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IMPACT OF CLIMATE CHANGE ON WHEAT PRODUCTION IN MAJOR WHEAT GROWING STATES OF INDIA

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Abstract

In this paper we statistically analyzed time series data of wheat productivity for the States of Uttar Pradesh, Haryana, Punjab and Madhya Pradesh. We have drawn samples based on assumption that the technological improvements and input have improved the productivity while the decrease in the productivity is due to the impact of climate change. The one tailed t test used to test the null hypothesis. The analysis shows that there is significant impact on the productivity of the land in majority of districts. The impact is not realized in many districts, as there are strong mitigation systems exist and the weather patterns vary from place to place.

1.1 Introduction

Agriculture is a weather-sensitive operation. The weather conditions impact the crops right from the sowing to harvesting and even in the post-harvesting. The productivity of the land for crops is impacted by the variations in weather. [2] mentions that temperature and CO2 elevation not only affects wheat yield but also make wheat vulnerable to many diseases. High temperature causes a high rate of transpiration, that causes drought and ultimately leads to low productivity. Global warming causes intense drought in 60% of wheat-growing areas of the world. Currently, drought affects 15% of wheat productivity. Every 2°C shift of temperature may cause severe water shortage in the next 20 to 30 years. Water shortage at milking and grain filling stage will affect yield.

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Wheat is one of the most important agricultural crops. The total area under the crop is about 29.8 million hectares in India. The production of wheat in India has increased from 75.81 million MT in 2006-07 to a record high of 94.88 million MT in 2011-12. The productivity of wheat was 2602 kg/hectare in 2004-05 has increased to 3140 kg/hectare in 2011-12. Higher area coverage is reported from Madhya Pradesh in the recent past.

The production and productivity of Wheat were quite low, in 1947. The production of wheat was only 6.46 million MTs and productivity was 663 kg per hectare in 1950-51. That was not sufficient to feed the population. India used to import wheat in large quantities from the USA and Australia to meet its needs. The reasons for the low productivity of wheat at that time were (a) lodging of tall plants (b) the poor tillering (c) higher pests and diseases susceptibility (d) higher sensitivity to thermal and photo variations, etc., resulting in poor adaptability, and (e) long exposure of plants to weather due to longer crop life. India appointed a commission in 1961 to assess the feasibility of increasing wheat production. As a result, the wheat scenario in India improved. Due to increase in production and productivity of wheat in the 'Green Revolution' in late sixties, India became self-sufficient in wheat. At present, India is producing excess wheat and the stocks are flooded.

1.2 Wheat Growing Requirements

All the crops require favorable conditions to grow. The farmers know the weather patterns suitable for sowing, growth and harvesting for each crop they grow. The normal weather pattern from sowing in November – December, growth flowering, ripening and harvesting is all associated with the prevalent weather.

1.2.1 Climate Requirement

Wheat is grown in tropical and sub-tropical climates, and also in temperate climates and the cold climate around the 60 degree north latitude. Wheat can tolerate severe cold and snow and resumes growth with the setting in of warm weather in spring. It can be cultivated at elevations from sea level to as high as 3300 meters. The best quality of wheat is produced in areas of cool, moist weather during the major portion

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of the growing period followed by dry, warm weather to enable the grain to ripe and get dried. The optimum temperature range, ideal for the germination of wheat, is 20-25°C though the seeds can germinate at 3.5 to 35 °C. Rains after sowing hamper germination and the crop is susceptible to seedling blight. Areas with a warm and damp climate do not suit wheat growing. During the heading and flowering, very high or low temperatures and drought are harmful. Clouds with high humidity and low temperature increase the chances of rust. The wheat crop requires about 14-15 °C average temperature for ripening. The temperature at the time of grain filling and development are crucial. Temperatures above 25 °C at this stage may reduce grain weight. When temperatures are high, too much energy is lost in transpiration by the plants, and the reduced residual energy results in poor grain formation and low yields.

1.2.2 Soil

Wheat is grown in a variety of soils. Soils with a clay loam or loam texture, good structure, and moderate water-holding capacity are ideal for wheat. Very porous and excessively drained soils need be avoided. Soil should be neutral in its reaction. Heavy soil with good drainage is suitable for wheat under dry conditions. These soils absorb and retain water well. Wheat is sensitive to water logging. Heavy soils with poor structure and poor drainage are not suitable. Wheat can be successfully grown on light soils provided their water and nutrient holding capacity are improved.

