AGRICULTURAL FLOOD RISK ASSESSMENT IN CHINA AT THE PROVINCIAL SCALE

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ABSTRACT: Based on the annual crop area covered by flood disasters and annual crop area affected by flood disasters and annual sown area of crops from 1971 to 2010 in each province of China, agricultural flood risk in China was assessed at the provincial scale using the soft histogram method. Firstly, the agriculture disasters were classified to five grades according to the percentage of crop area covered by flood disasters and crop area affected by flood disasters respectively. Then a comprehensive agricultural flood index was developed based on the above two indicators using grey correlation analysis method. The probability of agricultural flood disasters of five grades was calculated using the soft histogram method. Finally, the agricultural flood risk of each province in China was assessed using the weighted sum of the probability of different disaster grade.

Key Words: Agricultural Flood Risk, Grey Correlation Analysis, Soft Histogram, Provincial Scale, China

1. INTRODUCTION

China has been an agricultural country since ancient times. In China, despite the growing importance of industry, agriculture has a central role in ensuring the food security and welfare of 1.3 billion people (Piao *et al*., 2010). China is one of the countries most afflicted with frequent and severe floods (Huang *et al*., 2012) and flood is one of the main agricultural meteorological disasters in China (Wang *et al*.,2007). During the 40 years from 1971 to 2010, the average of crop area covered by flood disasters is 10,522,000 hm^2 and the average of crop area affected by flood disasters is 5,680,000 hm^2. Crop area covered refers to the sown area of crops for which the crop yield decreased by more than 10% as a result of flood disasters. If the same block repeatedly affected the same crop in the same season, only most affected crop area was counted. Crop area affected refers to the sown area of crops for which yield decreased by more than 30% in response to flood disasters.

Much research has focused on the comprehensive flood risk in China but somewhat less has been written about the agricultural flood risk over china. In this study, the agricultural flood risk in China at the provincial scale is assessed based on the soft histogram method.

2. DATA SOURCES

The data analyzed in this paper mainly include annual crop area covered and annual crop area affected by flood disasters and annual sown area of crops for each province in China from 1971 to 2010. These data are extracted from the disaster database and crop database from the Department of Crop Production, Ministry of Agriculture of PRC.

3. AGRICULTURAL FLOOD RISK ASSESSMENT

3.1 Quantitative assessment of flood disaster grade

The percentage of crop area covered by flood disasters and percentage of crop area affected by flood disasters are selected to assess the agricultural flood risk. Referring to the grade classification method developed by Zhao (Zhao and Ma, 1993), Yu (Yu and Shen, 1997) and Liu (Liu *et al*., 1995), we divided flood disasters into five grades: Catastrophe, severe disaster, medium disaster, small disaster and micro-disaster. The grade indexes and the grade classification method are shown in Table 1.

Table 1 The grade indexes and grade classification of agricultural flood disaster

	catastrophe	severe disaster	medium disaster	small disaster	micro-disaster
percentage of crop area covered(%)	(40,100]	(4,40]	(0.4,4]	(0.04,0.4]	(0.004,0.04]
percentage of crop area affected (%)	(20,100]	(2,20]	(0.2,2]	(0.02,0.2]	(0.002,0.02]

In order to adopt a unified classification standard to divide the disaster grades for the above two indexes, the function 1 and function 2 were developed to transform the above grade classification standard shown in Table 1 to new grade classification standards. As shown in Table 2, the new standards are the same for the above two indexes, and also the ranges for different disaster grades are the same.

$$U(x)=\begin{cases} 0.8+1/300(x\text{-}40) & 40< x \le 100 \\ 0.2\lg(10^3 x/4) & 0.004< x \le 40 \\ 0 & x \le 0.004 \end{cases} \quad [1]$$

$$U(y)=\begin{cases} 0.8+1/300(2y\text{-}40) & 20< y \le 50 \\ 0.2\lg(10^3 y/2) & 0.002< y \le 20 \\ 0 & y \le 0.002 \end{cases} \quad [2]$$

Where x is the percentage of crop area covered(%), y is the percentage of crop area affected (%), $U(x)$ and $U(y)$ is new grading standard for agricultural flood disaster.

Table 2 New grading standards for agricultural flood disaster

Grade	catastrophe	severe disaster	medium disaster	small disaster	micro-disaster
$U(x)$	(0.8-1]	(0.6-0.8]	(0.4-0.6]	(0.2-0.4]	(0-0.2]
$U(y)$	(0.8-1]	(0.6-0.8]	(0.4-0.6]	(0.2-0.4]	(0-0.2]

In order to assess the agricultural flood disaster comprehensively, a comprehensive flood disaster index is developed based on the above two indexes using the grey correlation analysis method (Yang,1997).

Let a time series: $U_0=(u_{0j}),(u_{0j}=1)(j=1,2,3,\cdots,n)$ be a reference sequence, u_{0j} = 1 represents the catastrophe grade. Let a time series: $U_{ij}(u_{ij}),(i=1,2,3,\cdots,m; j=1,2,3,\cdots,n)$ be a comparison sequences.

