

**RESEARCH NOTE**

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## **Changing Climate Pattern and Its Impact on Paddy Productivity in Ludhiana District of Punjab**

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ABSTRACT

Relevant time series data/information on temperature, rainfall and relative humidity over considerable period of about 4 decades has been analysed using simple statistical tools such as periodic mean, mean deviation and t-test to ascertain the changing climate pattern in Ludhiana district of Punjab. During past 40 years, the region experienced significant increase in average minimum temperature for all months in *kharif* season in the range of 1.4-2.1°C. The average maximum temperature has increased only for the month of August (0.5°C), while it decreased for the months of June (1.4°) and September (0.6°C). In totality, rise in average monthly temperature during *kharif* season has enhanced the level of warming. The average rainfall of the region showed an increasing trend with significant results for September (46.7 mm) and October (15.2 mm). The average relative humidity during the study period has been consistently and significantly increased in the range of 1.5-10 per cent during all these months. Climate change has the ability to influence the crops productivity either positively or negatively. Most of the studies have utilised various simulation models to estimate the likely impact of climate change on paddy productivity, while very few studies have considered how rising temperature and erratic rainfall or as a whole changing climatic factors have actually affected crop productivity and production. Weekly correlation between each climatic factor and periods of the crop season were computed to develop the empirical relationship and to identify all potential weeks climate affecting paddy productivity. The study identified climate-composite technological index model as a better fitted model to describe the impact of climate as well as technology on paddy productivity in Ludhiana district of Punjab. Increase in the maximum temperature has negative impact on paddy productivity, while increase in the minimum temperature, rainfall and relative humidity has positive impact though non-significant.

**Keywords:** Climate change, Minimum/maximum temperature, Rainfall/relative humidity, Impact analysis, Crop productivity.

**JEL:** Q150, Q250, Q200

I

INTRODUCTION

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. Climatic factors such as temperature, rainfall, relative humidity, sunshine hours etc., on earth is changing naturally in its slow pace from long millennia; however, the increased rate of climate change since pre-industrial times and more rapidly after 1970s is the major concern of 21st century. During the past 100 years, a South-Asian country India has experienced significant increase of 0.6°C surface air temperature which is considered higher than

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that for the previous century. During the same period, the nation has experienced decrease in light to moderate rainfall, number of wet days and enhanced level of relative humidity (Rupa *et al.*, 2006). The nation has also noticed a marked change in the rainfall pattern as indicated by the drought years 1972, 1979, 1987, 2002 and 2009 (Rao, 2010). During the last 40 years, the mean minimum temperature and humidity level had gone up by 1°C and 8-10 per cent respectively revealing change in climatic value in Punjab State (Anonymous, 2012a). In case of Ludhiana, it has been reported based on 24 years time series data (1970-1994) that the annual minimum temperature has increased by 1.6°C, while annual maximum temperature has declined by 0.9°C (Mahi, 1996).

