Evolution Characteristics of Flood Disaster in Hunan

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Evolution Characteristics of Flood Disaster in Hunan

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Abstract: With the global climate changing, floods increasingly impede human social and economic development. Extracting flood information from historical flood data and improving human's awareness of flood control and disaster relief promote scientific risk management regarding flood and accurate evaluation about reducing disaster risks. Take Hunan Province as an example. Firstly, this paper selected three indexes - flood-hit population, death toll and total direct economic loss – as independent variables, with taking the skewed distribution characteristics of flood data into consideration, to build a nonlinear model of comprehensive evaluation index of flood disaster in Hunan. Then, from the angle of these three indexes, the disaster situation in Hunan was compared with the national average disaster situation in order to get general understanding of consequences of flood in Hunan. In addition, to eliminate influence of dimension and inflation on the analysis results, the indexes were quantified by using statistical methods from the perspective of economics. Finally, average flood disaster index value of China and Hunan were calculated respectively according to the model. The research shows that Hunan is a flood-prone area in China and that degree of damage by floods in Hunan is always the severest among the country no matter from which angle we choose among the three indexes. Further analysis indicates that severe flood occurs every four years in Hunan, on average.

KeyWords: Hunan, Flood Disaster, Situation of Disaster, Comprehensive Evaluation

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1.Introduction

Flood is a natural phenomenon; However, we call it disaster when it has a destructive impact on human society and natural resources. Throughout history, flood disaster has been a serious problem faced by human-beings. As the global climate warming, the frequency of extreme hydrological events such as torrential rain and flood keep increasing. In the past 20 years, since the number of catastrophic floods has more than doubled(Zhao et al. 2019), and development of economy has accelerated, the economic losses caused by flood disasters have increased year by year(https://www.undrr.org/publication/human-cost-disasters-2000-2019). Preventing and mitigating the losses is a huge challenge during human sustainable development. Lots of authorities has viewed combining flood control works and non-engineering measures of flood control as a highly unified strategic decision-making on flood problem(Jiang et al. 2002).

Scholars around the world have also carried out extensive research on the related issues of flood disasters(Chen and Quan 2006). The research on flood disaster assessment and its evolution is a hot issue(Barrera et al. 2006; Jia et al. 2019; Cortes et al. 2017; Llasat et al. 2014; Qing et al. 2013). In order to evaluate magnitude of a disaster and scientifically define features of the disaster, scholars have proposed a concept named disaster degree to measure the damage to human life, property and social economy and also asserted a quantitative formula to measure disaster degree. In China, after Zongjin Ma building a double index model with death toll and social economic loss as variables, scholars have continuously been perfecting the contents of disaster degree. Jinghai Xu et al.(2012) put forward a disaster degree calculation model which reveals the relationship between disaster degree and three factors such as flood-hit population, death toll and total direct economic loss, definitions of which are given by the United Nations Disaster Relief Agency. Xiang Chen (Chen et al. 2007) discussed impact of using different dimensions in the calculation of disaster loss on results and showed a method to measure flood-hit population and death toll by economic losses, and further proposed calculation of disaster loss from the perspective of economic losses.

Affected by natural geography, features of flood disasters around China are different. Information extracted from historical data enables us to improve efficiency of works related to disaster prevention and mitigation. Hunan is an agricultural province and a flood-prone area in China, which means that agricultural production suffers from flood frequently. Therefore, this article takes Hunan flood disasters as object to study consequences and evolution characteristics of the disasters. To be specific, the paper constructed a comprehensive evaluation index model for flood disasters on the basis of disaster degree, and results of the model were analyzed to get evolution law of flood disasters in Hunan. The paper provides scientific foundations on flood control and relief

management in Hunan and improves level of flood risk management.

2.Materials and methods

2.1. Area and data

Hunan is located in the central part of China. Due to subtropical monsoon, torrential rains in Hunan usually occurs from June to September. Range of average annual rainfall is from 1300mm to 1800mm, and water resources is rich. In addition, there are four rivers and one lake in Hunan with a well-developed water system; three sides except North of Hunan Province are surrounded by mountains with high terrain and steep slope. Vice versa, the central and northern parts are dominated by plains and hills with low terrain and flat slope. Floods occur annually, causing serious losses of human life, property and social economy, hindering agricultural development in Hunan.