Then the grey correlation coefficient is calculated using the following function 3. The range of $\Delta_{0j}(j)$ is [0,1], so the range of $\xi_{0i}(j)$ the grey correlation coefficient is [0.5,1].

$$\xi_{0i}(j) = \frac{1}{1+\Delta_{0j}(j)} \qquad [3]$$

Where $\Delta_{0j}(j) = \left|U_0(u_{0j}) - U_i(u_{ij})\right|, (i = 1,2,3,\cdots,m; j = 1,2,3,\cdots,n)$.

According to the function 3, grey correlation coefficients for each index are calculated. If there are *m* indexes, equal weights are used to calculate the grey correlation degree.

$$r_{0i} = \frac{1}{m}\sum_{j=1}^{m}\xi_{0i}(j) \qquad [4]$$

Where r_{0i} is the grey correlation degree. Apparently, the range of r_{0i} is [0.5,1]. Based on the grey correlation theory, the closer to 1 the grey correlational degree is, the higher the flood disaster grade is; the closer to 0.5 the grey correlational degree is, the lower the flood disaster grade is. The value of the grey correlation degree can reflect flood disaster severity, so the agricultural flood disaster grade can be evaluated according to the grey correlation degree shown in Table 3.

Table 3 Grey correlation degree and agricultural flood disaster grade

Grade	catastrophe	severe disaster	medium disaster	small disaster	micro-disaster
Grey correlation degree	0.9-1	0.8-0.9	0.7-0.8	0.6-0.7	0.5-0.6

In this paper, the comprehensive flood disaster index is represented by the grey correlation degree.

3.2 Probability of agricultural flood disaster grade

The information diffusion method is good for the probability calculation of small sample (n<30) (Huang, 2005; Liu *et al.*,2010), the soft histogram based on information distribution theory is good for the probability calculation of large sample (n≥30). In this study, the sample number is 40, so the soft histogram is used to calculate the probability of agricultural flood disaster grade.

First, traditional frequency histogram is established and divided into m=5 sections with width h=0.1. Let u_j is the midpoint of I_j .The control point set $U = \{u_1, u_2, \cdots, u_m\}$ with step $\Delta = h$. In this study, the correlation degree of agricultural flood disaster ranges from 0.5 to 1, so

$$U = \{u_1, u_2, u_3, u_4, u_5, u_6\} = \{0.55, 0.65, 0.75, 0.85, 0.95\}$$

Based on the one-dimensional linear distribution formula 5, all the distribution information q_{ij} is calculated, then the original information distribution $Q = \{Q_1, Q_2, Q_3, Q_4, Q_5\}$ of each province X on U is calculated.

$$q_{ij} = \begin{cases} 1 - \frac{|x_i - u_j|}{\Delta}, |x_i - u_j| \le \Delta \\ 0, \text{otherwise} \end{cases} \qquad [5]$$

Finally, the soft frequency histograms for all provinces in China are calculated. The probability of the comprehensive flood disaster index under five grades is shown in Table 4.

Table 4 Probability of the comprehensive flood disaster index under five grades

province	micro-disasters (Grade 1)	small disaster (Grade 2)	medium disaster (Grade 3)	severe disaster (Grade 4)	Catastrophe (Grade 5)
Beijing	0.3021	0.4624	0.2304	0.0051	0.0000
Tianjin	0.3532	0.1970	0.3131	0.1091	0.0276
Hebei	0.0752	0.5374	0.3567	0.0307	0.0000
Shanxi	0.0193	0.4678	0.4873	0.0256	0.0000
Inner Mongolia	0.0746	0.3426	0.5424	0.0404	0.0000
Liaoning	0.0929	0.3428	0.4432	0.1091	0.0120
Jilin	0.0593	0.3429	0.4536	0.1238	0.0204
Heilongjiang	0.0510	0.3563	0.4322	0.1605	0.0000
Shanghai	0.5638	0.1831	0.2272	0.0259	0.0000
Jiangsu	0.0128	0.3624	0.5223	0.0958	0.0067
Zhejiang	0.0324	0.2723	0.6165	0.0789	0.0000
Anhui	0.0255	0.2490	0.5720	0.1300	0.0235
Fujian	0.0186	0.3288	0.5585	0.0940	0.0000
Jiangxi	0.0239	0.2190	0.6215	0.1310	0.0047
Shandong	0.0298	0.3601	0.5674	0.0427	0.0000
Henan	0.0244	0.4044	0.5026	0.0687	0.0000
Hubei	0.0549	0.1581	0.5911	0.1959	0.0000
Hunan	0.0148	0.1829	0.6459	0.1564	0.0000
Guangdong (include Hainan)	0.0162	0.2125	0.7010	0.0703	0.0000
Guangxi	0.0542	0.3194	0.5624	0.0641	0.0000
Sichuan (include Chongqing)	0.0493	0.2672	0.6314	0.0521	0.0000
Guizhou	0.0212	0.3207	0.6177	0.0404	0.0000
Yunnan	0.0207	0.3689	0.6034	0.0070	0.0000
Tibet	0.3572	0.3087	0.2847	0.0493	0.0000
Shannxi	0.0597	0.3041	0.5710	0.0652	0.0000
Gansu	0.0751	0.3602	0.5588	0.0059	0.0000
Qinghai	0.1421	0.4653	0.3877	0.0050	0.0000
Ningxia	0.1235	0.5121	0.3606	0.0038	0.0000
Xinjiang	0.2992	0.4838	0.2170	0.0000	0.0000

