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## Effect of weather parameters on wheat yield in Bihar

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### Abstract

Crop yield is mainly affected by two factors: technological change and weather variability. It can be assumed that technological factors will increase yield smoothly over time; therefore, years or some other parameter of time can be used to study the overall effect on yield. Weather variability, both within and between seasons is the second and only out-of-controlled variability in the yield. Weather variables affect crops differently during different stages of development. The crop weather analysis model is a practical research tool for analyzing crop yield responses to weather and climatic variations when only climatic data are available.

The present study focused on analyzing the effect of weather parameters on wheat yield in Bihar. For this purpose, district-wise yield and meteorological data were collected from the Directorate of Economics and Statistics, Patna, and IMD, Patna division, respectively. Subsequently, district-wise yield data were categorized into different zones, viz. zone-I, zone-II, zone-III, and whole Bihar. Pearson's correlation was applied to compare weather with yield, and a regression model for yield was also developed, followed by regression analysis. Based on these analyses, the effect of weather on the yield response was easily determined.

**Keywords:** Weather, yield, wheat, correlation, regression

### Introduction

Agriculture and allied sectors are the largest components of the Indian economy. In the agricultural sector, wheat is an important *rabi* crop in India, which is not only a staple food crop in India but also a staple food for the world. Among the major wheat-producing states in India, Uttar Pradesh has the highest contribution to production. In Bihar production of the crop is 59.89 million tonnes and 21.06 million hectares of area with an average yield of 2843 kilograms per hectare in 2016-17. Directorate of Economics and Evaluation Department, Government of Punjab, Pakistan. of Bihar. Bihar has experienced an impressive rate of growth over the past few decades.

The relevant data for wheat yield and weather collected from 1995-96 to 2024-25 were collected from the Directorate of Economics & Statistics (DoE & S), Government of Bihar, Patna. Weather data were collected from the Meteorological Division in Patna.

Weather affects crops differently during different stages of crop growth. Thus, the extent of weather influence on crop yield depends not only on the magnitude of weather variables but also on the distribution pattern of weather over the crop seasons.

Several studies have been conducted in India and abroad on the crop-weather relationship. These studies broadly fall under two groups viz. (i) fitting the distribution of meteorological factors and (ii) correlation and regression analysis between yield and weather factors during different phases of crop growth.

A model based on precipitation, maximum and minimum temperatures, global radiation, evaporation and time was used to explain the complex relationship between yield and weather. The most important elements were precipitation for the summer-fallow period and in May, June, and August; maximum temperatures in June and July; and global radiation in May. Improved technology appeared to have little influence on wheat yield trends after weather trends were taken into account. The model accounted for 73% of the yield variability and provided realistic functions for explaining the curvilinear influence of individual weather elements on the wheat yield. The model is readily adaptable for assessing the influence of past and current weather on the expected yield at any time during crop growth.

## Materials, Methods and Description Area

### Description of the study area

For this study, three agro-climatic zones comprising the following districts were considered.

#### Zone-1

Saran, Siwan, Gopalganj, East-Champaran, West-Champaran, Muzaffarpur, Sitamarhi, Shiwahar, Vaishali, Darbhanga, Madhubani, Samastipur and Begusarai.

#### Zone-2

Saharsa, Supaul, Madhepura, Purnia, Kishanganj, Araria, Katihar, and Khagaria.

#### Zone-3

Patna, Nalanda, Arwal, Bhojpur, Buxar, Bhabhua, Rohtas, Gaya, Jahanabad, Nawada, Aurangabad, Munger, Sheikhpura, Lakhisarai, Jamui, Bhagalpur, and Banka.

### Source of data

The study was based on secondary data on wheat yield productivity in three agro-climatic zones of Bihar and for the whole of Bihar. Time series wheat yield data were collected for the period from 1995-96 to 2024-25 from the Directorate of Economics and Statistics Department. of Bihar, Patna. The weather data were collected from Patna

### Analytical tools and techniques employed

A regression model was used to estimate the yield based on weather parameters. Time-series secondary data on weather parameters were collected from Patna for 21 years, that is, from 1995 to 2015. Five parameters were considered: maximum temperature, minimum temperature, relative humidity (%) at 7:00 h, and relative humidity (%) at 14:00 h.

