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A study on impact of climate change on rice production in Faizabad district of Uttar Pradesh

MOHD. AZFAR, B. V. S. SISODIA, V. N. RAI and SUNIL KUMAR

Narendra Deva University of Agril. & Tech., Kumarganj, Faizabad (U. P.) – 224 229, India

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e mail : mazfar38@gmail.com

सार -इस शोध पत्र में भारत के उत्तर प्रदेश के फैजाबाद जिले में धान के उत्पादन पर जलवायु परिवर्तिताओं में परिवर्तन के प्रभाव का अध्ययन करने का प्रयास किया गया है। इस अध्ययन में वर्ष 91-1990से 10-2009तक के 20 वर्षों के धान उत्पादन के श्रृंखलावार आँकड़ों तथा फसल ऋतु के लिए सात मौसम परिवर्तिताओं के साप्ताहिक आँकड़ों का उपयोग किया गया है। मौसम सूचकांक एवं समाश्रयण परिवर्तिताओं के रूप में समय प्रवृत्ति का उपयोग करते हुए तथा समाश्रयण के रूप में धान के उत्पादन का क्रमवार समाश्रयण विश्लेषण कर प्रत्येक मौसम परिवर्तिताओं के प्रभाव का अध्ययन किया गया। इससे प्राप्त हुए परिणामों से यह पाया गया है कि समय प्रवृत्ति सहित प्रत्येक मौसम परिवर्तिताओं के वेटेड मौसम माध्य का धान की फसल पर उल्लेखनीय रूप से प्रभाव पड़ा है। इसमें यह भी पाया गया है कि अधिकतम तापमान को छोड़कर सभी सात मौसम परिवर्तिताओं के मान में बढ़ोतरी की वजह से फसल के पकने और उसके परिपक्व होने की अवस्था धान के उत्पादन के लिए हानिकारक है। समग्र परिणाम यह दर्शाता है कि जलवायु परिवर्तिताओं में परिवर्तन के फलस्वरूप धान के उत्पादन के विभिन्न चरणों में इनका प्रभाव कहीं कहीं हानिकारक है तथा कहीं कहीं लाभदायक पाया गया है जिनका प्रभाव अन्तत :धान के उत्पादन पर पड़ता है।

ABSTRACT. The present paper attempts to study the effect of changes in climatic variables on rice production in Faizabad district of U. P., India. Time series data on rice yield and weekly data of seven weather variables for the crop-season for 20 years covering the period 1990-91 to 2009-10 have been used in the study. Effect of individual variable has been studied by carrying out step-wise regression analysis using weather indices and time trend as regressor variables and rice yield as regressand. It has been found that weighted weather indices of each weather variable including time trend have exhibited significant effect on the rice yield. It has also been found that rise in all seven weather variables except maximum temperature has been detrimental to rice yield during ripening and maturity phase of the crop. The overall results indicate the fact that changes in climatic variables show detrimental as well as beneficial role depending upon the phases of crop production in getting out its final output.

Key words – Weather variables, Weather indices, Climate change, Regression model.

1. Introduction

The climate change and climate variability cause a significant impact on the agricultural production. Particularly, Indian agriculture is quite vulnerable to the effect of changes in climate variables. The success of Indian agriculture depends on the performance of the south-west monsoon and also on favorable weather conditions. Aberrant weather conditions worry the farmers as well as the policy makers. During recent years, burning of fossil fuels by the vehicles, coal burning by the power plants, emission of greenhouse gas from the industrial sectors, the large scale deforestation etc. caused increase in the earth's surface temperature and shift in rainfall pattern. These changes in climate variables have caused loss of moisture, increases in occurrence of cyclones, thunderstorms, floods and also caused the rising of the sea-level, which ultimately might result in inundation of many coastal cities and towns. As far as food grain production is concerned, even a slight rise in the earth's surface temperature could cause drop in the country's wheat production substantially and could much impair the quality of rice (especially of the basmati rice), fruits, vegetables and medicinal plant's products much valued for the export. Various research workers (Ranjana *et al*., 1983 & 86; Jain *et al*., 1980; Kaul and Ram (2008); Rathore *et al*., 2001; Saseendran *et al*., 1999; Mall *et al*., 2006) have worked in this direction to workout relationship between crop yield and weather variables. An attempt has been made in the present paper to study the impact of changes in weather variables on rice yield by developing suitable statistical models.

