

Article

Multi-Hazard Meteorological Disaster Risk Assessment for Agriculture Based on Historical Disaster Data in Jilin Province, China

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Abstract: The impact of global climate change is gradually intensifying, and the frequent occurrence of meteorological disasters poses a serious challenge to crop production. Analyzing and evaluating agricultural multi-hazard meteorological disaster risks based on historical disaster data and a summary of disaster occurrences and development patterns are important bases for the effective reduction of natural disaster risks and the regulation of agricultural production. This paper explores the technical system of agricultural multi-hazard meteorological disaster risk assessment and establishes a disaster risk assessment model based on the historical disaster data at the regional level from 1978–2020 in the first national comprehensive natural disaster risk census, carrying out multi-hazard meteorological disaster risk assessments in 18 major grain-producing regions in Jilin province. The empirical evidence shows: (1) drought and flood disasters are the key disasters for agricultural meteorological disaster prevention in Jilin province. Hotspots of drought and flood disasters are widely distributed in the study area, while hail and typhoons are mainly concentrated in the eastern region with a certain regionality. (2) The risk values of the four major meteorological disasters all decreased with the increase of the disaster index. Under the same disaster index, the disaster risk of various disasters in the main grain-producing areas is as follows: drought > flood > typhoon > hail. Under different disaster indices, Jiutai, Nongan, Yitong, Tongyu, and other places all presented high and medium–high risk levels. (3) From the spatial evolution trend, along with the rising disaster index, the risk of multi-hazard meteorological hazards is spatially oriented in a southeastern direction, and the risk level of multi-hazard meteorological hazards in the central part of the study area decreases gradually along with the increasing damage index. In addition, regional agricultural multi-hazard meteorological disaster risk reduction recommendations are made in three aspects: institutional construction, management model, and reduction capacity.

Keywords: historical disasters; multi-hazard meteorological disasters; risk assessment; major grain-producing areas; Jilin province



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1. Introduction

The Sixth Assessment Report of the IPCC, held in August 2021, noted that climate change has affected the occurrence of a number of extreme weather and climate events in all regions of the world [1]. Global warming and urbanization have brought about changes in the intensity and frequency of weather-causing factors and in the exposure of crop-bearing bodies, which have important implications for agricultural production's ability to withstand natural disasters, and the assessment of agricultural multi-hazard disaster risks is important for formulating disaster reduction measures and increasing farmers' income [2–5]. China is one of the countries that is most severely affected by natural disasters in the world due to its vast territory, complex geographical environment, large climate fluctuations, poor

ecological stability, and high frequency and intensity of multiple disaster types. Although agricultural production has gradually declined in the process of economic development due to rapid economic growth, it is undeniable that agriculture plays a major role in ensuring people's living standards and the stable operation of the national economy. Natural disasters pose a major challenge to China's food security. The analysis and evaluation of agricultural multi-hazard meteorological disaster risks based on historical disaster data and the summary of disaster occurrence patterns are important bases for regulating agricultural production and effectively mitigating natural disaster risks. The total grain output of Jilin province in 2021 was 80.784 billion pounds, maintaining the fifth position among all provinces in the national ranking; the grain yield was 941.3 pounds/acres, increasing by 48.7 pounds/acres compared with the previous year. The yield maintained Jilin province's position of fourth place among all provinces in China (http://www.moa.gov.cn/xw/qg/202112/t20211227_6385576.htm, accessed on 5 May 2022). All data reflect that Jilin province's food security production cannot be ignored.

Agricultural production relies on the natural environment for animal and plant growth and is more vulnerable to natural disasters than other industries. In recent years, agricultural disaster risk assessment has been carried out in various large food-producing regions. Kim et al. used the heavy rain damage risk index (HDRI) to analyze flood risk levels in the southern region of Korea, to determine high-risk cities and five causes of damage, and to propose reduction and control programs based on regional risk levels and hazard types [6]. Liu et al. used a comprehensive multi-indicator evaluation method, combined with an entropic information diffusion model, to assess the risk of agricultural droughts and floods in the middle and lower reaches of the Yangtze River, proposing relevant policy recommendations based on the assessment results [7]. Summarizing the past studies, it was found that the agricultural multi-disaster risk assessment mainly focused on single-hazard or single-crop studies, and there were few multi-hazard risk assessments. Furthermore, in terms of the use of historical disaster data, the historical disaster data were mostly based on regional or national assessment units, and there was little guidance for disaster risk assessment and work in small regions.

Since the 21st century, various countries have gradually tried to establish national or regional disaster risk databases, such as the Emergency Disaster Database (EM-DAT) of the National Centre for Research on the Epidemiology of Disasters of the University of Leuven in Belgium, the Natural Disaster Database (Nat-Cat) of the Munich Reinsurance Company in Germany, and the database of the Swiss Reinsurance Company (Sigma), etc. [8–11]. However, these databases are often based on regional or national statistical units, and the spatial distribution of risks is vague and thus cannot accurately guide the local agricultural safety production and disaster reduction work. Moreover, historical disaster information of small-scale regional units often exists in the form of reports, yearbooks, news reports, disaster records, etc. The statistical caliber of disaster indicators varies especially greatly among different departments, making it difficult for disaster reduction departments to effectively collect and use early historical disaster data.

China plans to carry out the first national comprehensive natural disaster risk census in 2020–2022, which is a survey of China's natural disaster risk potential and basic national conditions, and this work is currently under intense progress [12]. The construction of historical disaster surveys and databases is the highlight of the first comprehensive natural disaster risk survey. The Emergency Management Department coordinates the collection of historical disaster archives from 1978 to 2020 by various sectors (e.g., Water, Meteorological, Agricultural). This is the first large-scale and comprehensive risk survey since the founding of the People's Republic of China. This data survey is characterized by a large amount of data with many sectors involved featuring a full range of disaster types. The collected data are of great significance for the future assessment of natural disaster risk and the sustainable development of agriculture in China.

In this study, we used the meteorological disaster data and related historical disaster files from the first comprehensive natural disaster risk census, and used the crop disaster

index to characterize the impact range of each disaster. After combining the historical disaster database of the first comprehensive natural disaster risk census and the actual situation in the main grain-producing areas of Jilin province, the agricultural multi-hazard meteorological hazards in the study area were confirmed. We analyzed and evaluated the risk of agricultural multi-hazard meteorological disasters in the region by constructing an agricultural multi-hazard meteorological disaster risk assessment model, and obtained the risk level and spatial variation of agricultural multi-hazard meteorological hazards under different disaster indices. The study is a useful exploration of the application of natural disaster census data to multi-hazard meteorological disaster risk assessment methods at the county level, and provides a quantitative basis for relevant departments to scientifically formulate disaster reduction and mitigation policies and plans. The main contributions of the article are as follows:

1. Disaster risk identification: confirm the hotspots of various disasters in the study area;
2. Disaster risk analysis: calculate the meteorological disaster risk value of the study area and the weight of a single disaster risk in each region;
3. Disaster risk assessment: determine the multi-hazard risk level and spatial differentiation in the study area;
4. Disaster risk reduction: put forward three suggestions for the reduction of food safety production in the study area.

2. Materials and Methods

2.1. Study Area

Jilin province is located at mid-latitudes on the eastern side of the Eurasian continent ($121^{\circ}38' \text{ E}$ – $131^{\circ}19' \text{ E}$, $40^{\circ}52' \text{ N}$ – $46^{\circ}18' \text{ N}$). It has a land area of about 187,400 km². The area is rich in products and is fertile; the main grain crops are corn and rice. It is one of the three major black soil distribution areas in the world. The eastern part of Jilin is the Changbai Mountains, the central part is Song Liao Plain, and the western part is the Horqin Grassland. The terrain is high in the southeast and low in the northwest, with significant differences in geomorphology and obvious spatial differentiation in land use types [13,14]. Climatic conditions are an important factor influencing the layout and structure of food crops. The study area is influenced by the westerly wind circulation and the low-pressure system of Lake Baikal. In terms of seasonal distribution, rapid warming and high insolation rates in spring provide light resources for the early stages of crop production. High temperatures and rain in summer with long daylight hours are favorable for crops to photosynthesize. Autumn has sufficient light, a large temperature difference between day and night, more sunshine, and less rain, which is conducive to nutrient accumulation in food crops. Cold and long winters reduce the occurrence of pests and pesticide use, which is conducive to the rest and recuperation of arable land. There are obvious seasonal variations and regional differences in temperature and precipitation in Jilin province [15–17]. The average winter temperature is below -11°C , and the average summer temperature is above 23°C . The frost-free period is 100–160 days, and there is an annual average of 2259–3016 h of sunshine with a sunshine rate of 50–70%. The average annual precipitation is 400–600 mm, with summer exceeding the sum of spring, autumn, and winter, just at the peak of crop development and growth with light, heat, and rain arriving simultaneously; this is a unique advantage for crop cultivation in Jilin province [18–20]. There is an obvious wet to semi-humid to semi-arid transition from the east to the west, and the alluvial plain area covered by sand dunes in the west is a sensitive area for climate change response and an important agricultural production base in China; thus, there is some theoretical significance and practical value to studying the integrated risk law of multi-hazards in the study area. Combining the available data, the article classifies the province's grain yield using the natural intermittent classification method based on the grain yield data of 60 districts in Jilin province in 2020, and finally obtains 18 districts with high and medium-high yield grades as the study area (Figure 1a). The study area is mostly arable land with an arable land cover of 70% (Figure 1b).

