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Risk Assessment for Drought-flood Abrupt Alternation in the Pearl River Basin, China

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Abstract. Risk assessment of drought and flood sudden turn is very important for flood control and drought relief in summer. Based on the mechanism of drought and flood disaster risk, a risk model of drought and flood sudden turn in the Pearl River Basin is constructed. Results show that the risk values of drought and flood sudden turn in the Pearl River Delta and the North-South Panjiang River are large and fluctuate with time. The risks of Drought-flood abrupt alternation (DFAA) in the eastern and western parts are relatively higher than that in the central part, which indicates that the distribution of DFAA in the Pearl River basin is affected by large-scale weather system and local topography.

1. Introduction

The fifth assessment report of the United Nations Intergovernmental Panel on Climate Change (IPCC) pointed out that global warming of the climate system has become an indisputable fact. The global average temperature rose by 0.72°C from 1951 to 2012, causing extreme weather events due to climate warming. Increasing frequency and increasing intensity are a global trend [1]. The occurrence of extreme weather events has a significant and far-reaching impact on agriculture and food security, water resources security and ecological environment security [2], among which drought and flood disasters have a wide range of impacts, high frequency, and long duration. The characteristics of economic loss are the most prominent due to these two extreme weather events, posing a serious threat to the survival and development of mankind.

Drought-flood abrupt alternation (DFAA) is a remarkable manifestation of summer monsoon anomaly on a seasonal scale [3], which has already affected various aspects of the world, especially for the agriculture [4]. Due to the changing climate, extreme drought and flooding events are occurring with increasing frequency and magnitude across the globe [5]. Some regions will experience severe soil water scarcity, and others will experience excessive rain water. Inevitably, drought and flooding will occur IOP Conf. Series: Materials Science and Engineering 452 (2018) 022029 doi:10.1088/1757-899X/452/2/022029

one after another in a one region, among which, drought followed by flooding is the most common [6]. Drought and flood are main disasters for the Northern and Southern China.

DFAA can occur at any time. Most of the previous studies used the monthly or seasonal precipitation anomalies and anomalies to define the drought and flood index, which was calculated when the monthly or seasonal precipitation is calculated. The process of frankening precipitation has not reflected the detailed process of drought and flood and the specific transfer points. In order to better assess the risk of drought and flood, this paper uses daily-scale precipitation data to identify droughts and floods. The drought and flood rate is calculated. In addition, based on the disaster risk theory, the drought and flood risk assessment model is proposed to evaluate the spatial and temporal distribution of droughts and floods, which has a powerful auxiliary role for policy makers to formulate comprehensive management strategies. Moreover, this paper uses the Pearl River Basin as a research area to evaluate the risk of drought and flood through using ArcGIS and disaster risk theory.

2. Another section of your paper

2.1. Overview of the case study

The Pearl River Basin is located between 102°12′~115°53′ east longitude and 21°31′~26°49′ north latitude (Figure 1), across through six provinces including Yunnan, Guizhou, Guangxi, Guangdong. This paper considers multiple factors including geographical location, geological conditions, river system characteristics, climate hydrology, soil vegetation, natural geography and socio-economic data of the basin. These factors can be further divided into four aspects, involving the hazard, exposure, vulnerability, and disaster prevention. Risk assessment index system of the DFAA as shown in Table 1.



Figure 1. The case area for calculating the DFAA

Criterion	Index
Hazards	DFAA rate, Slope, Elevation
Vulnerability	Vegetation drought/Waterlogging tolerance index
Exposure	Population/GDP density
Disaster prevention and	Flood control storage/Beneficial reservoir capacity density, Water resource
reduction	utilization coefficient

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2.2. Methods

The data sources of each evaluation index are different in the multi-index evaluation system. And they have different dimensions and orders of magnitude. If the original index value is directly used for analysis, when the level of each index varies greatly, it will outburst the role of the index with higher value in the comprehensive analysis and weaken it with lower value. Therefore, in order to ensure the reliability of the results, the original index data needs to be normalized to remove the unit limitation of the data and transform it into a dimensionless pure value, so that the indexes of different units or orders of magnitude can be weighted and compared.

The data need to be normalized before the DFAA calculation. Normalization includes two aspects: homogenization processing and dimensionless processing. Data homogenization processing refers to the same nature of different nature indicators, so that different nature indicators can directly sum to reflect the comprehensive results of different forces, and solve the problem of different nature data. Data dimensionless processing refers to the conversion of raw data into dimensionless pure values, which facilitates the comparison and weighting of indicators of different units or magnitudes. The most typical one is the normalization of data, that is, the original data are uniformly mapped on the [0, 1] interval, which lays the foundation for the calculation of DFAA.

The normalized formula for the positive indicators as follows:

$$i = (x_i - x_{min}/1.05)/(x_{max} \times 1.05 - \frac{x_{min}}{1.05})$$
(1)

The normalized formula for the negative indicators as follows:

$$i = 1 - (x_i - x_{min}/1.05) / (x_{max} \times 1.05 - \frac{x_{min}}{1.05})$$
(2)

Where *i* is the normalized value of each index variable; x_i is the value of the corresponding variable *i* in the evaluated region, and x_{min} and x_{max} are the minimum and maximum value of the data series corresponding to the variable *i* in the evaluation region, respectively.

Use Analytical Hierarchy Process (AHP) to determine the weight of the indicator. AHP is a multiobjective decision analysis method that combines qualitative and quantitative and systematic hierarchical. When determining the weight of each index, the AHP analyses the weight coefficient of the index by comparing the relative importance of each index at the same level. The purpose of this method is to present the empirical judgments of decision makers (mainly experts and scholars) in a quantitative manner to enhance the accuracy of decision-making.

