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# Analysis of Hazard Risk of Lightning Disasters in Different Geographical Areas of Liaoning Province

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***Abstract:*** *In order to define the degree of lightning disaster risk of different areas and counties, taking Xiuyan County in Anshan, Linghai City in Jinzhou and Dashiqiao City in Yingkou of Liaoning Province as examples, this paper uses lightning locator data and geographic information data, adopts normalization method and natural break point method, and considers two evaluation indexes: the risk of disaster causing factors and the sensitivity of disaster causing environment. The lightning hazard zoning model was established by selecting ground lightning density, ground lightning intensity, altitude, topographic relief and soil electrical conductivity, and the lightning hazard zoning map was drawn. The results showed that the northwest and northeast of Xiuyan County, the northwest of Linghai City and the southeast of Dashiqiao City were high to very high risk areas, and the other areas were low risk areas and general risk areas.*

***Keywords:*** *Ground lightning; Hazard factor; Hazard inducing environment; Hazard risk*

## 1. Introduction

Thunder and lightning is a cloud discharge phenomenon accompanied by lightning and thunder. Due to the small spatio-temporal scale and strong abruptness, it is difficult to predict and predict, so when the estimation is insufficient, it will cause great harm[1]. The social hazards of lightning are second only to flood and geological disasters. Lightning disaster is a type of disaster with high frequency and serious impact all over the world. Lightning often causes casualties, farmland disasters and fishery losses, which seriously restricts social and economic development[2]. Therefore, it is of great significance to carry out the risk assessment and zoning of lightning disaster for reducing the personal and property losses caused by lightning and protecting the social security.

In recent years, Chinese meteorologists have made many studies on the risk assessment and zoning of thunder and lightning disasters. Jiang Yin et al.[3] Feng Guili et al.[4] revealed the spatio-temporal distribution characteristics of ground lightning frequency and intensity in Shenzhen and Shandong, respectively. Zhu Hao[5] et al. studied the relationship between ground lightning density from 2010 to 2015 and thunderstorm days from 1961 to 2015 in Anhui Province.

Yuan Xiangling et al.[6] obtained the lightning disaster risk regionalization model of Heilongjiang Province by using the analytic hierarchy process. At present, the research on lightning disaster risk regionalization model has been carried out in various provinces in China, but the research on lightning disaster risk regionalization in Liaoning Province is relatively lacking. With the rapid development of GIS technology, geographic information data has been applied more and more widely in the meteorological field. It will greatly improve the accuracy of meteorological disaster risk regionalization. This paper takes Xiuyan County in Anshan, Linghai City in Jinzhou and Dashiqiao City in Yingkou of Liaoning Province as examples to carry out the hazard assessment of lightning hazard risk from 1978 to 2020.

## 2. Data and methods

### *2.1. Data description*

The ground lightning data were obtained from the detection data of the ADTD lightning location monitoring system in Liaoning Province from January 1, 2012 to December 31, 2020. The accumulated time, latitude and longitude, lightning current amplitude, steepness and location mode were extracted.

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Soil electrical conductivity was obtained from 1:1 million soil grid number of China produced and published by Nanjing Soil Institute according to the results of the second national land survey. The DEM elevation data are obtained from the Digital elevation Model database of National Basic Geographic Information Center[7].

### *2.2. Data processing methods*

#### *2.2.1. Processing method of ground lightning data*

The data of flash occurrence time, longitude, latitude and current intensity are extracted from the original data monitored by the ground lightning positioning system. The data of ground lightning with lightning current amplitude of 0 ~ 2 kA and above 200 kA were excluded. The probability of more than 200kA is very small and may exceed the detection range of the system, and the error rate is also high. LLS of lightning current below 2kA is usually difficult to measure accurately, and the basic lower limit of domestic power system is 3kA.

#### *2.2.2. Normalization method*

The risk assessment of lightning disaster is carried out by weighted synthesis of multiple indexes. In order to eliminate the dimensional difference of each index, the value of each index is normalized. Normalization is to transform the dimensional value into a dimensionless value, and then eliminate the dimensional difference of each index. The calculation formula is:

$$D_{i,\ j} = 0.5 + 0.5 \times \frac{A_{i,\ j} - \min_i}{max_i - min_i} \tag{1}$$

In the formula: $D_{i,j}$ is the normalized value of the ith index of point j station (grid); $A_{i,j}$ is the ith index value of point j station (grid), $\min_i$ and $\max_i$ are the minimum and maximum value of the ith index value, respectively.