In accordance with definitions by the United Nations Office for Disaster Risk Reduction(https://www.undrr.org/publication/human-cost-disasters-2000-2019) and statistical data of flood and drought disasters from the Ministry of Water Resources of People's Republic of China, the study selected three indexes such as flood-hit population, death toll and total direct economic loss to construct a nonlinear model of comprehensive evaluation index of flood disaster in Hunan and draw conclusions. Flood-hit population and death toll reflect the effect of non-engineering measures on flood prevention and risk reduction, while total direct economic loss refers to losses in industries such as agriculture, forestry, transportation and water conservancy establishment, which implies the impact of flood control projects on flood control and disaster mitigation. Data of these indexes were obtained from the "Statistical Communique of Water Conservancy Disasters" issued by the Ministry of Water Resources from 2006 to 2018. The statistical data cover 31 provinces (autonomous regions, municipalities) except Taiwan Province, Hong Kong Special Administrative Region and Macau Special Administrative Region. Others such as Consumer Price Index (CPI) of Hunan Province and Gross Domestic Product (GDP) of Hunan Province were collected from Wind.

2.2. Method

2.2.1. Data Processing

Obviously, the focus of study on flood disaster is a statistical problem about economic loss measured from plenty of angles. This paper studies the economic relationship between the three indexes and builds a comprehensive index evaluation model of disaster. If inflation is taken into consideration, it is unreasonable to

directly make an analysis by nominal value of disaster economic losses. For example, assuming that the nominal values of economic loss in 1980 and 2020 are 100 million yuan both, the severity degrees of the two are obviously different. Therefore, in order to guarantee validity of the research results, it is necessary to eliminate inflation factor and consider the real values of economic loss. Therefore, the data were processed as follows: the annual total direct nominal economic losses from disasters were converted into real losses with the year 1978 as base year where conversion factor is CPI of Hunan Province; flood-hit population and death toll were converted into real economic losses with the year 1978 as base year (Cortes et al. 2017); that is, economic loss of death population is 100,000 yuan per capita and that of disaster-affected population is 10,000 yuan per capita.

2.2.2. comprehensive evaluation index model of flood disaster

Once the conversions done, the difference in numerical value was obvious; To be specific, the annual total direct real economic loss of flood disasters (100 million yuan per unit) was much greater than the sum of the economic losses of the rest two indexes (10,000 yuan per unit). Meanwhile, the economic loss of flood-hit population was much larger than that of death toll. In this case, if the three numbers are added, truncation error leads to least significant bits thrown away. Therefore, a key problem that needs to be solved is to eliminate such error. In addition, after taking a close look at the data, it shows that the data are almost skewed distributed. Thus, the second problem in the research is related to heteroscedasticity and smoothing the data. Moreover, with the development of economy, China puts forward an idea named Scientific Outlook on Development, advocating that human-beings matters and that value of human-beings should be emphasized. According to that, the comprehensive evaluation index model must lay emphasis on population losses.

Based on the above analysis and consideration of small-sample time series data, the research was guided by the concept of disaster degree (Llasat et al 2014), using logarithmic function and exponent properties to map the value of economic loss of the three indexes between 0 and 10; then, degree of flood damage was represented by comprehensive evaluation index. On this basis, a comprehensive evaluation index model of Hunan flood disaster was constructed, which is as follows:

$$y = log_{10}(1 + 10 * x1) + log_{10}(x2) + 10^{\frac{x3}{x4}} \quad (1)$$

Where $x1$ is economic value of death toll; $x2$ is that of flood-hit population; $x3$ is total direct nominal economic loss of disaster; $x3$ is gross domestic product of Hunan in 1978; y is the comprehensive evaluation index.

3. Results and analysis

3.1. Trend and comparison of annual population loss between Hunan and China

The population loss includes flood-hit population and death toll for flood. Obviously, affected by natural conditions like topography, water system and climate, it is inevitable that Hunan suffers from flood constantly. Also, compared with features of floods occurred in other administrative regions in China, Hunan is unique and special. From the perspective of risk management, one feature – social attribute - is, to a large extent, related to population loss. The statistical data of the population loss embody the efficiency of emergency response and population migration. Therefore, the information related to population loss was used in the study to reflect the level of management in flood disaster over China, which also marks the efficiency of non-engineering management in flood. According to the data from "Statistical Communique of Water Conservancy Disasters" published by the Ministry of Water Resources from 2006 to 2018, the average of the population affected by floods and the population killed by the disaster in 31 provinces including autonomous regions and municipalities was computed and visualized to make comparisons (Fig. 1 and Fig. 2).

