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Effect of Weather Variables on Wheat Yield

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ABSTRACT

This study examines the effect of climatic factor e.g. Temperature (Maximum and Minimum), Relative humidity (Morning and Evening), Evaporation and Rainfall variation on the yield of different stages of wheat in Samastipur district of Bihar by using regression analysis statistical method. The data of wheat yield of 29 Years (1984-2013) was taken from Department of Agricultural Economics, RAU, Pusa and Weather Variables (1984-2013) was taken from Agro-metrology Unit, RAU, Pusa. Regression analysis have used to estimate the relationship of climate variables on the wheat yield. The main effects of all the variables were observed to have statistically non-significant contribution towards changing crop yield except relative humidity (morning). However, the interaction of relative humidity with other weather variables was estimated to have statistically significant contribution towards yield variability.

Key words: *Climate change, Wheat yield, Weather variable, Regression analysis.*

INTRODUCTION

Evidently climate change is being realized in every walk of our life. Palpable impact is seen on growth and development, water use and productivity of major crops including wheat. Recently much attention has been given to the effects of climate change on agricultural output, because of the relevance of agriculture to the world economy, and the sensitivity of crop yields to climate conditions. Climate change impacts on India can have far-reaching consequences, as well; India is the world's second largest producer of agricultural outputs, and any changes in production due to climate change could materially impact global agricultural imports and exports. Agriculture is the most vulnerable sector to climate change. Agriculture productivity is being affected by a number of factors of climatic change including rainfall pattern, temperature, relative humidity, evaporation, changes in sowing and harvesting dates, water availability, and evapo-transpiration4 and land suitability. All these factors can change yield and agricultural productivity. The impact of climate change on agriculture is many folds including diminishing of agricultural output and shortening of growth period for crops. Countries lying in the tropical and sub-tropical regions would face callous results, whereas regions in the temperate zone would be on the beneficial side.

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Although the climate change in some areas of the world, particularly the areas located within the northern widths above 55 , will have positive effects on agricultural production[2], but the negative impacts of these changes will be so severe in hot and dry areas[5], so in developing countries the rise in temperature and the decrease in rainfall have been more severe and moreover the frequency and intensity of the occurrence of rare climatic phenomena (drought, heat, coldness and flood) will also be intensified[3]. Undoubtedly, any change in climatic condition will affect the agricultural production systems of the world. Mall and Singh[4] observed that small changes in the growing season temperature over the years appeared to be the key aspect of weather affecting yearly wheat yield fluctuations. Pathak *et al*[6]., concluded that the negative trends in solar radiation and an increase in minimum temperature, resulting in declining trends of potential yields of wheat in the Indo-Gangetic plains of India. Selvaraju[7] analyzed the relationship between Indian Summer Monsoon Rainfall (SMR) and food grain production in India. He found that the inter-annual variations are closely related. However, the magnitude of change in food grain production is smaller than the rainfall. Recent trends of a decline or stagnation in the yield of rice-wheat cropping system in Indo- Gangetic plain and north western India have raised serious concern about the regions food supply[1,6]. Easterling *et al*[8]., looked at studies that made quantitative projections of climate change impacts on food security. The first was that climate change would likely increase the number of people at risk of hunger compared with reference scenarios with no climate change. In 2006, the global estimate for the number of people under nourished was 820 million. This study aims to contribute to assessing how changing pattern of weather variables have affected the yields of major crops in India, over a 29-year time period from 1984-2013.

MATERIAL AND METHODS

This research deals with methods, procedures and measurement techniques followed for carrying out the research work entitled "statistical analysis of wheat yield and climatic change in Samastipur district, Bihar". The present study has been carried out to focus on the overall impact of climate change on the wheat yield.

The methodology includes:

1. Locale of the study
2. Data and variables
3. Various statistical tools

General description of the study area:

The study was carried out in Samastipur district of Bihar in India. This is situated in Agro- climatic zone I (Northern West). The traditional agricultural practice is prevalent in this district. Then latitude and longitude is 25° 51′47.48″ N and 85° 46′48.04 0″ E respectively. It is situated at an elevation of about 52 m above mean sea level. The climate of the site is characterized by hot and humid summers and cold winters with an average rainfall of 1200 mm, 70 percent (941 mm) of which occurs during July -September and average temperature is maximum 36.6°C and minimum temperature is 7.7°C. Frequent droughts and floods are common in the region.

Data and variables:

Wheat productivity data 1984-2013 is collected from Dept. of Agricultural Economics, RAU, Pusa, Samastipur, Bihar on wheat productivity. We consider the average amount of wheat productivity in tones /hectare. The direct impact of climatic variables on wheat yield. The data regarding the climatic variables is collected data source from the Agro-meteorology Unit, RAU, Pusa, Samastipur Bihar.

Following are the climatic factor and their units which are taken in this research:

1. Maximum temperature (°C)
2. Minimum Temperature (°C)
3. Relative Humidity (morning) (%)
4. Relative Humidity (evening) (%)
5. Rainfall (mm)
6. Evaporation (mm/m^2)

Sowing time of wheat is mid of November i.e. 15thNov-20thNov and harvesting time is start from first week of April.

