# How Susceptible is India's Food Basket to Climate Change?

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## Abstract

Food security in India is largely associated with the sufficiency of cereals especially fine cereals in the country. In fine cereals like paddy and wheat crop productivity is decelerating. The deceleration in productivity has different kind of implications for the land-scarce society. This deceleration in productivity is often explained with technological maturity, resource use inefficiency, resource degradation and similar other factors. Interestingly the effect of climate change on productivity is often ignored. Whereas, significant changes in climate are being reported from all around the world. Experiment-based simulation studies have also found significant effect of changes in climate on the productivity of crops in certain part of country. Incidentally the field-based studies that clearly shows effect of climate change on agriculture are not too many. Results of some of the field-based studies on the above subject are too aggregate; the effect of changes in climate will however vary across crops. The relative susceptibility of different cereals to the climatic change has potential to reorient the existing cereal basket of country for achieving the food security.

In this backdrop the present study evaluates effect of climate change on the acreage and productivity of important cereals in the country. Cereals in the present analysis are paddy, wheat, maize, bajra and sorghum. The states selected for the analysis are Bihar, Gujarat, Haryana and Tamil Nadu. These states located in different regions of country present different climatic situations. The study is based on secondary information; time series data on climate related variables like temperature and rainfall are collected from Indian Meterology Department, Ministry of Earth Sciences, Government of India, New Delhi. Whereas information on the yield of crop is obtained from Department of Economics and

Statistics, Ministry of Agriculture, Government of India, New Delhi. Reference period for the present study is 1990-91 to 2007-08. The study uses non parametric Mann-Kendall test to ascertain trend of temperature and rainfall in each of the selected states.

Analysis of climate related variables suggests that temperature both minimum and maximum is rising for most of the months. There are some exceptions; the minimum temperature in the selected cold months (December, January) has declined in states like Bihar, Haryana and Gujarat. Rainfall pattern is changing and this change is varying across states. Rainfall during monsoon (June-October) has increased in Gujarat and Haryana but decreased in Bihar and Tamil Nadu. The above state-wise trend in rainfall is observed during the non-monsoon season as well. The month-wise trend in rainfall also indicates towards the changing pattern of rainfall; rainfall during June and August is showing an increased trend, while rainfall is decreasing in the month of July.

Further to ascertain effect of climate change on important cereals the present study works out association of crop acreage and yield with climate related variables and deviation in these variables. The climate related variables are the maximum- and minimum-temperatures and rainfall during the season. The deviation in temperature and rainfall is assessed from average of these variables during the period 1961-90. This period is often considered as benchmark for comparing the global warming related changes. The yield of individual crop is again regressed on climate related variables and time trend. Findings from analysis will elucidate relative sensitivity of different cereals to the ongoing changes in the climate. The study will be able to delineate distinct changes in the climate and the same will be helpful for farmers, extension workers, plant breeders, policy makers and to all alike.

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## I. Introduction

A significant change in the statistical distribution of weather over a long period is widely referred to as climate change.[1] The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) concludes that the warming of the climate system is unequivocal.[2] There is a chance of more frequent floods and droughts, disease outbreaks and water scarcity in countries. This will seriously impact the agriculture sector (Nelson et al., 2010) and threaten the food security of countries (Parry et al., 2005). The food security related impacts are reported to be potentially more acute for regions like sub-saharan Africa and South Asia (Lobell et al., 2008). Such concerns are important for India as more than 20 percent of India's population is undernourished (FAO, 2010). India ranks 66th in the Global Hunger Index of 118 countries (IFPRI, 2011). The country, however, spends around 1.3 percent of its gross domestic product (GDP) on subsidy for the food security of the nation (GOI, 2012).

The warming of the climate system will further aggravate the food security related capabilities of India. Though food and food security is a broad concept[3], from the perspective of government intervention in India for food security, food basket is the minimum-cost combination of food grains that provide an adult 2,100 calories (in urban areas) or 2,400 calories of energy in urban and rural sectors of country. Food security at the aggregate level is often perceived to be associated with the sufficiency of fine cereals

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[1] In relation to climate change 'long period' refers generally to period varying from a decade to centuries. The IPCC considers the average of climatic variables during 1960-90 as the benchmark to measure change in climatic factors during a period.

[2] The IPCC reports that 11 out of the 12 years between 1995 and 2006 have been the warmest since 1850 (IPCC, 2007).

[3] Food includes any nourishing substance taken into the body to sustain life. Food security warrants that all people at all time have physical and economic access to sufficient, safe and nutritious food to meet dietary needs for an active and healthy life (FAO, 1989);

(paddy and wheat) in the country. Following the bio-chemical technology of the 1960s, the country to a large extent has also achieved self-sufficiency in fine cereals. The dominance of fine cereals under the public distribution programme has altered the cereal-eating habits of people in favour of fine rather than coarse cereals. This has also resulted in concentration of fine cereals (paddy and wheat) in the cereal production of country.[4] Climate change related threats will increase in a concentrated production system for food.

Nevertheless, a continued emphasis on fine cereals in the public distribution programme of the country in the light of the decreasing factor productivity of these cereals[5] has caused an increase in the acreage under paddy and wheat. But considering the intense competition in India for land, the acreage-induced increase in production has serious implications for the production of other crops and the nutrition security of individuals in the country. The deceleration of factor productivity in cereals is often explained with factors like technology fatigue and degradation of resources; the effect of changes in climate is often ignored. The present study attempts to address some of the above concerns for the country. The study has the following specific objectives; first, to assess changes in climatic factors like temperature and rainfall; second, to study the effect of certain climatic factors like rainfall and temperature on the productivity of paddy and wheat. The present paper is organized in to five sections; the next section (Section II) on methodology discusses the data, analytical techniques, reference period and reference-states of this study. The results of the above objectives are discussed separately in Section III and Section IV respectively. Section V concludes the study.

## II. METHODOLOGY

The present paper studies changes in climate with variables like temperature (maximum and minimum) and rainfall. Climate related data are obtained from 'Data Archive' of the Indian Institute of Tropical Meterology (IITM), Pune. In the above archive temperature data are available from 1901 to 2003 while rainfall data are available from 1871 to 2010 for the selected climatic regions of the country. The reference periods for analysis of data

[4] Paddy and wheat together account for four-fifths of total cereal production in the country. (GOI 2011)
[5] There is enough literature to suggest a decline in the factor productivity of fine cereals in the country (Paroda, 1998).

for temperature and rainfall are 1901-2003 and 1871–2010 respectively. The non parametric Mann-Kendall (MK) test is used to discern trend in climatic variables: maximum-, minimum- temperature and rainfall. While identifying trend in climatic variables the MK test has certain advantages over other methods (Gilbert, 1987). The MK statistics (S) is calculated using the following formula:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad \dots(1)$$

$$sgn(x_j - x_k) = \begin{cases} +1 \ if \ x_j - x_k > 0 \\ 0 \ if \ x_j - x_k = 0 \\ -1 \ if \ x_j - x_k < 0 \end{cases} \quad \dots(2)$$

Where, n is the number of observed data series, $x_j$ and $x_k$ are values in periods j and k, respectively, and j>k. A positive value of S is an indicator of an increasing trend, while negative value indicates a decreasing trend. To statistically quantify significance of the above trend, Kendall presents a normal-approximation test for data sets with more than 10 values, and there are not many tied values within the date set. The normalized test statistics Z is as under,

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} \ if \ S > 0 \\ 0 \qquad if \ S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} \ if \ S < 0 \end{cases} \quad \dots(3)$$

VAR(*S*) is determined as:

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \int_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right] \quad \dots(4)$$

where, q is the number of tied groups and $t_p$ is the number of data values in the pth group.