Climate and its attributes are important contributory factors for agricultural growth, development and production can have profound effects on the productivity of the crops. Climate change is expected to impact the crop productivity in both positive and negative ways, however, the damage and loss from climate change to yields is more severe and irreparable as compared to gains occurred from it. Recent findings confirm that climate change and its impact may be serious for agricultural productivity in South-Asian countries like India where on one hand agriculture is one of the important contributors to Indian gross domestic product (GDP) (14.2 per cent), while on the other agriculture is itself dependent on climate. In India, about eighty per cent of the total rainfall occurs during the three months (between June and September) as a result of the South-west monsoon (Government of India, 2001). Any distraction in these would definitely affect the crop productivity and sometimes the condition is so severe that there may be chance of total crop failure. As mentioned earlier, India has already faced the change in temperature, relative humidity, sunshine hours etc., along with rainfall. Thus, concern is raised of the potentiality of these factor or factors to cause irreparable damage to national agriculture via reducing crop productivity, enhancing survival and distribution ability of insect, pest and pathogen, reducing water availability for irrigation etc (Pathank *et al.*, 2003). Punjab state of India though small in geographical coverage has an incredible contribution to the national food basket (especially rice 29.5 per cent and wheat 42.2 per cent in 2009-10) to feed the rapid growing population. In the state, the area occupied by rice crop is 2.7 million ha, with the total production of about 11.0 m tonnes and productivity about 4.0 t/ha. Rice is grown under well assured irrigated conditions in Punjab, because of which scanty rainfall does not lead to crop failure. However, supplying irrigation through ground water would lead to problem like depletion in water table, huge energy loss to pump water, lower profitability due to raised cost of production and burning of diesel which may raise the level of CO<sub>2</sub> the prime culprits for climate change (Anonymous, 2012b). Studies reported that with an increase in temperature upto 1.0°C, yield of Punjab paddy decreased by 3 per cent. Additionally, if the temperature increased of 1°C is combined with decreased radiation of 5 per cent, grain yield would decline by 9 per cent from normal (Hundal and Kaur, 2007).

Most of the studies have utilised various simulation models to estimate the impact of climate change on the agricultural system, while rare study has considered how rising temperature and erratic rainfall or as a whole changing climatic factors have actually affected crop production. Kaul and Ram (2008) made an effort on such lines to study the impact of changing climate on paddy production in India using linear regression model and concluded that excessive rains and extreme variations in temperature would affect the productivity of paddy crop thereby adversely affecting the incomes of the farming families in a negative manner. The present study is an attempt to analyse the change in climatic pattern and its impact on paddy crop productivity in Ludhiana district of Punjab. The study has been carried out with the following specific objectives: (1) To comprehend the changing pattern of the important climatic parameters, viz., minimum and maximum temperature, rainfall, and relative humidity in Ludhiana and (2) to analyse the impact of such changing climatic parameters on the productivities of paddy in Ludhiana.

## II

### MATERIALS AND METHODS

The study was conducted in Ludhiana district of Punjab which is at 30°55' N latitude and 75°51' E longitude. To analyse the changing pattern of important climatic parameters, daily data on surface air temperature (minimum and maximum), rainfall and relative humidity have been collected from Department of Agricultural Meteorology, Punjab Agricultural University, Ludhiana, for the period of 1972-2010. Daily data were averaged out on monthly as well as on weekly basis. The prepared mean monthly data during *khari*f season over the period of 39 years were divided into three periods consisting of thirteen years each to evaluate the periodical movements in such climatic parameters. The periods have been distinguished as Period I (1972-84), Period II (1985-97) and Period III (1998-2010) and overall Period IV (1972-2010). Simple statistical tools such as mean and mean deviation along with t-test were employed to study the significance between the sample means. To analyse the impact of changing climatic parameters on the paddy crop productivity, additional required data on productivity of paddy as well as various technological variables such as area under high-yielding varieties, fertiliser consumption, irrigated area, and farm mechanisation (tractorisat<sup>i</sup>on), etc. pertaining to the period 1972-2010 were collected from various issues of *Statistical Abstracts of Punjab*. To analyse the impact of climatic and technological factors on paddy crop productivity, weekly data on each climatic factor pertaining to specific crop growing period were correlated. Using correlation techniques, an attempt was made to find the degree and nature of relationship between paddy productivity and weekly climate, i.e., 23rd to 41st weeks to identify the potential week(s) affecting the paddy productivity. For assessing the technological impact on paddy productivity, the collected technological data over the period of 39 years was transformed into desired form for meaningful

analysis. Functional analysis was used to investigate the impact of various climatic as well as technological factors on paddy productivity. Linear as well as log-linear functions have been employed for the purpose. R-square value, number and significance level of variables and prior expected sign of coefficients were the criteria, considered to select the better fit model in all cases. Step by step regression technique was used to diagnose the potential climate and technological variables impacting paddy productivity, to be included in the final regression model. To avoid the problem of multi-collinearity among various technological variables, composite technology index was formed. The form of linear regression and log-linear regression (Cobb-Douglas) function used were as follows:

#### Linear Regression

$$y = a_0 + \sum_{i=1}^n a_i x_i + u \quad \dots(1)$$

#### Log-Linear Regression

$$y = a_0 + \prod_{i=1}^n x_i^{a_i} + e^u \quad \dots(2)$$

where:

$a_0$ =regression constant

$a_i$ = regression coefficients

$x_i$ = independent variables  $i=1,2,3,4,\dots,n$

$u$ =error term.

The final equations used for paddy in Ludhiana district was as follows:

#### *Log-Linear Function*

$$\log y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + b_4 \log x_4 + b_5 \log x_5 + b_6 \log x_6 + b_7 \log x_7 + b_8 \log x_8 + u \quad \dots(3)$$

where:

$y$  = paddy productivity (grain, kg/ha)

$x_1$  = average minimum temperature during 27th-30th weeks ( $^{\circ}\text{C}$ )

$x_2$  = average minimum temperature during 38th-41st weeks ( $^{\circ}\text{C}$ )

$x_3$  = average maximum temperature during 32nd week ( $^{\circ}\text{C}$ )

$x_4$  = average maximum temperature during 37th week ( $^{\circ}\text{C}$ )

$x_5$  = average maximum temperature during 41st week ( $^{\circ}\text{C}$ )

- $x_6$  = average rainfall during 40th week (mm)  
 $x_7$  = average relative humidity during 40th-41st weeks (per cent)  
 $x_8$  = composite technological index  
 $a$  = technical efficiency parameter  
 $b_i$ 's = elasticity coefficient of independent variables  
 $u$  = error term.

## III

## RESULTS AND DISCUSSION

The results have been discussed under the following two major sub-heads:

- I. Periodical deviation in the important climatic parameters
- II. Impact of climate change on paddy productivity.

I. *Periodical Deviation in the Important Climatic Parameters*(A) *Temperature*(a) *Minimum Temperature*

Deviation in average minimum temperature and its significance over the Period I, II and III was examined for the months during *kharif* seasons (June-October) and the results have been demonstrated in Table 1. All these months witnessed abrupt rise in the average minimum temperature in the range of 1°C to 1.7°C during Period II over Period I. Almost similar picture of such deviations emerged in Period III over Period II, depicting an increment in mean minimum temperature for all the *kharif* months, though only increase in July (0.4°C) and October (1.1°C) turned out to be significant. Deviations in minimum average temperature during Period III over base Period I visibly depicted increment in all the months in *kharif* season. More specifically, deviation assessment indicated that there has been significant increase of 1.4°C, 1.5°C, 1.6°C, 1.9°C and 2.1°C in the average minimum temperature during June, July, August, September and October respectively.

TABLE 1. PERIODICAL DEVIATION IN MONTHLY AVERAGE MINIMUM TEMPERATURE DURING *KHARIF* SEASON IN LUDHIANA DISTRICT OF PUNJAB, 1972-2010

Months (1)	1985-97 over 1972-84 Mean difference (°C) (2)	1998-10 over 1985-97 Mean difference (°C) (3)	1998-10 over 1972-84 Mean difference (°C) (4)
June	1.0*** (0.40)	0.3 <sup>NS</sup> (0.3)	1.4*** (0.41)
July	1.1*** (0.25)	0.4** (0.22)	1.5*** (0.24)
August	1.6** (0.66)	0.1 <sup>NS</sup> (0.63)	1.6*** (0.25)
September	1.7*** (0.41)	0.2 <sup>NS</sup> (0.31)	1.9*** (0.41)
October	1.0** (0.47)	1.1*** (0.43)	2.1*** (0.51)

\*\*\*, \*\* and \* indicates 1, 5 and 10 per cent level of significance respectively.