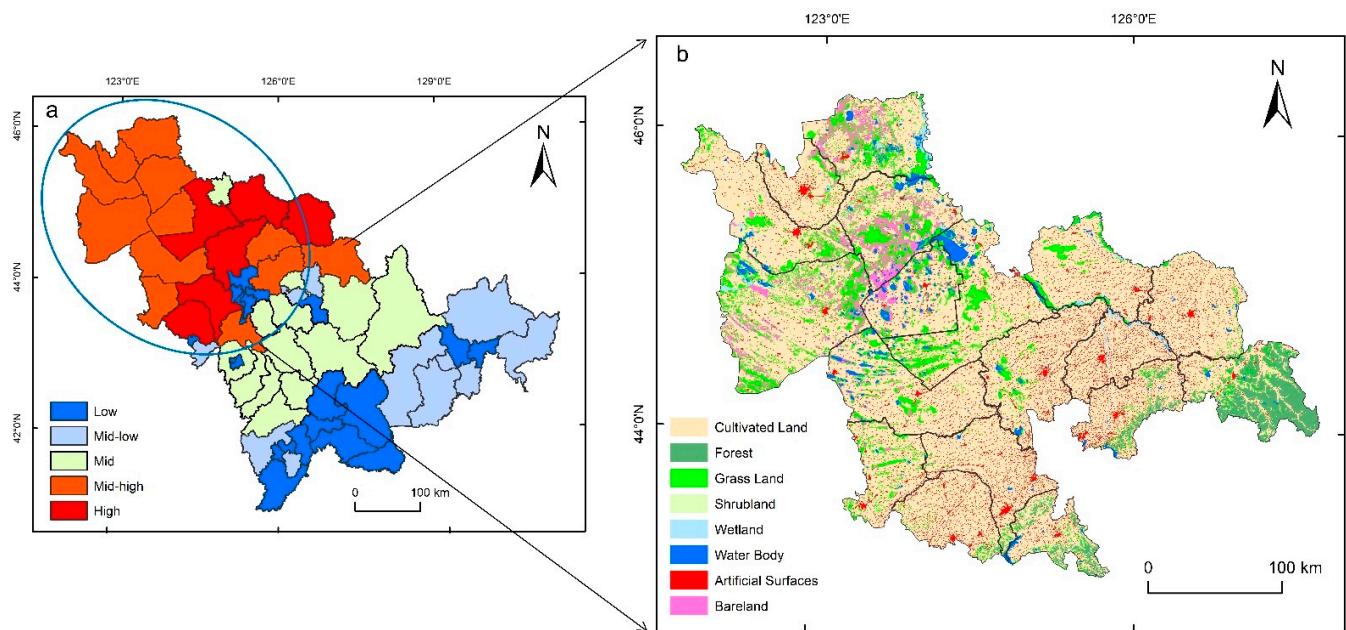


Figure 1. The main grain-producing area of Jilin province, China: (a) distribution of grain yield classes in Jilin province (left); (b) distribution of land use types in the study area (right).

2.2. Data Sources

The historical disaster survey of the first national comprehensive natural disaster risk census uses the district as its basic survey unit. Seven types of disasters, namely, drought, flood, typhoon, hail, sandstorm, freezing, and snowstorm, were investigated in the historical disasters from 1978 to 2020. Because of the wide distribution of historical disaster files, non-uniform statistical indicators, and a lack of data precision, the management of historical disaster files has been confusing in various industries. The first national comprehensive natural disaster risk census historical disaster database is the most comprehensive coverage of disaster database construction since the founding of the People's Republic of China, which is of great significance for the subsequent statistics and predictions of natural disaster risk. The data underlying this study were derived from this historical disaster database (<https://fxpc.mem.gov.cn/NationalDisastersProject/#/LoginPage>, accessed on 14 January 2022). Through the collation and measurement of all survey data, we obtained basic data for the last 43 years. The basic data and the disaster data, such as sown area, crop damage, and house damage, for each disaster type in the past years were obtained. Taking the main grain-producing areas in Jilin province as the basic evaluation unit, the multi-hazard meteorological disaster risk was studied from the perspective of disaster loss, using the crop damage area and annual sown area data of each disaster in the past years, as well as the grain production data in 2020, as the original data. With the help of the disaster index (disaster index = affected area/sown area), which reflects the degree of agricultural disaster, the larger the index is, the greater the impact of the disaster and the higher the crop yield reduction due to the disaster.

The disaster information for seven major disaster types in the study area was extracted from the historical disaster database of the first comprehensive natural disaster risk census. It mainly includes statistics on the average affected area, average demolished area, and frequency of disasters in the main grain-producing areas of Jilin province (Figure 2). In terms of average affected area, drought has the largest disaster area, while floods, typhoons, and freezing have little difference in disaster areas, indicating that the main grain-producing areas in Jilin province are prone to large disaster areas due to drought. The average demolished area refers to the sown area where the crop yield has been reduced by more than 80% compared with the normal year due to the disaster. The average demolished area can reflect the severity of disasters from the side. The average demolished area of four

disasters, namely, drought, flood, hail, and typhoon, exceeds 1000 hm², indicating that four disasters have a high degree of impact on agricultural production in Jilin province. In terms of the frequency of disasters in the main grain-producing areas, the frequency of droughts, floods, hail, and typhoons all exceed 50 times, which are high-frequency disasters in the main grain-producing areas of Jilin province. Freezing events and snowstorms are common after November, but the main grain-producing areas in Jilin province have completed harvesting and transferring the crop yield into a warehouse, as well as other tasks, by this time, so the impact on the large area of grain damage is minimal. Similarly, sandstorms tend to occur in March, when crops have not been sown and do not cause serious damage. Grain crops in Jilin province are sown in April and harvested in October. These three disasters (freezing, snowstorm, and sandstorm) do not cause widespread damage. Based on the above analysis, four disasters, namely, drought, flood, hail, and typhoon, were selected as the disasters for our study.

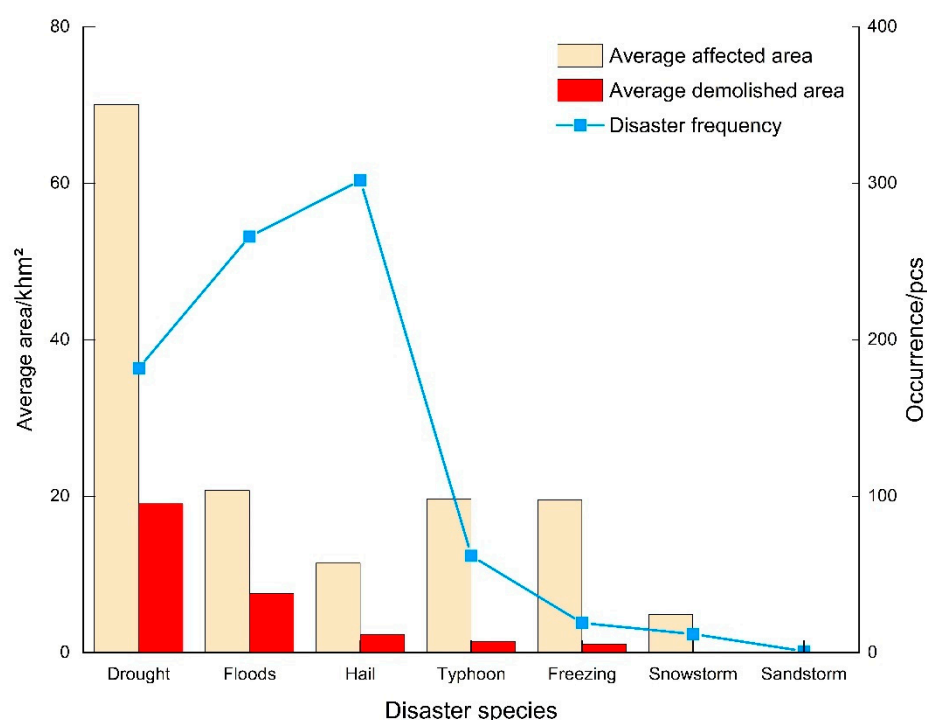


Figure 2. Average affected (demolished) area and frequency of each disaster species in the study area.

From the original data, four disasters affected the main grain-producing areas in Jilin province (Table 1). The average disaster index for drought in Taonan and Qianan in the western region of the study area was greater than 0.5, and the severity of the disaster was more serious compared with other places. Floods and hail occurred with high frequency in the study area but did not cause larger-scale disasters to occur, and the average disaster index was below 0.3. The average disaster index of typhoons in Yitong and Jiutai is relatively high, and the others are at relatively low levels, with certain regional characteristics. In general, there are many kinds of disasters in the main grain-producing areas of Jilin province, and the wide distribution of the affected areas and the multi-hazard meteorological disasters pose a greater threat to the agricultural safety production in the province's main grain-producing areas, which should attract the attention of local governments and experts.

Table 1. Average damage index of four disaster species in the main grain-producing areas.

Evaluation Unit	Drought	Flood	Typhoon	Hail
Jiutai (JT)	0.390631	0.148485	0.235727	0.124041
Nongan (NA)	0.394813	0.116918	0.095588	0.038850
Yushu (YS)	0.343445	0.084944	0.021053	0.043148
Dehui (DH)	0.285873	0.122036	0.194169	0.031608
Gongzhuling (GZL)	0.175963	0.079955	0.066505	0.054757
Shulan (SL)	0.216273	0.070940	0.110332	0.123191
Lishu (LS)	0.302651	0.089038	0.081240	0.069131
Yitong (YT)	0.313006	0.161347	0.370114	0.084881
Shuangliao (SL)	0.300570	0.197455	0.026547	0.046671
Qianguo (QG)	0.346500	0.081293	0.042080	0.059420
Changling (CL)	0.383543	0.098864	0.080606	0.043555
Qianan (QA)	0.532736	0.131110	0.070101	0.044578
Fuyu (FY)	0.160851	0.034925	0.109651	0.020429
Taobei (TB)	0.479668	0.203550	0.026796	0.149567
Zhenlai (ZL)	0.442655	0.293019	0.020543	0.032686
Tongyu (TY)	0.254391	0.228752	0.006609	0.031698
Taonan (TN)	0.576323	0.274184	0.000000	0.084189
Daan (DA)	0.277935	0.123955	0.065271	0.078949

2.3. Methodology

In this study, we arrived at comprehensive disaster risk assessment research results by using historical disaster data over the years to calculate the disaster index of various disasters, and then using the fuzzy mathematical method for small-area and small-sample risk assessment to infer the risk value of disaster risk occurrence under different disaster indices. The risk level of disaster evaluation was classified using the risk recurrence period, and the risk assessment level and spatial distribution of multi-hazard meteorological disasters at the county level were obtained by weighting each disaster type based on the entropy weighting method. The used multi-hazard risk assessment technical route is shown in Figure 3.

For disaster risk identification, the average affected area was used to calculate the local Getis-Ord G_i^* index, and the cold hotspot area of each single disaster species and the dominant disaster species of multi-hazard meteorological hazards in the region were determined. Based on the average affected area of each region, the entropy weight method was used to reflect the amount of information contained in the disasters in the main grain-producing areas so as to obtain the risk assessment weight of each disaster type in each assessment unit.

