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Statistical Evaluation of Hail Suppression Effect in Akesu, Xinjiang

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Abstract: In order to objectively evaluate the systematic differences in the area of annual disaster relief before and after the scientific implementation of artificial flood control in the Akesu area of Xinjiang, the effect of artificial flood control in the area was analyzed. This paper uses the data of the annual disaster area of the Akesu area from 1978 to 2013, and starts the year of artificial flood control operation in 1996 as a science. Using the statistical methods such as sequence test, unpaired rank sum test and Welch test, artificial prevention of science The systematic differences in the annual disaster area of each 18a before and after the operation were analyzed. The results show that the hail disasters in the Akesu area are significantly reduced after the artificial anti-mite operation. The non-parametric unpaired rank sum test has a significance level of 0.05, the parametric Welch test has a significance level of 0.01, and the average annual disaster area is reduced by 15063 hm2. The reduction rate was 43.14%. Combined with agricultural economic data, the annual average reduction of disaster relief losses is 281.09 million yuan, the annual input-output ratio is 1:6, and the statistical significance level reaches 0.1. Therefore, after the scientific implementation of artificial flood control operations in the Akesu area, the hail disaster losses are significantly reduced, and the social and economic benefits of disaster reduction are significant.

Keywords: Hail Suppression, Effect, Evaluation, Akesu

1 Introduction

1.1. Research Significance

Xinjiang is one of the most frequent occurrences of hail disasters in northwest China [1]. The Akesu area is located in the southern part of the Tianshan Mountains and the northern edge of the Tarim Basin. The climate is warm and humid, with little rainfall, large evaporation, and abundant light and heat resources. There are many terrains such as mountains, plains, deserts, rivers and lakes in the territory, and the types of landforms are complex. The main features are: mountains in the north, deserts in the south, plains, rivers, lakes, etc. in the middle. The surface conditions in the whole region are uneven, undulating, and it is easy to form hail weather. The Weigan River Basin and the Akesu River Basin in the region are two of the nine major hail occurrence areas in Xinjiang [2]. Economic losses caused by natural disasters such as hail and flood reach tens of millions or even hundreds of millions of yuan every year, which has seriously affected the economic and social development of the region.

With the global warming in recent years, the strong hailstone weather in Akesu region is on the increase [3]. Beginning in 1994, using the World Bank loan project, the Akesu area began construction of the first C-band Doppler weather radar in Xinjiang in Shaya County, and was 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 a scientific artificial flood control operation system was established.

1.2. Previous Research Progress

In recent years, many scholars in China have analyzed the climatic characteristics, temporal and spatial distribution, and disaster situation of hail weather [4-6], prediction and warning methods [7-11], hail formation mechanism, hail prevention catalysis principle and hail prevention and reduction effect [12-14] of hail weather in various regions. However, due to the scientific complexity of the formation and evolution of severe convective weather system, as well as the technical complexity of the artificial catalysis operation, there is still no scientific and practical method to test the effect of artificial hailstorm prevention.

1.3. The Starting Point of this Study

This paper is based on the data of the disaster relief area of the Akesu area in 1996 before and after the artificial flood control operation, and the non-parametric and parametric statistical test methods are used to determine the annual disaster reduction area reduction rate. Combined with agricultural economic data, the input-output ratio of artificial flood control operations was initially obtained.

1.4. Key Issues

It provides a certain technical method and scientific basis for scientific and quantitative evaluation of the effect of artificial hailstorm prevention, so as to further improve the level of scientific operation of artificial hailstorm prevention.

2. Materials and Methods

The information on the area of disaster relief from 1978 to 2013 was provided by 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 data of the eight counties and one city in the Akesu area, and are subject to rigorous verification and verification, in which individual abnormalities and repeated data are analyzed, consulted, and reviewed.

The area in this paper is cultivated land area. The reason for not using the sowing area as the benchmark is that the sown area will be enlarged due to factors such as frost and wind disasters in the beginning of spring, which will cause some sown farmland to be reseeded or reseeded. The agricultural output value after removing the output value of forestry and animal husbandry was taken as the standard, considering that the hail disaster mainly caused losses to crops in the planting industry.

