Application of AHP in WUI fire risk assessment

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Abstract. In order to achieve the purpose of assessing the fire risk in the WUI, this paper digitizes the fire risk influencing factors based on the remote sensing data, meteorological data and vegetation information of the southwest corner of Qingyuan Mountain in Quanzhou City, and obtains a total of 8 indicators in 4 categories of meteorological factors, vegetation factors, terrain factors and human factors as the primary indicators for fire risk assessment, and divides the 4 categories of factors into natural factors and human factors as the secondary indicators to construct a hierarchical structure model. Spatial modelling was performed by ArcGIS, AHP was used to assess the fire risk in the WUI, and weighted superposition analysis was performed on the burning probabilities calculated from different fire risk factors, and finally the results of fire risk zoning in the forest-town junction domain were obtained. The results showed that the high-risk area mainly existed within the area east of Pu Xian Road to the southwest corner of Qingyuan Mountain. The assessment results show that the method can provide a reference basis for fire risk assessment and zoning in the WUI.

Keywords: Wildland-urban interface, AHP, Fire risk assessment, Fire risk area division.

1 Introduction

Wildland-Urban Interface (WUI)[1] refers to the residential living areas built adjacent to mountains, scattered distribution or gathering, and the most important feature of this area is that residential living areas and forests are mixed in a junction. In this paper, based on remote sensing data, meteorological data and national statistical yearbook, the WUI fire risk is assessed by Analytic Hierarchy Process (AHP)[2] as the main research method, and factor weighted overlayer analysed by AreGIS to obtain the WUI fire risk assessment and zoning results.

2 Fire risk assessment model for WUI

2.1 Fire risk impact factor analysis

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The assessment process of the WUI is complex and can hardly be accomplished with just a few simple common indicators. In order to make a comprehensive assessment of the fire risk situation in the WUI, it is necessary to consider separately what factors will affect the WUI. Based on this, a system of WUI is constructed. The system mainly includes two aspects of the first-level indicators. Each first-level indicator and its secondary indicators are analysed one by one below.

2.1.1 Natural factors

Meteorological influences in forest fires mainly include temperature, relative humidity, etc. Its direct impact on the occurrence and spread of forest fires through changes to the environment, such as large-scale spontaneous combustion forest fires. For forest fires, vegetation is the material basis that causes them to occur. Different vegetation types[3] provide different amounts of combustible material and have different fire resistance properties. In addition to the type of vegetation, the vegetation cover[4] is also one of the important factors affecting the generation and spread of fire. Topography[5] directly influences the occurrence and spread of forest fires mainly through air currents and local microclimate. In conducting forest fire risk assessment, slope is an important parameter characterizing the influencing factors of terrain. Slope orientation, on the other hand, affects the type of combustible material and thus causes changes in the relative humidity of the ground.

2.1.2 Human Factors

The fire risk in the WUI not only stems from the threat of forest fires, but can also be influenced to a large extent by human activities, which are one of the main causes of forest fires. Anthropogenic fire sources mainly include productive fire sources such as burning and ash accumulation of fertilizer and non-productive fire sources such as smoking in the wild and burning paper on graves.

3 Study area data acquisition and example applications

3.1 Overview of the study area

Qingyuan Mountain is located in south-eastern Fujian Province, between 118°30′~118°37′ East longitude and 24°54′~25°0′North latitude. The study selected the southwest corner of Qingyuan Mountain as the main study area, totalling 804.17 hectares. The study area is shown in Figure 1.

3.2 Fire risk level assessment

3.2.1 Extraction of natural factors

In this paper, based on the average temperature of Quanzhou City in 2021, temperature was selected as the meteorological factor in the study area for analysis. Using the results of Wang Jinghua on the correlation analysis between temperature and forest fires in meteorological factors, as shown in Figure 2. Based on the data of the forest resources class II survey, the vegetation was classified and graded according to the burning performance of different vegetation as shown in Figure 3. For the vegetation cover index, the 10-point method was used to characterize its fire risk level, as shown in Figure 4. Based on the DEM data and the distribution of water systems in Quanzhou City, the topographic factor elements were graded in ArcGIS environment with reference to the requirements in the Technical Provisions for Forest Resources Planning and Design Survey, and the slope factor fire risk level was divided into six classes based on the conclusion of the influence of slope and slope direction on forest fire in Wang Zhengfei's forest fire spread model, as shown in Table 1 and Figure 5; the slope direction factor fire risk The slope factor fire risk level was divided into nine categories, which are shown in Table 2 and Figure 6.

Table 1. Slope factor fire risk rating table.

Serial number	Slope Type	Slope range	Fire risk level
1	Flat Slope	0°～5°	2
2	Gentle Slope	6°～8°	6
3	Slope	9°～15°	7
4	Sharp slopes	16°～25°	5
5	Steep slopes	26°～35°	9
6	Dangerous slopes	＞35°	1

Table 2. Slope direction factor fire risk rating table.