1.2.3 Fertilizer

The research for finding time and placement of fertilizer has made progress. 120 kg nitrogen, 60 kg phosphorus, and 30 kg potash per hectare give optimum productivity. The nitrogen need be used in two doses of 60 kg as basal and the 60 kg at first irrigation. Phosphorus and potash are used as basal. A few new wheat varieties have responded up to 180 kg of nitrogen per hectare with an optimum dose of around 150 kg/ha. In the Indo-Gangetic plains, the application of 25 kg/ha zinc in rice-wheat system was found to increase the yield. The use of sulfur has also been found beneficial for increasing productivity and protein in wheat. Response to manganese in pockets of Indo-Gangetic plains and boron in the eastern and far eastern region has also been found beneficial.

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In intense farming, deficiency of nutrients is widespread. The work conducted under the All India Coordinated Research Project on Micronutrient in Crops and Soils, has shown widespread deficiency of zinc in soils in India. The deficiency of sulfur has also been found in a wide range of soils. To realize the potential yield, strategies include site-specific nutrient management for targeted yields. Integration of crop residues, bio-fertilizers with inorganic fertilization, tillage techniques like FIRBS are used to increase nutrient application.

1.3 Research objective

There have been continuous efforts for increasing the wheat production. The land is limited. Thus inputs are the main contributors and a continuous growth trend in the production and productivity was observed. However, in some years, there are sudden drops in the production and productivity. Such sudden fall in productivity is attributed mainly to vagaries of weather.

Objective of this research is to statistically determine the impact of climate change on the wheat productivity of the land in the major wheat producing States of India e.g. States of Uttar Pradesh, Haryana, Punjab and the Madhya Pradesh.

1.4 Research Hypothesis

The null hypothesis (H0) is:

1. Climate Change does not impact the per hectare wheat production.
2. The impact of climate change is uniform thought the State.

1.5 Research Design

Climate Change results from the accumulation of excess Green House Gases (GHGs) in the atmosphere. This is a very slow process and temperature change is about 1 °C in the past 150 years. The change is not uniform. In some areas, particularly in the cities, the temperature rise is in the range of 6-11 °C due to urban heat island effect. In rural areas, the temperature rise is not that high. The observations have detected an increase in the average temperature of the earth. Studies on many sectors have detected impacts on those sectors. The foremost impact is on the rainfall patterns,

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with dry areas becoming drier and wet areas becoming wetter. This has serious impacts on water availability and accordingly on agriculture. Further the temperature and the humidity, which are part of the climate, also impact agriculture. The other sectors are being impacted but the most serious appears to be on food production.

We have chosen to statistically study the wheat production in the high wheat-producing districts. We selected the region having the best infrastructure for farming, the best soils, high availability of fertilizers, farmers' ability to use the best machinery, the best inputs, etc. The only reason for production going down is the unfavorable weather, and the damage due to droughts and floods. The impacts of pests and disease are controlled through application of pesticides and insecticides in a very timely manner as the farmers in this region are well-educated and they are very alert.

We have taken district-wise crop yield data, that is prepared by the Directorate of Statistics, Department of Agriculture and Farmers' Welfare on the inputs received from the districts and States, Department of Space, Department of Sample Survey and inputs obtained through crop cutting experiments. This data has been compiled by ICRISAT with the help of TATA Cornell Institute and the Ministry of Agriculture and published on their website [1]. The data is available from 1966-2017 i.e. for a period of 52 years. As climate change is already established, we just analyze the time series of productivity with respect to time.

We explored the observations on productivity of the land for wheat for the data of 52 years. A quantitative research has been adopted to test the proposed null hypothesis [5]. It is assumed that this is an appropriate tool for understanding the impact of climate change on wheat production.

1.6 Sampling Procedure

Out of the 52 years' data, we have randomly picked up a 5% to 10% of the data. Every 11th or 21st record was picked up to have a 10 % or 5 % random sample. Because the data is for 52 years, the selection of 11th or 21st record ascertained that the districts and years were randomly chosen. To study the effect of climate, records

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were selected based on the criteria of more than 10% decrease in productivity over previous year.

1.7 One-tailed Test

While making a data analysis plan it is required to decide if the statistical test used should be a one-tailed or a two-tailed. The tail refers to the end of the distribution of the test statistic for a particular analysis. A two-tailed test is appropriate if it is required to determine if there is any difference between the groups being compared e.g. if a group scored higher or lower than the other group, then better to use a two-tailed test. The two-tailed test uses both the positive and negative tails of the distribution. A one-tailed test is appropriate if required to determine a difference between groups in a specific direction. If interested to determine the group scored higher than the other, then use a one-tailed test. The advantage of using a one-tailed test is that it has more statistical power than a two-tailed test at the same significance level. The results are more likely to be significant for a one-tailed test if there is truly a difference between the groups in the direction used. A one-tailed test is justified for this analysis as direction of the difference is falling production is on one side.

