Effects of water-saving technology application, disaster type and occurrence stage on disaster area of cotton field

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Abstract. The purpose of this paper is to analyze the impact of the application of water-saving technology, types of agricultural disasters and disaster stages on the affected area of cotton field by using the survey data. In this study, bootstrap method was used for quantile regression analysis of cotton disaster area. Four quantiles were selected in the analysis, which was 0.25, 0.5, 0.75 and 0.90. The results were compared with those of OLS regression analysis. The results indicate that the application of drip irrigation water-saving technology and the increase of irrigation expenditure have obvious negative correlation with cotton disaster area. Wind disaster, hail disaster, rain and waterlogging, drought, freezing damage and insect pests have obvious positive effects on the affected area of cotton, and the disease has no significant impact on the affected area of cotton field because of its strong controllability. The results of the study estimated the impact of water-saving technology and disaster types on cotton field disaster area in detail.

1. Introduction

At present, the research on the disaster situation of cotton field in China mainly focuses on the specific types of disaster, and the research on the disaster area of cotton field from the perspective of farmers is less. Xinjiang is the largest cotton growing area in China, its cotton production accounts for more than 80% of China’s cotton production in recent years. Therefore, taking Xinjiang cotton field as the research object, it has strong representativeness. The agricultural ecological environment in Xinjiang is relatively fragile, and there are often serious natural disasters. In the process of agricultural planting, drought and hail disasters become the most common natural disasters in the process of agricultural development in Xinjiang. Based on the analysis of the temporal and spatial distribution and hazard assessment of hail disaster in the growing period of crops in Xinjiang, Wang Yun et al. found that the number of hail disaster and the contribution rate of the planting area of crops to the linear growth trend of the disaster area were 93% and 7%, respectively. The planting area of crops was an important factor to explain the temporal and spatial changes of Hail Disaster[1]. Du Zhangying et al. found that the change of drought and flood disasters on agricultural stress is greatly affected by the topography through studying the drought and flood disasters and their impact on the change of agricultural stress in Anhui Province, which is manifested in the obvious spatial distribution difference of stress index of drought and flood disasters on agriculture in Anhui Province[2]. Based on the analysis of the characteristics of agrometeorological disasters in Guizhou Province, Yao Qingfu found that there were obvious differences in the impact of four agrometeorological disasters, namely, flood, drought, hail and freezing, on the yield of three main crops, namely, rice, wheat and corn[3]. Wang Huan found a
strong correlation between the distribution characteristics of flood affected area and economic loss and the spatial characteristics of precipitation in Huaihe River Basin by analyzing the temporal and spatial changes of flood affected area and economic loss[4]. Based on the analysis of remote sensing data in 1990, 2000 and 2010, Xu Huiyan found that there was a significant correlation between the decrease of lake water area and the occurrence of urban waterlogging[5]. Zhu Mengyuan used the disaster census data of flood, drought, wind hail and low temperature in Liaoning Province in recent 30 years (1987-2016) and crop yield data, and found that the impact of four agricultural meteorological disasters on crop yield was drought, wind and hail, flood and low temperature[6]. Based on the above facts, this paper starts from the types and stages of disasters, combined with the application of water-saving technology, the types of cotton field disaster, the disaster stage and the basic characteristics of farmers and other factors to conduct in-depth study on the changes of the affected area of cotton field in Xinjiang.

2. Data source and basic information of samples

2.1. Data source
The data used in this paper are from the questionnaire survey from 2015 to 2018. We mainly visited more than 20 villages and towns in Tacheng, Changji and Bozhou, A total of 216 valid questionnaires were collected.

2.2. Basic information of sample
From the overall situation of the sample, the basic characteristics of cotton farmers show the characteristics of low education, high age and low net income. Under the situation of declining cotton market, the market risk of cotton farmers is increasing, and the deterioration of ecological environment makes the natural disaster risk that farmers need to bear increase. Therefore, both farmers’ production experience and external agricultural disaster risk will have a strong impact on cotton disaster area, which is directly reflected in the change of cotton field disaster area.