2. Material and methodology

2.1. *Area and crop covered*

The study has been conducted for Faizabad district of Eastern Uttar Pradesh, India which is situated between 26° 47' N latitude and 82° 12' E longitudes. It lies in the

Eastern Plain Zone (EPZ) of Uttar Pradesh. It has average 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 favourable climate, soil and the availability of ample irrigation facilities make growing of rice a natural choice for the area. Rice crop is generally cultivated during the Kharif season when there is a better environment in terms of water availability for the cultivation of the rice crop.

2.2. *Data description*

2.2.1. *Yield data*

Time series data on yield for rice crop of Faizabad district of Uttar Pradesh for 20 years (1990-91 to 2009-10) have been collected from Directorate of Agricultural Statistics and Crop Insurance, Govt. of Uttar Pradesh.

2.2.2. *Weather data*

Weekly weather data on the weather variables of Faizabad district of Uttar Pradesh during the different growth phases of rice crop pertaining to the period 1990-91 to 2009-10 have been obtained from the Department of Agro Meteorology, N. D. University of Agriculture & Technology Kumarganj, Faizabad. The data on seven weather variables, *viz*., minimum temperature, maximum temperature, relative humidity, rainfall, wind-velocity, number of rainy days and sun-shine (hr) have been used in the present study.

2.2.3. *Crop season*

Rice is generally sown from the third week of June in Faizabad District when average daily temperature falls around 41 °C. Sowing of rice when temperature is lower results in poor germination, reduced tillering and early onset of flowering and thereby exposing the floral parts to the hot damage. All these factors depress the crop yields. The different crop growth phases are early growth phase, grand growth phase and maturity phase. The early growth phase includes period from sowing to emergence and initial growth phase of the crop which covers 5 weeks from June 18 (25^{th} SMW) to July 22 (29^{th} SMW). The grand growth phase includes active lag vegetative and reproductive growth periods which covers 12 weeks from July 23 (30^{th} SMW) to October 14 (41^{th} SMW). The maturity phase includes the ripening and harvest stage of crop which covers 4 weeks from October 15 (42^{th} SMW) to November 11 (45^{th} SMW). Therefore, 21 weeks data (25^{th} SMW to 45^{th} SMW) on each weather variable under consideration have been utilized for this study.

2.3. *Individual effect of weather variables*

In order to study the effect of individual weather variable, two new variables from each weather variable are generated following the procedure developed by Ranjana *et al*. (1986).

Let X_{iw} be the value of the i^{th} weather variable X_i at w^{th} weeks (w = 1, 2,…..n). In this study n is 21.

Let r_{iw} be the simple correlation coefficient between weather variable X_i at w^{th} week and adjusted crop yield (Y) for trend effect over a period of K years. The generated variables are then given by

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

For $j = 0$,

we have unweighted generated variable

$$Z_{i0} = \sum_{w=1}^{n} X_{iw} \Big/ n \tag{2}$$

and for $j = 1$, we get weighted generated variables

$$Z_{i1} = \sum_{w=1}^{n} r_{iw} X_{iw} \Big/ \sum_{w=1}^{n} r_{iw} \tag{3}$$

The new variables Z_{i0} and Z_{i1} were generated for each weather variable i (i =1, 2….p). The following model is then fitted to study the effect of individual weather variable on crop yield

$$Y = a_0 + a_1 z_{i0} + a_2 z_{i1} + cT + \varepsilon \quad ; i = 1, 2,\ldots p \tag{4}$$

where, Y is the actual crop 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. The above model is fitted using step wise regression method for each weather variable.

