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Regression Analysis of Artificial Hail Suppression Effect in Akesu Prefecture of Southern Xinjiang

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Abstract: To further evaluate the differences of annual hailstorm areas before and after the scientifically carrying out artificial hail suppression period in Akesu in the hope of analyzing the effect. In this paper, the method of the regression test of areas was applied, the differences of annual hailstorm areas before and after 18a of the scientifically carrying out artificial hail suppression period in Akesu were analyzed with annual hailstorm areas data from 1978 - 2013 in Akesu and Kashi with 1996 as the year of artificial hail suppression. The results showed that the average annual hail area was reduced 23802 hm^2, and the relative loss rate was 54.5% after the operation of scientifically artificial hail suppression in Akesu. Combined with the agricultural economic data, the average annual reduction of hail disaster loss was 444,170,000 RMB, annual input and output ratio nearly was 1:10. The statistical significant level highly reached α=0.01. Therefore, through scientifically carrying out artificial hail suppression operations, it is obvious that hail disaster losses reduced and the social and economic benefits are great in Akesu.

Keywords: Artificial Hail Suppression, Regression Test of Areas, Performance and Effect Evaluation

1. Introduction

1.1. Significance

Xinjiang is one of the most frequent occurrences of hail disasters in northwestern China [1]. The Akesu region and the Kashgar region are located in the southern and western margins of the middle Tianshan Mountains, and from the northern margin to the northwestern margin of the Tarim Basin. The summer is hot and humid, with little rainfall, large evaporation, and abundant light and heat resources. There are many underlying surface distributions in the two regions, such as mountains, plains, deserts, oases, rivers, reservoirs, etc., and the types of landforms are complex. The main features of the terrain are: mountains in the north, deserts in the south, plains, oases, rivers, reservoirs, etc. in the middle. The surface conditions are uneven, undulating, and it is easy to form hail weather. The Yarkant River Basin, the Sui River Basin and the Akesu River Basin in the region are three of the nine major hail occurrence areas in Xinjiang [2]. The annual economic losses caused by natural disasters such as hail and floods amount to several hundred million yuan, which has seriously affected the economic and social development of southern Xinjiang. With the global warming in recent years, the strong hail weather in the Akesu and Kashgar areas is increasing [2-3]. Since 1994, the Akesu area has used the World Bank loan project to build the first C-band Doppler weather radar in Xinjiang in Shaya County, and officially put into operation in 1996. Subsequently, 148 sets of new artificial weather-influencing rocket launching systems, 1 new-generation weather radar, and 1 X-band dual-polarized weather radar were introduced, and an advanced artificial flood control system was established. In the Kashgar area, it was only in the past two years that the artificial flood control work was carried out scientifically and systematically.

1.2. Predecessor Research

In recent years, many scholars in China have analyzed the climatic characteristics, temporal and spatial distribution, and disaster situation of hail weather [4-6], forecasting and early warning methods [7-11] and hail formation mechanism, anti-cluster catalysis principle and flood control and mitigation effects [12-14] Research has been carried out in other areas. Because Xinjiang is a flood-prone area; in the face of serious disasters that threaten the economic development of agriculture and animal husbandry in Xinjiang, Xinjiang meteorologists have carried out targeted research work, Wang Qiuxiang et al [15] systematically analyzed the distribution characteristics of disaster losses in Xinjiang. It is pointed out that the Akesu area is the most serious area for disaster relief in Xinjiang, and it is necessary to carry out key defenses; Chen Hongwu [16], Wang Xu, Ma Wei [17-18] studied the time of occurrence of Xinjiang hail, and statistically analyzed the systematic hail weather. The circulation situation; Yang Lianmei et al [19] reached a meaningful conclusion in the climate characteristics and defense countermeasures of Xinjiang hail; Li Lihua et al [20] completed the risk zoning of five risk zones in the Akesu region by means of ArcGIS. These research results basically reveal the occurrence and changing characteristics of the hail weather in Xinjiang. However, based on the scientific complexity of the formation and evolution of the strong convective weather system and the technical complexity of the artificial catalytic operation, it is very difficult to test the effect of artificial flood control.