For the disaster risk analysis, using the agricultural disaster indices of each disaster species, the single sample observations were converted into fuzzy sets by information diffusion coefficients. Meanwhile, a quantitative analysis of regional agricultural multi-hazard meteorological hazards was carried out, and the probability values and risk values of multi-hazards under different disaster indices were calculated for each evaluation unit. In addition, based on the risk values of the disaster risk analysis, the risk recurrence period of each disaster under different disaster indices was calculated, and five risk evaluation levels under different disaster indices were classified according to the actual situation of risk values.

In the disaster risk assessment, the assessment weights in the risk identification stage and the risk evaluation levels in the disaster risk analysis stage were weighted and summed to obtain the risk assessment results of agricultural multi-hazard meteorological hazards for each assessment unit under different disaster indices. In addition, the spatial directionality and predictability of the risk assessment results of agricultural multi-hazard meteorological hazards were studied to obtain their spatial distribution.

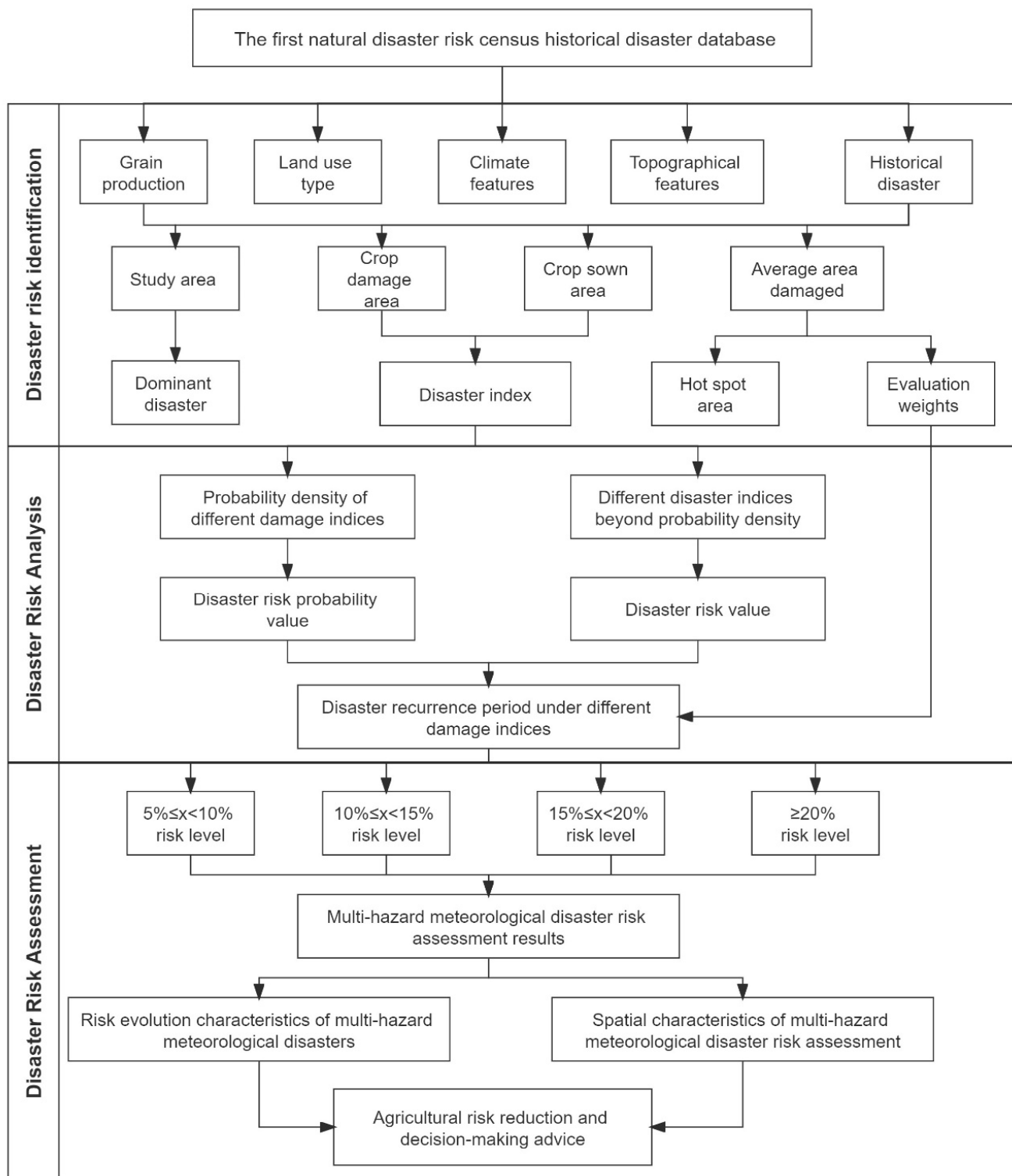


Figure 3. Multi-hazard risk assessment technical route.

2.3.1. Fuzzy Risk Analysis Model

The risk analysis and evaluation of agricultural multi-hazard meteorological disasters was based on the method of fuzzy mathematics to collect the traditional observation sample points in order to solve the problem of insufficient sample data and improve the accuracy of information processing [21–23]. The specific operation steps are as follows:

Assume that y_1, y_2, \dots, y_m are the actual values (observations) of risk factor indicators (hazard indicators) in year m , and the set of observation samples is:

$$y_j = \{y_1, y_2, \dots, y_m\} \quad (1)$$

where: y_j —sample observation points; m —total number of sample observations.

Let the universe of y_j (u_i), $u_i (i = 1, 2 \dots n)$ be the control point of the universe of disaster index:

$$u_i = \{u_1, u_2, \dots, u_n\} \quad (2)$$

where: u_i —any discrete real value obtained by discretizing at a fixed interval in the interval $[0, 1]$; n —the total number of discrete points.

The information carried by each single observation sample value y_j is diffused to each member of the indicator domain u_i based on the following equation, the information diffusion equation for y_j :

$$f_j(u_i) = \frac{1}{h\sqrt{2\pi}} e^{\left[-\frac{(y_j - u_i)^2}{2h^2}\right]} \quad (3)$$

where: h —the diffusion coefficient, which is determined according to the number of samples. It is given by the following equation:

$$h = \begin{cases} 0.8146(b-a), & m = 5 \\ 0.5690(b-a), & m = 6 \\ 0.4560(b-a), & m = 7 \\ 0.3860(b-a), & m = 8 \\ 0.3362(b-a), & m = 9 \\ 0.2986(b-a), & m = 10 \\ \frac{2.6851(b-a)}{(m-1)}, & m \geq 11 \end{cases} \quad (4)$$

where: b —the maximum value in the sample set; a —the minimum value in the sample set; m —the number of samples.

If marked:

$$C_j = \sum_{i=1}^n f_j(u_i), \quad j = 1, 2, \dots, m \quad (5)$$

then any observation sample y_j becomes a fuzzy set with $\mu_{y_j}(u_i)$ as the affiliation function, and the affiliation function of the corresponding fuzzy subset is:

$$\mu_{y_j}(u_i) = \frac{f_j(u_i)}{c_j} \quad (6)$$

where: c_j is the sum of $f_j(u_i)$; $\mu_{y_j}(u_i)$ is the normalized information distribution of sample y_j . Then, let:

$$Q(u_i) = \sum_{j=1}^m \mu_{y_j}(u_i) \quad (7)$$

From the set of observation samples $\{y_1, y_2, \dots, y_m\}$, it is inferred by information diffusion that if the sample observation can only take one of $\{u_1, u_2, \dots, u_n\}$, the number of samples with observation u_i is $q(u_i)$ when all y_j are considered as sample representatives. $Q(u_i)$ is usually not a positive integer, but must be a number not less than 0.

$$Q = \sum_{i=1}^n q(u_i) \quad (8)$$

Q is the sum of the number of samples at each u_i point, so theoretically it should be $Q = m$, but due to the error of numerical calculation, Q is slightly different from m .

$$P(u_i) = \frac{q(u_i)}{Q} \quad (9)$$

$P(u_i)$ is the probability value of the sample falling at u_i , which can be used as a probability estimate. For a single-valued observation sample indicator $y_j = \{y_1, y_2, \dots, y_m\}$, take y_j as an element u_i in the theoretical domain u . The probability value of exceeding u_i should be:

$$P(u \geq u_i) = \sum_{k=i}^n P(u_k) \quad (10)$$

where $P(u_i)$ is the value of the frequency of the sample falling at u_i , which is the value of the probability of exceeding u_i ; $P(u \geq u_i)$ is called the risk value or loss value of the hazard factor.

2.3.2. Entropy Weight Method

The entropy weight method is a mathematical formula that calculates a comprehensive index based on the comprehensive consideration of the information provided by various factors. As an objective comprehensive weight determination method, it mainly determines the weight according to the amount of information that each indicator transmits to decision makers. The entropy weight method can accurately reflect the amount of information contained in the disasters of major grain-producing areas and can solve the problems of a large amount of information and the difficulty of accurate quantification for each index of multi-disaster agricultural risk assessment [24–29].

If the study area has n assessment units, there are m evaluation indicators reflecting its disaster indicators, which are $X_i (i = 1, 2 \dots m)$, and the statistical values of each evaluation indicator in each county are obtained. Let its matrix be:

$$R' = (r'_{ij})_{m \times n} \quad (i = 1, 2 \dots m; j = 1, 2 \dots n) \quad (11)$$

where r'_{ij} is the statistical value of the j th district on the i th index. In order to eliminate the influence of the dimension, the extreme value method is used to standardize the statistical data on R' , and the index standardization matrix r_{ij} is obtained:

$$r_{ij} = \frac{r'_{ij} - \min_j |r'_{ij}|}{\max_j |r'_{ij}| - \min_j |r'_{ij}|} \times 10 \quad (12)$$

After normalization, the information entropy of each index can be calculated. The entropy H_i of the i th index can be defined as:

$$H_i = -t \sum_{j=1}^n f_{ij} \ln f_{ij} \quad (13)$$

In the formula

$$f_{ij} = \frac{r_{ij}}{\sum_{j=1}^n r_{ij}}, \quad t = \frac{1}{\ln n} \quad (14)$$

The entropy weight w_i of the i th indicator is as follows:

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^m H_i} \quad (15)$$

2.3.3. Hotspot Analysis

Hotspot and cold spot analysis are performed to delineate the spatial cluster of the average affected area of each single disaster in Jilin province based on the Getis-Ord G_i^* statistic using a fixed distance band in ArcGIS software. The local Getis-Ord G_i^* was used to identify hotspots with statistical significance, and the extremes and hotspots were spatially superimposed to explore the clustering characteristics of each disaster distribution in the study area. The Z-score obtained using ArcGIS software identifies regions that have high or low clustering in space. A larger Z-score indicates a stronger clustering of high values (hot spots), a smaller Z-score indicates a stronger clustering of low values (cold spots), and a Z-score closer to zero indicates no significant spatial clustering [30–33].