NS: Non-significant. Figures in parentheses are the standard errors.

(b) *Maximum Temperature*

Periodical deviations in monthly average maximum temperature during *kharif* season (1972-10), presented in Table 2 brought out that all months in *kharif* season experienced decrease in maximum temperature, though only decrease in the month of October (0.5°C) came out to be significant, during Period-II over base Period-I. In Period-III over base Period-II, the significant decrease of 1.2°C has been noticed during June and significant increase of 0.8°C has been observed in August. Deviation in the average maximum temperature during Period-III over base Period-I brought out that June (1.4°C) and September (0.6°C) were noticed with significant decrease, and August (0.6°C) was noticed with significant increase in the average maximum temperature.

TABLE 2. PERIODICAL DEVIATION IN AVERAGE MONTHLY MAXIMUM TEMPERATURE IN LUDHIANA, PUNJAB, 1972-2010

Months (1)	1985-97 over 1972-84 Mean difference (°C ) (2)	1998-10 over 1985-97 Mean difference (°C ) (3)	1998-10 over 1972-84 Mean difference (°C ) (4)
June	-0.3 <sup>NS</sup> (0.54)	- 1.2 <sup>**</sup> (0.60)	- 1.4 <sup>***</sup> (0.55)
July	-0.4 <sup>NS</sup> (0.48)	0.1 <sup>NS</sup> (0.63)	- 0.3 <sup>NS</sup> (0.38)
August	-0.3 <sup>NS</sup> (0.37)	0.8 <sup>**</sup> (0.39)	0.5 <sup>*</sup> (0.33)
September	-0.4 <sup>NS</sup> (0.45)	- 0.2 <sup>NS</sup> (0.34)	- 0.6 <sup>*</sup> (0.42)
October	-0.5 <sup>NS</sup> (0.36)	0.6 <sup>NS</sup> (0.46)	0.1 <sup>NS</sup> (0.46)

\*\*\*, \*\* and \* indicates 1, 5 and 10 per cent level of significance respectively.

NS: Non-significant. Figures in parentheses are the standard errors.

(B) *Rainfall*

Deviation in monthly average rainfall during *kharif* season over the periods of 39 years has been summarised in Table 3. During Period-II over base Period-I, the average rainfall has lessened during June and July, though are insignificant. On the other hand, August, September and October months witnessed an increase in the average rainfall, whereas increase in the month of September by 116.6 mm turned out to be significant.

TABLE 3. PERIODICAL DEVIATION IN AVERAGE MONTHLY RAINFALL IN LUDHIANA DISTRICT OF PUNJAB, 1972-2010

Months (1)	1985-97 over 1972-84 Mean difference (mm) (2)	1998-10 over 1985-97 Mean difference (mm) (3)	1998-10 over 1972-84 Mean difference (mm) (4)
June	- 4 <sup>NS</sup> (16.12)	29.9 <sup>NS</sup> (23.9)	25.9 <sup>NS</sup> (24.39)
July	- 42.8 <sup>NS</sup> (55.1)	44.7 <sup>NS</sup> (59.87)	1.9 <sup>NS</sup> (53.35)
August	26.5 <sup>NS</sup> (51.57)	- 54.3 <sup>NS</sup> (53.15)	- 27.7 <sup>NS</sup> (38.3)
September	116.6 <sup>**</sup> (61.94)	- 70 <sup>NS</sup> (63.19)	46.7 <sup>**</sup> (20.73)
October	5.7 <sup>NS</sup> (4.69)	9.5 <sup>NS</sup> (10.71)	15.2 <sup>*</sup> (10.02)

\*\*\*, \*\* and \* indicates 1, 5 and 10 per cent level of significance respectively.

NS: Non-significant. Figures in parentheses are the standard errors.

