constant	*68.375 (19.467)*		*57.8%*	26.623	110.128
Z_{10}	- 1.492** (0.571)	0.020		- 2.717	- 0.267
Z_{11}	- 0.036*** (0.008)	0.001		- 0.054	- 0.018
T	- 0.059 (0.094)	0.53		- 0.261	0.142

From the persual of table 2 maximum temperature weather variable for rice crop. The results indicates that un-weighted & weighted maximum temperature regression coefficients were found to be negatively significant at 5% & 1% level of significant and time trend T was found negatively non-significant. The value of R^2 (%) is 57.8

Minimum temperature

The multiple regression equation obtained is

$$Y = -30.562 + 2.224\, Z_{20} - 0.331 Z_{21} - 0.155\, T$$

Table 3: Individual effect of Minimum Temperature

Variable	Regression Coefficient (Standard Error)	*P value*	R^2	95% Confidence Interval	
				Lower	*Upper*
Constant	- 30.562 (19.981)		*30.1%*	- 73.418	12.293
Z_{20}	2.224 (1.481)	0.155		- 0.953	5.400
Z_{21}	- 0.311 (1.149)	0.790		- 2.775	2.153
T	- 0.155 (0.136)	0.27		- 0.445	0.136

From the persual of table 3 minimum temperature weather variable for rice crop. The results indicates that un-weighted & weighted minimum temperature regression coefficients were found to be non-significant and time trend T was also found negatively non-significant. The value of R^2 (%) is 30.1

Rainfall

The multiple regression equation obtained is

$$Y = 15.286 + 0.014\, Z_{30} + 0.036\, Z_{31} - 0.037\, T$$

Table 4: Individual effect of Rainfall

Variable	Regression Coefficient (Standard Error)	*P value*	R^2	95% Confidence Interval	
				Lower	*Upper*
Constant	15.286 (1.983)		*52.4%*	11.033	19.539
Z_{30}	0.014 (0.040)	0.735		- 0.072	0.099
Z_{31}	0.036** (0.013)	0.018		0.007	0.064
T	- 0.037 (0.100)	0.71		- 0.252	0.178

From the persual of table 4 Rainfall weather variable for rice crop. The results indicates that un-weighted rainfall regression coefficients were found to be nonsignificant & weighted rainfall regression coefficients were found to be significant at 1% level of significant and time trend T was found negatively non-significant. The value of R^2 (%) is 52.4

2.4 Wind velocity

The multiple regression equation obtained is

$$Y = 21.307 - 0.482\, Z_{40} + 0.011\, Z_{41} - 0.157\, T$$

Table 5: Individual effect of Wind velocity

Variable	Regression Coefficient (Standard Error)	*P value*	R^2	95% Confidence Interval	
				Lower	*Upper*
Constant	21.389 (3.627)		*5.32%*	13.611	29.168
Z_{40}	-.405 (0.460)	.394		-1.393	.583
Z_{41}	.001 (0.040)	.979		-.086	.088
T	.040 (0.138)	.775		-.256	.336

From the persual of table 5 Wind velocity weather variable for rice crop. The results indicates that un-weighted & weighted Wind velocity regression coefficients were found to be non-significant and time trend T was also found nonsignificant. The value of R^2 (%) is 5.32

2.5 Sunshine (Hr.)

The multiple regression equation obtained is

$$Y = 33.628 - 2.287\, Z_{50} - 0.630\, Z_{51} - 0.111\, T$$

Table 6: Individual effect of Sunshine (Hr.)

Variable	Regression Coefficient (Standard Error)	*P value*	R^2	95% Confidence Interval	
				Lower	*Upper*
Constant	33.628 (4.661)		*54.2%*	23.631	43.626
Z_{50}	-2.287*** (0.758)	0.009		-3.912	-.662
Z_{51}	-0.630* (0.297)	0.052		-1.267	0.007
T	-0.111 (0.107)	0.318		-0.341	0.119

From the persual of table 6 sunshine (Hr.) weather variable for rice crop. The results indicates that un-weighted & weighted sunshine (Hr.) regression coefficients were found to be negatively significant at 1% & 10% level of significant and time trend T was found negatively non-significant. The value of R^2 (%) is 54.2

Conclusion

All the weather variables which are used in this study is found to be important for the yield of rice crop in district Jaunpur, 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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