The Getis-Ord local statistic is given as:

$$G_i^* = \frac{\sum_{j=1}^n w_{ij}x_j - \bar{x} \sum_{j=1}^n w_{ij}}{S \sqrt{\frac{n \sum_{j=1}^n w_{ij}^2 - \left(\sum_{j=1}^n w_{ij}\right)^2}{n-1}}} \quad (16)$$

where x_j is the attribute value for feature j , w_{ij} is the spatial weight between features i and j , n is equal to the total number of features, and:

$$\bar{x} = \frac{\sum_{j=1}^n x_j}{n} \quad (17)$$

$$S = \sqrt{\frac{\sum_{j=1}^n w_j^2}{n} - (\bar{x})^2} \quad (18)$$

The G_i^* statistic is a Z-score, so no further calculations are required.

2.3.4. Ordinary Kriging

Kriging in geostatistics refers to a family of generalized least square regression methods. It helps to estimate the unknown variable values at unobserved locations based on the observed known values at surrounding locations [34,35]. The general expression of the ordinary kriging to estimate missing value of variable Z in space is given by:

$$Z(x_0) = \sum_{i=1}^n \lambda_i Z(x_i) \quad (19)$$

where $Z(x_0)$ refers to the estimated missing value of variable Z (multi-hazard risk assessment levels in this study) at desired location x_0 ; λ_i is the kriging weights associated with the observation at location x_i with respect to x_0 ; and n indicates the number of observed data points.

3. Results and Discussion

3.1. The Characteristics of Agricultural Multi-Hazard Meteorological Disasters

Grasping the development characteristics of disaster risk is one of the important links for effective disaster reduction and control. The statistical analysis of the affected area of the major meteorological disasters in Jilin province was carried out by combination with the previous statistical data. The purpose of this section is to provide a preliminary understanding of the disaster situation in the region and to provide a reference for the determination of the dominant disaster types later. However, due to the different degrees of retention of historical records, there is missing data for some years.

The drought disaster not only affected a large area of crops, but also affected a wide range; all the major food production areas have been affected by the drought disaster. Nongan and Yushu were seriously affected by the drought, with the average affected area exceeding 100 km² (Figure 4a). The average affected area caused by flood disasters

has decreased compared with drought, and the average affected area of each main grain-producing area is below 40 km²; however, the average affected area in Taonan, Tongyu, and Zhenlai is higher compared with other places, which has a certain correlation with the water system, such as Nen Jiang River or Jiao Liu River, in the region (Figure 4b). Typhoon disaster presents a certain regional correlation in the main grain-producing areas of the eastern regions of Jiutai, Nongan, Dehui, Yitong, and other places where the more obvious impact is the focus on regional prevention (Figure 4c). Hail disasters have the least impact on the main grain-producing areas, with an average affected area of 20 km²; only Changling and Tongyu are relatively high and need to focus on prevention (Figure 4d). From a comprehensive point of view, among the four hazard disasters studied, drought disasters and flood disasters are the core disasters in the main grain-producing areas of Jilin province and need to be the focus of prevention methods. The average disaster losses of crops from hail and typhoon disasters are relatively lower, but regional hail and typhoon disasters occur frequently, and their resulting regional impacts cannot be ignored.

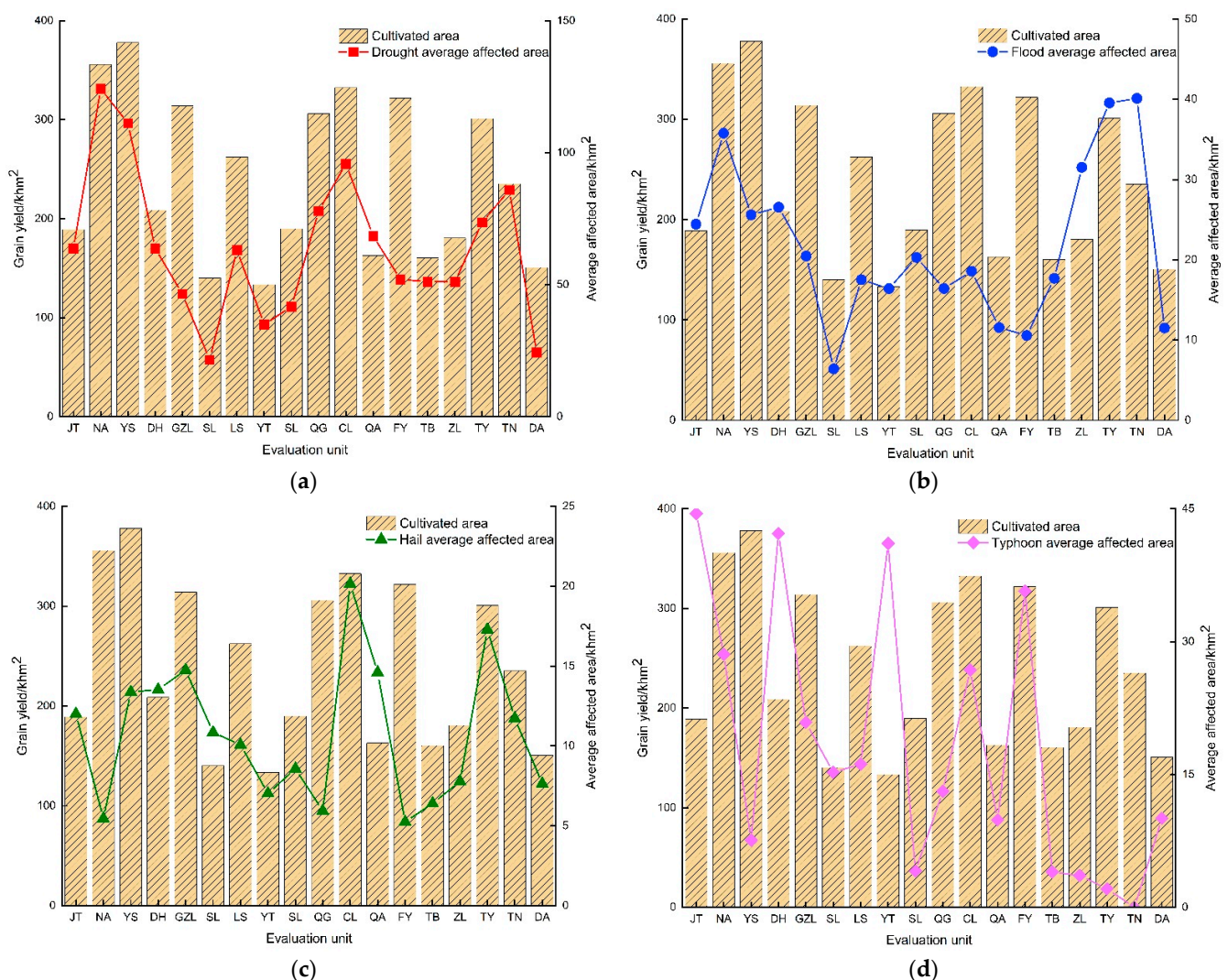


Figure 4. Grain production and average area affected by each disaster in major grain-producing areas ((a). Drought; (b). Flood; (c). Hail; (d). Typhoon).

Based on the average disaster area of 18 major grain-producing areas, the local Getis-Ord G_i^* index was used to study the degree of clustering of the spatial distribution of variables, which can respond well to the distribution of cold hotspots on the local spatial area of variables. The distribution of hotspot areas for each disaster was analyzed for 18 major grain-producing areas, and the degree of clustering was expressed according to

the significance Z . The higher and greater that Z was than 0, the tighter the target object's high-value clustering (forming a hotspot); the lower and greater that Z was than 0, the tighter the target object's low-value clustering (forming a cold spot). The hotspot and cold spot are calculated by Formulas (16)–(18). In hotspot analysis, the natural intermittent point method was used to divide the cold hot spot area into five categories, namely, core hot spot area, sub-core hot spot area, transition area, sub-core cold spot area, and core cold spot area. The results show that the hotspot areas for drought hazards are widely distributed in the study area. Qianguo, Nongan, Dehui, and Jiutai are the core hotspot areas of drought disasters, and Taonan and Tongyu, in the western part of the study area, are the sub-core hotspot areas (Figure 5a). Flood disasters are similar to drought disasters, with Taonan and Tongyu as the core hotspot areas and Jiutai and other places in the eastern region as the sub-core hotspot areas (Figure 5b). This means drought and flood disasters are widely distributed and many hotspot areas are affected. Hail disasters present core hotspot areas and sub-core hotspot areas in the five eastern places of study, while Tao Nan is also a hotspot area (Figure 5c). In addition, the hotspot area of typhoon disasters is mainly concentrated in the eastern part of the study area (Figure 5d). This means the distribution of hail and typhoon disasters has a certain regional nature.