Deviation assessment of Period III over base Period II brought out that June, July and October are the months with increased average rainfall ranged from 9.5 mm to 44.7 mm, though statistically non-significant. The rest of the months during the same period experienced significant decrease in average rainfall. Deviation of average rainfall in Period III over base Period I brought out that June, July, September and October received increased average precipitation, though this increase during the month of September (46.7 mm) and October (15.2 mm) were statistically significant.

### (C) Relative Humidity

The deviation in monthly average relative humidity during *kharif* season over the periods I, II and III were analysed and demonstrated in Table 4. It reflects that the average relative humidity has increased all across the months during *kharif* seasons during Period II over base Period I, though only the increase in the month of June (4 per cent) has been found as statistically significant. The observed positive mean difference in five months during Period III over base Period II revealed that the average relative humidity has increased during these months, i.e., June (6 per cent), July (4.4 per cent), September (4.5 per cent) and October (4.7 per cent) in the region. During Period III over base Period I, the analysis brought out that all months have experienced increased average relative humidity, i.e., June (10 per cent), July (6 per cent), September (6.8 per cent) and October (6 per cent), have been found significant.

TABLE 4. PERIODICAL DEVIATION IN AVERAGE RELATIVE HUMIDITY IN LUDHIANA DISTRICT OF PUNJAB, 1972-2010

Months (1)	1985-97 over 1972-84 Mean difference (per cent) (2)	1998-10 over 1985-97 Mean difference (per cent) (3)	1998-10 over 1972-84 Mean difference (per cent) (4)
June	4** (1.98)	6** (2.59)	10*** (2.66)
July	1.6 <sup>NS</sup> (2.42)	4.4** (2.26)	6.0** (1.98)
August	1.1 <sup>NS</sup> (1.97)	0.4 <sup>NS</sup> (1.5)	1.5 <sup>NS</sup> (1.3)
September	2.3 <sup>NS</sup> (1.97)	4.5*** (1.67)	6.8*** (1.81)
October	1.3 <sup>NS</sup> (1.6)	4.7*** (1.74)	4.7*** (1.74)

\*\*\* and \* indicates 1, 5 and 10 per cent level of significance respectively.

NS: Non-significant. Figures in parentheses are the standard errors.

## II. Impact of Climate Change on Paddy Productivity

### (A) Minimum Temperature

The weekly minimum temperature during 27th, 28th, 29th, 30th, 34th, 35th, 38th, 39th, 40th and 41st standard meteorological weeks (SMW) were selected due to their higher degree of correlation with paddy productivity. These SMW were clumped and formed variables, i.e., 27th to 30th weeks as variable  $X_1$ , 34th to 35th weeks as variable  $X_2$  and 38th to 41st weeks as variable  $X_3$ , based on similar nature and regularity of the relationship. The formed variables were regressed with paddy

productivity using better fitted linear model. The results showed that the impact of variable  $X_1$  and  $X_3$  were positive as well as statistically significant. It indicates that  $1^\circ\text{C}$  rise in minimum temperature during 27th-30th weeks and 38th-41st weeks would lead to increase the paddy productivity by 341 and 141 kg/ha respectively. The R-square value was 0.41 showing that 41 per cent paddy productivity variations were explained by the minimum temperature alone.

(B) *Maximum Temperature*

The maximum temperature during 32nd, 37th and 41st SMWs were found highly correlated with paddy productivity in Ludhiana district. These SMWs maximum temperature were regressed on paddy productivity using better suited linear function. The results depicted that an increase of  $1^\circ\text{C}$  maximum temperature in the 32nd week significantly increased the paddy productivity by 169 kg/ha, while its increase during 37th and 41st week significantly lowered the paddy productivity by 145 and 198 kg/ha respectively. This variable (maximum temperature) could explain 27 per cent variation in paddy productivity.

(C) *Rainfall*

Rainfall during 24th, 33rd and 40th SMWs had potentiality to affect the paddy productivity. Rainfall during SMWs was regressed on paddy productivity using better fitted linear model. The analysis brought out that every 1 mm rise in rainfall during 40th week resulted in 44 kg/ha increase in paddy productivity. The  $R^2$  value was 0.23 showing that 23 per cent paddy productivity variations were explained by the rainfall alone.