The effects were obtained by differentiating the fitted model (4) with respect to X_{iw} for each weather variable X as follows:

$$\frac{\partial Y}{\partial X_{iw}} = a_1 / n + a_2\, r_{iw} \Big/ \sum_{w=1}^{n} r_{iw} \tag{5}$$

Let Y_0 be the yield of the crop estimated from fitted model (4) by replacing X_{iw} by $\overline{X}_{iw}$ where $\overline{X}_{iw}$ is the average of X_i (i^{th} weather variable) at w^{th} week over k years. Y_0 is then given by

$$Y_0 = \hat{a}_0 + \hat{a}_1 \sum_{w=1}^{n} \overline{X}_{iw} \Big/ n + \hat{a}_2 \sum_{w=1}^{n} r_{iw} \overline{X}_{iw} \Big/ \sum_{w=1}^{n} r_{iw} \;;$$

ignoring trend effect

where, $\hat{a}_i^{'s}$ (i = 0, 1, 2) are estimated value of $\hat{a}_i^{'s}$.

3. Results and discussion

New weather variables (unweighted and weighted mean of weekly weather data) have been generated. The effect of individual weather variable on crop yield are studied by carrying out stepwise regression analysis. The effects of one unit increase above average in climatic variables at various weeks of crop growth have been obtained from fitted models. The effects of one unit decrease below the average can be obtained by reversing the vertical scale. These effects are given in Table 8.

The results are presented and discussed in the following section.

3.1. *Minimum temperature*

The step wise regression analysis yielded the following model

$$Y = 37.878 - 0.727^{*} Z_{11} + 0.128^{*} T \qquad (6)$$

The summary of the result is given in Table 1. The results indicate that weighted mean of minimum temperature and time trend during the entire period of crop production has been found to be relatively more important to exhibit significant effect on crop yield.

The effects were obtained from

$$\frac{\partial Y}{\partial X_{iw}} = -0.727\, r_{iw} \Big/ \sum_{w=1}^{n} r_{iw}$$

It can be observed from Table 8 that during initial growth phase, the effect of 1 °C above the average has been found to be beneficial. However, during early active lag vegetative growth stage, the effects were also beneficial but in reproductive stage it revealed detrimental effect in general with few exceptions. The effects have been found to be detrimental in general during ripening and maturity stage of the crop. Such results have also been found by Ranjana *et al*. (1986) in Puri district of Orissa.

TABLE 1

Effect of minimum temperature

Variable	Regression coefficient (standard error)	P value	R^2
Constant	37.878(7.086)	0.00001	
Z_{11}	-0.727*(0.286)	0.021	39.5*
T	0.128*(0.055)	0.032	

*P<0.05; Figures in parentheses are standard error

TABLE 2

Effect of maximum temperature

Variable	Regression coefficient (standard error)	P value	R^2
Constant	44.212(5.100)	0.00001	
Z_{21}	-0.694**(0.145)	0.0001	64.4**
T	0.128**(0.042)	0.007	

** P< 0.01; Figures in parentheses are standard error

TABLE 3

Effect of relative humidity

Variable	Regression coefficient (standard error)	P value	R^2
Constant	11.998 (3.215)	0.002	
Z_{31}	0.118*(0.047)	0.022	39.3*
T	0.122*(0.055)	0.039	

*P< 0.05; Figures in parentheses are standard error

3.2. *Maximum temperature*

The step wise regression analysis yielded the following model

$$Y = 44.212 - 0.694^{**} Z_{21} + 0.128^{**} T \qquad (7)$$

The summary of the results is given in Table 2. The results indicate that weighted mean of maximum temperature and time trend during the entire period of crop production show significant effect on crop yield.

The effects were obtained from

$$\frac{\partial Y}{\partial X_{iw}} = -0.694\, r_{iw} \Big/ \sum_{w=1}^{n} r_{iw}$$

One degree celcious increase above the average weekly maximum temperature has revealed beneficial effect on the yield of rice during initial growth and early lag vegetative growth phases of the crop (Table 8). This increase in maximum temperature has shown reverse effect on rice yield during reproductive phase. During the ripening and maturity stage, the rises in maximum temperature were found to be beneficial in general.

3.3. *Relative humidity*

The multiple regression equation obtained is

$$Y = 11.998 + 0.118^{*} Z_{31} + 0.122^{*} T \qquad (8)$$

The summary of the results is given in Table 3. The result indicated that the weighted mean of relative humidity and time trend have made significant impact on the rice yield.