An obvious expectation is that in the frost free regions the yield per hectare will go down if there is an impact. Therefore we use a negative trend in the yield. Thus to select a sample we have chosen the percentage of reduction in yield over the previous year. If the reduction is less than or equal to 10%, this is ignored. A 10% reduction in crop yield in relation to potential yield is not considered drought [3]. Thus in the data of negative trend we picked the data where the reduction is more than 10%.

The important wheat producing districts of the state of Uttar Pradesh are Meerut, Aligarh, Agra, Muzaffarnagar, Saharanpur, Bulandshahar, Kanpur, and Mathura. [4]. We noticed that the general trend is overall productivity increase but there are dips almost every alternate year. 1974 and 2014 have sharp declines in productivity. In Bulandshahar there are three sharp falls in 1974, 1984, and 2014. Meerut has shown a sudden increase in productivity in 1985. Thus nearby districts are not similarly productive and weather patterns vary from district to district.

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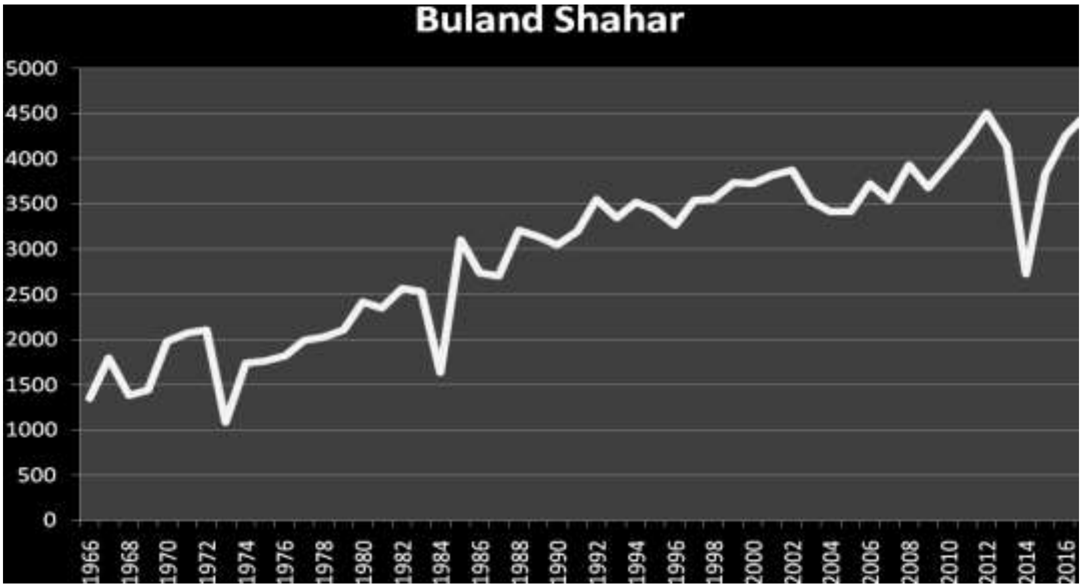
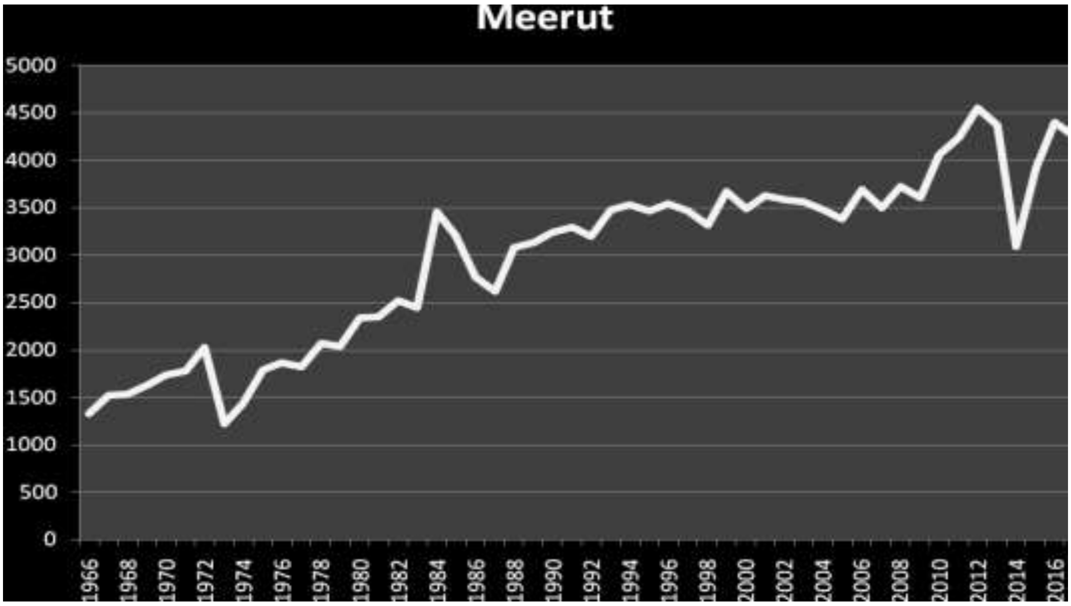