The $Z_{1-\alpha/2}$ is the critical value of Z from the standard normal table; for 95% level of confidence the value of $Z_{1-\alpha/2}$ is 1.96. If $|Z|>Z_{1-\alpha/2}$, null hypothesis is rejected and a significant trend exists in the time series. A positive value of Z indicates an upward trend while negative value of Z indicates downward trend in variable.

The present study attempts to assess changes in climatic factors and study its effect on fine cereals in the country. The states of Bihar, Gujarat, Haryana and Tamilnadu chosen from East, West, North-West and South of country respectively represents different climatic regions of the country.[6] These states also present different historical stages in adoption of bio-chemical technology for the above crops in the country. The effect of changes in climate will not only vary across regions but also across stages of crops in a region. The crop stage particularly sensitive to high temperature is flowering for paddy while it is grain filling for wheat.[7] These stages occur during the month of September in paddy and March in wheat crops in the study region.

The states chosen to assess the effect of climatic variables on paddy are Bihar, Haryana and Tamil Nadu; whereas the states chosen for wheat are Bihar, Gujarat and Haryana. The study hypothesizes that the changes in climatic variables (maximum- and minimum-temperature, rainfall) may affect productivity of crops in different way. An increase in temperature for instance will affect yield of crops adversely by reducing the life cycle of plant. However the increase of temperature in association with the increased concentration of carbon dioxide may affect yield of same crop positively. The present study however hypothesizes that the increase in temperature will affect yield of paddy and also wheat adversely. The adverse relationship between climatic variable like temperature and productivity will be particularly strong during flowering and grain filling stage of paddy occurring during September in paddy and March in wheat.

The minimum temperature can be construed as the night temperature. A high night temperature is often due to presence of cloud in the sky; cloud restricts radiations of harmful rays out of the crop environment. This also restricts formation of dews. The dews in particular are important for crops like wheat in the flowering and grain-filling stage of crop. The increase in night temperature is therefore hypothesized to effect crop productivity adversely. The present study hypothesize that rainfall has favourable effect on productivity of crops; the effect of rainfall on wheat is ignored since wheat is largely

[6] The IITM divides country in several climatic regions. Regions on the basis of rainfall are North West (NW), West Central (WC), Central North East (CNE), North East (NE), and Peninsular (PE) India. Whereas regions on the basis of temperature are Western Himalaya (WH), North West (NW), North Central (NC), North East (NE), Interior Peninsular (IP), East Coast (EC), and West Coast (WC) of India.

[7] In paddy high temperature during flowering and inflorescence stage causes sterility of spikelet and poor grain formation. Similarly in wheat high temperature and dearth of rain during the stage of grain filling discourages formation of bold grains in wheat

an irrigated crop in the country. Previous studies also suggest that winter crops are more sensitive to temperature rather than rainfall (Boomiraj et al. 2010).

To test the above hypotheses, crop yield is regressed separately on different climatic variables for period between 1980 and 2010. Besides the above climatic factors the present study also uses time-trend in regression. Infact in the climate change related impact studies linear time trend has been frequently used to remove non-climatic influences such as technology improvement (Li Xiang et al., 2011), adoption of new cultivars, and crop management practices (Lobell and Field, 2007).The regression analysis uses different variants of regression models to capture different kind of relationships between climatic variables and yield of fine cereals. Information on the yield of paddy is obtained from Agriculture Statistics at a Glance published from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India (GOI), New Delhi and Fertilizer Statistics published from Fertilizer Association of India, New Delhi.

## III. Pattern of Changes in Climatic factors

Several studies including the fourth Assessment Report of the IPCC have observed increasing trend in global surface temperature and sea levels; many of these studies have also found significant changes in precipitation trend across regions, countries, continents and globe (IPCC, 2007).[8] Several India specific studies also observe increase in temperature and changes in the pattern of rainfall across space and time (IMD, 2010).[9] The pattern of changes in climatic factors has been studied by many researchers with different objectives (i.e., Krishna Kumar et al., 2004, Kothawale et al., 2010 etc.). The present study assesses changes in climate in the selected regions of countries. These regions present diversity of climate and are also important cereal growing regions of the country.

[8]The IPCC suggests increase of precipitation trend in the Eastern parts of North and South America, Northern Europe and Northern and Central Asia; while a significant decreasing precipitation trend in the Sahel, the Mediterranean, Southern Africa and parts of Southern Asia.

[9] According to IMD (2010), between 1901 and 2005 annual mean temperature (AMT) for the country as a whole has risen by 0.51°C; the AMT has been consistently above normal since 1993, normal is based on period 1961-1990.

The present section illustrates pattern of changes in climatic variables like temperature (maximum and minimum) and rainfall for chosen regions across months. A brief account of results of MK statistics is presented in Table 1; while detailed results of MK statistics and its associated estimates are presented in Appendix Table 1A. As is reflected from table maximum-temperature is increasing for most of months in the chosen regions of country. There are few exceptions to the above trend; maximum-temperature has decreasing trend for months like May and June in Haryana. The decreasing trend in maximum temperature is however statistically insignificant.

The month-wise trend of minimum-temperature in the chosen regions present mixed results. The increasing trend in minimum-temperature is more conspicuous; the increasing trend is also statistically significant in many cases. The minimum-temperature is decreasing in many months, though the above decrease is often statistically insignificant. The decreasing trend in minimum-temperature is generally observed in pre-monsoon and monsoon months[10]. However the minimum-temperature is increasing during post-monsoon and winter months. Interestingly the minimum-temperature is also decreasing in certain cold months like January.

At regional level trend in minimum temperature presents slightly different picture. In the coastal regions (Gujarat, Tamilnadu) minimum temperature is largely increasing; whereas in the Indo-gangetic plain (Bihar, Haryana) decreasing trend in minimum-temperature dominates. The minimum temperature in these regions has also declined in relatively cold month of January. The collation of trends in maximum- and minimum-temperatures suggests interesting findings; in certain months like January the maximum-temperature is increasing in Haryana (NW) while the minimum temperature is decreasing during the same month. This indicates towards the widening of range of diurnal temperature in the forthcoming years.