#### *2.2.3. Natural break point method*

Jenks Natural Breaks Method is a map grading algorithm. The algorithm considers that the data itself has breakpoints and can use this characteristic to grade. The principle of the algorithm is a small cluster, and the clustering end condition is the maximum between-group variance and the minimum between-group variance. The calculation formula is:

$$SSD_{i-j} = \sum_{k=1}^{j} A[k]^2 - \frac{\left(\sum_{k=1}^{j} A[k]\right)^2}{j-i+1} \quad (1 \le i < j \le N) \tag{2}$$

In the formula: SSD — variance; i, j — the ith and Jth element; A — an array of length N; K — the number between i and j, representing the kth element in group A.

## 3. Results and analysis

### *3.1. Lightning disaster hazard risk*

The two conditions that lightning disaster must have are disaster - causing factor and disaster - bearing environment. The disaster factor mainly considers two aspects of lightning point density and ground lightning intensity. ground lightning density reflects the possibility of lightning disaster in the study area.

The ground lightning intensity reflects the probability of lightning disaster in the study area. The higher the ground lightning intensity is, the higher the density is, the higher the risk of lightning disaster is. Sensitivity assessment of hazard inducing environment is an important part of lightning hazard risk zoning. Appropriate hazard inducing environmental factors are selected according to disaster type, disaster intensity and frequency, and a reasonable and optimized index combination and weight are established. The impact factors of the hazard inducing environment selected in this paper are topographic impact index, altitude and soil electrical conductivity, and the lightning hazard hazard process is established (Figure 1).

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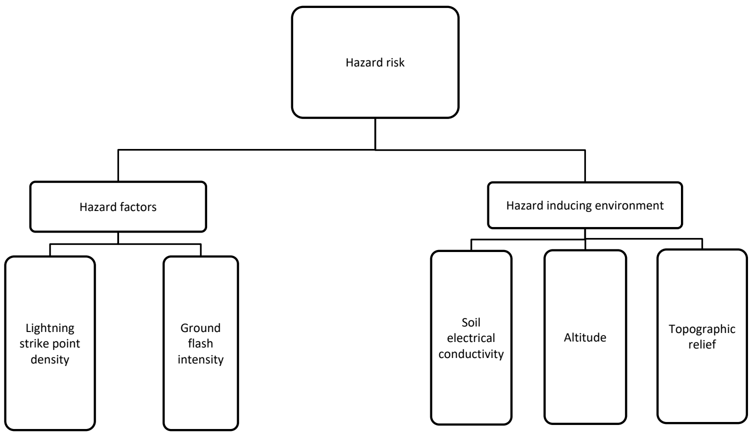


*Figure 1: Process of lightning disaster hazard risk*

### *3.2. Analysis of hazard factor risk*

Based on the ground lightning data obtained from Liaoning ADTD ground lightning locator from January 2012 to December 2020, after quality control, the extracted ground lightning intensity data of nearly 9 years were used to divided the lightning current amplitude into 5 levels according to the percentile method (Table 1). According to the principle that the higher the magnitude level of lightning current, the greater the role it plays in the formation of lightning disaster, the weight of ground lightning disaster factor was determined. The weight was calculated from level 1 to level 5 according to the magnitude of lightning current, that is, according to Formula (3), and normalized to form the raster data of ground lightning intensity:

$$L_n = \sum_{i=1}^{5}\left(\frac{i}{15}\times F_i\right) \tag{3}$$

In the formula: $L_n$ is ground lightning intensity; i is lightning current amplitude level; $F_i$ is the normalized value of the ground lightning frequency with the amplitude of lightning current level i.

*Table 1: Level of lightning current amplitude*

| Amplitude of lightning current / F Percentiles (P) | P≤60% | 60％<P≤80% | 80％<P≤90% | 90％<P≤95% | P>95% |
|---|---|---|---|---|---|
| Xiuyan | F≤29.51 | 29.51<F≤41.97 | 41.97<F≤54.61 | 54.61<F≤71.40 | F>71.4 |
| Linghai | F≤30.88 | 30.88<F≤43.91 | 43.91<F≤58.48 | 58.48<F≤77.4 | F>77.4 |
| Dashiiqiao | F≤36.17 | 36.17<F≤46.37 | 46.37<F≤60.50 | 60.50<F≤81.09 | F>81.09 |
| Level | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |

Ground lightning density reflects the current probability of lightning strikes in an area and represents the annual ground lightning frequency per unit area. The ground lightning data were divided into 1km × 1km grids by using the mask technology in GIS software and processed by fishing nets. The number of ground lightning in each grid was counted and then divided by the grid area and age to obtain the ground lightning density of each grid (times /$km^2$. a).