1.3. Entry point of this Study

Li Bin et al [21] have used some statistical methods to evaluate the effect of artificial flood control in the Akesu area. However, in order to further evaluate the effectiveness of artificial anti-mite operation, it is necessary to use different statistical evaluation methods, especially to evaluate more efficient and accurate regional regression analysis. This paper is based on the information on the area of disaster relief in the Akesu area in 1996 before and after the artificial flood control operation (these are called the historical period and the operation period), and the information on the disaster area in Kashgar from 1978 to 2013, targeting the Akesu area. District, Kashgar area as a comparison area, using regional regression analysis to determine the reduction rate of disaster relief area in Akesu area, combined with the agricultural economic data of the area, the input-output ratio of artificial flood control operation. In order to make use of different statistical evaluation methods, it provides a technical method and scientific basis for scientifically quantitative evaluation of artificial flood control operations, and further improves the level of artificial flood control scientific operations.

2. Materials and Methods

2.1. Materials

The area of disaster relief in Akesu and Kashgar from 1978 to 2013 came from the climate center of the Meteorological Bureau of Xinjiang Uygur Autonomous Region. The corresponding cultivated land area and agricultural output value data are derived from the Xinjiang Statistical Yearbook. The above data are the sum of the corresponding annual data of 8 counties and 1 city in Akesu area and 11 counties and 1 city in Kashgar, and carry out rigorous verification and verification, in which individual abnormalities, repeated data are analyzed, consulted, and rejected after review.

The area of the text is the area of cultivated land, and the unused planted area is used as the benchmark. The reason is that considering the factors such as frost in the spring and gale disasters, some cultivated land that has been planted will be re-broadcast or re-broadcast, and the planting area will increase. The output value is based on the agricultural output value after the removal of forestry and animal husbandry output value. It is considered that the hail disaster mainly causes loss to crop crops.

2.2. Methods

The regional regression analysis is to establish a statistical regression equation corresponding to the statistical variables of the historical time series of the target area and the comparison area based on the historical data by means of one or more comparison areas. Assuming that the statistical variables of the two regions in the operation period satisfy the above regression relationship, the statistical regression equation is used to derive the natural value of the statistical variable in the target area of the operation period from the statistical variable value of the comparison period in the operation period, which is also called the natural statistical variable of the target area in the operation period. The expected value is compared with the actual statistical variable value in the target area of the operation period, and the evaluation result of the statistical variable of the target period of the operation period can be obtained.

Information on the annual disaster area (in ha) in the Kashgar area as a comparison area and the Akesu area as a target area. The annual disaster area of the contrast area is x_i', the annual disaster area of the target area is y_i', the area of the annual disaster relief area in the comparison area is x_i, and the area of the annual disaster area is y_i, $x_i' = x_i^4$, $y_i' = y_i^4$, the relevant calculation results are as follows:

Table 1. *Results of regression statistical analysis and calculation with the annual hail damaged areas in object – comparative areas.*

Years	x_i'	y_i'	x_i	y_i	$(x_i-\bar{x})^2$	$(y_i-\bar{y})^2$	$(x_i-\bar{x})(y_i-\bar{y})$
(Historical period)							
1978	0	3004	0.0000	7.4033	56.6338	36.0315	45.1730
1979	120	12974	3.3098	10.6726	17.7729	7.4712	11.5233
1980	50507	25995	14.9912	12.6976	55.7364	0.5017	-5.2879
1981	5533	19749	8.6247	11.8546	1.2082	2.4066	-1.7052
1982	1000	31622	5.6234	13.3351	3.6181	0.0050	0.1346
1983	0	0	0.0000	0.0000	56.6338	179.7185	100.8868
1984	78	43880	2.9690	14.4733	20.7624	1.1392	-4.8635