The effects were obtained from

$$\frac{\partial Y}{\partial X_{iw}} = 0.118\, r_{iw} \Big/ \sum_{w=1}^{n} r_{iw}$$

The rise of one per cent above the average weekly humidity has shown in general beneficial effect on the rice yield through out the crop growth period except in the last stage, *i.e.*, ripening and maturity period. Hence, rise in humidity during last four - five weeks before the harvest could be detrimental to the rice yield.

3.4. *Wind velocity*

The step wise regression analysis yielded the following model

$$Y = 22.004 - 0.674^{**} Z_{41} + 0.163^{**} T \qquad (9)$$

The summary of the result is given in Table 4. The results indicate that weighted mean of wind velocity and time trend during the entire period of crop production have exhibited significant effect on rice yield. However, it is known that high wind velocity during maturity stage may lead to lodging of the crop that result to reduction in rice yield. The results also show in general that higher is the wind velocity the higher is the loss in yield.

The effects were obtained from

$$\frac{\partial Y}{\partial X_{iw}} = -0.674\, r_{iw} \Big/ \sum_{w=1}^{n} r_{iw}$$

TABLE 4

Effect of wind velocity

Variable	Regression coefficient (standard error)	P value	R^2
Constant	22.004 (0.755)	0.00001	
Z_{41}	-0.674**(0.170)	0.001	56.7**
T	0.163**(0.047)	0.003	

**P<0.01; Figures in parentheses are standard error

TABLE 5

Effect of sunshine hour

Variable	Regression coefficient (standard error)	P value	R^2
Constant	24.897 (0.982)	0.0001	
Z_{51}	-0.878** (0.155)	0.0001	71.1**
T	0.158**(0.038)	0.001	

** P< 0.01; Figures in parentheses are standard error

TABLE 6

Effect of rainfall

Variable	Regression coefficient (standard error)	P value	R^2
Constant	18.194 (0.566)	0.00001	
Z_{61}	0.015**(0.003)	0.00001	69.5**
T	0.129**(0.039)	0.004	

** P< 0.01; Figures in parentheses are standard error

TABLE 7

Effect of number of rainy days

Variable	Regression coefficient (standard error)	P value	R^2
Constant	17.027 (0.989)	0.00001	
Z_{71}	0.127**(0.035)	0.002	53.1**
T	0.118**(0.048)	0.025	

** P< 0.01; Figures in parentheses are standard error

One unit increase above the average weekly wind velocity has shown fluctuating effect on crop yield during the entire period of rice production. It may be observed from the Table 8 that rise in wind velocity has shown in general adverse affect on rice yield during flowering and grain formation as well as ripening and maturity stage of the crop production.

TABLE 8

Per cent change in yield due to per unit increase in weather variable over its average value

Week	Weather variables						
	Min. temp.	Max. temp.	Relative humidity	Wind velocity	Sun-shine hours	Rainfall	No. of rainy days
1.	-0.042	-1.167	0.127	0.367	-1.047	0.036	0.367
2.	-0.231	-0.629	0.072	-2.380	-0.328	0.039	-0.039
3.	-0.160	-0.994	0.112	-3.719	0.162	0.023	0.099
4.	0.008	0.354	0.008	0.216	0.494	0.006	0.126
5.	0.020	1.117	0.109	-2.813	0.421	-0.019	0.022
6.	0.033	0.101	0.074	-0.165	0.268	0.017	0.249
7.	0.055	0.655	-0.173	1.062	1.279	0.012	-0.294
8.	-0.146	0.763	-0.008	-3.023	-1.315	0.020	0.133
9.	-0.086	-0.259	0.229	-1.754	-0.171	0.012	0.180
10.	-0.218	-0.497	-0.007	0.464	1.128	0.003	-0.143
11	-0.081	-0.114	0.007	0.578	0.528	0.017	-0.089
12.	-0.218	-0.118	0.118	-0.847	0.265	-0.023	0.051
13.	0.007	-1.094	0.260	-1.688	-1.573	-0.004	0.180
14.	-0.181	-0.608	-0.042	1.572	-1.191	0.042	0.196
15.	0.055	0.393	-0.136	-1.319	0.057	-0.013	-0.153
16.	0.006	-1.940	0.156	1.044	-1.649	0.033	0.235
17.	-0.007	-0.779	0.180	-0.016	-0.584	-0.033	-0.056
18.	-0.207	0.041	-0.198	-0.872	-0.392	-0.048	-0.078
19.	-0.015	-0.199	-0.178	0.163	-1.792	-0.042	-0.303
20	0.074	0.065	0.124	0.408	-0.886	0.028	0.243
21.	-0.036	1.413	-0.296	-0.251	1.449	-0.032	-0.203