2.1. Materials

The annual variation of hail disaster area in Akesu region from 1978 to 2013 is shown in figure 1. In the historical period of 18a from 1978 to 1995, the annual cultivated land area was about 31.5×10^4 hm^2, and the annual hail disaster area was 49397.6 hm^2, accounting for 15.68% of the annual cultivated land area. In the 18a operation period in 2013, due to the expansion of population size, the demand for cultivated land increased continuously [15-16], and the cultivated land was increased by land reclamation. The average annual cultivated land area increased to 43.3×10^4 hm^2, and the average annual disaster area was 19854.3 hm^2, accounting for the total annual 4.59% of the cultivated area. After the scientific implementation of artificial flood control, the average annual disaster rate was reduced by 11.09 percentage points.

In terms of economic losses, the average annual hailstorm loss in 18a in the historical period was RMB 4,638.81 million yuan, while the average annual hailstorm loss in 18a in the operational period was RMB 15,9519 million yuan, which was RMB 1,13138 million more than the average annual hailstorm loss in the historical period. The reason is that in recent years, crop structure adjustment in planting industry, cotton, melon and fruit, red dates and other economic crops with higher added value have increased the planting area, and various agricultural resources, water and electricity, human resources and other prices have increased and input has increased. However, according to the annual average agricultural output value of hail disaster, the annual average agricultural output value of the whole region in the historical period was about 930 million yuan, and the annual hail disaster loss accounted for 4.99%. The average annual agricultural output value of the operation period is about 8080 million yuan, and annual hail disaster loss accounts for 1.97%. In comparison, after the scientific implementation of artificial hailstorm prevention, the proportion of loss caused by hail disaster to agricultural output value decreased by 3.02 percentage points.

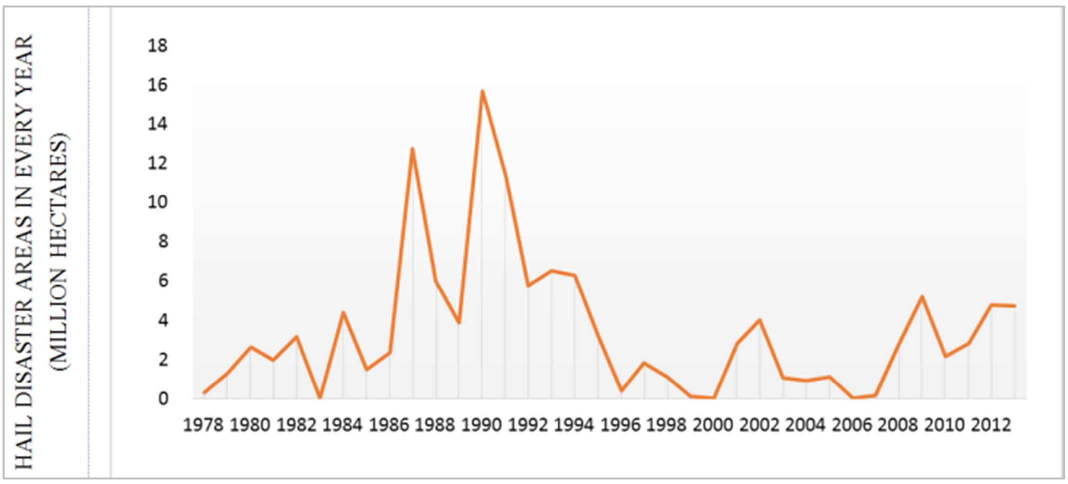

Figure 1. *Inter annual of hail damaged areas during 1978-2013 in Akesu.*

2.2. Methods

The test of the effect of artificial flood control mainly includes three methods: statistical test, physical test and numerical simulation test. In this paper, the statistical test method is based on mathematical statistics, and it is divided into non-parametric test and parametric test. Nonparametric tests were performed using the unpaired rank sum test for significance testing. Parametric test According to the test conditions, the Welch test was used for the significance test. The test results were all significant, and the significance level was 0.05 or more. In the test of variable distribution form, the Kolmogorov fit suitability test in the nonparametric test method is adopted; for the test of the equal variance of the two normal populations in the operation period and the historical period, the parametric test method is adopted. The F test is used for inspection.

3 Results and Analysis

3.1. Sequence Test

According to the historical data of the disaster area in the target area, the historical average value of the disaster area in the target area is obtained as the expected value of the natural disaster reduction area during the operation period, and then compared with the measured value to obtain an estimate of the effect of artificial flood control and disaster reduction area [17].