Years	x_i'	y_i'	x_i	y_i	$(x_i-\bar{x})^2$	$(y_i-\bar{y})^2$	$(x_i-\bar{x})(y_i-\bar{y})$
1985	0	14906	0.0000	11.0494	56.6338	5.5530	17.7338
1986	14933	23445	11.0545	12.3741	12.4535	1.0647	-3.6413
1987	28240	127521	12.9633	18.8971	29.5694	30.1532	29.8599
1988	28972	59917	13.0465	15.6454	30.4811	5.0154	12.3643
1989	16107	38388	11.2656	13.9974	13.9883	0.3499	2.2124
1990	2667	156862	7.1861	19.9012	0.1152	42.1888	-2.2048
1991	65847	113772	16.0189	18.3658	72.1374	24.6000	42.1258
1992	12053	57477	10.4780	15.4837	8.7167	4.3170	6.1343
1993	980	65069	5.5951	15.9714	3.7267	6.5818	-4.9526
1994	0	62731	0.0000	15.8260	56.6338	5.8567	-18.2123
1995	23140	31844	12.3337	13.3585	23.1182	0.0 023	-0.2281
Total	250177	889156	135.4598	241.3065	S_x=5.5303	S_y=4.5566	S_{xy}=13.3560
Average	13899	49398	7.5255	13.4059			
Years (Operation period)							
1996	20000	3804	15.8260	7.8534			
1997	15000	17976	11.0668	11.5791			
1998	140000	11121	19.3434	10.2692			
1999	0	913	0.0000	5.4969			
2000	694	0	5.1334	0.000			
2001	0	28309	0.000	12.9712			
2002	908	40096	5.4891	14.1506			
2003	157	10642	3.5415	10.1568			
2004	8432	8952	9.5827	9.7270			
2005	9825	10950	9.9560	10.2295			
2006	0	0	0.0000	0.0000			
2007	1631	1336	6.3546	6.0458			
2008	3000	27541	7.4008	12.8823			
2009	70491	51750	9.1630	15.0826			
2010	544181	21251	15.2734	12.0738			
2011	334511	27866	13.5239	12.9202			
2012	316951	47755	13.3429	14.7827			
2013	38076	47116	13.9689	14.7330			
Total	407069	357378	158.9662	180.9542			
Average	22615	19854	8.8315	10.0530			

3. Results and Analysis

3.1. Determination of Target Area and Comparison Area

According to the selection requirements of the target area and the comparison area: the target area affected by artificial catalysis should be located in the downwind direction of the working point; the contrast area not affected by artificial catalysis requires: first, it is in the upwind direction of the working area or perpendicular to the wind direction. The side is not affected by artificial catalysis; the second is that the topography, landform, area, etc. should be roughly equivalent to the working area; third, the correlation coefficient of the two-zone sample should be more than 0.05 [22].

The Kashgar region is located in the western part of the Akesu region, while the weather system in Xinjiang moves from west to east, so it is located in the upper reaches of the Akesu region in terms of the movement of the weather system. Both the Kashgar and Akesu regions are in the southern foothills of the Tianshan Mountains and the northern margin of the Tarim Basin. Therefore, the two regions meet the selection requirements of the comparison area and the target area respectively.

3.2. Selection of Statistical Variables

The selection of statistical variables is as follows: the target area and the comparison area should have corresponding data for more than 10 years before the operation period; secondly, the regional correlation between the target area and the comparison area should be better, and the natural variation of the statistical variable itself is smaller. The significance level of the sample correlation coefficient should be above 0.05, and it is suitable for statistical tests. If the t-test is used, the statistical variables are required to have or be close to a normal distribution [22].

3.2.1. Sample Condition

Both the selected target area and the comparison area have 18 years of non-operational period data, which meets the non-operational period sample quantity requirement.