### Results & Discussion

In the present study, the effect of weather parameters on wheat yield in different zones and in complete Bihar was discussed. There are 21 observations for yield (1995-2015) years were taken as a dependent variable and 5 weather parameter namely maximum temperature (X1), minimum temperature (X2), RH at 7:00 hrs (X3), RH at 14:00 hrs (X4) and Rainfall (mm) (X5) were taken in the part of study. For each zone correlation matrix of weather parameter of wheat yield were calculated and presented in table from Zone-I

In zone I, when the temperature is at its maximum, the yield decreases, and when the temperature is at its minimum, the yield also decreases. While in case of high Relative humidity (RH) yield increases and in low RH yield decreases and also when rainfall is very high yield decreases. The correlation matrix for the weather parameters is given in Table 1. The weather-based regression model given in table 2

**Table 1:** Correlation matrix of weather parameters of wheat yield in zone-I

| Dependent parameter | No. of observations | Weather parameters    |                       |                       |          |               |
|---------------------|---------------------|-----------------------|-----------------------|-----------------------|----------|---------------|
|                     |                     | Temperature (°C)      |                       | Relative humidity (%) |          | Rainfall (mm) |
|                     |                     | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr               | 14.00 hr |               |
| Yield               | 15                  | 0.0134                | -0.2022               | 0.4268                | -0.0594  | -0.4007       |

**Table 2:** Regression model for weather parameters of wheat yield in zone-I

| Dependent parameter | No. of observations | Constant | Weather parameters    |                       |                           |                            |                              |                |
|---------------------|---------------------|----------|-----------------------|-----------------------|---------------------------|----------------------------|------------------------------|----------------|
|                     |                     |          | Temperature (°C)      |                       | Relative humidity (%)     |                            | Rainfall (mm) X <sub>5</sub> | R <sup>2</sup> |
|                     |                     |          | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr (x <sub>3</sub> ) | 14.00 hr (x <sub>4</sub> ) |                              |                |
| Yield               | 15                  | -99.0145 | 1.5716                | -1.8956               | 1.1628                    | 0.1180                     | -0.1844                      | 0.4771         |

$$\hat{Y} = -99.0145 + 1.572X_1 - 1.896X_2 + 1.163X_3 + 0.118X_4 - 0.1844X_5$$

#### Zone II

In this zone, if the temperature increases, the yield decreases slightly, whereas if the temperature decreases, the yield decreases significantly. When the RH increased, the yield increased, and when the RH decreased, the yield decreased.

In the case of high rainfall, the yield decreases. The correlation matrix for the weather parameters is given in Table 3. The weather-based regression model is given in Table 4.

**Table 3:** Correlation matrix of weather parameters of wheat yield in zone-II

| Dependent parameter | No. of observations | Weather parameters    |                       |                       |          |               |
|---------------------|---------------------|-----------------------|-----------------------|-----------------------|----------|---------------|
|                     |                     | Temperature (°C)      |                       | Relative humidity (%) |          | Rainfall (mm) |
|                     |                     | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr               | 14.00 hr |               |
| Yield               | 15                  | 0.4823                | -0.7317               | 0.6388                | -0.6208  | -0.6923       |

**Table 4:** Regression model for weather parameters of wheat yield in zone-II

| Dependent parameter | No. of observations | Constant | Weather parameters    |                       |                           |                            |                              | R <sup>2</sup> |
|---------------------|---------------------|----------|-----------------------|-----------------------|---------------------------|----------------------------|------------------------------|----------------|
|                     |                     |          | Temperature (°C)      |                       | Relative humidity (%)     |                            | Rainfall (mm) X <sub>5</sub> |                |
|                     |                     |          | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr (x <sub>3</sub> ) | 14.00 hr (x <sub>4</sub> ) |                              |                |
| Yield               | 15                  | 20.5742  | 0.1107                | -0.3968               | -0.0759                   | 0.1709                     | -0.3581                      | 0.5805         |

$$\hat{Y} = 20.7542 + 0.1107X_1 - 0.3968X_2 - 0.0759X_3 + 0.17909X_4 - 0.3581X_5$$

#### Zone-III

In this zone, the yield decreases with increasing temperature, whereas a sudden fall in temperature results in a decrease in yield. When RH (%) increases, the yield

increases, whereas the yield decreases with increasing high rainfall (mm). The correlation matrix for the weather parameters is given in Table 5. The weather-based regression model is given in Table 6.