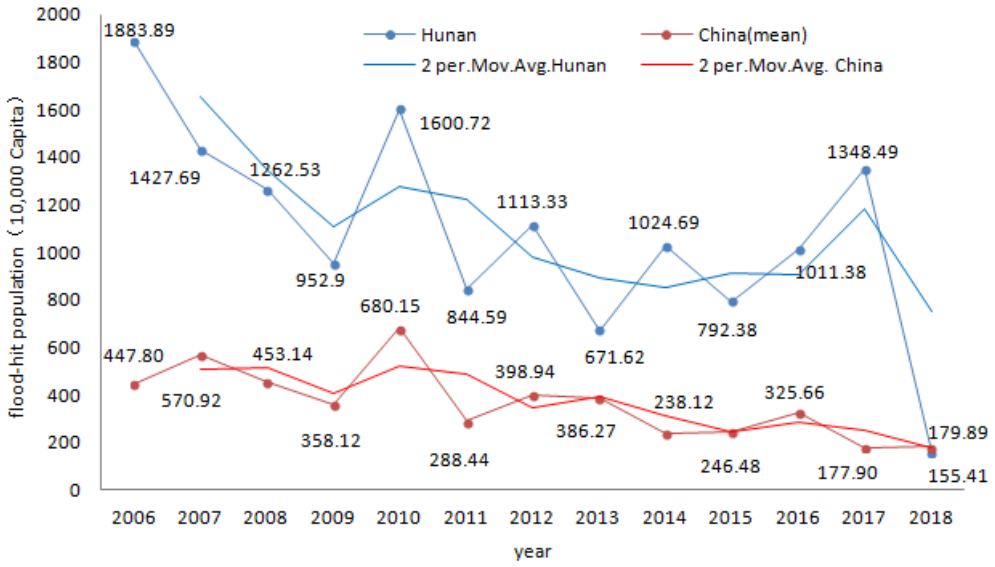

Fig. 1 Trend of flood-hit population& comparison between Hunan and China(mean)

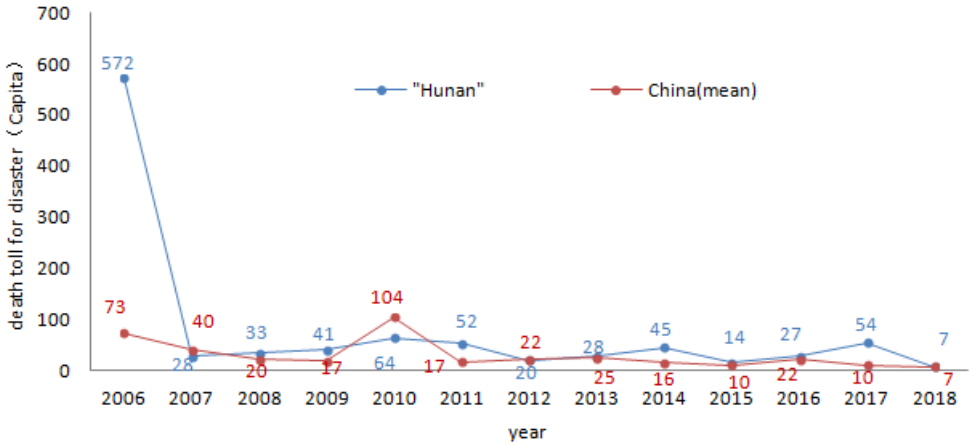

Fig. 2 Trend of flood death toll and comparison between Hunan and China(mean)

Fig. 1 shows that from 2006 to 2018, the number of flood-hit population in Hunan was generally much higher than that of the average flood-hit population around the country, but the trends of the population affected by floods in Hunan was basically consistent with that in China (moving average by 2 years), and the overall trend was downward. In addition, the outliers appeared in 2007, 2014 and 2017. Based on 2006, number of flood-hit population in Hunan in 2007 showed a downward trend while for the whole country the number increased slightly in 2007. However, unlike in 2007, the number of people affected by flood in Hunan increased in both 2014 and 2017, while the mean of flood-hit population around the country was in a downward trend. The reason is that in July 2006, Xiangjiang River Basin suffered from severe tropical storm Bilis, causing a great loss of economy and population (Chen et al 2006). So, under the premise that the country suffered heavily from floods in 2007, if the loss of Hunan in 2006 is regarded as Isolated point, the flood loss of Hunan in 2007 showed a downward trend compared with the national average level. In terms of overall trends, losses in Hunan by floods are much larger than the national average loss.

Fig. 2 illustrates trend of death toll from 2006 to 2018. It is quite obvious that the death toll in Hunan was above the national average, except for year 2010 where the number was lower than the national average. In 2006, the floods occurred in the Xiangjiang River Basin, due to Typhon, directly killed 346 people (Chen et al. 2006) so that number of deaths in Hunan was significantly higher than that in the national average.