Rainfall is another important climatic variable; the month-wise trend in rainfall for country suggests decreasing trend during monsoon and winter months. It may be noted

[10] As per the IMD, there are four season in India; the months with corresponding seasons are: Winter Season – January and February; Pre-Monson Season – March, April, and May; Monson Season – June, July, August, and September and Post-Monson Season – October, November and December.

that more than 85 percent of rainfall in the country is reported during these period. The month-wise trend in rainfall is statistically insignificant for most of the months. Rainfall trends are increasing during pre- and post-monsoon months; but it is decreasing in monsoon and winter months. At the regional level there is wide disparity in rainfall trends across months. In Haryana in 10 out of 12 months rainfall trend is increasing. Whereas in Gujarat (West Coast region), in eight out of 12 months rainfall trends are decreasing. Rainfall trend in Tamil Nadu (East Coast region) has been insignificant for all the reference months; in seven out of 12 months rainfall is increasing. In Bihar also in seven out of 12 months rainfall is increasing. The increase has been significant in May incidentally this is the month just before the monsoon season starts. Infact rainfall is decreasing during key monsoon months: June, August and September. This possibly indicates towards the changes in the pattern of monsoon

The above discussions on the month-wise trend in temperatures suggest that there is an unambiguous increase in day temperature as it is reflected with the maximum temperature across regions. The increasing trend in night temperature or minimum-temperature is more conspicuous in the South of tropics. Incidentally the night temperature is decreasing for many months in the North of Tropics, though this decrease is often statistically insignificant. The rainfall trend across months and regions suggests towards the changes in pattern of rain in the forthcoming years. Rainfall trend also appears to have been shifting across regions and also months.

**IV. Effect of Climate Change on Productivity of Paddy and Wheat**

The above changes in climatic factors will affect agriculture and economy adversely (Nelson et al., 2009). The studies to assess effect of changes in climatic variables on agriculture production in the Indian context can broadly be grouped in two; the first, experiment-based simulation studies, examples of such studies are Saseendran et al., 2000; Pathak et al., 2003; Aggarwal, 2008; Kalra et al 2008; and Boomiraj et al. 2010. Some of the above studies undertaken during the latter years have found significant negative effect of changes in climate on the yield of crops in the country. However the results of controlled agricultural experiments in a laboratory-like setting differ from the realized outcomes at the level of farm. The studies that use actual field-based data are therefore important; studies in this category are Kumar and Parikh, 1998; Kumar and Parikh, 2001; Sanghi et.al., 1998; Kumar, 2009.

The field-based studies to assess effect of changes in climate on agriculture are based on the Ricardian approach (Mendelsohn et al. 1994) that establishes functional relationship between land values and climatic variables along with other control variables. The land values in the Indian context are often replaced by the farm level net revenue. The results from such studies often present a generalized scenario.[11] Though such results are very useful in generalizing impact of climate change on agriculture; it is too naïve to presume that certain changes in climatic factors will affect all crops uniformly throughout their physiological life. The present study infact argues that changes in climatic factors (temperature, rainfall) will affect yield of different crops in different way; such effects for a crop will also vary across regions and stages of a crop like panicle initiation, flowering, maturing and ripening of crops. The present study is about analyzing the effect on fine cereals: paddy and wheat in India. The underlying assumptions for relation between climatic variables and the yield of crops at times differ, so differs the specification and variables used in the regression analysis. The results of these crops have therefore been presented and discussed separately in following sub-sections.

### 4.1 Effect of Climate Change on Productivity of Paddy

Several studies suggest that paddy as compared to many other crops is more sensitive to climatic factors (Peng, 2004; Auffhammer et al. 2006; Welch et al. 2010). The changes in the climatic variables (maximum- and minimum-temperature, rainfall) are hypothesized to affect productivity of crops in different way. To test the above hypotheses paddy yield is regressed on temperatures: maximum, minimum and rainfall during the entire period of summer season (May-October), and also on the maximum- and minimum-temperature during the month of September. Since regression of yield on different climatic variables together is not providing us logical results, the yield is regressed separately on climatic variables. Time-trend is other explanatory variable besides climatic factors. After several

[11] Kumar (2009) for instance envisages that an increase in temperature by two degree and change in precipitation by seven percent would result in decline of farm-level net revenue by nine percent. This decline is estimated to be 3 percent once spatial effect using the spatial-error model is account for.

iterations with different forms of equations (log-linear, others) the log-linear form of equation is finally chosen as this was the most robust of all the estimated equations for paddy.

The estimated results of multiple regressions are presented in Table 2. Table shows estimated equation coefficients with t-statistics and adjusted-$R^2$. In the above table temperature during the entire summer season (May to October) is referred as ‘TW’; while temperature during flowering and grain filling stage in paddy (September), is abbreviated as ‘tw’. The significance of trend coefficients in all equations (Table 2) suggests importance of non-climatic variable in explaining yield of paddy in reference states: Haryana, Bihar and Tamil Nadu. The value of intercept is high and statistically significant in all equations. This indicates that there are variables other than in the current specification that affect yield of paddy in reference states.

The estimates of maximum temperature in all equations are negative; these estimates are statistically significant for TN and Haryana. These estimates suggest that increase of maximum temperature during summer season is affecting yield of paddy adversely. In Haryana, estimates of minimum temperature are negative and also significant suggesting that the increase of minimum temperature is affecting yield of paddy adversely. The above results to some extent are in line with the simulation based studies (Sinha and Swaminathan 1991, Hundal an Kaur 1996, Pathak et al. 2003).

The above relational analysis with temperature for a shorter summer period ‘tw’ (September) presents similar results. The estimates of maximum temperature are negative in each of the referred state, while the estimates of minimum temperature are negative only in Haryana. The negative sign of estimate for minimum temperature during the month of September is also significant in Haryana. Interestingly paddy yield is more sensitive to minimum than to the maximum temperature in Haryana. Peng et al., (2004) have also found similar results from locations where spikelet sterility on account of high temperature is rarely observed.

Table 2 indicates that rainfall ‘R’ has significant positive effect on the yield of paddy in Bihar. The rainfall has negative effect on the yield of paddy in Haryana and Tamil Nadu; though the negative effect of rainfall is statistically not significant. In Bihar bulk of cultivated area under paddy is rainfed or unirrigated, therefore the effect of rain on the yield of paddy is positive and also significant. Whereas the most of area under paddy in the latter states is irrigated; with assured irrigation in these states effect of rain on the current yield of paddy in these states is not significant. There are infact evidences of rain increasing the chances of pest infestation and affecting yield of paddy adversely.

The above discussion in brief highlights importance of non-climatic variables on the yield of paddy. Among different climatic variables rainfall has significant positive effect on the yield of paddy in Bihar. The increase in day temperature is affecting yield of paddy adversely in all the chosen states; the effect is significant for Haryana and Tamil Nadu. The increase of temperature during the month of September has significant negative effect on the yield of paddy at least in Haryana. The night temperature is also affecting yield of paddy adversely in Haryana.

### 4.2 Effect on Productivity of Wheat

Wheat is also sensitive to climatic factors. This requires long period of low temperature (November-March) for physiological growth and moderately high temperature at the time of ripening of grain (April). In the life cycle of wheat, two most important stages that require water are crown root initiation (20-22 day after sowing, in December) and the stage of flowering and grain filling (March). Inspite of the sensitivity of wheat to water, effect of rain on the yield function of wheat is not significant since bulk of wheat is cultivated on the assured irrigated area.