The average annual disaster area of the 18-year historical period in the Akesu region is $\bar{x}_2 = 49398$ hm^2, The average annual hailstorm area in 18a is $\bar{x}_1 = 19854$ hm^2, Then, the absolute value and relative value of anti-hail operation effect are:

$$\Delta R = \bar{x}_1 - \bar{x}_2 = -29544(\text{hm}^2)$$

$$E = \frac{|\bar{x}_1 - \bar{x}_2|}{\bar{x}_2} = 59.81\%$$

In other words, the average annual hailstorm area was 29544 hm^2 lower in the period of hailstorm prevention than in the historical period of hailstorm prevention, and the average annual hailstorm reduction rate was 59.81%.

3.2. Nonparametric Test

The unpaired rank sum test is a nonparametric test. In some cases, the artificial flood control history data record time is short, the selected statistical variables obey the distribution uncertainty, the overall mean and standard deviation are unknown, so nonparametric tests such as rank sum test are used. The significance of the changes in the statistical indicators of artificial flood control history and operation period is tested [18].

The hail disaster areas of 18a and 18a in the history and operation periods of manual hailstorm prevention in Akesu area are listed in table 1 in order from small to large. The rank of historical period and operational period T are the corresponding rank sum respectively. Take the rank sum of the operation period with a small value of T=257. It is known that the sample capacity of artificial hail suppression operation period and historical period is n1=18 and n2=18 respectively.

Table 1. *The effect of hail suppression by W-M-W test with the annual hail damaged areas as statistical variables in Akesu Prefecture (hm^2).*

Rank	**2**	**2**	**2**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Years	83	00	06	99	07	78	96	04	03	05	98	79	85	97
History	0					3004						12974	14906	
Working		0	0	913	1336		3804	8952	10642	10950	11121			17976

Rank	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Years	81	10	86	80	08	11	01	82	95	89	02	84	13	12
History	19749		23445	25995				31622	31844	38388		43880		
Working		21251			27541	27866	28309				40096		47116	47755

Rank	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**Sum of Rank T**
Years	09	92	88	94	93	91	87	90	
History		57477	59917	62731	65069	113772	127521	156862	409
Working	51750								257

When n1, n2>10, the rank sum T approximates a normal distribution N($\frac{n_1(n_1+n_2+1)}{2}$, $\sqrt{\frac{n_1 n_2 (n_1+n_2+1)}{12}}$), where n1 is the sample size of the quantity for which the rank sum is calculated. At this point, a normal distribution can be used to verify

$$u = \frac{T - Mean}{Standard\ Deviation} = \frac{T - \frac{n_1(n_1+n_2+1)}{2}}{\sqrt{\frac{n_1 n_2 (n_1+n_2+1)}{12}}} \quad (1)$$

For bilateral tests, if u value falls within (-1.96, +1.96), the difference is not significant. If the u value falls outside (-1.96, +1.96), the difference is significant, with a significance level of 0.05. If u is greater than or equal to 1.64 (or u is less than or equal to minus 1.64) in unilateral test; The difference is significant. Otherwise, the significance level is 0.05 [8].

Substituting n1=18, n2=18, rank and T=257 into equation (1) to calculate $u \approx -2.41$. Therefore, for the unilateral test $u < -1.64$, it indicates that the artificial flood control operation period in the Akesu area and the scientific anti-mite operation are significantly reduced compared with the historical period, indicating that the artificial flood control operation has achieved obvious effects and significates. The level is 0.05 [19].

3.3. Parametric Test

3.3.1. Parametric Test Condition

In the parametric test method, the commonly used t-test method requires that the statistical variables in the historical period obey the normal distribution, and the variances of the two normal populations in the operation period and the historical period are required to be equal, and the variance of the statistical variables is not changed before and after the operation. For the historical period statistical variables to obey the normal distribution, Kolmogorov can be tested with the fitness test; for the two normal populations with the same working period and the historical period, the test is tested by the F test.