3.2.2. Statistical Variable Distribution Condition

The Kolmogorov distribution function and the fitness test were used to test the normal distribution of the historical disaster area in the two regions. Since the numerical value of the disaster relief area naturally varies greatly, in order to make the statistical variables closer to the normal distribution, the area of the disaster relief of the two areas is numerically transformed before the normal distribution test is performed. Through experimental analysis, the area of the disaster area in the target area and the comparison area was taken four times. After calculation, the fitting values of the historical values of the target area and the comparison area are 0.73 and 0.84, respectively, which are both greater than the required 0.5. Therefore, it is considered that the disaster area of the target area and the comparison area all meet the normal distribution of the fourth power root. According to the principle of mathematical statistics, it is possible to transform the annual disaster area of the two regions, establish a regression equation and perform statistical tests [23].

3.2.3. Sample Correlation and Significance Conditions

The correlation and its significance were tested. For the area data of historic hail disaster that the fourth root of target area and contrast area obey normal distribution, the correlation coefficient r of the statistical variables of the two areas is calculated by using the formula below:

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2\sum_{i=1}^{n}(y_i-\bar{y})^2}} = \frac{S_{xy}}{S_x S_y}$$

$$S_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2},\ S_y = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(y_i-\bar{y})^2},\ S_{xy} = \frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})$$

R =0.53 was calculated, t test is used to calculate $t = r \times \sqrt{\frac{n-2}{1-r^2}}$, t=2.5, unilateral test close to $t_{0.01}$=2.583. Therefore, the significance level of correlation coefficient is close to 0.01, much higher than the required 0.05. Relevance meets the requirements.

Therefore, the choice of statistical variables meets the requirements.

3.3. Regional Regression Analysis

3.3.1. Establish the Historical Regression Equation

According to the principle of historical regression statistics, the linear fitting relation *y=a+bx* between the four roots of hail disaster area in two regions was calculated by using the least square method, and the coefficient was calculated by the following formula:

$$b = \frac{S_{xy}}{S_x^2},\quad a = \bar{y} - b\bar{x}$$

Calculated b≈0.4367, a≈10.1196. Therefore, the historical regression equation of the target area based on the comparison area is:

$$\hat{y}_k = 10.1196 + 0.4367\bar{x}_k$$

$\hat{y}_k$ is the expected value of the fourth root of the annual disaster area in the target area of the operation period, and $\bar{x}_k$ is the fourth root of the actual annual disaster relief area of the comparison area during the operation period.

The historical regression equation and sample distribution results are shown in Figure 1. The samples are evenly distributed on both sides of the regression line, and the area of the annual disaster relief in the two regions after the transformation basically meets the linear relationship.