Among climatic factors temperature is important; the yield of wheat is regressed separately on the maximum- and minimum- temperature for period between 1980 and 2003. In the above relational analysis the yield is regressed first on the maximum temperature during the entire winter season (November to April) referred as 'winter temperature ($TW_x$)'; and also on the maximum temperature during flowering and grain filling stage (March) of crops, abbreviated as '$tw_x$'. The other explanatory variable, besides temperature, in the present regression is the time-trend.

After iterations with several specifications of equations the log-linear form of equation is finally chosen for Bihar and Gujarat; while quadratic is preferred for wheat in Haryana. Interestingly in Haryana also the log-linear form of equation is the most suitable to capture the effect of maximum temperature during the month of March. The estimated equations with adjusted-$R^2$, estimated coefficients and t-statistics are presented in Table 3.

A glance to equations in Table 3 suggests that many estimates for climatic variables are not significant; yet most of the equations on the basis of coefficient of determination adjusted with degree of freedom ($\bar{R}^2$) are found robust. The degree of robustness varies across states and also forms of specifications. The significance of trend coefficients in all equations (Table 3) suggests importance of non-climatic variables in explaining yield of wheat in the chosen states Bihar, Gujarat and Haryana.

The results of climatic variables are discussed below. The estimates for maximum temperature during the winter season ($TW_x$) are weak for all the chosen states. The signs of estimates also vary across states; it is negative in Gujarat but positive in Bihar with the similar specification (log-linear). The estimate for Bihar is however too weak to be considered seriously. In Haryana a quadratic specification with positive sign for linear-variable and negative sign for square term of variable ($TW_x$) suggest that increase of temperature ($TW_x$) initially increases productivity of wheat but subsequent increase in $TW_x$ affects productivity of wheat in Haryana adversely.

The coefficient for maximum temperature during the month of March ($tw_x$) fits into log-linear form of specification for all states. The sign of the estimate for the above variable is negative; though the estimate is significant only in the state of Gujarat. The negative sign suggests that increase in day temperature during the month of March affects yield of wheat adversely in the chosen regions of country; the adverse effect is particularly strong in Gujarat.

The minimum temperature can be construed as the night temperature. The increase in night temperature is reported to have adverse effect on productivity of crop (Peng et al., 2004). The sign of the above estimate for chosen states is as per expectation. The estimated coefficient for minimum temperature is negative in log-linear specification for Bihar and Gujarat. The estimate for minimum temperature is significant though weak (at 10 percent) for Bihar; while the estimate is not significant for Gujarat. In Haryana relation between minimum temperature during winter season (Nov-April) and yield of wheat is captured in quadratic form with the negative sign for square of the variable.

The above discussion highlights importance of temperature: maximum and minimum for the yield of wheat in country. The nature and strength of relation between climatic variables and yield of wheat however varies across states. The effect of increase in temperature during winter season (on the yield of wheat) in a relatively colder place like Haryana is captured in quadratic and not log-linear form of equation as of Bihar and Gujarat. A different specification for crop in different states has important implications / suggestions for relation between productivity and temperature of wheat in the country. The effect of temperature is strong for state like Gujarat where tempearture is relatively higher than the state like Hayana.

The results and discussions above clearly indicate towards the warming of climate system. The same has also started affecting productivity of fine cereals in the country. The productivity-induced growth in cereals is however important for food security and also balanced growth of agriculture and economy. The effect of climate related aberrations on the yield of crops may vary across crops: paddy and wheat. There are limited studies that work out relative vulnerability of crops in the light of changes in climatic factors (Jharwal, 2011, Kumar et al., 2011). These studies based on actual field based data suggest that fine cereals are less vulnerable than coarse cereals.[12] Again in coarse cereals Kumar et al., 2011 found that jowar and bajra are more vulnerable than maize. The theoretical literateur however suggests that coarse cereals and millets are more resistant to climatic variability (Deshpande and Rao, 2004). In this perspective importance of cereals other than paddy and wheat can not be over-emphasized. The existing incentive structure for paddy and wheat however restricts farmers to produce other cereals. Much of this incentive has emerged from the existing cereal basket of public distribution programme of the country. The study therefore argues for diversification of cereal basket in the existing public distribution programme of the country.

[12] The relative vulnerability of these cereals can not be compared since fine cereals are largely cultivated in irrigated conditions while coarse cereals are mostly rain-fed in the country. Nevertheless the coarse cereals are often cultivated on marginal lands.

## CONCLUSIONS

Using a non-parametric test the study ascertains trends in temperature and rainfall across months in selected regions of the country. The maximum temperature or day temperature has risen consistently in the chosen states: Bihar, Gujarat, Haryana and Tamilnadu. The minimum or night temperature has risen for most of the months in coastal states (Tamil Nadu, Gujarat). Though the increasing night temperature is the most conspicuous trend in Haryana and Bihar; for few months the night temperature has also declined. The decreasing trend in the night temperature has been statistically insignificant. A comparison of the maximum and minimum temperatures suggests increased disparity in temperatures during the day. Rainfall shows different patterns across the chosen states; rainfall is increasing in Haryana but decreasing in Bihar, Gujarat and Tamil Nadu. The month-wise trend in rainfall also indicates the changing pattern of rainfall across months. Though India gets the bulk of its rain during monsoon (June-October); the pattern of rain during monsoon months has changed. Rainfall is increasing between August and October months and decreasing in other months of the season.

The effect of the above changes in climatic factors on the yield of fine cereals is assessed in a multiple regression framework. The estimated equations with limited variables have been robust and significant. A highly significant estimate of the time-trend in all equations suggests that non-climatic factors are important for crop productivity in the country. The present analysis also establishes the importance of rainfall on the yield of fine cereals in the rain-fed regions of the country. The effect of temperature on the productivity of cereals varies across crops, states, seasons and months. While assessing the effect of day temperatures on the yield of fine cereals two variants of temperature were used: first, maximum temperature during the entire crop season; and second, maximum temperature during the month of flowering and the grain-filling stage of crops. Though regression tries various specifications, the log-linear captures the relationship between the temperature and productivity of crops in the large part of country. The above relationship has, however, been quadratic for wheat in Haryana.

Though there is enough evidence to suggest that the temperature has started affecting productivity of cereals, the estimates in many cases remain weak. One of the most important reasons for weaknesses is the poor quality of data.[13] Changes in climatic factors and its effect on the productivity of fine cereals warrants actions from different stakeholders of development. Although farmers are adopting certain agricultural practices based on their perception of climate changes;[14] other agents of growth also need to recognize such problems and act appropriately. In the emerging scenario the widening of the cereal basket in the public distribution programme of the country will be one of the most important actions in relation to the food security of India.

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[13] The IITM data archive does not provide data on temperature for the years after 2003. Another important limitation of the data on temperature and rainfall as available to the ordinary researcher is the level of aggregation of data. The climate variable available in the IITM archive is for month. In actual, few days extreme weather in a month can cause irreparable damage to plants without any significant reflection of same on the average data for the month.