Using Kolmogorov with the suitability test method, the normal distribution of the annual disaster area in the 1978-1995 historical period was tested. The result was $y_0 = \sqrt{n}D_n \approx 0.5821$, less than $y_{0.5}$=0.83 when the given reliability α =0.5, indicating that the annual disaster relief area in the historical period conforms to the normal distribution. According to $k(y_0)$=0.11 corresponding to y_0=0.5821, the fitness is obtained as:

$$P(\sqrt{n}D_n \geq y_0) \sim 1 - k(y_0) = 0.89$$

Using the F-test, the change of the variance of the annual disaster area in the historical period and the operation period was significantly tested. Calculated:

$F = \frac{S_2^2}{S_1^2} \approx 6.16$, S_2^2 and S_1^2 are the area variances of the annual disaster and the annual disaster relief during the operation period. For degrees of freedom n_2-1=17, n_1-1=17, when given reliability α=0.05, $F_{0.05}$=3.24, there is $F>F_{0.05}$. This indicates that there is a significant difference in the overall variance of the statistical variables between the artificial flood control period and the historical period, and thus does not meet the requirements for testing using the t-test, and the t-test cannot be used for statistical testing.

In the operating period and historical period statistical variables - the annual disaster area obeys the normal distribution, but the variance of the two samples is significantly different, you can use the Welch test to test.

3.3.2. Welch Test

The test statistic z value is calculated by:

$$z = \frac{\bar{x}_2 - \bar{x}_1}{\sqrt{\frac{s_2^2}{n_2} + \frac{s_1^2}{n_1}}} \quad (2)$$

Degree of freedom ν' is calculated as follows:

$$\nu' = \frac{\left(\frac{s_2^2}{n_2} + \frac{s_1^2}{n_1}\right)^2}{\frac{1}{n_2{}^2}\frac{(s_2^2)^2}{n_2 - 1} + \frac{1}{n_1{}^2}\frac{(s_1^2)^2}{n_1 - 1}} \quad (3)$$

In the above formula, $\bar{x}_1$ and $\bar{x}_2$ 、 S_1^2 and S_2^2 、 n_1 and n_2 , and are the mean, variance and sample size of the statistical variables of the artificial flood control period and the historical period, respectively (Table 2). Substituting the relevant data into equation (2) is calculated as z≈2.664, which is taken into equation (3) $\nu' \approx 22.377$. According to the degree of freedom ν' and the given significance level α value, from the t-distribution table, when the reliability α = 0.01 (unilateral test), $t_{0.01}$ = 2.503 is obtained. Since $z>t_{0.01}$, it can be considered that the average annual disaster area in the artificial flood control operation period is significantly lower than the artificial flood control history period, and the significance level is α=0.01.

Table 2. *Calculation of the sample difference significance test with the annual hail damaged areas as statistical variables in Akesu Prefecture.*

	Years	x_2(hm^2)	$(x_{2i} - \bar{x}_2)^2$		Years	x_1(hm^2)	$(x_{1i} - \bar{x}_1)^2$
	1978	3004	2152361997		1996	3804	257613200.1
	1979	12974	1326675399		1997	17976	3528136.1
	1980	25995	547679606.5		1998	11121	76271111.1
	1981	19749	879036846.5		1999	913	358774108.4
	1982	31622	315970375.3		2000	0	394194552.1
	1983	0	2440118495		2001	28309	71481388.4
	1984	43880	30443419.3		2002	40096	409725069.4
	1985	14906	1189667405		2003	10642	84867085.4
	1986	23445	673535139.9		2004	8952	118860872.1
History Period	1987	127521	6103272572	Working Period	2005	10950	79287152.1
	1988	59917	110658711.4		2006	0	394194552.1
	1989	38388	121210313.5		2007	1336	342928669.4
	1990	156862	11548606820		2008	27541	59084844.4
	1991	113772	4144069098		2009	51750	1017333552
	1992	57477	65277422.5		2010	21251	1950677.8
	1993	65069	245594171		2011	27866	64186802.8
	1994	62731	177780740.8		2012	47755	778447200.4
	1995	31844	308127312.6		2013	47116	743198469.4
	n_2=18				n_1=18		
	$\bar{x}_2 = \frac{1}{n_2}\sum_{j=1}^{n_2} x_{2j}$ = 49397.6				$\bar{x}_1 = \frac{1}{n_1}\sum_{j=1}^{n_1} x_{1j}$ = 19854.3		
	$s_2^2 = \frac{1}{n_2 - 1} = \sum_{j=1}^{n_2}(x_{2j} - \bar{x}_2)^2$ = 1904710932.3				$s_1^2 = \frac{1}{n_1 - 1} = \sum_{j=1}^{n_1}(x_{1j} - \bar{x}_1)^2$ = 309172202.6		