3. Model construction and variable selection
In this paper, quantile regression is used to analyze the whole data sample. Therefore, the influencing factors analysis model of the disaster area of cotton field constructed in this paper is as follows:

\[ Y_i = a_0 + \sum_{i=1}^{n} a_i x_i + \varepsilon \quad (n=19) \]  

(1)

In the formula (1), \( Y_i \) is the disaster area of cotton. In this paper, OLS regression analysis and quantile regression analysis are used simultaneously, and their coefficients are compared. It is found that OLS regression analysis can’t fully describe the distribution of cotton disaster area, while quantile regression can better describe the distribution of cotton disaster area. In order to investigate the influencing factors of cotton disaster area on different quantiles, the quantile regression model is established as follows:

\[ Q_q(Y_i | X_i) = X_i \beta_q \]  

(2)

In the formula (2), \( x_i \) is the independent variable in the formula (1); \( \beta_q \) is the coefficient vector; When \( x_i \) is given, \( Q_q(Y_i | X_i) \) is the conditional quantile corresponding to the quantile (0<q<1).

\[ \beta_q = \text{argmin}\{\sum_{t:price_t \geq X_i \beta_q} q|Y_t - X_i \beta_q| + \sum_{t:price_t < X_i \beta_q} (1-q)|Y_t - X_i \beta_q|\} \]  

(3)

In the actual analysis process, this paper uses bootstrap intensive algorithm technology to estimate quantile regression coefficient, and sets the number of samples to 400. The specific variables and main statistics of influencing factors in the model are shown in Table 1.
Table 1. Model explanatory variable selection and processing instructions.

| Variable name                        | Variable code | Option                                                                 | Effective number of households | Effective percentage | Mean value |
|--------------------------------------|---------------|------------------------------------------------------------------------|-------------------------------|----------------------|------------|
| Affected area of cotton (hm²)        | Y             |                                                                        | 198                           |                      | 3.86       |
| Basic characteristics of farmers     |               |                                                                        |                               |                      |            |
| Number of labor force                | $X_1$         |                                                                        | 216                           | 2.20                 |            |
| Cotton production period (year)      | $X_2$         |                                                                        | 216                           | 20.70                |            |
| Own cultivated land (hm²)            | $X_3$         |                                                                        | 211                           | 2.16                 |            |
| Rented cultivated land (hm²)         | $X_4$         |                                                                        | 210                           | 4.71                 |            |
| Education level of head of household | $X_5$         | 1 = Illiteracy; 2 = Primary school; 3 = Junior high school; 4 = Senior high school; 5 = Vocational and Technical college; 6 = University; | 216                           | 2.95                 |            |
| Age of head of household             | $X_6$         | 1 = Under 20; 2 = 21-30; 3 = 31-40; 4 = 41-50; 5 = 51-60; 6 = over 60; |                               | 4.08                 |            |
| Application of water saving technology|               |                                                                        |                               |                      |            |
| Application of drip irrigation water saving technology | $X_7$         | Yes = 1                                                                | 146                           | 73.73%               | 0.75       |
| Irrigation expenditure per hectare   | $X_8$         | No = 0                                                                 | 52                            | 26.27%               |            |
| Types of agricultural disasters      |               |                                                                        |                               |                      |            |
| Wind disaster                        | $X_9$         | No = 0                                                                 | 27                            | 13.64%               | 0.83       |
| Disaster caused by Hail              | $X_{10}$      | Yes = 1                                                                | 171                           | 86.36%               |            |
| Rain And Waterlogging                | $X_{11}$      | No = 0                                                                 | 148                           | 74.75%               | 0.24       |
| Drought                              | $X_{12}$      | Yes = 1                                                                | 50                            | 25.25%               |            |
| Freeze Injury                        | $X_{13}$      | No = 0                                                                 | 213                           | 98.6%                | 0.01       |
| Disease                              | $X_{14}$      | Yes = 1                                                                | 3                             | 1.4%                 |            |
| Insect pest                          | $X_{15}$      | No = 0                                                                 | 138                           | 69.70%               | 0.30       |
| Disaster stage and remedy or not     |               |                                                                        |                               |                      |            |
4. Empirical results and analysis

In this paper, bootstrap method is used for quantile regression analysis of cotton disaster area. Under the existing data samples, this paper selects four representative quantiles, which are 0.25, 0.5, 0.75 and 0.90 respectively. In order to make comparison easier, this paper also lists the estimation results of OLS regression analysis. The quantile regression analysis results are shown in Table 2.