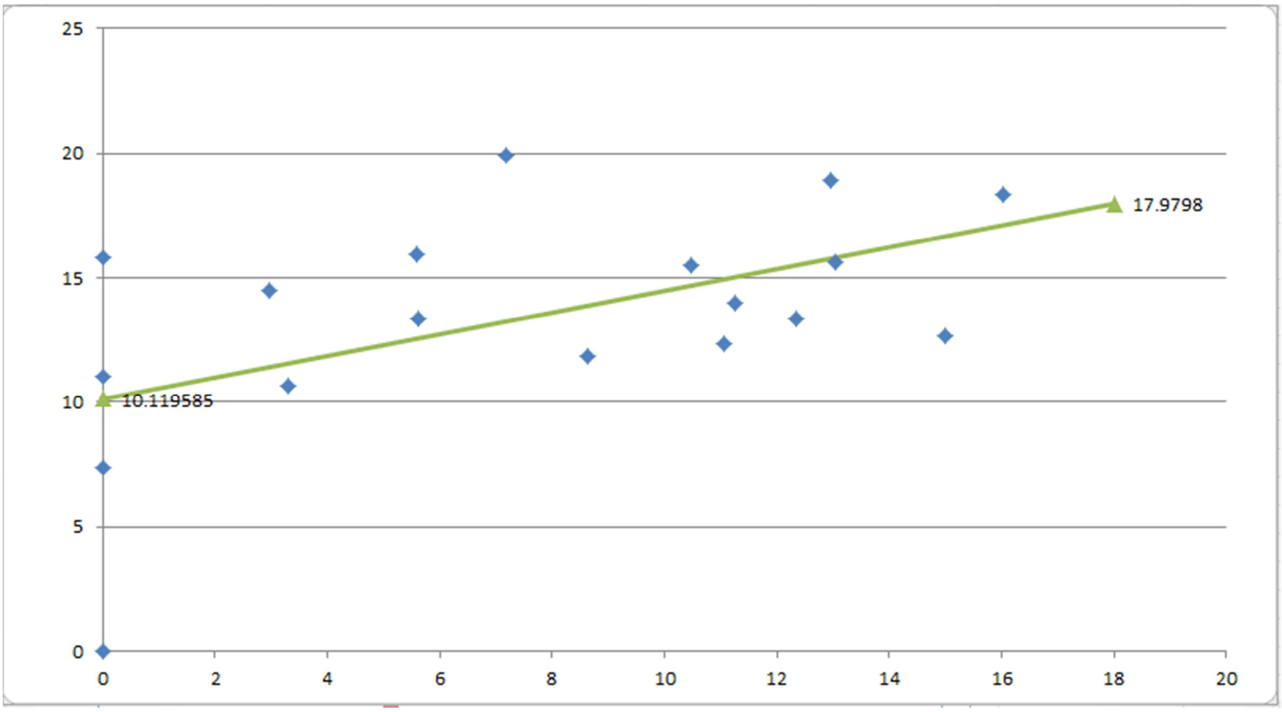

Figure 1. *Linear regression results with the samples distribution.*

3.3.2. Test for Significance of Linear Regression Equation

The significance of regression equation was determined by using the f-test method of variance analysis under the condition that the four roots of the historic hailstorm area in the target area and the comparison area were generally normal distribution and the correlation between them was good [24]. $F = \frac{Q_{\text{return}}/1}{Q_{\text{remaining}}/(n-2)}$ obeys the F distribution with 1 degree of freedom and (n-2). The linear regression equation is significant when F>, F end (1, n-2); the reverse is not significant. Among them: $Q_{\text{return}} = b^2 \sum_{i=1}^{n}(x_i - \bar{x})^2$, $Q_{\text{remaining}}=\sum_{i=1}^{n}(y_i - \bar{y})^2 - Q_{\text{return}}$

By calculation, F≈6.25>F0.05=4.49. Therefore, the linear regression equation is significant, with a confidence level of 96%. This linear regression equation can be used to estimate the expected value of the fourth square root of the natural annual hail disaster area in the operating period.

3.3.3. Effect Evaluation and Statistical Test

By operation phase contrast area real annual hail area, by the four generations into the linear equation root transformation, can be calculated from the corresponding target zone in estimates of the hailstorm area of four root $\hat{y}_k$, by compared with areas of real annual hail area, it can evaluate the operational period the change of the target zone in hail area value: $\Delta y = y_k - \hat{y}_k$. If delta y <0, the artificial hail suppression operation is effective, and the effectiveness needs further test for significance.

To reduce the impact of natural variability, the t-test method of multiple events was used to quantitatively estimate the effect of artificial hail suppression operation [24].

$$t = \frac{\bar{d}_k}{\sqrt{\frac{1-r^2}{n-2}\sum_{i=1}^{n}(y_i - \bar{y}_n)^2 \left[\frac{1}{k} + \frac{1}{n} + \frac{(\bar{x}_k - \bar{x}_n)^2}{\sum_{i=1}^{n}(x_i - \bar{x}_n)^2}\right]}}$$

Among them: $\bar{d}_k = \frac{1}{k}\sum_{i=1}^{k}(y_i - \hat{y}_i) = \bar{y}_k - \bar{\hat{y}}_k$; n and r are the correlation coefficients of the sample size and the correlation coefficients between the contrast region and the target region statistical variables when establishing the linear regression equation, respectively; $\bar{x}_n, \bar{y}_n$ contrast area and target zone respectively in the history of the hailstorm area of four root average; k is the sample size during the operation period; $\bar{x}_k, \bar{y}_k$contrast area and target zone respectively in hail area of four root mean value of k times test; $\bar{\hat{y}}_k$ for target zone in hailstorm area of four root estimate average test k times.