[14] Most farmers in Haryana have substituted late-sown wheat with other suitable crops; this is an example of farmers' adjustment or adaptation to climate change. Such acts of adjustment can become stronger with proper dissemination of knowledge about the changes in the climate.

**Table 1: Pattern of Climatic Variables in India and the Selected States (Bihar, Gujarat, Haryana and Tamilnadu)**

| State | **Maximum Temperature** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J1 | F | M1 | A | M2 | J2 | J3 | A | S | O | N | D |
| Bihar | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** |
| Gujarat | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** | **I** |
| Haryana | **I** | **I** | I | **I** | D | D | I | **I** | **I** | **I** | **I** | **I** |
| Tamilnadu | **I** | **I** | **I** | **I** | I | I | **I** | **I** | **I** | **I** | **I** | **I** |
| India | **I** | **I** | **I** | **I** | I | I | **I** | **I** | **I** | **I** | **I** | **I** |
| | **Minimum Temperature** | | | | | | | | | | | |
| Bihar | D | **I** | I | I | I | D | D | D | D | I | **I** | **I** |
| Gujarat | D | I | I | I | I | **I** | I | **I** | **I** | **I** | **I** | **I** |
| Haryana | D | I | I | D | D | D | D | D | I | I | I | D |
| Tamilnadu | **I** | **I** | **I** | **I** | I | D | I | **I** | I | **I** | **I** | **I** |
| India | D | **I** | **I** | I | D | D | D | D | D | **I** | **I** | **I** |
| | **Rainfall** | | | | | | | | | | | |
| Bihar | D | D | I | I | **I** | D | I | D | D | I | I | I |
| Gujarat | D | D | D | D | **D** | I | D | I | D | I | **I** | D |
| Haryana | D | I | I | **I** | I | I | I | **I** | I | I | **I** | D |
| Tamilnadu | D | I | I | I | D | D | I | D | I | D | I | I |
| India | D | I | I | **I** | I | D | D | I | D | I | I | D |

*Note:* Direction of trend is drawn from Table 1A, 2A, and 3A, (ii). I = Increasing and D = Decreasing, (iii) J1 = January, F = February, M1 = March, A = April, M2 = May, J2 = June, J3 = July, A = August, S = September, O = October, N = November, and D = December. (iv) Trends represented by bold letter are statistically significant at 5 % level.

**Table 2: Estimated Yield Equations in Relation to Climatic Factors for Paddy in the Selected State**

| | | |
|---|---|---|
| $Ln(Y^{W}_{b}) = 452.77 + 0.04\ R + 20.69\ TND$ | $\bar{R}^2 = 0.46$ | …1 |
| (2.25) (2.41) (4.58) | | |
| $Ln(Y^{W}_{b}) = 5127.50 - 13.93\ TW_X + 33.18\ TND$ | $\bar{R}^2 = 0.70$ | …2 |
| (1.72) (-1.45) (7.22) | | |
| $Ln(Y^{W}_{b}) = 2748.78 - 6.38\ tw_x + 31.47\ TND$ | $\bar{R}^2 = 0.68$ | …3 |
| (1.22) (-0.86) (7.01) | | |
| $Ln(Y^{W}_{b}) = -1403.39 + 9.95\ TW_N + 27.08\ TND$ | $\bar{R}^2 = 0.68$ | …4 |
| (-0.57) (0.89) (4.93) | | |
| $Ln(Y^{W}_{b}) = -127.66 + 4.16\ tw_n + 29.38\ TND$ | $\bar{R}^2 = 0.68$ | …5 |
| (-0.06) (0.47) (6.34) | | |
| $Ln(Y^{W}_{h}) = 2636.80 - 0.04\ R + 16.58\ TND$ | $\bar{R}^2 = 0.26$ | …6 |
| (15.00) (-1.33) (3.19) | | |
| $Ln(Y^{W}_{h}) = 8275.36 – 16.18\ TW_X + 8.57\ TND$ | $\bar{R}^2 = 0.16$ | …7 |
| (3.38) (-2.35) (1.51) | | |
| $Ln(Y^{W}_{h}) = 6448.95 – 11.49\ tw_x + 5.99\ TND$ | $\bar{R}^2 = 0.17$ | …8 |
| (4.06) (-2.47) (1.11) | | |
| $Ln(Y^{W}_{h}) = 8125.53 – 23.46\ TW_N + 9.06\ TND$ | $\bar{R}^2 = 0.14$ | …9 |
| (3.27) (-2.25) (1.56) | | |
| $Ln(Y^{W}_{h}) = 6005.96 – 14.89\ tw_n + 5.91\ TND$ | $\bar{R}^2 = 0.14$ | …10 |
| (3.87) (-2.24) (1.08) | | |
| $Ln(Y^{W}_{tn}) = 2460.64 - 0.02\ R + 26.00\ TND$ | $\bar{R}^2 = 0.14$ | …11 |
| (5.81) (-0.24) (2.44) | | |
| $Ln(Y^{W}_{tn}) = 22696.92 – 60.20\ TW_X + 49.26\ TND$ | $\bar{R}^2 = 0.44$ | …12 |
| (3.06) (-2.76) (4.11) | | |
| $Ln(Y^{W}_{tn}) = 10943.82 - 26.38\ tw_x + 48.11\ TND$ | $\bar{R}^2 = 0.30$ | …13 |
| (1.80) (-1.43) (3.39) | | |
| $Ln(Y^{W}_{tn}) = 21121.77 – 73.71\ TW_N + 52.52\ TND$ | $\bar{R}^2 = 0.31$ | …14 |
| (1.70) (-1.52) (3.42) | | |
| $Ln(Y^{W}_{tn}) = 7040.82 -19.05\ tw_n + 42.29\ TND$ | $\bar{R}^2 = 0.24$ | …15 |
| (0.64) (-0.43) (2.82) | | |

*Notes:* $Y^{W}_{b}$ = Rice Yield in Bihar, $Y^{W}_{g}$ = Rice Yield in Haryana, $Y^{W}_{tn}$ = Rice Yield in Tamilnadu, R = Rainfall, $TW_X$ = Maximum temperature during winter (*Rabi*) season, $tw_x$ = Maximum Temperature during flowering season, $TW_N$ = Minimum temperature during winter (*Rabi*) season, $tw_n$ = Minimum Temperature during flowering season, and TND = Trend.