Table 2. Empirical analysis results.

| Variable name                                      | 0.25     | 0.5     | 0.75     | 0.9     | OLS     |
|---------------------------------------------------|----------|---------|----------|---------|---------|
| Basic characteristics of samples                  |          |         |          |         |         |
| Number of labor force                              | -0.3590**| -1.8698***| -2.5033**| -2.9896***| -2.6065***|
| Cotton production years                            | -0.6143* | -0.9514***| -1.3579**| -0.6550**| -1.7051***|
| Education level of farmers                         | -1.6726**| -2.3780**| -2.2354* | 2.6487* | -1.5237**|
| Age of head of household                           | -3.2440**| -6.8184***| -9.6810**| -4.9224**| -12.8541**|
| Own cultivated land                                | 0.4786***| 0.6414***| 0.6388***| 0.9193***| 0.5784***|
| Renting cultivated land                            | 0.2508***| 0.4236***| 0.5453***| 0.8147***| 0.2676***|
| Application of water-saving technology             |          |         |          |         |         |
| Application of drip irrigation water saving technology| -6.5145* | -14.0152***| -13.2274***| -4.324**| -16.709**|
| Irrigation expenditure per hectare                 | -0.1948***| -0.1552***| -0.0595***| -0.1021***| -0.2266***|
| Disaster type                                      |          |         |          |         |         |
| Wind disaster                                      | -0.2239  | 2.2023***| 7.7345***| 9.2401***| 12.5087***|
| Disaster caused by hail                            | 8.0215** | 6.6082**| 17.2702**| 13.3021**| 11.187**|
| Insignificant waterlogging                         | 43.5580  | 7.9285  | 30.1166  | 3.0261  | 53.6525 |
| Drought                                            | 0.3277*  | 4.3486* | 0.8805*  | 7.1761* | 3.1693* |
| Freeze disaster                                    | 5.1735*  | 10.2235*| 12.7365* | 4.9418* | 7.7682* |
| Disease                                            | -2.4137  | 6.9060  | 6.4414  | 5.3984  | 0.7680  |
| Insect pest                                        | -1.9758* | 1.2177* | 2.2815* | 0.4646* | 7.1615* |
| Disaster stage and disaster recovery                |          |         |          |         |         |
| Sowing time                                        | 16.1349**| 10.9763**| 4.0824** | 7.1083**| 16.3506**|
| Growth period                                      | 11.6668**| 9.4937***| 1.0709** | 2.1117***| 10.6990***|
| Harvest time                                       | 23.0086**| 14.7006**| 21.3537**| 15.0048**| 25.7275**|
| Disaster recovery                                  | -2.0537**| -5.1630**| -12.2620**| -8.8513**| -1.4874**|
| Constant term                                      | 14.6734  | 22.2635  | 21.9787  | 9.7281  | 41.6909 |

4.1. Impact of basic characteristics of farmers

In the basic characteristics of the sample, the number of labor force, production years, years of education, the age of the head of household are inversely proportional to the cotton disaster area. From
the actual investigation, the increase of the number of household labor force will increase the ability of farmers to deal with agricultural disasters, such as timely completion of post disaster replanting, plastic film mulching, cleaning up field debris, etc. With the increase of production years, education level and the age of the head of household, the cotton planting experience of farmers has gradually accumulated, and the ability to deal with agricultural disasters has gradually increased. With the accumulation of production experience and skills, farmers can more quickly carry out disaster recovery. In the case of appropriate remedial measures, it can effectively reduce the losses caused by agricultural disasters.

Both self owned cultivated land and leased cultivated land are in direct proportion to cotton disaster area. Because the common disasters encountered by cotton farmers are universal, whether they are self owned or leased farmland, the types of disasters in the same area are the same, and will not change with the amount of cultivated land. Therefore, there is an obvious positive correlation between the disaster area and the total cultivated land area.

4.2. Impact of water saving technology application

From the empirical results, the application of drip irrigation water-saving technology and the increase of irrigation expenditure can reduce the cotton disaster area. Based on the reality of agricultural production, the application of drip irrigation water-saving technology is more common in Xinjiang. In addition to water-saving function, the technology can also improve the ability of farmland to resist common farmland disasters such as freezing, dry hot wind, salinization and so on. The application of drip irrigation water-saving technology can effectively reduce the losses caused by agricultural disasters. In the actual investigation, it was found that different application of drip irrigation fertilizer had a greater impact on the final yield of cotton. Reasonable application of drip irrigation fertilizer can improve the survival rate and growth status of cotton during development, and enhance the disaster resistance of cotton. Therefore, the application of drip irrigation water-saving technology and the increase of irrigation expenditure can reduce the disaster area of cotton under the condition of improving cotton growth.

