Drought and crop production in Chengde City: Based on Logistic and Prais-Winsten regression analysis

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Abstract. Drought has a great impact on agricultural production and threatens food security. Chengde city is located in the border of North China and Inner Mongolia Plateau, where drought often occurs. In this study, logistic regression and multiple regression were used to analyze the relationship between drought and grain yield. It is found that drought is an important reason for agricultural production reduction.

1 Introduction

Drought is one of the most destructive natural disasters, causing huge economic and ecological losses [1-2]. Due to the close relationship between drought and food security [3], scholars often pay attention to the problem of drought [4-5]. Since 2004, China's grain output has reached a record high for 15 consecutive years and stabilized at more than 1.3 trillion Jin for five consecutive years. But earlier, China's agricultural production was more affected by meteorological disasters, and crop production was unstable. Especially in northern China, precipitation is an important factor restricting agricultural development. This study established the relationship between drought and crop production, which has guiding significance for agricultural production.

2. Research area, data and methods

2.1 Survey of Research Areas

Chengde is located in the northeastern part of Hebei Province (40°12'-42°37'N, 115°54'-119°15'E), which is the transition zone connecting North China and Northeast China. The district of the city is located in the Yanbei Mountains and the Inner Mongolia Plateau in the north. It belongs to the transition zone from warm temperate zone to sub-frigid zone. It has a semi-humid and semi-arid continental monsoon climate. The average annual precipitation in the urban area is 519.8mm. The city has large interannual precipitation changes and rainy years. The precipitation is 835.9 mm, and the annual precipitation is 326.7 mm with low rainfall. The ecological environment is relatively fragile. The precipitation in Chengde City is mainly concentrated in July and August. The precipitation in the two months exceeds half of the annual precipitation. There is little precipitation in spring and spring drought is prone to occur.

Chengde's agriculture is dominated by food crops grown in dry land, including corn, sorghum, and millet. Drought is one of the main factors affecting agricultural production in Chengde.

Table 1: Monthly average precipitation in Chengde City

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|-------|
| Precipitation | 2.0 | 4.3 | 7.4 | 21.9 | 43.7 | 83.8 | 145.8 | 133.6 | 49.0 | 20.8 | 5.2 | 2.2 | 519.8 |

(Data source: Chengde Meteorological Bureau)

2.2 Data

This study collected the cumulative intensity and maximum intensity of the extreme drought in Chengde from 1961 to 1990, and the population data, planting area and output value data from 1960 to 1990. Stata 15 was used to analyze the impact of drought on the unit output value of the planting industry in Chengde.

Table 2: Variable list

| Variable | Description |
|----------|-------------|
| Y₁       | whether the output is reduced |
| Y₂       | the output value of planting industry |
| X₁       | the planting area |

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X2 the number of population at the end of the year
X3 the maximum value of annual extreme drought intensity
X4 the average value of extreme drought cumulative intensity
X5 the frequency of drought.

2.3 Methods
The correlation coefficient was used to judge the impact, and the relationship between drought and crop production was established by logistic regression and Prais-Winsten regression.

3. Process

3.1 Normal distribution test
Through normal distribution test, we can judge whether the correlation should be determined by parametric method or nonparametric method.

| Variable | Obs | Pr(Skewness) | Pr(Kurtosis) | adj chi2(2) | Prob>chi2 |
|----------|-----|--------------|--------------|-------------|-----------|
| Y1       | 31  | 0.4372       | 0.7566       | 0.73        | 0.6929    |
| X1       | 31  | 0.2010       | 0.3583       | 2.70        | 0.2591    |
| X2       | 30  | 0.6116       | 0.0238       | 5.21        | 0.0737    |
| X3       | 30  | 0.0204       | 0.9474       | 5.22        | 0.0735    |
| X4       | 30  | 0.1185       | 0.9637       | 2.66        | 0.2640    |
| X5       | 30  | 0.0013       | 0.0074       | 13.45       | 0.0012    |

From the test results, X2, X3 close to the significance level of 0.05, X5 is less than the significance level of 0.05, the test correlation should be non parametric method.

3.2 Pearson rank sum test

| Variable | X1  | X2  | X3  | X4  | X5  |
|----------|-----|-----|-----|-----|-----|
| spearman | -0.5519** | 0.7264*** | -0.1153 | -0.2153 | 0.1662 |
| Prob > | 0.0016 | 0.0000 | 0.5441 | 0.0531 | 0.3802 |

4. Result
From the perspective of time series, the output value of the planting industry was greatly affected by drought before the reform and opening up, and the change in the agricultural output value after the reform and opening up was significantly less affected by the drought.
4.1 Logistic regression

$Y_1$ is the binary variable and the $X_4$ is independent variable, the logistic univariate regression analysis was carried out. Finally, the model is obtained.

Logit $Y_1 = 1.3014X_4 + 0.0115$ (1)

From the regression results, the average value of extreme drought accumulation intensity has a significant correlation with the yield reduction of planting industry in Chengde city.

| Variable | Odds Ratio | Std. Err. | z  | P>|z|  | [95% Conf. Interval] |
|----------|------------|-----------|----|------|---------------------|
| $X_4$    | 1.301353   | .1728902  | 1.98| 0.047| [1.00302 1.688422]  |
| Cons     | .0115227   | .0267298  | -1.92| 0.054| [.000122 1.08675]   |

4.2 Prais-Winsten regression

Using the Prais-Winsten regression, $X_1$, $X_2$, $X_4$ should be included in the model.

$Y_2 = 563.7104X_1 + 0.1793125X_2 - 1031.919X_4 - 339744.6$ (2)

| Variable | Coef  | Std. Err. | t    | P>|t| (95%) | [95% Conf. Interval] |
|----------|-------|-----------|------|--------|---------------------|
| $X_1$    | 563.7104 | 241.602    | 2.33 | 0.028  | 67.09029 1060.331 |
| $X_2$    | .1793125 | .0330018   | 5.43 | 0.000  | .1114763 .2471488 |
| $X_4$    | -1031.919 | 475.4389   | -2.17| 0.039  | -2009.198 -54.64029 |
| Cons     | -339744.6 | 149285.7   | -2.28| 0.031  | -646605.7 -32883.48 |

| Source   | SS     | df       | MS       |
|----------|--------|----------|----------|
| Model    | 7.7263e+09 | 3       | 2.5754e+09 |
| Residual | 2.2639e+09 | 26      | 87071752.8 |
| Total    | 9.9902e+09 | 29      | 344490046  |
The model significance level $P < 0.0001$; $R^2$ is 0.7734; The adjusted $R^2$ is 0.7472; D-W original value 2.35206; D-W converted value 1.971624. The model has high significance level, good fitting degree and no significant autocorrelation. According to the regression results, the output value of planting industry decreased by 1031.92 yuan per unit of annual extreme drought accumulation intensity in Chengde city.

5 Conclusion

From 1960 to 1990, the planting production in Chengde city was not stable. Especially before the reform and opening up, the planting industry in Chengde city was greatly affected by drought. But the impact of drought on crop production is not decisive. After the reform and opening up, with the development of planting technology, the impact of drought becomes smaller.

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