3.2. Trends of total direct real economic losses for flood in Hunan

Fig. 3 Comparison of direct real economic losses (1978 as base year) between Hunan and China(mean)

In order to avoid impact of price changes caused by economic development on results, this paper converted the total nominal direct economic losses into real losses with year 1978 as base year. Then, according to the Statistical Communique of Water Conservancy Disasters published by the Ministry of Water Resources from 2006 to 2018, mean values of the total direct economic loss for flood disasters in 31 provinces were computed and compared with the values in Hunan Province (Fig. 3). The figure shows that the total direct economic losses for flood in Hunan in 2013 and 2018 were lower than the mean losses of China and that the losses in Hunan and those in China were almost the same in 2011 and 2012. However, for the losses in the rest years, the loss in Hunan each year exceeded the national average flood loss by more than 1.5 times. Especially in 2017, the total economic loss of Hunan accounted for 18.6% of the country's total economic loss, which was nearly five times greater than the national average flood loss. It can be explained by the catastrophic flooding occurred in July 2017.

Through the analysis, the severity of flood disaster in Hunan is intuitively evident, the degree of which is also in front ranks over the country. By further exploring the direct economic losses in Hunan in 2006, 2014 and 2017 (respectively account for 11.5%, 7.3% and 18.6% of the total direct economic loss in China) and comparing the three ratios with the national mean ratio, which is about 3.2%, the total direct economic losses in Hunan was 3.59 times, 2.3 times and 5.8 times as large as the average level separately. Fig. 4 more directly reflects the proportion of total direct economic losses in Hunan and other 30 provinces (autonomous regions and

municipalities) in the three abnormal years (the sum of each proportion is 100%).

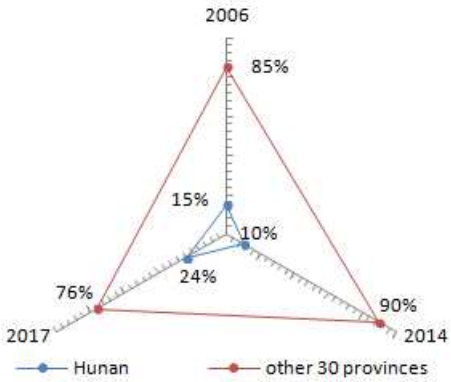

Fig. 4 Proportion of total direct economic losses in Hunan and other 30 provinces

The conclusions draw from Sections 3.1 and 3.2 show that every kinds of losses caused by the floods in Hunan are undoubtedly larger than the national average loss for most years and that the losses in Hunan caused by floods still remain enormous. However, from the perspective of the effectiveness of disaster risk reduction management, this article believes that the so-called risk management is nothing more than reducing the loss of life and properties as much as possible with the aid of flood control works. Therefore, in this sense, although the total direct economic loss caused by the flood disaster in Hunan seems to be severe due to natural conditions, and also the number of individuals affected by the disaster is large, the death toll due to flood is relatively small. Especially, the number of deaths has gradually been decreasing since an outbreak in 2006; now, the number fluctuates slightly above and below the national average, indicating that flood risk management worked out.

3.3. Trend of comprehensive evaluation index of flood disaster in Hunan

By employing the comprehensive evaluation index of flood disaster (Equation 1), the comprehensive indexes for each year in Hunan from 2006 to 2018 were computed (Table 1).

Table 1 Comprehensive evaluation indexes of Hunan flood disaster

Year	Total direct economic loss (1MM CNY)	Economic loss of flood-hit population (10000CNY)	Economic loss of death toll (10000CNY)	Comprehensive Index	Contribution Rate of Total direct economic loss	Contribution Rate of Economic loss of flood-hit population	Contribution Rate of Economic loss of death toll
2006	32.571	1883.89	5720	8.70	19.15%	37.65%	43.20%
2007	14.637	1427.69	280	6.86	18.34%	45.99%	35.68%
2008	14.568	1262.53	330	6.88	18.27%	45.10%	36.63%
2009	9.810	952.9	410	6.76	17.26%	44.08%	38.66%
2010	34.620	1600.72	640	7.73	22.25%	41.45%	36.30%
2011	7.591	844.59	520	6.77	16.64%	43.24%	40.12%
2012	15.129	1113.33	200	6.62	19.16%	46.06%	34.78%
2013	8.275	671.62	280	6.41	17.75%	44.09%	38.16%
2014	18.977	1024.69	450	7.01	19.20%	42.95%	37.85%
2015	12.734	792.38	140	6.27	19.48%	46.27%	34.25%
2016	25.954	1011.38	270	6.94	21.64%	43.31%	35.04%
2017	62.397	1348.49	540	8.52	31.19%	36.74%	32.07%
2018	2.266	155.41	70	5.07	20.43%	43.20%	36.37%