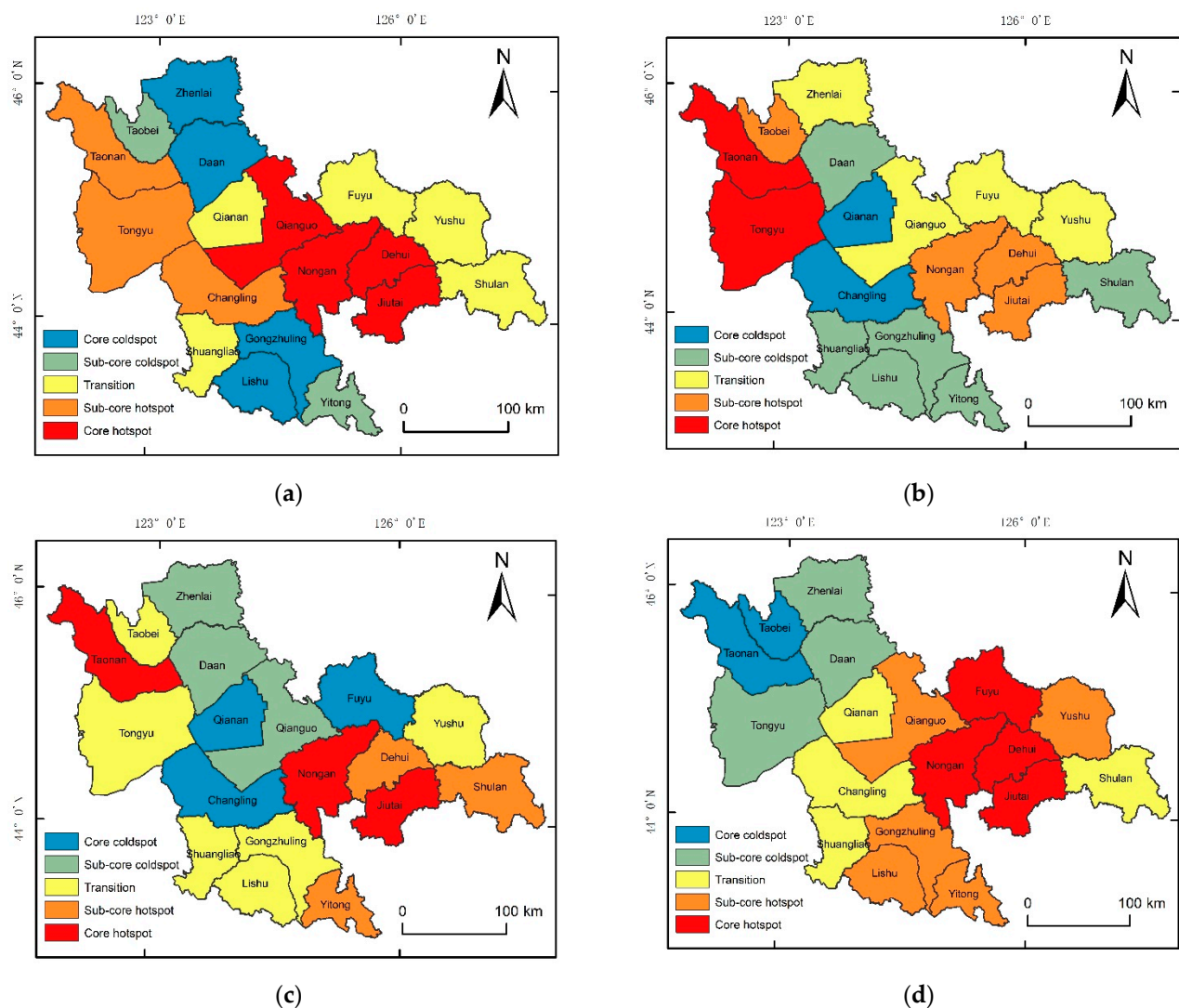


Figure 5. Distribution of each disaster hotspot area in the main grain-producing areas of Jilin province ((a). Drought; (b). Flood; (c). Hail; (d). Typhoon).

After standardizing the average area affected in each district, the entropy weights of multi-hazard meteorological hazards were calculated using Formulas (11)–(15) to obtain the weights of four meteorological hazards in 18 major grain-producing regions, and the results are shown in Table 2.

Table 2. Weight of single disaster species in the main grain-producing areas of Jilin province.

Evaluation Unit	Drought	Flood	Hail	Typhoon
Jiutai (JT)	0.11	0.13	0.38	0.39
Nongan (NA)	0.29	0.24	0.19	0.28
Yushu (YS)	0.36	0.22	0.32	0.10
Dehui (DH)	0.16	0.22	0.07	0.55
Gongzhuling (GZL)	0.11	0.18	0.38	0.33
Lishu (LS)	0.19	0.14	0.42	0.25
Yitong (YT)	0.06	0.14	0.12	0.68
Shuangliao (SL)	0.25	0.49	0.09	0.18
Qianguo (QG)	0.30	0.15	0.30	0.24
Changling (CL)	0.30	0.14	0.19	0.37
Qianan (QA)	0.44	0.14	0.11	0.32
Fuyu (FY)	0.18	0.07	0.01	0.73
Taobei (TB)	0.15	0.16	0.61	0.07
Zhenlai (ZL)	0.26	0.63	0.00	0.11
Tongyu (TY)	0.28	0.51	0.18	0.04
Taonan (TN)	0.25	0.38	0.37	0.00
Shulan (SL)	0.00	0.00	0.55	0.45
Daan (DA)	0.04	0.19	0.32	0.46

3.2. Multi-Hazard Meteorological Hazard Risk Analysis in Agriculture

The discrete domain is constructed according to the scope of disaster, the maximum value of the intensity of disaster, and the possible value of disaster; the discrete domain is constructed and the probability of disaster risk under different disaster indices in the main grain-producing areas is obtained according to Formulas (1)–(10). The probability density reflects the probability of the occurrence of major meteorological disasters under different disaster indices in the main grain-producing areas of Jilin province, so that the probability of the occurrence of different disaster levels can be inferred (Figure 6). The results show that the disaster indices of four meteorological disasters span the whole disaster index axis and all have the possibility of large area damage, among which the disaster areas of hail, typhoon, flood, and drought do not exceed 20%, 30%, 50%, and 80% of the total sown area, respectively. The density of exceedance probability can laterally reflect the level of risk of major meteorological disasters in Jilin agriculture under different disaster indices (Figure 7). The results show that the risk values of four major meteorological disasters decrease with the increase of disaster indices, and the disaster risk of each disaster in the main grain-producing areas under the same disaster indices is: drought > flood > typhoon > hail. From the frequency of disasters and the scope of disaster impact, drought disaster is the main natural disaster that harms Jilin province's main natural disaster for grain production.

In order to give managers and decision makers a clearer understanding of the risk level based on the disaster risk values obtained from the fuzzy risk model, and to make the risk assessment results more intuitive, the grading criterion of risk recurrence period ($T = 1/P$) was used to calculate the risk levels of meteorological hazards under different disaster indices. To facilitate the analysis and evaluation of the spatial distribution characteristics of each meteorological disaster risk in 18 major grain-producing areas in Jilin province, the main meteorological risk assessment grades for 18 major grain-producing areas were developed by combining the actual situation of the main meteorological risk values in each area (Table 3). The multi-hazard meteorological hazard risk assessment levels were divided into five levels of high, medium-high, medium, medium-low, and low under different damage indices, and were assigned 5, 4, 3, 2, and 1, respectively. The classification of disaster risk level is mainly based on the previous research results and the actual situation

of disaster risk value. The high risk implies a short period of occurrence and a high frequency of recurrence of disasters under the same crop damage.

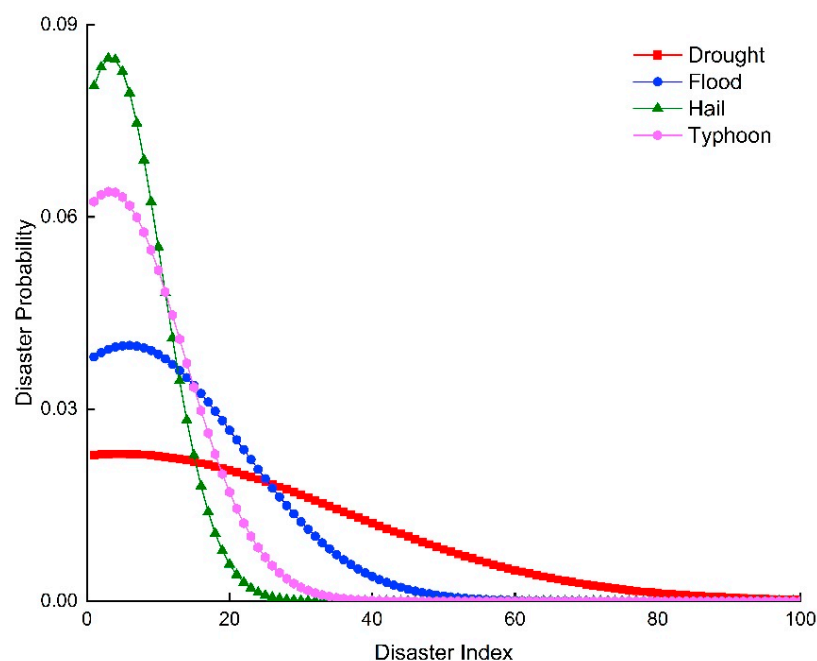


Figure 6. Probability density of multi-hazard meteorological hazards in major grain-producing areas.

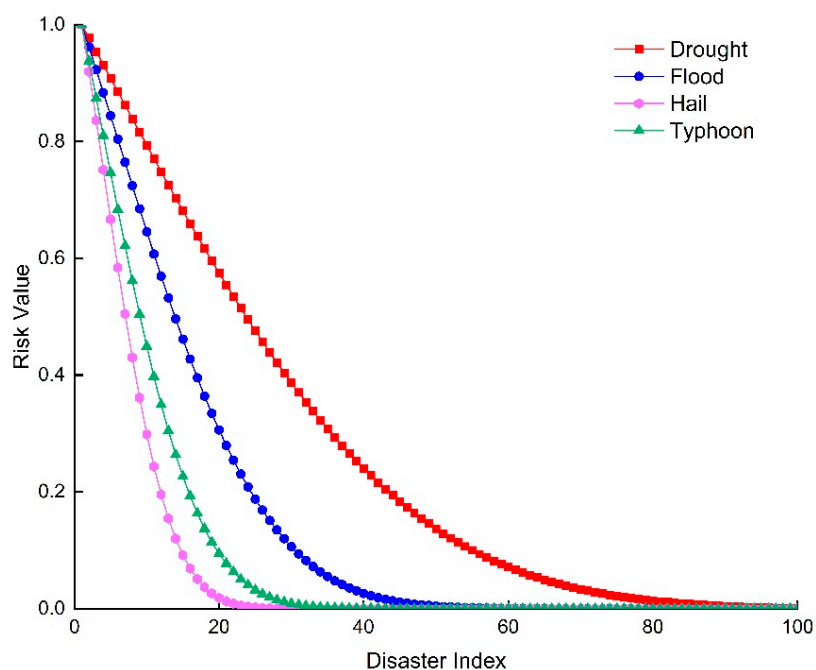


Figure 7. Risk values of multi-hazard meteorological hazards in major grain-producing areas.

Table 3. The main meteorological risk assessment scale of Jilin province.