(D) *Relative Humidity*

Correlation analysis depicted that relative humidity during 23rd, 24th, 30th, 31st, 40th and 41st SMWs had higher potentiality to affect the paddy productivity. These weeks were assembled based on similar nature and regularity in relationship and formed variables, i.e.,  $X_1$  (23rd-24th weeks),  $X_2$  (30th-31st weeks) and  $X_3$  (40th-41st weeks). These variables were regressed on paddy productivity using better fitted linear model. The results indicated that 1 per cent increase in relative humidity during 40th-41st weeks would lead to significant increase in paddy productivity by 5 kg/ha. The variables included in the function explained 26 per cent variation in paddy productivity.



(E) *Climatic Factors*

Having analysed the impact of partial climate on paddy productivity, effort was also made to examine the impact of whole climate parameters (minimum and maximum temperature, rainfall and relative humidity). For this all variables appeared as significant in partial climate assessment have been amalgamated in one equation. Both linear and log-linear function were tried and found that linear function as better suited.

The analysis brought out that paddy productivity in Ludhiana has been positively impacted by increased minimum temperature (during 27th-30th weeks), minimum temperature (during 38th-41st weeks), maximum temperature (during 32nd week), rainfall (during 40th week) and relative humidity (during 40th-41st weeks), while negatively influenced by maximum temperature (during 37th week), maximum temperature (during 41st week). Further, the result indicated that if minimum temperature increases by 1°C during 27th-30th weeks, paddy productivity would be significantly augmented by 332 kg/ha. Similarly, an increase of 1°C in maximum temperature during 32nd week, the paddy productivity would increase by 125 kg/ha (Table 5).

TABLE 5. ESTIMATES FOR IMPACT OF CLIMATE FACTORS ON PADDY PRODUCTIVITY IN LUDHIANA DISTRICT OF PUNJAB

Variables (1)	Linear Coefficient (2)
Constant	-3069.48 <sup>NS</sup> (5684.22)
X <sub>1</sub> (Tmin 27th-30th weeks)	332.69** (126.02)
X <sub>2</sub> (Tmin 38th-41st weeks)	94.78 <sup>NS</sup> (88.58)
X <sub>3</sub> (Tmax 32nd week)	125.29* (68.84)
X <sub>4</sub> (Tmax 37th week)	-82.63 <sup>NS</sup> (68.86)
X <sub>5</sub> (Tmax 41st week)	-125.64 <sup>NS</sup> (84.89)
X <sub>6</sub> (Rain 40th week)	17.69 <sup>NS</sup> (23.28)
X <sub>7</sub> (Relative humidity 40th-41st weeks)	12.39 <sup>NS</sup> (28.81)
R-square	0.573

\*\* and \* indicate Significance at 5 and 10 per cent level respectively and NS indicates non-significant. Tmin indicates average minimum temperature. Tmax indicates average maximum temperature. Figures in parentheses are the standard errors.

(F) *Technological Factors*

To estimate the impact of mechanisation (tractor) on paddy productivities in the sample district, tractor population was regressed on paddy productivities using better

suited log-linear (Cobb-Douglas) function. The result showed that tractor mechanisation had positive and significant impact on paddy productivities. Elasticity coefficients of mechanisation implied that 1 per cent increase in tractor population would lead to increase in paddy productivity by 0.19 per cent in Ludhiana district. Fertiliser usage had positive and significant impact on paddy productivities, which implied that 1 per cent increase in fertiliser usage significantly increased the paddy productivity by 0.29 per cent. Similarly, increased high-yielding varieties area had positive and significant impact on paddy productivity, i.e., with 1 per cent increase in high-yielding varieties area, paddy yield would increase by 1.11 per cent. The results further highlighted that irrigation had positive and significant impact on paddy productivities. With 1 per cent increase in irrigated area the paddy productivity would increase by 1.62 per cent in Ludhiana district.