The total direct economic loss, the economic loss of flood-hit population and that of the death toll in Table 1 were all converted to real economic loss with year 1978 as the base year by CPI of Hunan Province. The contribution rates of the three indices listed on the right sides refer to the contribution rates to the comprehensive index. It is clear that the economic loss of flood-hit population and the death toll contributed a lot to this index, both of whose rates were more than 30%, and the sum of the two contribution rates almost reached 80%. Although the losses of the two were much smaller than the total direct economic loss, they weighted a lot in the comprehensive evaluation index, which is in line with the contemporary people-oriented thought. Therefore, the comprehensive evaluation index can accurately reflect the degree of flood disaster in Hunan and also provide a theoretical foundation for disaster performance evaluation. Fig. 5 shows comparison between comprehensive index of Hunan and China.

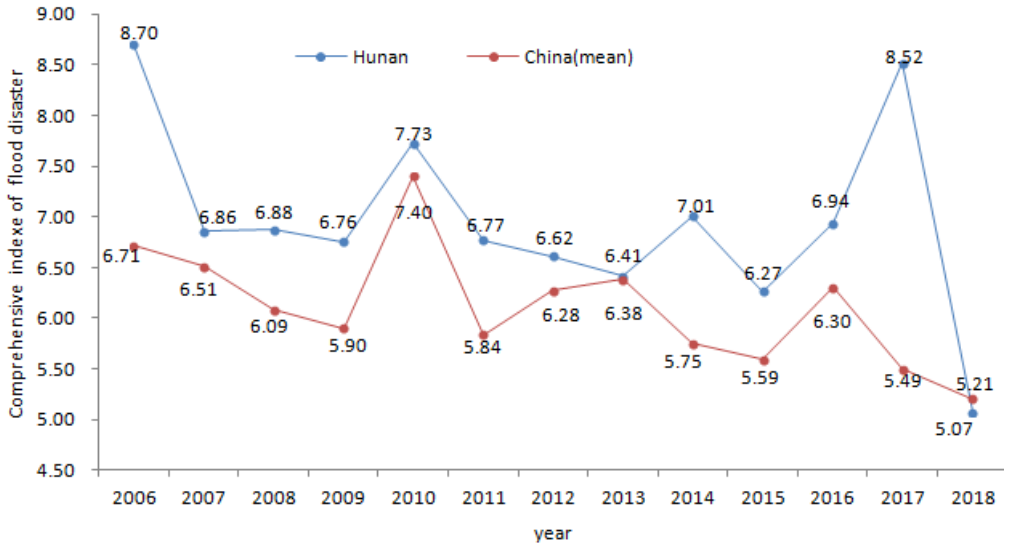

Fig. 5 Comprehensive evaluation indexes of Hunan and China flood disaster(mean)

The figure directly reflects the relationship between the disaster situation in Hunan and the average disaster situation in the country under the condition of multi-index comprehensive evaluation. It can be seen from the figure that, except for 2018, the indexes of Hunan were greater than the indexes of the nation. In general, disaster loss of Hunan is in front ranks among all provinces, and Hunan is one of the provinces that suffered severe losses due to floods.

4. Conclusions and Discussion

In order to find features of annual flood disaster in Hunan, the increment percentages of how much comprehensive index value in Hunan is more than the national comprehensive index were computed, and according to the numerators of all the percentages, flood situations in Hunan were classified into 3 levels by the standard that whether the numerator is (slightly)less than/(slightly)greater than/twice as great as the numerator of the nation. The classifications shown in Table 2.

Table 2 Level of flood feature in Hunan

Comprehensive Index Range	Level	Remarks
(0,6.62]	relatively mild	(slightly)less than index of the nation, loss is relatively mild
(6.62,7]	relatively severe	(slightly)greater than index of the nation，loss is relatively severe
(7,10)	extremely severe	twice as great as the index of the nation，loss is extremely severe

It is worth noting that the comprehensive indexes of Hunan in 2007 and 2010 were 6.86 and 7.73, respectively. Compared with that of the nation, which were 6.51 and 7.4 correspondingly, the increment percentage were not large, being 5.37% and 4.42%, respectively. However, according to the degree of flood disasters in China in the past two years, 2007 was the year of heavy flood disasters in China (Zhang et al. 2008), and 2010 was the year of serious flood disasters in China(ONFCDRH 2010), so these two indicators are still classified into classes where flood disasters are severe.