**Table 3: Estimated Yield Equations in Relation to Climatic Factors for Wheat in the Selected States**

$$\text{Ln}(Y^{W}_{b}) = 7.05 + 0.001TW_{X} + 0.018\ TND \qquad \bar{R}^2 = 0.66 \qquad \ldots1$$

(6.31) (0.18) (6.25)

$$\text{Ln}(Y^{W}_{b}) = 7.26 - 0.0005\ tw_{x} + 0.019\ TND \qquad \bar{R}^2 = 0.65 \qquad \ldots2$$

(10.87) (-0.02) (6.25)

$$\text{Ln}(Y^{W}_{b}) = 8.39 - 0.009\ TW_{N} + 0.022\ TND \qquad \bar{R}^2 = 0.71 \qquad \ldots3$$

(14.00) (-1.91) (7.30)

$$\text{Ln}(Y^{W}_{b}) = 8.11 - 0.007\ tw_{n} + 0.022\ TND \qquad \bar{R}^2 = 0.69 \qquad \ldots4$$

(15.04) (-1.59) (6.78)

$$\text{Ln}(Y^{W}_{g}) = 8.39 - 0.003\ TW_{X} + 0.008\ TND \qquad \bar{R}^2 = 0.12 \qquad \ldots5$$

(8.39) (-0.81) (2.18)

$$\text{Ln}(Y^{W}_{g}) = 8.32 – 0.002\ tw_{x} + 0.008\ TND \qquad \bar{R}^2 = 0.14 \qquad \ldots6$$

(11.87) (-1.06) (2.37)

$$\text{Ln}(Y^{W}_{g}) = 7.39 + 0.001\ TW_{N} + 0.006\ TND \qquad \bar{R}^2 = 0.10 \qquad \ldots7$$

(13.13) (0.33) (1.80)

$$\text{Ln}(Y^{W}_{g}) = 7.92 - 0.003\ tw_{n} + 0.007\ TND \qquad \bar{R}^2 = 0.11 \qquad \ldots8$$

(17.00) (-0.72) (2.21)

$$Y^{W}_{h} = -41805.68 + 303.68\ TW_{X} – 0.52\ TW_{X}^{2} + 80.52\ TND \qquad \bar{R}^2 = 0.90 \qquad \ldots9$$

(-0.84) (0.88) (-0.86) (11.56)

$$Y^{W}_{h} = 7.45 + 0.001\ tw_{x} + 0.03\ TND \qquad \bar{R}^2 = 0.88 \qquad \ldots10$$

(16.94) (0.82) (11.62)

$$Y^{W}_{h} = -53823.24 + 873.65\ TW_{N} – 3.39\ TW_{N}^{2} + 82.98\ TND \qquad \bar{R}^2 = 0.91 \qquad \ldots11$$

(-2.83) (2.96) (-2.96) (16.30)

$$Y^{W}_{h} = -5225.69 + 111.81\ tw_{n} – 0.41\ tw_{n}^{2} + 80.14\ TND \qquad \bar{R}^2 = 0.91 \qquad \ldots12$$

(-0.40) (0.56) (-0.53) (13.28)

*Notes:* $Y^{W}_{b}$ = Wheat Yield in Bihar, $Y^{W}_{g}$ = Wheat Yield in Haryana, $Y^{W}_{h}$ = Wheat Yield in Gujarat, $TW_{X}$ = Maximum temperature during winter (*Rabi*) season, $tw_{x}$ = Maximum Temperature during flowering season, $TW_{N}$ = Minimum temperature during winter (*Rabi*) season, $tw_{n}$ = Minimum Temperature during flowering season, and TND = Trend.

**Apndx. Table 1A. Trends in Maximum-Temperature in India and the Selected States (Bihar, Gujarat, Haryana, and Tamil Nadu)**

| State | Months | MK Statistic | K-Tau Stat | Z-stat | P-value | Conclusion |
|---|---|---|---|---|---|---|
| Bihar | January | 694 | 0.13 | 1.98 | 0.02 | Significantly increasing |
| | February | 1468 | 0.28 | 4.18 | 0.00 | Significantly increasing |
| | March | 576 | 0.11 | 1.64 | 0.05 | Significantly increasing |
| | April | 939 | 0.18 | 2.68 | 0.00 | Significantly increasing |
| | May | 661 | 0.13 | 1.88 | 0.03 | Significantly increasing |
| | June | 857 | 0.16 | 2.44 | 0.01 | Significantly increasing |
| | July | 946 | 0.18 | 2.70 | 0.00 | Significantly increasing |
| | August | 2323 | 0.44 | 6.64 | 0.00 | Significantly increasing |
| | September | 1458 | 0.28 | 4.17 | 0.00 | Significantly increasing |
| | October | 1930 | 0.37 | 5.51 | 0.00 | Significantly increasing |
| | November | 2758 | 0.53 | 7.87 | 0.00 | Significantly increasing |
| | December | 2409 | 0.46 | 6.87 | 0.00 | Significantly increasing |
| Gujarat | January | 2347 | 0.45 | 6.70 | 0.00 | Significantly increasing |
| | February | 2437 | 0.46 | 6.95 | 0.00 | Significantly increasing |
| | March | 1691 | 0.32 | 4.82 | 0.00 | Significantly increasing |
| | April | 1573 | 0.30 | 4.49 | 0.00 | Significantly increasing |
| | May | 1392 | 0.27 | 3.97 | 0.00 | Significantly increasing |
| | June | 1135 | 0.22 | 3.24 | 0.00 | Significantly increasing |
| | July | 1607 | 0.31 | 4.59 | 0.00 | Significantly increasing |
| | August | 1600 | 0.31 | 4.57 | 0.00 | Significantly increasing |
| | September | 2003 | 0.38 | 5.71 | 0.00 | Significantly increasing |
| | October | 1681 | 0.32 | 4.79 | 0.00 | Significantly increasing |
| | November | 2387 | 0.45 | 6.81 | 0.00 | Significantly increasing |
| | December | 3038 | 0.58 | 8.67 | 0.00 | Significantly increasing |
| Haryana | January | 562 | 0.11 | 1.60 | 0.06 | Significantly increasing |
| | February | 619 | 0.12 | 1.76 | 0.04 | Significantly increasing |
| | March | 335 | 0.06 | 0.95 | 0.17 | Insignificantly increasing |
| | April | 562 | 0.11 | 1.60 | 0.06 | Significantly increasing |
| | May | -1 | 0.00 | 0.00 | 0.50 | Insignificantly decreasing |
| | June | -71 | -0.01 | -0.20 | 0.58 | Insignificantly decreasing |
| | July | 69 | 0.01 | 0.19 | 0.42 | Insignificantly increasing |
| | August | 789 | 0.15 | 2.25 | 0.01 | Significantly increasing |
| | September | 640 | 0.12 | 1.82 | 0.03 | Significantly increasing |
| | October | 510 | 0.10 | 1.45 | 0.07 | Significantly increasing |
| | November | 995 | 0.19 | 2.84 | 0.00 | Significantly increasing |
| | December | 1172 | 0.22 | 3.34 | 0.00 | Significantly increasing |
| Tamilnadu | January | 1453 | 0.28 | 4.15 | 0.00 | Significantly increasing |
| | February | 1780 | 0.34 | 5.08 | 0.00 | Significantly increasing |
| | March | 1384 | 0.26 | 3.95 | 0.00 | Significantly increasing |
| | April | 810 | 0.15 | 2.31 | 0.01 | Significantly increasing |
| | May | 399 | 0.08 | 1.14 | 0.13 | Insignificantly increasing |
| | June | 27 | 0.01 | 0.07 | 0.47 | Insignificantly increasing |
| | July | 711 | 0.14 | 2.03 | 0.02 | Significantly increasing |
| | August | 555 | 0.11 | 1.58 | 0.06 | Significantly increasing |
| | September | 1295 | 0.25 | 3.70 | 0.00 | Significantly increasing |
| | October | 1052 | 0.20 | 3.00 | 0.00 | Significantly increasing |
| | November | 2198 | 0.42 | 6.27 | 0.00 | Significantly increasing |
| | December | 2456 | 0.47 | 7.01 | 0.00 | Significantly increasing |
| India | January | 844 | 0.16 | 2.41 | 0.01 | Significantly increasing |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **February** | 1370 | 0.26 | 3.91 | 0.00 | Significantly increasing |
| | **March** | 680 | 0.13 | 1.94 | 0.03 | Significantly increasing |
| | **April** | 779 | 0.15 | 2.22 | 0.01 | Significantly increasing |
| | **May** | 425 | 0.08 | 1.21 | 0.11 | Insignificantly increasing |
| | **June** | 269 | 0.05 | 0.77 | 0.22 | Insignificantly increasing |
| | **July** | 731 | 0.14 | 2.09 | 0.02 | Significantly increasing |
| | **August** | 1352 | 0.26 | 3.87 | 0.00 | Significantly increasing |
| | **September** | 1231 | 0.23 | 3.51 | 0.00 | Significantly increasing |
| | **October** | 1207 | 0.23 | 3.44 | 0.00 | Significantly increasing |
| | **November** | 1988 | 0.38 | 5.97 | 0.00 | Significantly increasing |
| | **December** | 2132 | 0.41 | 6.08 | 0.00 | Significantly increasing |