Disaster Index	High	Medium–High	Medium	Medium–Low	Low
$5\% \leq x < 10\%$	$T = 1$	$1 < T \leq 2$	$2 < T \leq 3$	$3 < T \leq 4$	$T > 4$
$10\% \leq x < 15\%$	$1 < T \leq 2$	$2 < T \leq 3$	$3 < T \leq 4$	$4 < T \leq 6$	$T > 6$
$15\% \leq x < 20\%$	$1 < T \leq 2$	$2 < T \leq 4$	$4 < T \leq 6$	$6 < T \leq 10$	$T > 10$
$\geq 20\%$	$1 < T \leq 2$	$2 < T \leq 5$	$5 < T \leq 10$	$10 < T \leq 20$	$T > 20$

In Table 3, $T = 1$ means the frequency of disaster occurrence is once a year, $1 < T \leq 2$ means the frequency of disaster occurs once every 1~2 years, $T > 4$ means the probability of disaster occurrence is greater than once every 4 years, and so on for the rest. According to the above risk analysis model and risk classification criteria, the results of meteorological disaster risk evaluation in 18 major grain-producing areas in Jilin province under different disaster indices are derived.

Overall, under different disaster index conditions, drought and flood are the dominant hazards affecting the 18 major grain-producing areas in Jilin province. The risk level of multi-hazard meteorological hazards is higher in Nongan when the disaster index is $5\% \leq x < 10\%$, and the risk level of multi-hazard meteorological hazards is at a higher level in Jiutai and Yitong when the disaster index is $10\% \leq x < 15\%$ and $15\% \leq x < 20\%$, respectively. As the disaster index rises to $x \geq 20\%$, Jiutai is at high risk of multi-hazard meteorological hazard risk and the probability of a large area of multi-hazard hazard risk is higher.

At the disaster index of $5\% \leq x < 10\%$ (Figure 8), the risk level of drought disaster in each major grain-producing area is at medium–high or high risk, and the risk probability is once every 1~2 years. A flood disaster is a secondary disaster affecting the main grain-producing areas in Jilin province, and the risk level of a flood disaster in each main grain-producing area is in the medium–high- or high-risk area, but it is low in Fuyu City, which is related to the lack of data that may be caused by the change of administrative division in the history of Fuyu. The risk level of hail disasters in each major grain-producing area is at a medium or low risk level, but Yushu and Shulan are at high and medium–high risk levels, showing that the probability of hail disasters in these three places is higher than in other places. The risk level of typhoon disaster in each major grain-producing area has a large difference. Specifically, the risk level of Yushu, Changling, Zhenlai, Tongyu, Changling, Taobei, Taonan, Yushu, and Daan is small, while Jiutai, Nongan, and Dehui are high, which is in line with the actual situation.

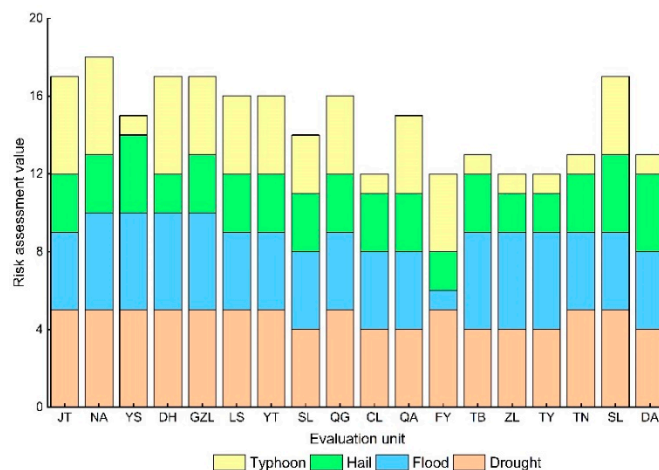


Figure 8. Risk evaluation value of multi-hazard meteorological disasters under the disaster index of $5\% \leq x < 10\%$.

At a disaster index of $10\% \leq x < 15\%$ (Figure 9), there was almost no change in the risk level of drought disaster and flood disaster in each major grain-producing area with a disaster index of $5\% \leq x < 10\%$. The risk level of hail hazards in each major grain-producing area was elevated, and only two areas (Shuangliao and Qianan) had no change in disaster risk level. Typhoon disaster risk is just the opposite of hail disaster risk. The risk level of most areas did not change, but the disaster risk level of Fuyu and Yitong increased to a high level.

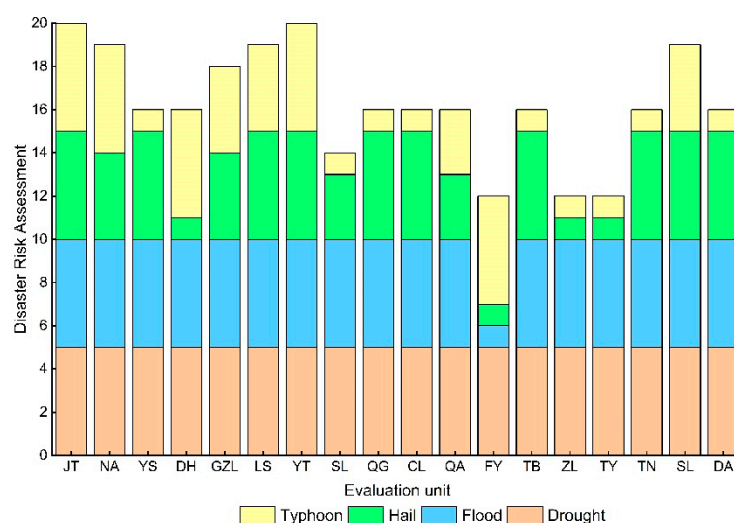


Figure 9. Risk evaluation value of multi-hazard meteorological disasters under the disaster index of $10\% \leq x < 15\%$.

At the disaster index of $15\% \leq x < 20\%$ (Figure 10), the risk of drought disaster was at high risk in all major grain-producing regions. The risk level of flood disaster in all other regions remained unchanged. The risk levels of hail disasters all decreased overall, but Jiutai, Yushu, Yitong, Changling, and Taobei were still at high-risk levels, and the chance of suffering large area damage remained high. There was no big change in the overall probability of typhoon disasters, and the disaster risk levels of Gongzhuling and Qianan have dropped to medium–low and low risk, that is, the recurrence period of typhoon disasters is more than once every 6 years.

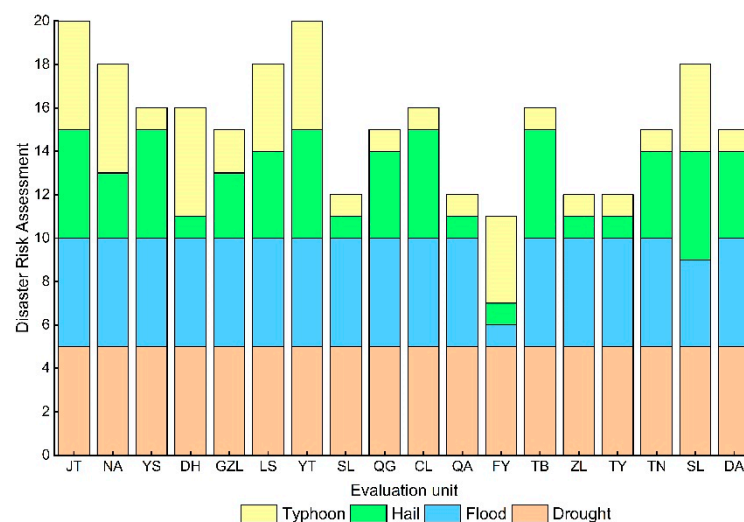


Figure 10. Risk evaluation value of multi-hazard meteorological disasters under the disaster index of $15\% \leq x < 20\%$.

At a disaster index of $x \geq 20\%$ (Figure 11), the risk levels of drought disaster and flood disaster in each major grain-producing area are at high and medium–high risk levels. This indicates that droughts and floods have a serious impact on the main grain-producing areas in Jilin province, with droughts and floods causing more than 20% damage, occurring about once every 5 years. With the rise of the disaster index, the risk level of hail disasters in most areas is at medium risk or below, but Jiutai and Yushu are still at high risk levels, indicating that these two areas have a high chance of being affected by hail disasters and are prone to large areas of hail disasters. The risk level of typhoon disasters appears to be widely different, with relatively high disaster risk in the eastern part of the study

area. Specifically, the risk levels of Jiutai, Nongan, Dehui, Yitong, Fuyu, and Shulan have remained medium–high or high, while other major grain-producing areas are at low risk.

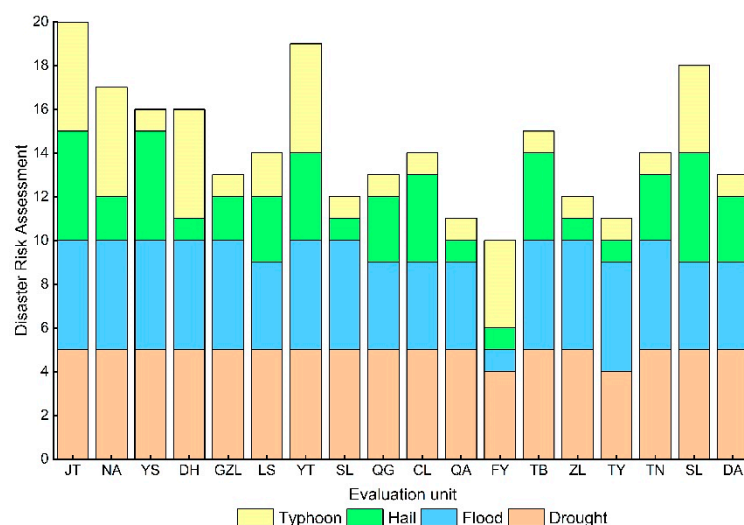


Figure 11. Risk evaluation value of multi-hazard meteorological disasters under the disaster index of $x \geq 20\%$.

3.3. Risk Assessment and Spatial Distribution of Multi-Hazard Meteorological Hazards in Agriculture

After completing the analysis and evaluation of multi-hazard meteorological disaster risk levels in agriculture, the multi-hazard meteorological disaster risk assessment results were weighted and summed with each disaster weight to obtain the multi-hazard meteorological disaster risk assessment results for 18 major grain-producing areas, according to the disaster index, disaster recurrence period, and risk level classification criteria. At the same time, the assessment results were classified into five levels (high, medium–high, medium, medium–low, and low) using the natural interruption point method, and the multi-hazard disaster risk assessment level maps were obtained for 18 major grain-producing areas under different disaster indices. Based on the results of agricultural multi-hazard meteorological disaster risk assessment, the spatial distribution pattern and regional distribution characteristics of agricultural multi-hazard disasters under 18 major grain-producing areas in Jilin province were analyzed.