According to Table 2, during the 13 years from 2006 to 2018, flood disasters in Hunan in 2012, 2013, 2015, and 2018 were relatively mild. In 2007,2008,2009,2011,2016, floods were relatively severe, while disasters in 2006, 2010, 2014 and 2017 were extremely severe.

In summary, Hunan's natural and geographical conditions have caused floods to occur every year; that is to say, floods are inevitable; but harsh floods occur every four years or so.

The flood damage in Hunan is generally more serious than the national average damage; More importantly, Hunan is also a major agricultural province in China. So how to effectively take advantages of its geography in flood disaster risk management, fostering strengths and avoiding weaknesses, implementing scientific disaster prevention and mitigation strategies are issues for our further research.

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Conflict of Interest

The authors declare that they have no conflict of interest. This article does not contain any studies with human participants or animals performed by any of the authors. Informed consent was obtained from all individual participants included in the study.

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Figures

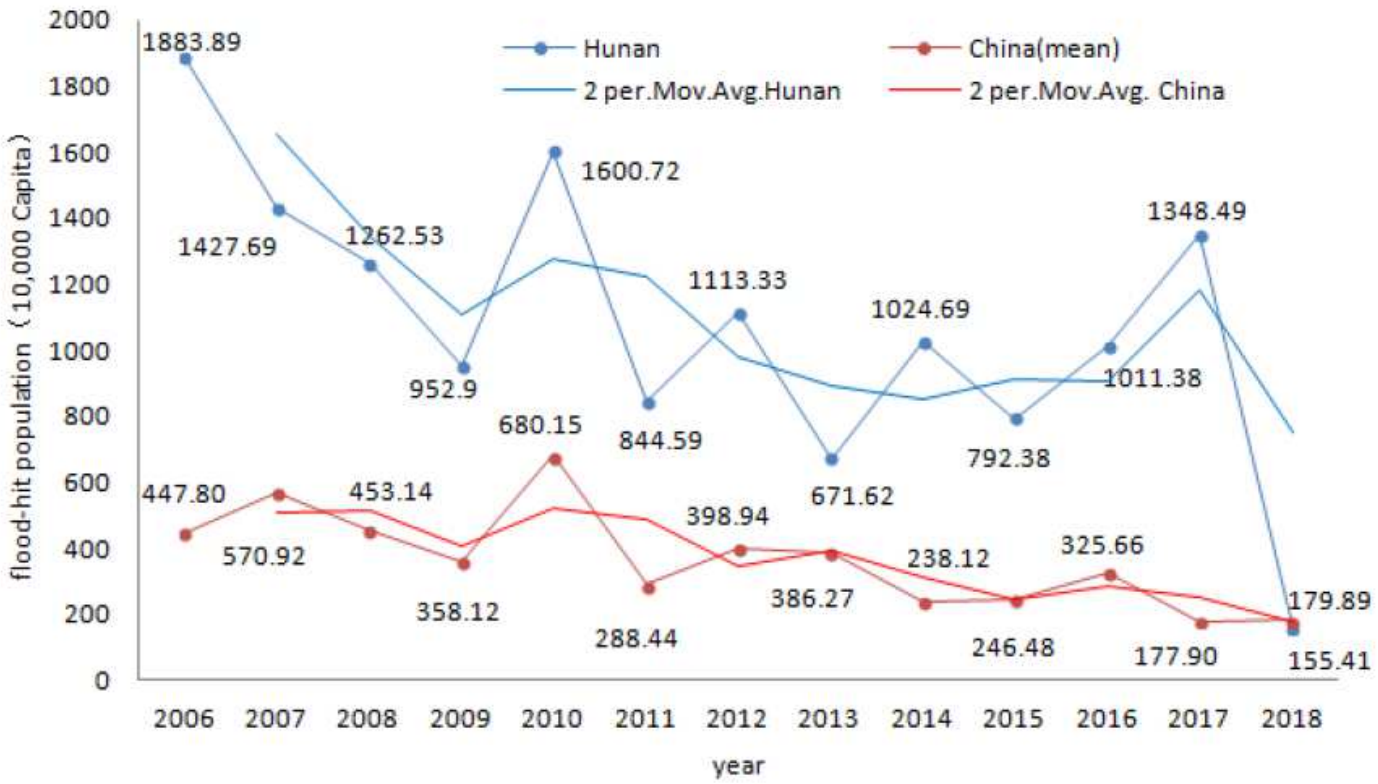

Figure 1

Trend of flood hit population & comparison between Hunan and China(mean)