#### (G) *Climate and Technological Factors*

Having analysed the impact of climate and technology in isolation, effort was also made to estimate the combined impact of both. For this all climate and technological variables have been amalgamated in one equation. To analyse the combined impact of climate and technology on paddy productivity, Cobb-Douglas production function was found better fit. The results based on Cobb-Douglas production function showed that minimum temperature (during 27th-30th weeks), minimum temperature (during 38th-41st weeks), maximum temperature (during 32nd week), maximum temperature (during 37th week) and rainfall (during 40th week), mechanisation (tractor), fertiliser usage and high-yielding varieties area have positive bearing, while maximum temperature (41st week), relative humidity (40th-41st weeks) and irrigation have negative bearing on paddy productivity in Ludhiana district. The estimates of mechanisation (tractor), fertiliser usage and maximum temperature came out to be significant. It indicated that 1 per cent increase in mechanisation (tractor) and fertiliser usage, paddy productivity would significantly be increased by 0.32 and 0.36 per cent respectively, while 1 per cent increase of maximum temperature during 41st week would lead to decrease in the paddy productivity by 0.85 per cent (Table 6).

#### (H) *Climate and Technological Factors-Refined Model*

As above used climate-technology function suffered from the problem of multicollinearity among various technological parameters, i.e., mechanisation (tractor), fertiliser, high-yielding varieties and irrigation, the modified form of climate-technology model was developed by amalgamating all the technological variables in the form of composite technological index. The results of refined and final climate-technology model has been retained and discussed from policy point of view.

TABLE 6. ESTIMATES FOR IMPACT OF CLIMATE AS WELL AS TECHNOLOGICAL FACTORS ON PADDY PRODUCTIVITY IN LUDHIANA DISTRICT OF PUNJAB

Variables (1)	Cobb-Douglas Coefficient (2)
Constant	24.86*** (8.88)
X <sub>1</sub> (Tmin in 27th -30th weeks)	0.56 <sup>NS</sup> (0.97)
X <sub>2</sub> (Tmin in 38th-41st weeks)	0.34 <sup>NS</sup> (0.30)
X <sub>3</sub> (Tmax in 32nd week)	0.39 <sup>NS</sup> (0.41)
X <sub>4</sub> (Tmax in 37th week)	0.1 <sup>NS</sup> (0.38)
X <sub>5</sub> (Tmax 41st week)	-0.85* (0.48)
X <sub>6</sub> (Rain 40th week)	0.01 <sup>NS</sup> (0.03)
X <sub>7</sub> (Relative humidity in 40th-41st weeks)	-0.26 <sup>NS</sup> (0.30)
X <sub>8</sub> (Tractor)	0.32** (0.13)
X <sub>9</sub> (Fertiliser)	0.36** (0.17)
X <sub>10</sub> (HYVA)	-3.88*** (1.33)
X <sub>11</sub> (Irrigation)	0.34 <sup>NS</sup> (0.25)
R-square	0.755

\*\*\*, \*\* and \* indicate level of significance at 1, 5 and 10 per cent respectively and NS indicates non-significant. Figures in parentheses are the standard errors. HYVA indicates high-yielding varieties area. Tmin indicates minimum temperature. Tmax indicates maximum temperature.

The modified climate-technological model based on better fitted Cobb-Douglas function brought out that the paddy productivity in Ludhiana district was negatively and significantly impacted by maximum temperature during 41st week. Elasticity coefficient of this variable indicated that with 1 per cent increase in maximum temperature during 41st week, the paddy productivity would decline by 0.55 per cent. Oppositely, an increase of 1 per cent in composite technological index, the paddy productivity would increase by 0.1 per cent. The value of coefficient of multiple determinations ( $R^2$ ) showed that about 62 per cent variations in paddy productivity in Ludhiana district has been captured by various independent variables included in the model (Table 7).

