

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.

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.

2. Research area, data and methods

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.

2.1 Survey of Research Areas

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

Y ₁	whether the output is reduced
Y ₂	the output value of planting industry
X ₁	the planting area

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X ₂	the number of population at the end of the year
X ₃	the maximum value of annual extreme drought intensity
X ₄	the average value of extreme drought cumulative intensity
X ₅	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.

Table 3: Normal distribution test

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob>chi2
Y ₁	31	0.4372	0.7566	0.73	0.6929
X ₁	31	0.2010	0.3583	2.70	0.2591
X ₂	30	0.6116	0.0238	5.21	0.0737
X ₃	30	0.0204	0.9474	5.22	0.0735
X ₄	30	0.1185	0.9637	2.66	0.2640
X ₅	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.

Since the variables do not conform to the normal distribution, the Spearman rank sum test was used to analyze the relationship between variables.

From the results of correlation coefficient, the effect of continuous drought is more significant than that of short-term extreme drought.

3.2 Pearson rank sum test

Table 4: Pearson rank sum test

Variable	X ₁	X ₂	X ₃	X ₄	X ₅
spearman	-0.5519 **	0.7264 ***	-0.1153	-0.2153	0.1662
Prob > t	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.

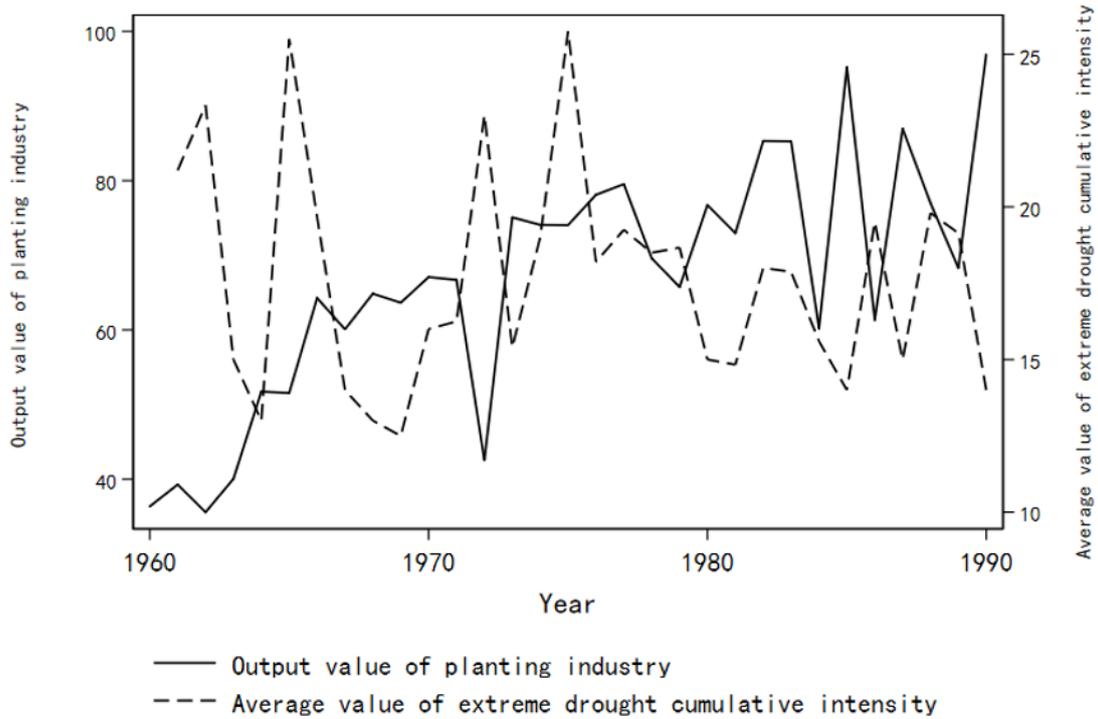


Figure 1: average cumulative drought degree and planting output value

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.

$$\text{Logit } Y_1 = 1.3014X_4 + 0.0115 \quad (1)$$

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.

Table 5: Logistic regression results

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	[.0001222 1.08675]

4.2 Prais-Winsten regression

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

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

Table 6: The results of Prais-Winsten regression

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

Table 7: Analysis of model variance

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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