Figure 2

Trend of flood death toll and comparison between Hunan and China(mean)

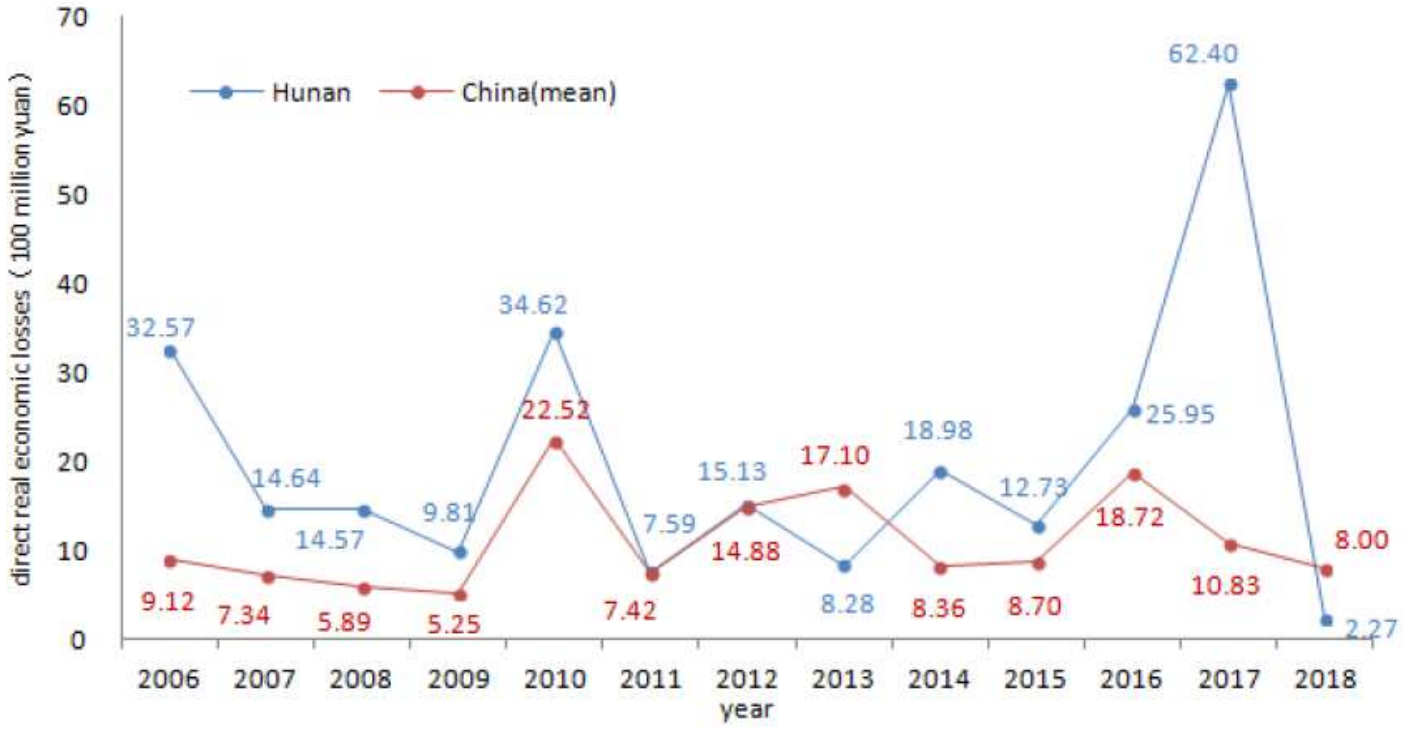

Figure 3

Comparison of direct real economic loss es 1978 as base year between Hunan and China(mean)