Regression Analysis

In statistical modeling, regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed. Most commonly, regression analysis estimates the conditional expectation of the dependent variable given the independent variables – that is, the average value of the dependent variable when the independent variables are fixed. Less commonly, the focus is on a quantile, or other location parameter of the conditional distribution of the dependent variable given the independent variables. In all cases, the estimation target is a function of the independent variables called the regression function. In regression analysis, it is also of interest to characterize the variation of the dependent variable around the regression function which can be described by a probability distribution. Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. However, this can lead to illusions or false relationships, so caution is advisable; for example, correlation does not imply causation.

We used regression models are given below: -

$$Y= ß_o+ß_1X_1+ß_2X_2…ß_6X_6+Ɛ$$

Regression Model with Interaction Terms

$$Y= ß_o+ß_1X_1+ß_2X_2+ß_3X_3+ß_4X_4+ß_5X_5+ß_6X_6+ß_7(X_1X_3) +ß_8(X_1X_4) +ß_9(X_2X_3) + ß_{10}(X_2X_4) +ß_{11}(X_6X_3) +ß_{12}(X_6X_4) +Ɛ$$

Where Y= Dependent variables

X= Independent variables

ß = Unknown Parameters, which may represent a scalar or vector.

RESULTS AND DISCUSSION

Regression Model with different climatic variables and wheat yield

Multiple linear regression models were used to estimate the effects of different weather variables on wheat yield. A relationship occurs when the magnitude of the effect of one independent variable on a dependent variable varies as a function of a second independent variable. The relationship between minimum temperature, maximum temperature, relative humidity (morning), and relative humidity (evening), evaporation on the wheat yield were included in the model. Table -1 shows the regression coefficients associated with each variable to indicate the change in yield corresponding to unit change in the respective weather variable. Statistically significant positive effects were observed for maximum temperature, morning humidity, evening humidity. There was statistically significant increase in yield by 0.446 mt/h due to increase in evaporation by 1 mm/m^2. However, the most variables with minimum temperature, maximum temperature, relative humidity (morning), and relative humidity (evening), were found to have positive impact on wheat yield only 28% of total variability in the wheat yield was explained by the regression model.

Regression Model with interaction term

Multiple linear regression models were used to estimate the effects of different weather variables on wheat yield. The regression model included the interaction term between some of the weather variables which are expected to have impact on yield on account of synergistic effects between them. An interaction occurs when the magnitude of the effect of one independent variable on a dependent variable varies as a function of a second independent variable. The interaction between minimum temperature and relative humidity, maximum temperature and relative humidity, and evaporation and relative humidity were included in the model. Table - 2 shows the regression coefficients associated with each variable as well as the interaction term to indicate the change in yield corresponding to unit change in the respective weather variable. Statistically non-significant negative effects were observed for maximum temperature, morning humidity, evening humidity. With increase in these variables by one unit, wheat yield was observed to decrease by 0.012 mt/h, 0.058 mt/h and 0.1 mt/h respectively. There was statistically significant decrease in yield by 0.108 mt/h due to increase in minimum temperature by 1˚C. However, the interaction term of most variables with morning and evening humidity were found to have positive impact on wheat yield. The interaction of minimum temperature was found to have detrimental effect on yield as a function of relative humidity in evening. 76% of total variability in the wheat yield was explained by the regression model.

Table 1: Regression Model of relationship between Wheat yield and Weather variables

Variables	Beta Coefficient	Standard Error	p Values
Intercept	-7.272	10.845	0.51
Maximum Temperature (X_1)	0.081	0.250	0.749
Minimum Temperature (X_2)	0.047	0.135	0.733
RH (Morning) (X_3)	0.041	0.047	0.396
RH (Evening) (X_4)	0.016	0.060	0.789
Rainfall (X_5)	0.000	0.000	0.933
Evaporation (X_6)	**0.446**	0.192	0.03

R^2= 0.282

Table 2: Regression Model with interaction term

Variables	Beta Coefficient	Standard Error	P Values
Intercept	-0.012	15.897	0.994
Maximum Temperature (x_1)	-0.058	0.311	0.854
Minimum Temperature (x_2)	-0.108	0.220	0.021
RH (Morning) x_3	0.100	0.076	0.28
RH (Evening) x_4	-0.079	-0.765	0.314
Rainfall (x_5)	0.001	0.002	0.797
Evaporation (x_6)	0.349	0.227	0.143
Maximum Temperature*RH (Morning) $x_{1.}$ x_3	0.037	0.121	0.045
Maximum Temperature*RH (Evening) $x_1.x_4$	0.028	0.089	0.759
Minimum Temperature*RH (Morning) $x_2.x_3$	0.033	0.026	0.026
Minimum Temperature*RH (Evening) $x_2.x_4$	-0.167	0.068	0.023
Evaporation*RH (Morning) $x_6.x_3$	0.038	0.120	0.052
Evaporation*RH (Evening) $x_6.x_4$	-0.060	0.088	0.506

R^2= 0.7613

CONCLUSION

Multiple linear regression models estimated the effects of different weather variables on wheat yield. Interaction term between some of the weather variables which are expected to have impact on yield on account of synergistic effects between them were included in the model. The main effects of all the variables were observed to have statistically non-significant contribution towards changing crop yield except relative humidity (morning). However, the interaction of relative humidity with other weather variables was estimated to have statistically significant contribution towards yield variability. It indicates that the role of an individual weather variable may not assess the actual impact on yield, however, its variation as a function of another weather variable may indicate change in the wheat yield as obtained from the regression results.

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