***Note:*** Significance in trend is decided at levels of 10 per cent.

**Apndx Table 2A. Trends in Minimum Temperature in India and the Selected States (Bihar, Gujarat, Haryana, and Tamil Nadu)**

| State | Months | Statistic | k-Tau Stat | Z | p-Value | Conclusion |
|---|---|---|---|---|---|---|
| **Bihar** | **January** | -126 | -0.02 | -0.36 | 0.64 | Insignificantly decreasing |
| | **February** | 870 | 0.17 | 2.48 | 0.01 | Significantly increasing |
| | **March** | 341 | 0.06 | 0.97 | 0.17 | Insignificantly increasing |
| | **April** | 23 | 0.01 | 0.06 | 0.47 | Insignificantly increasing |
| | **May** | 10 | 0.002 | 0.03 | 0.49 | Insignificantly increasing |
| | **June** | -565 | -0.11 | -1.61 | 0.95 | Insignificantly decreasing |
| | **July** | -916 | -0.17 | -2.62 | 0.99 | Insignificantly decreasing |
| | **August** | -289 | -0.05 | -0.83 | 0.79 | Insignificantly decreasing |
| | **September** | -1,395 | -0.27 | -3.99 | 1.00 | Insignificantly decreasing |
| | **October** | 192 | 0.04 | 0.54 | 0.29 | Insignificantly increasing |
| | **November** | 1,242 | 0.24 | 3.54 | 0.00 | Significantly increasing |
| | **December** | 1,499 | 0.29 | 4.28 | 0.00 | Significantly increasing |
| **Gujrat** | **January** | -350 | -0.07 | -0.99 | 0.84 | Insignificantly decreasing |
| | **February** | 347 | 0.07 | 0.98 | 0.16 | Insignificantly increasing |
| | **March** | 389 | 0.07 | 1.11 | 0.13 | Insignificantly increasing |
| | **April** | 396 | 0.07 | 1.12 | 0.13 | Insignificantly increasing |
| | **May** | 415 | 0.08 | 1.18 | 0.12 | Insignificantly increasing |
| | **June** | 613 | 0.12 | 1.75 | 0.04 | Significantly increasing |
| | **July** | 342 | 0.07 | 0.98 | 0.16 | Insignificantly increasing |
| | **August** | 661 | 0.13 | 1.89 | 0.03 | Significantly increasing |
| | **September** | 904 | 0.17 | 2.59 | 0.01 | Significantly increasing |
| | **October** | 517 | 0.10 | 1.47 | 0.07 | Significantly increasing |
| | **November** | 452 | 0.09 | 1.28 | 0.09 | Significantly increasing |
| | **December** | 446 | 0.09 | 1.27 | 0.10 | Significantly increasing |
| **Haryana** | **January** | -741 | -0.14 | -2.11 | 0.98 | Insignificantly decreasing |
| | **February** | 54 | 0.01 | 0.15 | 0.44 | Insignificantly increasing |
| | **March** | 83 | 0.02 | 0.23 | 0.41 | Insignificantly increasing |
| | **April** | -38 | -0.01 | -0.11 | 0.54 | Insignificantly decreasing |
| | **May** | -308 | -0.06 | -0.88 | 0.81 | Insignificantly decreasing |
| | **June** | -691 | -0.13 | -1.97 | 0.98 | Insignificantly decreasing |
| | **July** | -602 | -0.12 | -1.72 | 0.96 | Insignificantly decreasing |
| | **August** | -213 | -0.04 | -0.61 | 0.73 | Insignificantly decreasing |
| | **September** | 34 | 0.01 | 0.09 | 0.46 | Insignificantly increasing |
| | **October** | 19 | 0.004 | 0.05 | 0.48 | Insignificantly increasing |
| | **November** | 390 | 0.07 | 1.11 | 0.13 | Insignificantly increasing |
| | **December** | -138 | -0.03 | -0.39 | 0.65 | Insignificantly decreasing |
| **Tamilnadu** | **January** | 498 | 0.09 | 1.42 | 0.08 | Significantly increasing |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **February** | 956 | 0.18 | 2.72 | 0.00 | Significantly increasing |
| | **March** | 1,227 | 0.23 | 3.50 | 0.00 | Significantly increasing |
| | **April** | 848 | 0.16 | 2.42 | 0.01 | Significantly increasing |
| | **May** | 436 | 0.08 | 1.24 | 0.11 | Insignificantly increasing |
| | **June** | -10 | -0.002 | -0.03 | 0.51 | Insignificantly decreasing |
| | **July** | 372 | 0.07 | 1.06 | 0.14 | Insignificantly increasing |
| | **August** | 657 | 0.12 | 1.89 | 0.03 | Significantly increasing |
| | **September** | 420 | 0.08 | 1.21 | 0.11 | Insignificantly increasing |
| | **October** | 764 | 0.15 | 2.19 | 0.01 | Significantly increasing |
| | **November** | 728 | 0.14 | 2.07 | 0.01 | Significantly increasing |
| | **December** | 918 | 0.02 | 2.62 | 0.00 | Significantly increasing |
| **India** | **January** | -166 | -0.03 | -0.47 | 0.68 | Insignificantly decreasing |
| | **February** | 812 | 0.16 | 2.31 | 0.01 | Significantly increasing |
| | **March** | 600 | 0.11 | 1.71 | 0.04 | Significantly increasing |
| | **April** | 171 | 0.03 | 0.48 | 0.31 | Insignificantly increasing |
| | **May** | -145 | -0.03 | -0.41 | 0.66 | Insignificantly decreasing |
| | **June** | -496 | -0.09 | -1.42 | 0.92 | Insignificantly decreasing |
| | **July** | -295 | -0.06 | -0.84 | 0.80 | Insignificantly decreasing |
| | **August** | -95 | -0.01 | -0.27 | 0.60 | Insignificantly decreasing |
| | **September** | -264 | -0.05 | -0.75 | 0.77 | Insignificantly decreasing |
| | **October** | 614 | 0.12 | 1.75 | 0.04 | Significantly increasing |
| | **November** | 1040 | 0.19 | 2.96 | 0.00 | Significantly increasing |
| | **December** | 1070 | 0.20 | 3.05 | 0.00 | Significantly increasing |