Establish a judgment matrix. The target layer is decomposed into the criterion layer, and then the criterion layer is decomposed into the index layer. Finally, the judgment matrix is determined by pairwise comparison of each indicator in the index layer. When the AHP is used to judge the relative importance of the indicators, the scale of nine-point scale is used, as shown in Table 2.

Table 2. Scale meaning of judgement matrix

Scale	Meaning
1	Compared with the two factors, the two factors are of the same importance.
3	Compared with the two factors, the former is slightly more important than the latter.
5	Compared with the two factors, the former is obviously more important than the latter.
7	Compared with the two factors, the former is strongly important than the latter.
9	Compared with the two factors, the former is extremely important than the latter.
2,4,6,8	Indicates the intermediate value of the above adjacent judgment

Hierarchical single sorting is the basis of hierarchical total sorting. Common methods include square root method, sum product method, feature root method, least square method, etc. This paper uses the square root method to calculate:

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Calculating the product of each row element in the judgment matrix yields M_i :

$$M_i = \prod_{j=1}^n a_{ij} \tag{3}$$

Calculate the nth root of M_i and recorded as \overline{W} :

$$\overline{W} = \sqrt[n]{M_i} \tag{4}$$

Where i=1, 2, ..., n; Normalize the vector $\overline{W} = [\overline{W_1}, \overline{W_2}, ..., \overline{W_n}]^T$:

$$W_i = \overline{W_i} / \sum_{i=1}^n \overline{W_i} \tag{5}$$

Where i=1, 2, ..., n; Then $W_i = [W_1, W_2, ..., W_n]$ is the weight of the indicator under a single criterion. After obtaining the weights of each indicator, a consistency check is needed to determine whether the established judgment matrix has reasonable logic. If not, the calculated index weight result will be chaotic, which is not in line with logical thinking and leads to decision-making mistakes. The test steps are as follows:

Calculate the maximum characteristic square root of the judgment matrix λ_{max} :

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(AW)_i}{W_i} \tag{6}$$

Calculate the consistency indicator *CI* (consistency index):

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{7}$$

Determine the average random consistency indicator *RI* value: Calculate the consistency ratio *CR* (consistency ratio):

$$CR = \frac{CI}{RI} \tag{8}$$

According to the CR value judgment matrix consistency satisfaction, when CR < 0.1, the matrix is considered to have satisfactory consistency; when CR > 0.1, the judgment matrix needs to be adjusted to achieve satisfactory consistency.

Based on the theory of disaster risk system and the formation mechanism of drought and flood disaster risk, building risk model for DFAA, including multiplication model and addition model.

$$R = f(H, E, V, C) = (H * E * V)/C$$
(9)

$$R = f(H, E, V, C) = H + E + V + C$$
(10)

$$H = \sum_{i}^{n} W_{i} \times H_{i} \quad E = \sum_{i}^{n} W_{i} \times E_{i} \quad V = \sum_{i}^{n} W_{i} \times V_{i} \quad C = \sum_{i}^{n} W_{i} \times C_{i}$$
(11)

Where *R* is the Risk of Flood; *H* is the hazard; *E* is the exposure of the hazard; *V* is the vulnerability of the famine environment; C is Disaster Prevention. W_i is the weighting coefficient of each evaluation index, and $H_i E_i V_i$ and C_i are normalized for each indicator data.

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3. Results and Discussion

According to the mechanism of drought and flood disaster risk with multiple data associated with geographical location, geological conditions, river system characteristics, climate hydrology, soil vegetation, natural geography and socio-economic data, the hazard, exposure, vulnerability, and disaster prevention are used to identify the source of drought and flood risk, and to construct a drought and flood disaster risk assessment indicator system and assessment model. Using the GIS as the platform, the analytic hierarchy process calculates the weights, quantitatively assesses the risk of droughts and floods in the Pearl River Basin.



Figure 2. Two or more references. Risk of DFAA in the Pearl River Basin (a) Multiplication risk model (b) Addition risk model.

Using the additive risk model and multiplicative risk model of DFAA, the risk values of drought-flood rapid transition in the seven sub-basins of the Pearl River Basin are calculated, and the risk values of drought-flood rapid transition are obtained, as shown in Figure 2. Results reveal that the Risk of DFAA index show obvious changes in the Pearl River Basin, and it still has some temporal and spatial differences. In terms of spatial changes, the eastern and western parts of the basin have relatively higher risks, such as Pearl River Delta and North and South Pan River. In terms of temporal changes, the calculation of risk model shows that the risk values of the drought-flood transition in the Pearl River Delta and the North and South Pan River fluctuate greatly with time. The risk values of the Dongjiang River only fluctuate greatly from 2005 to 2009, and the trend of the other time is relatively gentle. The risk values of the drought-flood transition in other basins have an insignificant variation with time. The results of the two models have the similar trend, but the difference is that the risk value of drought-flood rapid turn in the multiplication model is obviously smaller than that in the addition model.

4. Conclusion

This paper establishes drought and flood risk assessment model to calculate the risk of drought and flood in the seven sub-basins of the Pearl River Basin from 2000 to 2016. Generally, the main conclusions are summarized as follows: (1) based on the meteorological, natural, geography and socio-economic data in the Pearl River Basin, the drought and flood risk were calculated. The DAFF risk of the eastern and western are relatively greater than that in the center part, meanwhile the eastern has a higher DAFF risk than the western; (2) there is a simple temporal change in the risk of DFAA across the region, where the Pearl River Delta and the North and South Pan River fluctuate greatly with time, while others have an insignificant variation with time. Moreover, the results of the two models have the similar trend.

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