The disaster risk level in the Yushu, Dehui, Nongan, and Jiutai areas in the eastern part of the study area has been at high and medium–high levels, and the areas at high and medium–high risk are expanding as the disaster index continues to increase. When the disaster index is $5\% \leq x < 10\%$, the southwest side of the study area is a medium-risk area, and the high hail is mainly concentrated on the northeast side of the study area in Nongan and Dehui, both of which are high-risk areas. That is, they suffered from a high frequency of multi-hazard impacts and caused a large area of agricultural losses (Figure 12a). When the disaster index was $10\% \leq x < 15\%$, the high-risk area was expanding. Jiutai, Tongyu, and Lishu were high-risk areas, and the risk level in some areas in the southeast of the region was decreasing (Figure 12b). When the damage index increases to 15%, the risk level in the central part of the study area is medium–low and low risk, i.e., there is a low chance of widespread, high-frequency, and strong damage. Jiutai and Lishu are high-risk areas, and three places in the western part of the study area are in medium–high-risk areas with the feasibility of suffering from large areas and high frequency (Figure 12c). When the disaster index is $x \geq 20\%$, the multi-hazard rating of the main grain-producing areas shows the characteristics of medium–high risk in the western region, low and medium–low risk in the central region, and high and medium–high risk in the eastern region. Among them, the danger of the disaster-causing factors of agricultural multi-hazard species in Dehui, Jiutai, and Lishu cannot be ignored, which are prone to causing large-scale damage and

forming disaster chains, and the task of coping with multi-hazard meteorological disaster prevention is arduous (Figure 12d).

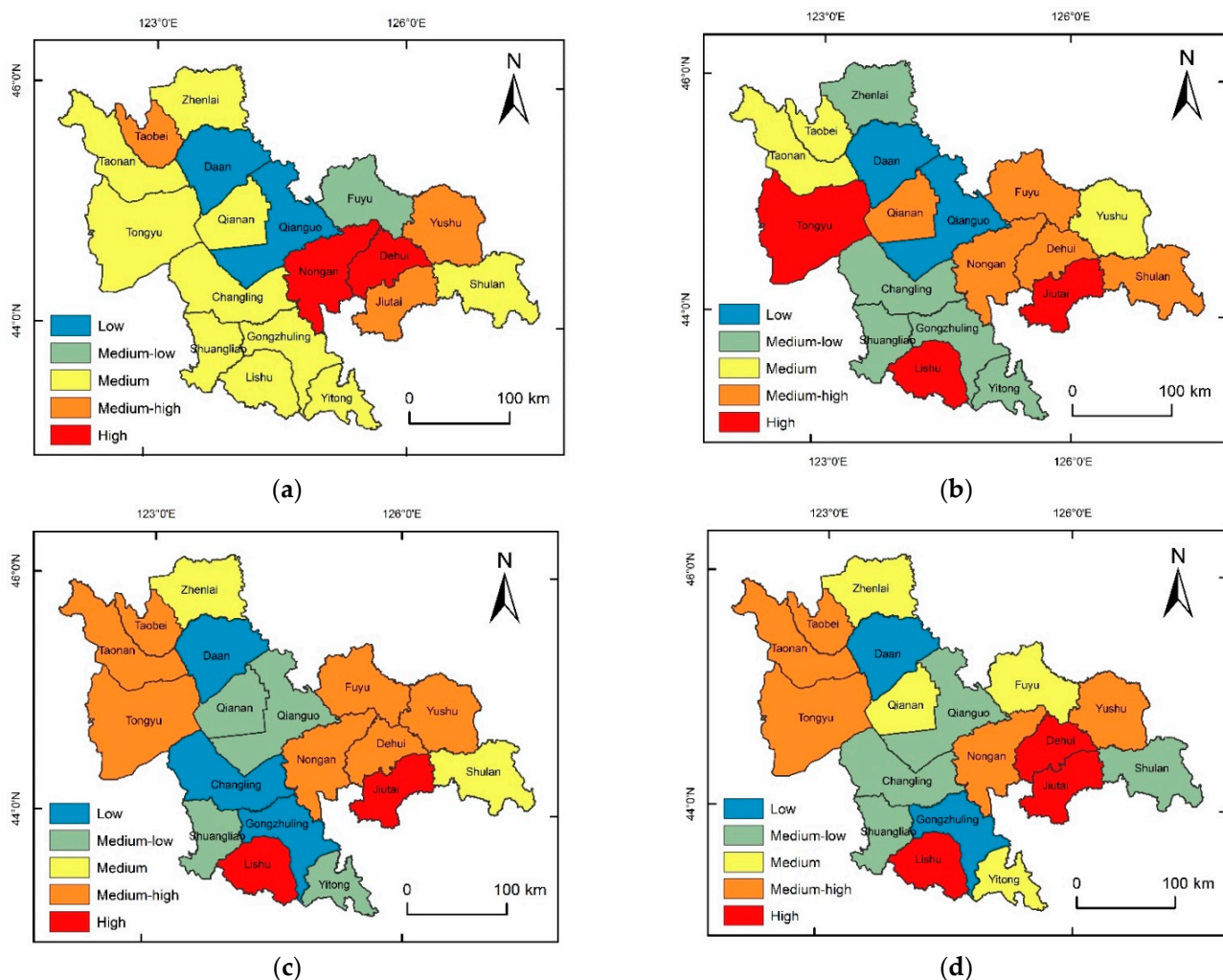


Figure 12. Risk assessment map of multi-hazard meteorological disasters under different disaster indices ((a). $5\% \leq x < 10\%$; (b). $10\% \leq x < 15\%$; (c). $15\% \leq x < 20\%$; (d). $x \geq 20\%$).

An ordinary kriging interpolation method based on variance function theory and structural analysis was used in this study for an unbiased optimal estimation of regionalized variables in a limited area. Specifically, it was used to predict the risk of agricultural multi-hazard meteorological hazards in the study area. The ordinary kriging to estimate the missing value of variable Z is calculated by Formula (19). The results show that the risk of multi-hazard meteorological hazards shows a southeastern direction. At the same time, the multi-hazard meteorological disaster risk level gradually decreases in both the southeast direction and the northwest direction, with the continuous increase of the disaster index. There are high- and medium-high-risk trends of multi-hazard meteorological disasters in Taonan, Taobei, Tongyu, Shulan, Jutai, Yitong, Yushu, and Dehui. Thus, they are the focus of agricultural multi-hazard meteorological disaster risk prevention.

Specifically, when the disaster index is $5\% \leq x < 10\%$ (Figure 13a), the multi-hazard rank trend in the central part of the study area shows medium-low risk, the multi-hazard rank trend in some districts and counties in the eastern part is high and medium-high risk, and this area is the key area for multi-hazard risk prevention. With the increase of the disaster index to $10\% \leq x < 15\%$ (Figure 13b), the trend of agricultural multi-hazard meteorological disaster risk level develops from the east and west to the middle, and the low-risk area in the middle of the study area expands. Shulan and Yushu may have

more than 10% of their crops affected by multiple hazards. When the damage index is $15\% \leq x < 20\%$ (Figure 13c), the range of low- and medium-low-risk areas is further expanded, and the risk levels in the central part of the study area all show low risk levels, while only some areas in Taonan, Yushu, and Shulan are medium-high risk, and the area covered by low risk is the most extensive at this time. When the disaster index is $x \geq 20\%$ (Figure 13d), the range of medium-high risk is further expanded, and the northeast of the study area and the western part of Taonan and other places present a medium-high-risk grade of agricultural multi-hazard meteorological disaster. Some areas in the northeastern direction suffer from the possibility of a multi-hazard meteorological disaster risk impact and a wide range of impact, which is the focus of regional agricultural prevention.

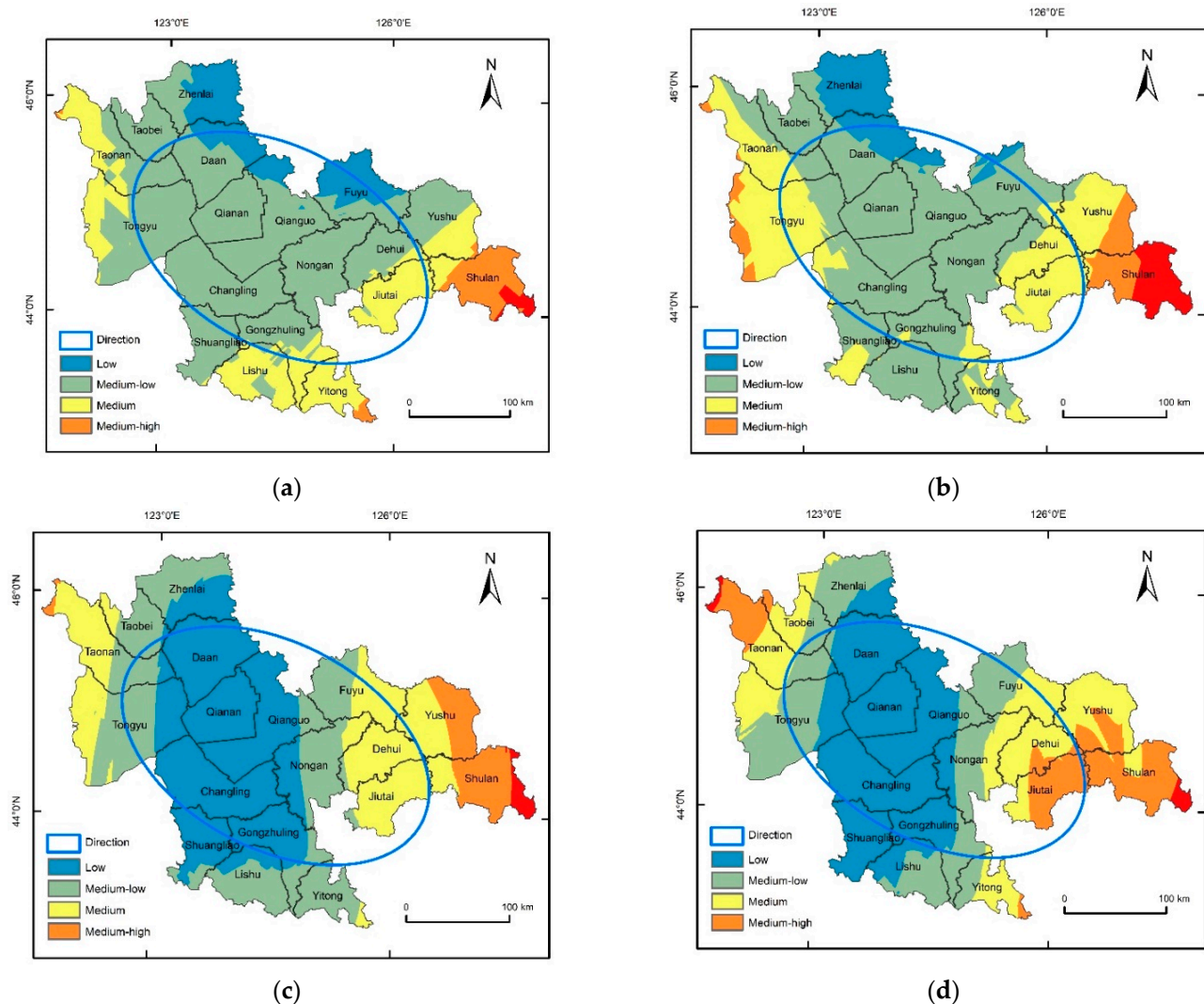


Figure 13. Risk trend of multi-hazard meteorological disasters under different disaster indices ((a). $5\% \leq x < 10\%$; (b). $10\% \leq x < 15\%$; (c). $15\% \leq x < 20\%$; (d). $x \geq 20\%$).