3.3 Assessment of agricultural flood risk at the provincial scale

The agricultural flood risk index is calculated using the following formula.

$$Z = \sum_{i=1}^{n} J_i P_i \qquad [6]$$

Where J_i is the weight of flood disaster grade *i*, P_i is the probability of the flood disaster grade *i*, *n* is the number of disaster grades. In this study, $J_i = i$, $n = 5$.

The agricultural flood risk for each province of China is shown in Table 5.

Table 5 Agricultural flood risk in each province of China

province	risk value	rank	province	risk value	rank
Beijing	1.9384	27	Henan	2.6156	16
Tianjin	2.2608	23	Hubei	2.9281	2
Hebei	2.3430	22	Hunan	2.9440	1
Shanxi	2.5190	20	Guangdong (include Hainan)	2.8253	5
Inner Mongolia	2.5486	19	Guangxi	2.6363	14
Liaoning	2.6044	17	Sichuan (include Chongqing)	2.6863	11
Jilin	2.7029	9	Guizhou	2.6773	12
Heilongjiang	2.7022	10	Yunnan	2.5967	18
Shanghai	1.7153	29	Tibet	2.0262	26
Jiangsu	2.7213	8	Shannxi	2.6417	13
Zhejiang	2.7420	6	Gansu	2.4956	21
Anhui	2.8770	3	Qinghai	2.2556	24
Fujian	2.7280	7	Ningxia	2.2446	25
Jiangxi	2.8736	4	Xinjiang	1.9178	28
Shandong	2.6231	15			

The agricultural flood risk values in each province of China are divided into five grades (very high risk, high risk, medium risk, low risk and very low risk) using the natural break method. The agricultural flood risk map is shown in figure 1.

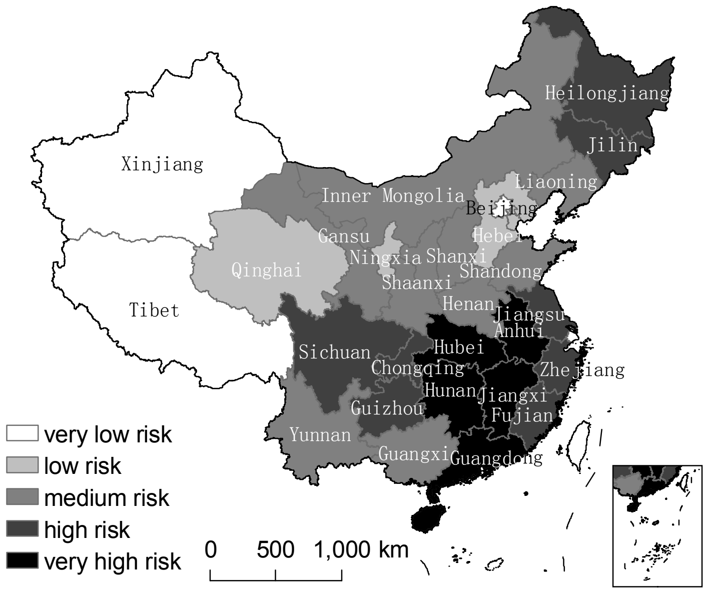

Figure 1: Agricultural Flood Risk for Each Province of China

From Figure 1, we know that four provinces along the middle and lower reaches of Yangtze River and Guangdong province have very high agricultural flood risk. Three eastern coastal provinces, two northeastern provinces and three southwest provinces have high agricultural flood risk.

4. DISCUSSION AND CONCLUSION

The disaster data from 1971 to 2010 were used in this study, so the risk assessment result is a comprehensive representation of agricultural flood disaster situation during these years. The assessment result based on the long-term disaster data may be useful for agricultural flood disaster prevention and mitigation plan. Historical flood disaster data based method is one of the primary methods for flood risk assessment and is simple and easily operated (Huang et al. 2007).

Referring to previous research in China, this study divided agricultural flood disasters into five grades based on two disaster indexes. In order to adopt a unified classification standard to divide the disaster grades for two different indexes, two transform functions were developed. Then grey correlation analysis method was used to calculate the grey correlation degree which can represent the comprehensive grade of agricultural flood disaster. Finally, the risk probabilities of different grades were calculated using the soft histogram method and agricultural flood risk was assessed by weighting summation of the risk probabilities. In this study, only two disaster indexes were used. If more disaster indexes can be available, such as economic loss and flood-hit population, the methods in this study are still suitable. These methods are also suitable for grade assessment and risk assessment of other natural disasters.

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