According to the distribution map of ground lightning density (see Figure 2), it can be seen that the southwest and southeast of Xiuyan County, and the central and southern part of Linghai City are the low value areas of ground lightning density. In the northwest of Xiuyan County, in the east of Linghai City and in the middle and east of Dashiqiao City, there are high values of ground lightning density.

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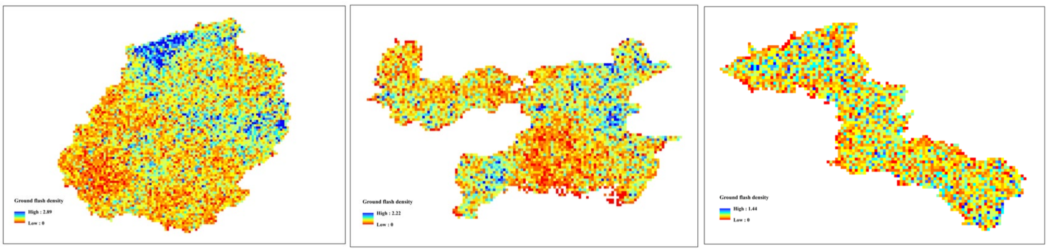

*Figure 2: Spatial distribution of ground lightning density in Xiuyan County, Linghai City and Dashiqiao City*

The natural breakpoint method in GIS software was used to classify the risk levels of disaster causing factors, and the raster data of ground lightning density and ground lightning intensity were processed into the same geographic coordinate system and projection coordinate system to draw the risk zoning map of disaster causing factors, as shown in Figure 3. The low risk areas of lightning disaster factor are mainly distributed in the southwest and southeast of Xiuyan County, the middle and south of Linghai City and the middle of Dashiqiao City. High risk areas are mainly distributed in the northwest of Xiuyan County, the southwest and northeast of Linghai City, and the northwest of Dashiqiao City.

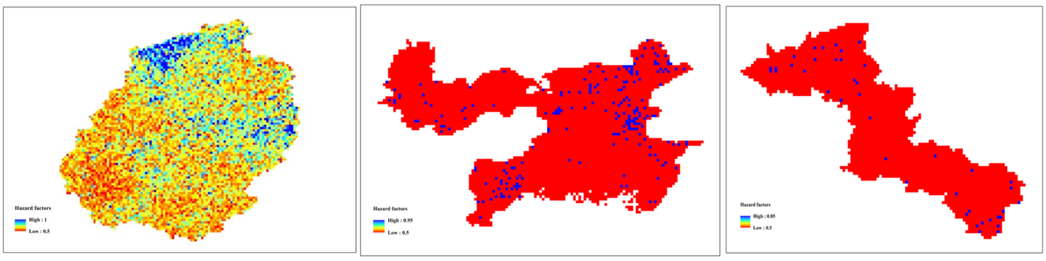

*Figure 3: Distribution map of hazard factor risk in Xiuyan County, Linghai City and Dashiqiao City*

### *3.3. Sensitivity analysis of hazard inducing environment*

Sensitivity assessment of hazard inducing environment is an important part of lightning hazard risk zoning. Appropriate hazard inducing environmental factors are selected according to disaster type, disaster intensity and frequency, and a reasonable and optimized index combination and weight are established. The sensitivity of hazard inducing environment is mainly affected by altitude, topographic relief degree and soil electrical conductivity[8]. The higher the altitude, the greater the topographic relief, the greater the soil electrical conductivity, and the higher the sensitivity of hazard inducing environment.

GIS software was used to calculate the standard deviation of terrain elevation and soil electrical conductivity in adjacent grids of 1km ×1km grid, and the sensitivity zoning map of hazard inducing environment was obtained (Figure 4). The southeastern part of Xiuyan County, the central, eastern, and southern parts of Linghai City, and the central and western parts of Dashiqiao City are low-sensitivity areas; the western and northeastern parts of Xiuyan County, the northwestern part of Linghai City, and the southeastern part of Dashiqiao City are high-sensitivity areas.