**Table 5:** Correlation matrix of weather parameters of wheat yield in zone-III

| Dependent parameter | No. of observations | Weather parameters    |                       |                       |          |               |
|---------------------|---------------------|-----------------------|-----------------------|-----------------------|----------|---------------|
|                     |                     | Temperature (°C)      |                       | Relative humidity (%) |          | Rainfall (mm) |
|                     |                     | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr               | 14.00 hr |               |
| Yield               | 15                  | -0.0493               | 0.1207                | 0.1393                | 0.1775   | -0.3364       |

**Table 6:** Regression model for weather parameters of wheat yield in zone-III

| Dependent parameter | No. of observations | Constant | Weather parameters    |                       |                           |                            |                              |                |
|---------------------|---------------------|----------|-----------------------|-----------------------|---------------------------|----------------------------|------------------------------|----------------|
|                     |                     |          | Temperature (°C)      |                       | Relative humidity (%)     |                            | Rainfall (mm) X <sub>5</sub> | R <sup>2</sup> |
|                     |                     |          | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr (x <sub>3</sub> ) | 14.00 hr (x <sub>4</sub> ) |                              |                |
| Yield               | 15                  | -12.1492 | 0.0006                | 0.0536                | 0.3587                    | 0.0740                     | -0.3798                      | 0.2135         |

$$\hat{Y} = -12.1492 + 0.0006X_1 + 0.0536X_2 + 0.3587X_3 + 0.0740X_4 - 0.3798X_5.$$

### Bihar

It was found that for the entire state of Bihar, the yield is directly proportional to RH (%) and adversely affected by rainfall (mm). If the temperature decreases, the yield also

decreases, and as the temperature increases, the yield decreases slightly. The correlation matrix for the weather parameters is given in Table 7. The weather-based regression model is given in Table 8.

**Table 7:** Correlation matrix of weather parameters of wheat yield in Bihar

| Dependent parameter | No. of observations | Weather parameters    |                       |                       |          |               |
|---------------------|---------------------|-----------------------|-----------------------|-----------------------|----------|---------------|
|                     |                     | Temperature (°C)      |                       | Relative humidity (%) |          | Rainfall (mm) |
|                     |                     | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr               | 14.00 hr |               |
| Yield               | 15                  | 0.0169                | -0.1450               | 0.01219               | 0.0846   | -0.2206       |

**Table 8:** Regression model for weather parameters of wheat yield in Bihar

| Dependent parameter | No. of observations | Constant | Weather parameters    |                       |                           |                           |                              |                |
|---------------------|---------------------|----------|-----------------------|-----------------------|---------------------------|---------------------------|------------------------------|----------------|
|                     |                     |          | Temperature (°C)      |                       | Relative humidity (%)     |                           | Rainfall (mm) X <sub>5</sub> | R <sup>2</sup> |
|                     |                     |          | Max.(x <sub>1</sub> ) | Min.(x <sub>2</sub> ) | 7.00 hr (x <sub>3</sub> ) | 14.00 hr(x <sub>4</sub> ) |                              |                |
| Yield               | 15                  | -24.3625 | 0.6697                | -0.9545               | 0.4903                    | 0.0423                    | 0.3694                       | 0.1881         |

$$\hat{Y} = -24.3625 + 0.6697X_1 - 0.9545X_2 + 0.4903X_3 + 0.0423X_4 + 0.3694X_5.$$

### Conclusion

Based on weather parameters, a regression model was developed for wheat yield in different zones of Bihar and for complete Bihar. Overall, it was found that after an increase in high temperature, and in the case of very low temperature, the yield was adversely affected, but in the case of RH, the yield also increased. However, in the case of high rainfall, the yield decreases. The interpretations may be seen from Tables 1 to 8, regarding the correlation matrix of weather parameters of wheat yield and regression model for weather parameters of wheat yield in different zones and also for complete Bihar.

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