Relevant data: $\bar{d}_k$ =-3.83, r=0.53, n=18, k=18, $\bar{x}_n$=7.53, $\bar{x}_k$=8.61, $\sum_{i=1}^{n}(x_i - \bar{x}_n)^2$=519.94, $\sum_{i=1}^{n}(y_i - \bar{y}_n)^2$=352.96 is substituted into the above formula to calculate t≈-2.858, the subject freedom argument ν=n-2=16 t distribution. According to the distribution table, t<-$t_{0.02}$=-2.583, indicating a significant reduction value of annual hailstorm area in the target area during the operation period, and unilateral significance level <0.01.

3.3.4. Estimation of Reduction in Disaster Losses

The measured annual average hailstorm area in the target area during operation period was 19854 hm^2, while the estimated annual average hailstorm area by linear regression equation was 43656 hm^2. Therefore, the absolute reduction value of the average annual hail disaster area is 23802 hm^2, and the relative reduction rate is 54.5%. Unilateral significance level was higher than 0.01.

According to the 18a year agricultural output value and annual cultivated land area in Akesu region, the output value per hectare can be estimated to be about 18,661 yuan. Therefore, the average annual loss of hail disaster was reduced by 444.17 million yuan, accounting for 5.51% of the annual average agricultural output value. After the scientific development of artificial hail prevention in Akesu region, the annual investment of artificial hail prevention is about 45 million yuan, so the average annual input and output ratio is 1:10.

4. Discussion

As the cloud and precipitation became too bad naturally, the spatial and temporal distribution of hail would change greatly, which made the area of hail disaster fluctuate greatly. The statistical test of the effect of artificial hail suppression is equivalent to extracting the "signal" of the effect of artificial hail suppression from these high "noises". Therefore, the efficacy of statistical test methods is often not high [22-23]. However, statistical test is one of the main methods to test the effectiveness of artificial hail suppression operation. From the perspective of statistics and artificial weather, compared with sequence test, non-pair rank sum test, t-test and Welch test, the regional regression test adopted in this paper has higher test efficacy and accuracy [22]. The so-called regression analysis is to find the statistical correlation of non-deterministic relations, and use it to estimate another variable of statistical correlation from one or more variables, and at the same time determine its accuracy. In the process of regression test analysis, first of all, the two variables should have a certain correlation r, which can be tested for significance by t test, otherwise the regression equation is meaningless [25]. Secondly, in order to analyze whether the variation of variables is mainly caused by independent variables or other factors, F test method is used to test the significance of regression equation [23]. While using statistical test, we should also pay attention to using information such as the change of echo of weather radar to carry out physical test so as to show the dynamic effect of artificial hail suppression.

5. Conclusion

According to the conditions of regional regression analysis, the analysis requirements are met in terms of the determination of the contrast region-target region, the selection of statistical variables and the number of samples.

The sample correlation of linear regional regression equation was established by t test. The established linear regression equation is 96% credible by F test, with high significance.

According to the regional regression analysis, the average annual hail disaster area in Akesu area decreased by 23802 hm^2 after the scientific and artificial hail suppression operation, the relative reduction rate was 54.5%, and the average annual hail disaster loss was reduced by 444.17 million yuan, accounting for 5.51% of the annual average agricultural output value, and the average annual input output ratio was 1:10. The statistical significance level was as high as 0.01.

Compared with sequence test, non-pair rank sum test, t-test and Welch test, the regional regression test has higher test efficacy and accuracy. However, the sample similarity, sample quantity, quality and calculation process require higher.

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