Graph 1.1: Year-wise productivity (kg/hectare) of district Bulandshahar, UP



Graph 1.2: Year-wise productivity (kg/hectare) of district Meerut, UP

We selected the 8 highest wheat producing districts and processed the data together for all the 8 districts. We calculated the frequencies of rising and falling productivity and found that the probability of falling productivity is 0.361. In 2014 it is more

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pronounced than in the earlier years. On applying t-test on randomly selected samples from the data we got the results as given in Table 1.1:

S. No.	Area Selected	Sample Selection Criteria	Sample Size	t value
1	8 districts UP	Starting at 1, every 11th record	10%, 32	0.056
2	Entire UP	Starting at 1, 21th record	5%, 48	0.748
3	MP	Starting at 1, every 21th record	5%, 97	0.341
4	Haryana	Starting at 1, every 11th record	10%, 37	0.236
5	Punjab	Starting at 1, every 11th record	10%, 29	0.335

Table 1.1: t-test on random samples

It shows the random samples strongly represent the entire data.

1.8 Impact of Climate Change

Though there is an increasing trend in general, there is a decline in the productivity in some years. Increase in the productivity is mainly due to technological improvements like new varieties of seeds, new technologies, a farmers' efforts, and the decline is mainly due to disasters like floods, and droughts. The pests and diseases are quickly controlled by the farmers as they are very alert and these incidents are usually in selected pockets. But the weather affects the larger area. A warmer atmosphere than the optimally suitable may reduce production, while a warmer atmosphere than critically low temperature may improve productivity e.g. if the area is snow covered, an increase in temperature may result in temperatures suitable for the crops. As we are studying the snow free area, we have taken the decline beyond 10% as effect of climate change.

The climate change is occurring is established by observations. It is a time series of the average temperature of the earth that signifies the temperature rise and subsequently the climate change. The year to year increase in the temperature is so small that the productivity of the land can not be directly linked to the temperature. The average temperature has increased by 1 °C in 150 years thus it is 0.067 °C per decade. But the weather patterns have been detected to change considerably. Though the temperature is increasing gradually and extremely slowly, rainfall patterns,

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droughts, and floods are occurring in a somewhat increased manner. Thus the suspect years of low rainfall and floods cause drop in the productivity. The years when productivity goes down as compared to the previous year are random. And this dip in productivity is taken to select as a sample data of the impact of climate change. The percentage drop is calculated by

$$(P_{n+1} - P_n) * 100 / P_n$$

where Pn is the productivity in nth year. We ignored cases where the loss was within 10%. We have taken samples out of the data and then calculated t-values and used one tail t-test to accept or reject the hypothesis and got results as given in Table 1.2:

S. No.	Area Selected	Population Mean	Sample size	T value	Critical value	Null Hypothesis
1	8 districts		50	6.71	2.009	Rejected
2	Entire UP	2177.574	346	15.02	1.961	Rejected
3	MP	1523.270	259	9.99	1.961	Rejected
4	Haryana	3177.469	37	2.96	2.027	Rejected
5	Punjab	3509.009	54	2.37	2.004	Rejected

Table 1.2: t-values for Productivity of wheat (kg/hectare)

1.9 Individual Districts

On analyzing 52 years data of 46 districts of Uttar Pradesh, we got following results:

S. No.	District	Population Mean	Sample Mean	Standard Deviation	Sample Size	T Value	Critical T Value 1 tailed α=0.05	Hypothesis
1	Saharanpur	2325.676	1736.8	594.04	6	2.43	1.943	Rejected
2	Muzaffarna	2763.532	1705.5	819.18	4	2.58	2.132	Rejected
3	Meerut	2965.283	2355.9	999.49	3	1.06	2.353	Fail to reject
4	Buland	2969.228	1923.1	772.90	5	3.03	2.015	Rejected
5	Aligarh	2993.543	2067.9	638.50	5	2.24	2.015	Rejected
6	Mathura	2707.591	2323.3	778.83	10	1.32	1.812	Fail to reject
7	Agra	2631.941	1998.8	792.45	8	2.26	1.860	Rejected
8	Bareilly	2096.37	1739.2	490.99	6	1.78	1.943	Fail to reject
9	Budaun	2251.45	1642.3	714.08	8	2.41	1.860	Rejected
10	Moradabad	2309.11	1491.3	642.52	8	3.60	1.860	Rejected
11	Shahjahanp	2451.33	1565.5	712.20	6	3.05	1.943	Rejected
12	Mainpuri	2502.47	1829.4	634.12	7	2.81	1.895	Rejected
13	Etah	2369.58	1767.7	568.15	5	2.37	2.015	Rejected

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14	Pilibhit	2371.681	1645.5	995.49	8	2.06	1.860	Rejected
15	Rampur	2564.264	2055.4	778.27	7	1.73	1.895	Fail to reject
16	Bijnor	2220.71	1980.5	1059.98	5	0.51	2.015	Fail to reject
17	Farrukhaba	2556.046	1364.4	374.73	4	6.36	2.132	Rejected
18	Etawah	2575.238	2003.5	612.13	8	2.64	1.860	Rejected
19	Kanpur	2539.944	1752.5	807.15	8	2.76	1.860	Rejected
20	Fatehpur	2088.53	1391.4	595.92	7	3.09	1.895	Rejected
21	Allahabad	1822.498	1550.2	475.86	9	1.72	1.833	Fail to reject
22	Jhansi	1701.863	1568.8	662.94	9	0.60	1.833	Fail to reject
23	Jalaun	2103.612	1676.0	725.69	11	1.95	1.796	Rejected
24	Hamirpur	1557.645	1216.1	406.65	12	2.91	1.782	Rejected
25	Banda	1313.021	1074.4	511.20	11	1.55	1.796	Fail to reject
26	Varanasi	1920.328	1859.2	539.72	12	0.39	1.782	Fail to reject
27	Mirzapur	1434.583	926.57	480.92	9	3.17	1.833	Rejected
28	Jaunpur	2107.22	1370.9	542.90	6	3.32	1.943	Rejected
29	Ghazipur	1941.83	1561.3	521.12	10	2.31	1.812	Rejected
30	Ballia	2041.322	1708.3	635.84	11	1.74	1.796	Fail to reject
31	Gorakhpur	2064.328	1897.2	338.50	7	1.31	1.895	Fail to reject
32	Deoria	2061.194	1899.3	506.49	6	0.78	1.943	Fail to reject
33	Basti	1959.992	1589.9	645.70	9	1.72	1.833	Fail to reject
34	Azamgarh	2030.33	1594.3	554.96	7	2.08	1.895	Rejected
35	Lucknow	1963.527	1559.7	544.56	7	1.96	1.895	Rejected
36	Unnao	1994.517	1478.7	434.92	7	3.14	1.895	Rejected
37	Rae-Bareily	1855.048	1370.3	367.42	7	3.49	1.895	Rejected
38	Sitapur	1925.18	1405.2	543.42	8	2.71	1.860	Rejected
39	Hardoi	2246.435	1849.8	780.56	8	1.44	1.860	Fail to reject
40	Kheri	2130.023	1877.5	842.79	7	0.79	1.895	Fail to reject
41	Faizabad	2199.134	1605.1	554.89	5	2.39	2.015	Rejected
42	Gonda	1923.407	1360.7	712.71	8	2.23	1.860	Rejected
43	Bahraich	1837.323	1354.5	719.52	9	2.01	1.833	Rejected
44	Sultanpur	2037.13	1497.6	601.03	8	2.54	1.860	Rejected
45	Pratapgarh	1870.24	1663.8	551.73	6	0.92	1.943	Fail to reject
46	Barabanki	2190.25	1628.2	720.45	8	2.21	1.860	Rejected

Table 1.3:The t values for downtrend cases in productivity in the districts of UP

Out of 46 districts, 29 districts, i.e in 64 % of the districts, the null hypothesis is rejected for 0.05 level of confidence. In the remaining 17 districts, the null hypothesis failed to reject. This table also shows that the impact is not uniform.

1.11 Conclusion

Some districts have strong drought mitigation systems, like extensive irrigation systems. The statistical analysis shows that there is significant impact of climate change on the productivity of wheat. The States of Haryana and Madhya Pradesh show impact of climate change. Farmers do not delay irrigation and thus the effect of

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climate change is reduced. Had these systems not been in operation, climate change would have shown full impact.

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