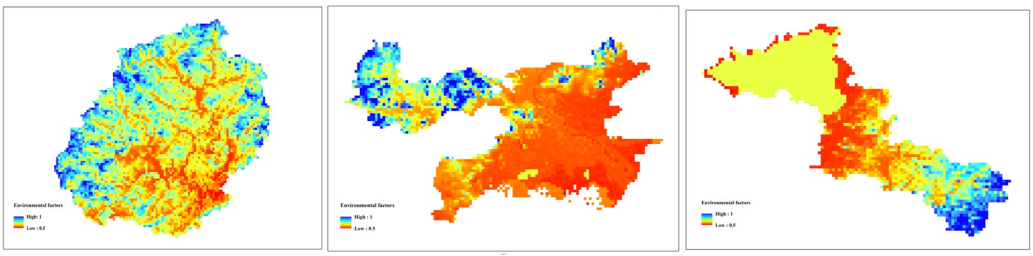

*Figure 4: Sensitivity distribution map of hazard inducing environment in Xiuyan County, Linghai City and Dashiqiao City*

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### *3.4. Hazard Risk Analysis of Lightning Disasters*

According to the hazard factors and the hazard inducing environment index, the disaster risk index RH model (Formula 4) of the implementation rules was used for calculation.

$$RH = \left(L_d \times wd + L_n \times wn\right) \times \left(S_c \times ws + E_h \times we + T_r \times wt\right) \tag{4}$$

In the formula: RH — risk of hazard factors; $L_d$ — ground lightning density, wd — the weight of ground lightning density; $L_n$ — ground lightning intensity, wn — the weight of ground lightning intensity; $S_c$ — soil electrical conductivity, ws — soil electrical conductivity weight; $E_h$ — altitude, we — altitude weight; $T_r$ — topographic relief, wt is topographic relief weight.

According to the calculated results of RH, the risk was divided into four levels (low, general, high and very high) according to the natural breakpoint method, and the hazard distribution map of the disaster factor was drawn to complete the hazard assessment of the disaster factor. The ground lightning density, lightning current intensity, topographic relief, altitude and soil resistivity were evaluated according to the corresponding weights (0.3165, 0.3592, 0.1440, 0.1267, 0.0536) to form the lightning disaster risk map (Figure 5). The results showed that the northwest northeast of Xiuyan County, the northwest of Linghai City and the southeast of Dashiqiao City were high to very high risk areas, and that the other areas were low risk areas and general risk areas.

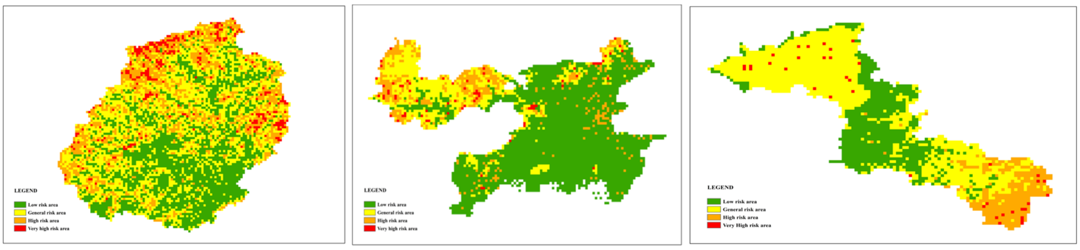

*Figure 5: Distribution map of hazard risk in Xiuyan County, Linghai City, and Dashiqiao City*

## 4. Conclusion

(1) Based on the theory of disaster risk formation, the relationship between the risk of hazard factors, the sensitivity of the hazard inducing environment and the risk of lightning disasters is discussed. A lightning disaster risk zoning model with multiple evaluation indicators and multi-level structures such as ground lightning density, ground lightning intensity, altitude, topographic relief, and soil electrical conductivity is constructed. Scientific assessment and judgment on the risk of lightning disasters are made.

(2) Analytic Hierarchy Process and GIS technology are applied to the zoning of the hazard risk caused by lightning disasters. The data of each risk index is normalized, rasterized and superimposed to form a lightning disaster risk zoning database with a unified format framework. Using the natural breakpoint method, a zoning map of the risk of lightning disasters is drawn, so as to clarify the regional distribution of different levels of risk. This provides an objective technical basis and decision-making reference for regional lightning risk management and meteorological disaster defense planning.

(3) The hazard risk of lightning disasters in Xiuyan County, Linghai City and Dashiqiao City was analyzed, which provided the basis for the targeted formulation of disaster prevention and risk avoidance and risk management measures. On this basis, take targeted risk prevention and risk management measures to eliminate potential safety hazards caused by lightning disasters, reduce the probability of disasters, and minimize the risk of lightning disasters.

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