Since the artificial flood control operation period is equal to the historical sample capacity, the variance difference is not very large, so the results obtained by the Welch test and the t-test are basically the same, so the interval estimation can be performed by the following formula [19]:

$$\bar{x}_0 \rangle \bar{x}_2 - t_{2\alpha} S\sqrt{\frac{1}{n_1}+\frac{1}{n_2}} \tag{4}$$

$s=\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}}$, $\bar{x}_{01}$ is the annual average disaster area in the Akesu area during the operation period without scientific artificial flood control. The probability that (4) holds is (1-α).

Take the confidence level (1-α)=0.9, according to degree of freedom $v=n_1+n_2-2$, From the t-distribution table, $t_{0.2}=1.307$ was obtained. Substituting the relevant data into equation (4), the calculation $\bar{x}_{01}>34917.2$ hm^2. That is, if the artificial flood control operation is not carried out scientifically during the operation period, the annual average natural disaster relief area will exceed 34917.2 hm^2, and the credible probability is 90%.

It is thus available that the scientific implementation of artificial flood control operations results in a reduction in the average annual disaster relief area:

$\Delta R = |\bar{x}_1 - \bar{x}_{01}| \approx 15062.9 (hm^2)$, relative reduction rate $E = \frac{|\bar{x}_1-\bar{x}_{01}|}{\bar{x}_{01}} \approx 43.14\%$.

According to the agricultural output value and the annual cultivated area in the 18 years of operation in the Akesu area, the output value per hectare can be estimated to be about 18,661 yuan. Therefore, after scientifically carrying out artificial flood control, the average annual reduction of disaster relief losses was 281.09 million yuan, accounting for 3.49% of the annual average agricultural output value. After the artificial flood control in the Akesu area, the annual expenditure on artificial flood control is about 45 million yuan, so the average annual input-output ratio is 1:6.

4. Discussion

Because the cloud and precipitation naturally become too different, the spatial and temporal distribution of the hail varies greatly, which makes the area of the disaster relief fluctuate greatly. The statistical test of the effect of artificial flood control is equivalent to extracting the "signal" of the effect of artificial flood control from these high "noises". Therefore, the effectiveness of statistical test methods is often not high [18, 19]. However, with regard to the current artificial flood control technology and inspection methods, the statistical test method is one of the main methods for testing the effect of artificial flood control operations. From the perspective of statistics and artificial weather influence, the method of sequence test is simple, but its reliability is limited. Without the rank sum test method, the effect can only be qualitatively tested, and interval estimation cannot be carried out. T-test method and Welch test method are more accurate and reliable for the effect test of the above two inspection methods, but have higher requirements for sample quantity, quality and calculation process. If the corresponding comparison area can be found, the regional regression test method will be adopted to test the efficacy and accuracy of the test [18]. In addition to statistical test, physical test should also be carried out with the information of weather radar echo change, so as to reflect the physical mechanism and effect of manual anti-hail operation.

5. Conclusion

Through the statistical evaluation test of the effect of manual hailstorm prevention, the preliminary evaluation on the effect of scientific artificial hailstorm prevention in Akesu area was carried out, and the following preliminary conclusions could be drawn:

(1) The annual disaster rate in Akesu was 11.09 percentage points lower than the previous average after the scientific operation. The annual loss of agricultural output caused by hail disaster decreased by 3.02 percentage points.

(2) According to the statistical evaluation test, the reduction effect of artificial hailstorm prevention in Akesu area is significant, with the significance level above 0.05. The significance level of Welch test was as high as 0.01.

(3) The results of scientific artificial hailstorm prevention after interval estimation were as follows: The average annual hailstorm area was reduced by 15062.9 hm2, the relative reduction rate was 43.14%, the average annual hailstorm loss was reduced by 281.09 million yuan, accounting for 3.49% of the annual average agricultural output, and the average annual input/output ratio was 1:6. Therefore, the statistical significance level is the q =0.1.

In the future, when evaluating the effect of manual anti-hail operation, we should make full use of radar, rainfall, hail precipitation and other data to carry out physical or physical statistical inspection.

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