3.4. Agricultural Multi-Hazard Meteorological Disaster Risk Reduction Recommendations

This paper assesses the risk of agricultural multi-hazards using the historical disaster data of the first natural disaster risk census in 18 major grain-producing areas in Jilin province, and obtains the risk of each multi-hazard meteorological disaster, which is an attempt to apply the data from the first natural disaster risk census. From the actual situation of food production areas, we put forward the following recommendations for the reduction of agricultural multi-hazard meteorological disaster risks so they might provide a reference for the reduction and resolution of major disaster risks under the new situation, ensuring the strategic goals of national food security and sustainable development.

3.4.1. Improve Regional Agricultural Multi-Hazard Risk Reduction System Construction

To develop effective agricultural multi-hazard reduction policies according to local conditions, appropriate mechanisms and legal system construction are very important, which is a necessary guarantee to improve the efficiency of disaster mitigation and reduction. Multi-hazard meteorological disaster risk reduction in agriculture involves multiple sectors and regions, with more emphasis on information sharing, horizontal collaboration, and up-down linkage, and it is necessary to strengthen the top design of the central government and make a good overall plan [36–39].

Firstly, accelerate the improvement of the system of multiple coordination mechanisms and real-time emergency plans to provide an all-round institutional guarantee to enhance regional agricultural multi-hazard risk reduction capabilities. Secondly, the government should increase its financial investment in agricultural water conservancy construction and subsidize the construction of small water conservancy projects on collective village farmland [40,41]. Thirdly, the government should increase its investment in agricultural insurance for natural disasters in Jiutai, Tongyu, and other places; moreover, it should increase its investment in rural social security, medical care, and minimum living security as well to improve disaster response capacity. The government could act as a reinsurer against agricultural losses so that it can provide protection for agricultural crop and livestock insurance initiatives, even if local insurers and international reinsurers are unwilling to provide excess-of-loss reinsurance [42]. Overall, combining normal disaster reduction and mitigation with extraordinary emergency disaster relief, enhancing the integration of laws and the whole disaster risk management system, and realizing coordinated operation and comprehensive management of multiple subjects are good strategies for multi-hazard risk reduction.

3.4.2. Optimize Regional Agricultural Multi-Hazard Risk Management Models

The inefficiency of disaster risk management in administrative regions independent of each other often leads to gaps in disaster risk management. In order to further change the idea of “disaster relief over disaster mitigation”, a whole-process disaster risk management model should be established. While developing emergency plans, the government should vigorously develop a watershed disaster management network system to form and coordinate a linkage [38,43–45]. From international experience, the United States has formed a triple system of federal, regional, and local emergency response mechanisms; the United Kingdom mobilizes the resources of the whole society to structure the emergency management system [46,47]; and Japan has established a prevention-centered emergency management system [48,49]. The experiences from which you can learn are as follows.

Firstly, in terms of the main body of disaster management, we should include social agricultural companies, agricultural volunteers, and grassroots organizations in the government to improve agricultural disaster mitigation capacity through these experts who are familiar with local agricultural disasters and land conditions so that they can become an important force in disaster mitigation [41,50]. Second, on the mechanism of disaster management, we should strengthen the unified dispatch and management of multi-hazard meteorological disaster risks (especially in several areas of the Nen Jiang and Heilongjiang River Basin), break the mechanism of independent management in each administrative region, realize the rational allocation of resources, and reduce disputes over the impact of disaster risks. Overall, the communication–feedback–supervision working mechanism should be continuously improved for the weak links of natural disaster risk management, especially the coupling aspect of multi-hazards, by insisting on the prevention-oriented methods combined with disaster reduction and relief, and improving the decision-making capacity of risk management.

3.4.3. Strengthened Regional Agricultural Multi-Hazard Risk Reduction Capacity

In the face of the severe and complex situation of major disasters and multi-hazard disaster risks, agricultural multi-hazard risk reduction should be incorporated into the

overall planning of social development to provide support for effectively enhancing the ability of the whole society to reduce major disaster risks. The first national comprehensive natural disaster risk census is also a survey of China's national situation and strength and is a fundamental work to enhance disaster risk reduction capacity, which is of great significance in mapping out the risk base [51–53].

Overall, in terms of proceeding with strengthening the capacity of agricultural production for disaster reduction and mitigation, first, the construction of farmland water conservancy facilities to improve the ability to resist drought and flooding, especially in small watersheds, should be strengthened [54–56]. Second, to strengthen the transformation of low-yielding fields, the “fertile soil project” should be implemented to improve the organic content of farmland and enhance fertilizer supply and water retention capacity, and thus to improve the ability of crops to withstand natural disasters [57,58]. Third, harmful biological early warning systems and disaster forecasting, monitoring, reduction, and control capacity should be strengthened.

Specifically, Nongan, Jiutai, and Yitong should strengthen agricultural drought-prevention systems, concentrating on the establishment of an effective early warning system for agricultural drought reduction and mitigation. In order to improve farmland water conservancy facilities in agricultural production areas, especially small farmland water conservancy facilities in villages and towns, deep ditches should be built, as should more profound ditches for agricultural water storage and farmland drainage to facilitate flood and drought reduction [59–63]. The western part of the study area should strengthen flood and drought control facilities, especially drainage facilities, to focus on construction. In addition to the construction of farmland water conservancy facilities, the resilience of crops themselves should be strengthened. Research and promotion of good crop varieties should be firmly supported. The application of high-quality and flexible crop varieties can improve the disaster resistance of crops. Dehui, Shulan, and Yushu should do a good job of laying and covering hail nets for each crop and should carry out reinforcement work for seedling sheds and breeding bases to reduce the impact of hail disasters on crops.

4. Conclusions

The difficult problem in disaster risk assessment is how to use incomplete information to derive the most accurate evaluation results possible. To this end, this paper proposes a multi-hazard meteorological disaster risk assessment method for agriculture based on historical disaster data, which mainly consists of three aspects: disaster risk identification, disaster risk analysis, and disaster risk assessment. Meanwhile, the authors made a preliminary attempt to conduct a multi-hazard meteorological disaster risk assessment for each major grain-producing area based on historical disaster data from the first national comprehensive natural disaster risk census of 18 major grain-producing areas in Jilin province. The results of the study provide a new idea for the application of historical disaster data at the small-scale area level in the later stage of the disaster risk census results and provide a basis for agricultural safety and disaster prevention and control in the main grain-producing areas. The main conclusions are as follows.

By a comprehensive analysis of the climatic conditions of crop growth in the study area and the disaster damage data in the database, four kinds of disasters, namely, drought, flood, typhoon, and hail, were identified as disasters in the study area. The frequency of drought and flood disasters is high, and the scope of the disasters is large. The core hotspots and sub-core hotspots are Jiutai, Nongan, Dehui, Tongyu, Taonan, and other places, which are the key disasters for agriculture meteorological disaster reduction in the main grain-producing areas of Jilin province. The hail and typhoon disasters are regional, and the core hotspots and sub-core hotspots are mainly in the east of the main grain-producing areas. Attention should be paid to these two disasters in the eastern part of the study area.

Using a fuzzy risk analysis model and the entropy weight method to calculate the meteorological disaster risk value in the study area and the single disaster risk weight in each region, respectively, the risk value of the four major meteorological disasters de-

creases with the increase of the disaster index, and the hazard of each disaster in the main grain-producing areas under the same disaster index is drought > flood > typhoon > hail. When the disaster index is $5\% \leq x < 10\%$, the disaster risk level for Nongan is high, and the comprehensive risk evaluation value rises with the rising disaster index; when $10\% \leq x < 15\%$ and $15\% \leq x < 20\%$, Yitong and Jiutai are multi-hazard meteorological disasters at high risk; when the disaster index is increased to $x \geq 20\%$, the risk level of Jiutai multi-hazard meteorological disaster is at an even higher level. The probability of the occurrence of a large area of multi-hazard disaster risk is high.

The risk value of each disaster and the weight of each assessment unit are weighted to obtain the multi-hazard comprehensive risk assessment risk level of each main grain-producing area. The risk assessment results of multi-hazard meteorological hazards showed that Jiutai, Nongan, Yitong, and Tongyu showed high and medium-high risk levels under different disaster indices. There is a wide range of high-frequency, strong disaster situations, and the risk of its multi-hazard-causing factors cannot be ignored. To deal with multi-hazard meteorological disaster prevention tasks is difficult. In addition, the risk of multi-hazard meteorological hazards is spatially oriented to the southeast, and the risk level of multi-hazard meteorological hazards in the central part of the study area is decreases gradually along with the increasing disaster index. Based on the severe and complex disaster risk situation in the study area, especially the complexity and high uncertainty of multi-hazard meteorological disaster risks, suggestions are given on three aspects: improving regional agricultural multi-hazard risk reduction system construction; optimizing regional agricultural multi-hazard risk management models; and strengthening regional agricultural multi-hazard risk reduction capacity, so as to face the severe and complex multi-hazard disaster risk situation.

Shortcomings and prospects: this paper evaluates the multi-hazard meteorological disaster risk of all crops to guide various regions in carrying out regional multi-hazard agricultural safety production and risk prevention. If the crops were further divided into specific food products (such as rice, corn, etc.), and the disaster resistance of each food product was added to the evaluation system, it could more accurately guide the agricultural disaster reduction and mitigation work in each grain-producing area.

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