4.3. Impact of agricultural disaster types

From the measurement results, wind disaster, hail disaster, rain and waterlogging, drought, freezing damage has a significant positive impact on cotton disaster area. Among the types of agricultural disasters, the occurrence of these four kinds of disasters has great harm to cotton field. It can cause cotton crop failure and devastating damage to water-saving facilities, when the wind power level is large and sustainable. Therefore, the wind disaster has a strong positive impact on the affected area of cotton field. From the results of the model, the wind disaster with low quantile is not significant for the affected area of cotton field, with high score there was a significant positive correlation between the sites, mainly due to the extensive damage caused by the wind disaster. Once the disaster occurred, the affected area of cotton field was larger, and the smaller affected cotton field was mostly caused by local agricultural disasters. In Xinjiang, from the beginning of April to the beginning of May and the middle and early ten days of each year, wind disaster is more likely to occur, and this period is in the critical period of cotton sowing and cotton seedling growth. The occurrence of wind disaster will have a great impact on the cotton sowing progress and quality, and damage the leaves of the unearthed cotton seedlings.

With the change of climate, hail disaster has gradually become a common disaster in the process of agricultural production in Xinjiang. Hail disaster usually occurs in the budding stage and flowering stage of cotton. Once it happens, it has a great impact on the affected area of cotton. The hail disaster can knock down the branches and leaves of cotton, and make cotton form a "bare pole". The more serious situation is to break the main trunk of cotton and make cotton lose its vitality. Therefore, the occurrence of hail disaster will increase the affected area.

The influence of the waterlogging disaster on the affected area is not significant. Waterlogging disaster only occurs in a few areas of Xinjiang. It will affect cotton growth in Xinjiang only when
there is a large amount of snow water melting and sudden increase of rainfall. Generally, flooding for two days will reduce the overall yield of cotton field by 30% - 40%. However, there are few waterlogging disasters in the research area. Therefore, in the sample data, the impact of waterlogging disaster on the affected area of cotton Not significant.

Drought is usually caused by high temperature and lack of water resources. In some areas, cotton fields cannot be irrigated in time or suffer from high temperature disasters. Missing the best irrigation time or continuous high temperature weather will have a great impact on cotton yield and quality.

The occurrence of freezing disaster will increase the affected area. The frost disaster usually occurs in the middle and late April in Xinjiang, which is the cotyledon stage of cotton. During this period, the frost resistance of cotton seedlings was the worst. Freezing can dehydrate cotton seedling cells, which can lead to the death of cotton seedlings. If freezing disaster occurs in the flowering and boll stage, it will have a serious impact on cotton production. Therefore, the occurrence of freezing disaster will increase the affected area of cotton field.

The occurrence of insect pest will increase the affected area of cotton. The data of low quantile were not significant. The main reason is that cotton farmers have a strong ability to control insect pests in small areas. However, the large-scale outbreak of insect pests will have a strong destructive capacity on cotton fields.

The effect of the disease on the affected area of cotton was not significant. At present, cotton varieties planted in Xinjiang have some resistance to Fusarium wilt, so the rate of disease field is low. However, cotton Verticillium wilt occurred slightly, and had a trend of aggravation in recent years. At the same time, due to the improvement of pesticide application, agricultural production technology and field management level, the disease disaster in Xinjiang cotton field is controllable.

4.4. Impact of disaster stage and remediation

From the results of empirical analysis, it can be seen that the disaster of cotton in the sowing, growth and harvest period will have a positive impact on the affected area of cotton, which has a sustained impact. At any stage of cotton growth, the disaster area will be increased, and good disaster recovery is an important way to reduce the disaster area. Through reasonable disaster recovery, the affected cotton fields can be reduced or even eliminated, and the benefits of cotton fields can be guaranteed.

5. Conclusions

In this paper, quantile regression model is used to analyze the influencing factors on the disaster area of cotton field. These factors include the basic characteristics of farmers, the application of water-saving technology, the types and stages of disasters etc. Through the empirical analysis of the model, the following conclusions can be drawn.

First, the number of labor, production years, years of education, the age of the head of household have a negative impact on the cotton disaster area. However, the area of cultivated land is directly proportional to the disaster area of cotton field.

Secondly, the application of drip irrigation water-saving technology and the increase of irrigation expenditure have a negative impact on the affected area of cotton, which shows that the extensive application of water-saving technology has a positive impact on reducing the disaster situation of cotton field.

Thirdly, wind disaster, hail disaster, rain and waterlogging, drought, freezing damage and insect pests have obvious positive effects on the affected area of cotton field. Due to the strong controllability, the disease has no significant impact on the affected area of cotton field.

Fourth, no matter what stage of cotton growth, agricultural disasters will have a positive role in promoting the affected area of cotton field. However, if the disaster recovery can be carried out in time, the loss can be effectively reduced and the income of cotton farmers can be guaranteed.
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