## IV

## CONCLUSIONS

It can be inferred from the climate parameters deviation assessment that positive change in periodical monthly average minimum temperature has been steady and significant for the months of June (1.4°C), July (1.5°C), August (1.6°C), September

TABLE 7. ESTIMATES FOR IMPACT OF CLIMATE AND COMPOSITE TECHNOLOGICAL INDEX ON PADDY PRODUCTIVITY IN LUDHIANA DISTRICT OF PUNJAB

Variables (1)	Cobb-Douglas Coefficient (2)
Constant	7.71* (4.24)
X <sub>1</sub> (Tmin 27th-30th weeks)	0.15 <sup>NS</sup> (0.88)
X <sub>2</sub> (Tmin 38th-41st weeks)	0.12 <sup>NS</sup> (0.35)
X <sub>3</sub> (Tmax 32nd week)	0.43 <sup>NS</sup> (0.46)
X <sub>4</sub> (Tmax 37th week)	-0.32 <sup>NS</sup> (0.43)
X <sub>5</sub> (Tmax 41st week)	-0.55* (0.31)
X <sub>6</sub> (Rain 40th week)	0.01 <sup>NS</sup> (0.02)
X <sub>7</sub> (Relative humidity 40th-44th weeks)	0.23 <sup>NS</sup> (0.31)
X <sub>8</sub> (Composite technological index)	0.09** (0.04)
R-square	0.623

\*\* and \* indicate significance at 5 and 10 per cent level respectively and <sup>NS</sup> indicates non-significant. Figures in parentheses are the standard errors. Tmin indicates average minimum temperature. Tmax indicates average maximum temperature.

(1.9°C) and October (2.1°C) during *khariif* season. The average maximum temperature has increased only during the month of August (0.5°C), while it decreased for the months of June (1.4°C) and September (0.6°C). The average precipitation received has increased during all months except August revealing *khariif* season rainfall has seen an increasing trend in Ludhiana. Further, the magnitude of increase during the months of September (46.7 mm) and October (15.2 mm) came out to be significant. The relative humidity during *khariif* season increased during almost all months i.e. June (10 per cent), July (6 per cent), August (1.5 per cent), September (6.8 per cent) and October (6 per cent).

After series of efforts, the study identified climate-composite technological index model as a better fitted model to describe the impact of climate as well as technology on paddy productivity. The analysis brought out that minimum temperature (during 27th-30th weeks), minimum temperature (during 38<sup>th</sup>-41<sup>st</sup> weeks), maximum temperature (at 32nd weeks), rainfall (at 40th week), relative humidity (during 40th-41th weeks), composite technological index have positive, while maximum temperature (at 37th week) and maximum temperature (at 41st week) have showed negative influence on paddy productivity in Ludhiana. The positive and significant coefficient of composite technology index implied that with an improvement in composite technological index by 1 per cent, the paddy productivity would be augmented by 0.095 per cent, whereas negative and significant coefficient of maximum temperature (at 41st week) implied that with 1 per cent increase in

maximum temperature (at 41st week), the paddy productivity would decrease by 0.546 per cent.

It is concluded based on the above discussion that Ludhiana district has experienced increase in the level of temperature, post-monsoon rainfall and relative humidity. Regarding the impact of climate change on paddy productivity, the study summarises that, there was a clear negative influence of temperature maximum (during 37th and 41st week) on yields, while positive influence was observed for increase in minimum temperature (both during 27th-30th and 38th-41st weeks), maximum temperature (during 32nd) and rainfall (during 40th week). Thus, policy makers, researchers, farmers and agro-based industries need to understand the changing scenario of climate and its impact on paddy productivity on time, so that, proper planning and development of suitable agronomic and cropping practices, as per the shifting condition and its intensity to effect the paddy crop, becomes possible.

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