***Note:*** Significance in trend is decided at levels of 10 per cent.

**Apndx. Table 3A. Trends in Rainfall in India and the Selected States (Bihar, Gujarat, Haryana, and Tamil Nadu )**

| **State** | Months | **Statistic** | **k-Tau Stat** | Z | **p-Value** | **Conclusion** |
|---|---|---|---|---|---|---|
| **Bihar** | **January** | -218 | -0.02 | 0.39 | 0.70 | Insignificantly decreasing |
| | **February** | -133 | -0.01 | -0.24 | 0.81 | Insignificantly decreasing |
| | **March** | 78 | 0.01 | 0.14 | 0.89 | Insignificantly increasing |
| | **April** | 608 | 0.06 | 1.10 | 0.27 | Insignificantly increasing |
| | **May** | 926 | 0.10 | 1.67 | 0.10 | Significantly increasing |
| | **June** | -661 | -0.07 | -1.19 | 0.23 | Insignificantly decreasing |
| | **July** | 128 | 0.01 | 0.23 | 0.82 | Insignificantly increasing |
| | **August** | -691 | -0.07 | -1.24 | 0.21 | Insignificantly decreasing |
| | **September** | -34 | 0.00 | -0.06 | 0.95 | Insignificantly decreasing |
| | **October** | 466 | 0.05 | 0.84 | 0.40 | Insignificantly increasing |
| | **November** | 738 | 0.08 | 1.41 | 0.16 | Insignificantly increasing |
| | **December** | 759 | 0.08 | 1.42 | 0.16 | Insignificantly increasing |
| **Gujrat** | **January** | -505 | -0.05 | -0.99 | 0.32 | Insignificantly decreasing |
| | **February** | -463 | -0.05 | -0.93 | 0.35 | Insignificantly decreasing |
| | **March** | -428 | -0.04 | -0.90 | 0.37 | Insignificantly decreasing |
| | **April** | -525 | -0.05 | -1.03 | 0.30 | Insignificantly decreasing |
| | **May** | -1313 | -0.13 | -2.41 | 0.02 | Significantly decreasing |
| | **June** | 98 | 0.01 | 0.18 | 0.86 | Insignificantly increasing |
| | **July** | -512 | -0.05 | -0.92 | 0.36 | Insignificantly decreasing |
| | **August** | 625 | 0.06 | 1.13 | 0.26 | Insignificantly increasing |
| | **September** | -313 | -0.03 | -0.56 | 0.57 | Insignificantly decreasing |
| | **October** | 321 | 0.03 | 0.58 | 0.56 | Insignificantly increasing |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **November** | 1061 | 0.11 | 2.01 | 0.05 | Significantly increasing |
| | **December** | -579 | -0.06 | 1.17 | 0.24 | Insignificantly increasing |
| **Haryana** | **January** | -410 | -0.04 | -0.74 | 0.46 | Insignificantly decreasing |
| | **February** | 496 | 0.05 | 0.89 | 0.37 | Insignificantly increasing |
| | **March** | 522 | 0.05 | 0.94 | 0.35 | Insignificantly increasing |
| | **April** | 1132 | 0.12 | 2.04 | 0.04 | Significantly increasing |
| | **May** | 323 | 0.03 | 0.58 | 0.56 | Insignificantly increasing |
| | **June** | 456 | 0.05 | 0.82 | 0.41 | Insignificantly increasing |
| | **July** | 167 | 0.02 | 0.30 | 0.76 | Insignificantly increasing |
| | **August** | 1012 | 0.10 | 1.82 | 0.07 | Significantly increasing |
| | **September** | 127 | 0.01 | 0.23 | 0.82 | Insignificantly increasing |
| | **October** | 287 | 0.03 | 0.52 | 0.60 | Insignificantly increasing |
| | **November** | 1385 | 0.14 | 2.65 | 0.01 | Significantly increasing |
| | **December** | -400 | -0.04 | -0.73 | 0.47 | Insignificantly decreasing |
| **Tamil** | **January** | -40 | 0.00 | -0.07 | 0.94 | Insignificantly decreasing |
| | **February** | 18 | 0.00 | 0.03 | 0.98 | Insignificantly increasing |
| | **March** | 1 | 0.00 | 0.00 | 1.00 | Insignificantly increasing |
| | **April** | 67 | 0.01 | 0.12 | 0.91 | Insignificantly increasing |
| | **May** | -455 | -0.05 | -0.82 | 0.41 | Insignificantly decreasing |
| | **June** | -623 | -0.06 | -1.12 | 0.26 | Insignificantly decreasing |
| | **July** | 788 | 0.08 | 1.42 | 0.16 | Insignificantly increasing |
| | **August** | -491 | -0.05 | -0.88 | 0.38 | Insignificantly decreasing |
| | **September** | 273 | 0.03 | 0.49 | 0.62 | Insignificantly increasing |
| | **October** | -62 | -0.01 | -0.11 | 0.91 | Insignificantly decreasing |
| | **November** | 703 | 0.07 | 1.27 | 0.21 | Insignificantly increasing |
| | **December** | 367 | 0.04 | 0.66 | 0.51 | Insignificantly increasing |
| **India** | **January** | -383 | -0.04 | -0.69 | 0.75 | Insignificantly decreasing |
| | **February** | 156 | 0.02 | 0.28 | 0.39 | Insignificantly increasing |
| | **March** | 219 | 0.02 | 0.39 | 0.35 | Insignificantly increasing |
| | **April** | 1007 | 0.10 | 1.81 | 0.04 | Significantly increasing |
| | **May** | 150 | -0.42 | 0.27 | 0.39 | Insignificantly increasing |
| | **June** | -762 | -0.08 | -1.37 | 0.91 | Insignificantly decreasing |
| | **July** | -1035 | -0.11 | -1.86 | 0.97 | Insignificantly decreasing |
| | **August** | 451 | 0.05 | 0.81 | 0.21 | Insignificantly increasing |
| | **September** | -571 | -0.06 | -1.03 | 0.85 | Insignificantly decreasing |
| | **October** | 585 | 0.06 | 1.05 | 0.15 | Insignificantly increasing |
| | **November** | 436 | 0.05 | 0.78 | 0.22 | Insignificantly increasing |
| | **December** | -75 | -0.001 | -0.13 | 0.55 | Insignificantly decreasing |

***Note:*** Significance in trend is decided at levels of 10 per cent.

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