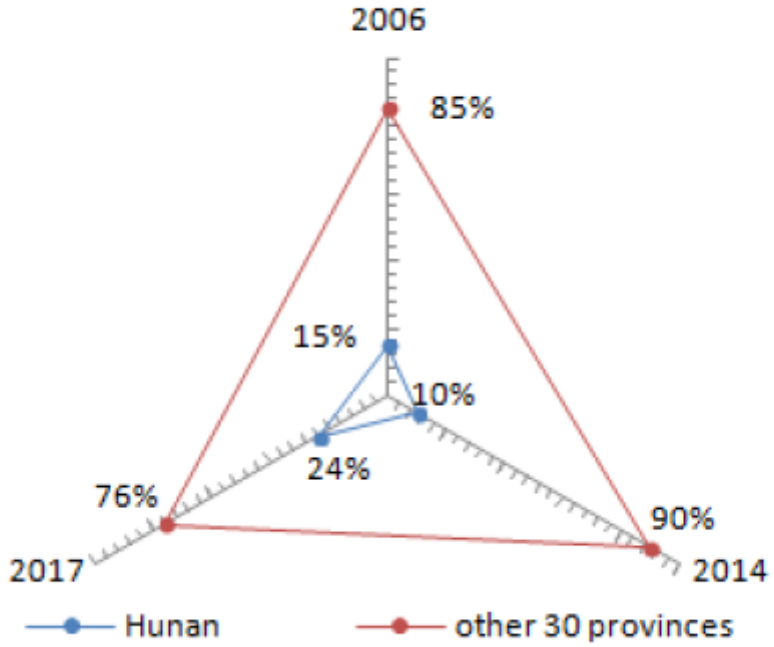

Figure 4

Proportion of total direct economic losses in Hunan and other 30 provinces

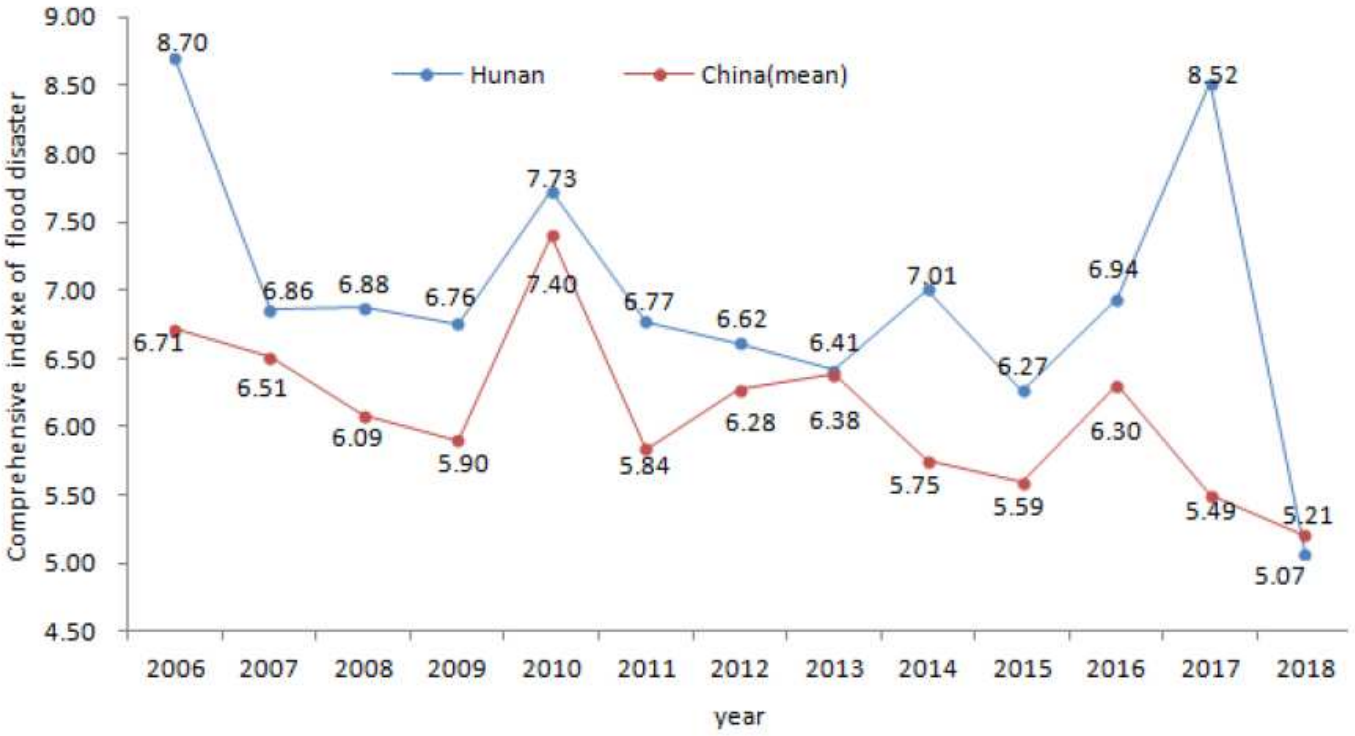

Figure 5

Comprehensive evaluation indexes of Hunan and China flood disaster(mean)