3.5. *Sunshine hour*

The step wise regression analysis yielded the following model

$$Y = 24.897 - 0.878^{**} Z_{51} + 0.158^{**} T \qquad (10)$$

The summary of the result is given in Table 5. The effect of weighted mean of sunshine (hour) and time trend during the entire period of crop production have been found to be significant on rice yield.

The effects were obtained from

$$\frac{\partial Y}{\partial X_{iw}} = -0.878\, r_{iw} \Big/ \sum_{w=1}^{n} r_{iw}$$

The effect of increase of one unit in sunshine hours above the average weekly sunshine hours have been found to be beneficial in general during initial growth phase and active lag vegetative growth stage (Table 8). On other hand, an adverse effect has been observed during reproductive as well as ripening and maturity stage of the crop due to unit rise in the sunshine hours .However, the Table 8 reveals that there has been around 1.5% increase in rice yield due to one hour rise in sun shine hours above the weekly sunshine hours during the last week of maturity of the crop.

3.6. *Rainfall*

The step wise regression analysis yielded the following model

$$Y = 18.194 + 0.015^{**} Z_{61} + 0.129^{**} T \qquad (11)$$

The summary of the result is given in Table 6. The results indicate that the effect of weighted mean of weekly rainfall and time trend during the entire period of crop production have been found to show significant impact on rice yield.

The effects were obtained from

$$\frac{\partial Y}{\partial X_{iw}} = 0.015\, r_{iw} \bigg/ \sum_{w=1}^{n} r_{iw}$$

Rise of the one mm in rainfall above the average weekly rainfall has shown beneficial effect in general upto the grand vegetative growth stage. The effects were, however, detrimental during reproductive, ripening and maturity stage of the crop production. It is also generally known that rise in rainfall during ripening and harvesting stage results to loss in rice yield.

3.7. *Number of rainy days*

The step wise regression analysis yielded the following model

$$Y = 17.027 + 0.127^{**} Z_{71} + 0.118^{**} T \qquad (12)$$

The summary of the result is given in Table 7. The results indicate that weighted mean of no. of rainy days and time trend during the entire period of crop production have shown significant effect on rice yield.

The effects were obtained from

$$\frac{\partial Y}{\partial X_{iw}} = 0.127\, r_{iw} \bigg/ \sum_{w=1}^{n} r_{iw}$$

The effect of increase in number of rainy days by one day above the average weekly number of rainy days were found to be beneficial in general from the beginning stage of the crop production till grand vegetative growth stage of the crop. The effect of rise in number of rainy days have been found to be detrimental during reproductive, ripening and maturity stage of the crop (Table 8).

4. Summary and conclusion

The weighted weekly means of all seven weather variables including time trend (T) have exhibited significant effect on the rice yield. The effect of rise in minimum temperature by 1 °C has been found to be detrimental in general during ripening and maturity stage of the crop. The rise in maximum temperature by 1**°C** has been found to be beneficial during initial growth, early active vegetative growth and during ripening, maturity and harvesting phase of the crop. However, it has been found to be detrimental during later phase of vegetative growth and flowering phase. The rise in humidity during last four-five weeks before the harvest could be detrimental to the crop yield, otherwise it has been beneficial, in general, during other growth phases of the crop. The rise in wind velocity has shown adverse affect on rice yield during flowering and grain formation as well as ripening and maturity phase of the crop.

It is interesting to note that there has been around 1.5% increase in rice yield due to one hour rise in sunshine hours during the harvesting phase of the crop. The rainfall and number of rainy days have very important role in all the phases of the crop production except during harvesting stage.

It can, however, be concluded from the overall results that the rise in all seven weather variables except maximum temperature has been found to be detrimental to rice yield during ripening and maturity phase of the crop. It also indicates the fact that changes in climatic variables exhibit detrimental as well as beneficial role depending upon the phases of crop production in getting out its final output.

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