Serial number	1	2	3	4	5	6	7	8	9
Slope orientation	N	NE	E	SE	S	SW	W	NW	Flat
Fire risk level	3	4	5	8	10	7	5	3	0

Fig. 1. Satellite map of the study area.

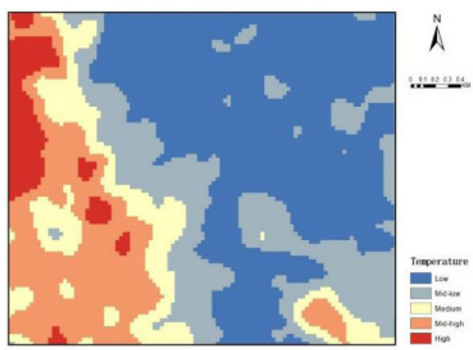

Fig. 2. Temperature factor level.

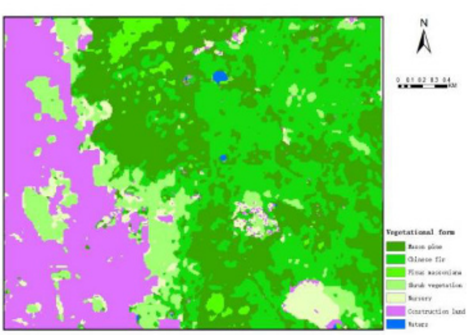

Fig. 3. Vegetation type factor level.

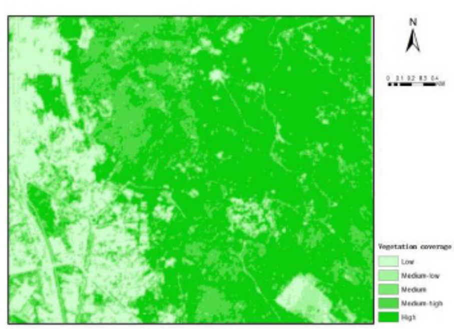

Fig. 4. Vegetation cover factor level.

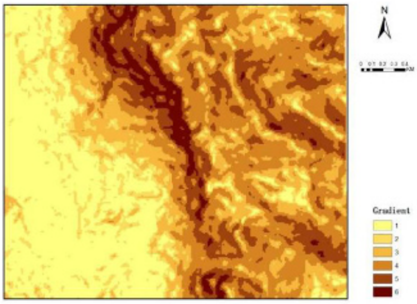

Fig. 5. Slope factor level.

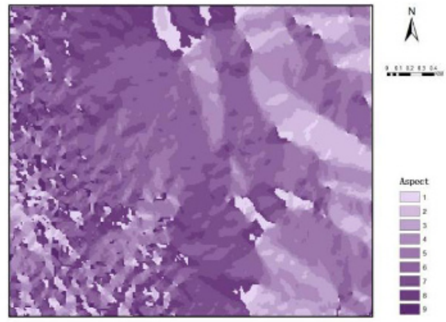

Fig. 6. Slope direction factor level.

3.2.2 Extraction of human factors

In this paper, based on the data of road distribution and settlement distribution in Quanzhou City, the distance to the road and the distance to the settlement are used as road buffer factors through the buffer analysis function in ArcGIS, and divided into four levels according to the classification criteria, see Table 3 and Figure 7. when the distance to the settlement ≤10m, the fire risk level is 0; when the distance to the settlement >10m, the fire risk level is 5 For the distribution of water systems in the study area, the distance to rivers and lakes is used as the buffer zone factor, and is divided into two levels. When the distance to rivers and lakes is <50m, the fire risk level is 0; when the distance to rivers and lakes is >50m, the fire risk level is 5, see Figure 9.

Table 3. Buffer factor fire risk rating table.

Serial number	Type	Fire risk level
1	＜50 m	10
2	51 m～100 m	8
3	101m～200 m	5
4	＞200 m	2

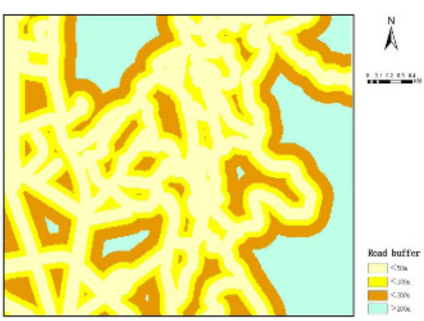

Fig. 7. Road buffer factor level.

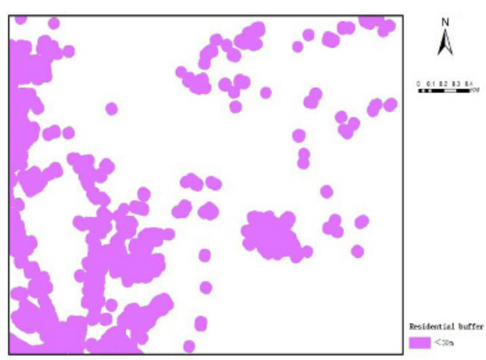

Fig. 8. Resident buffer factor level.

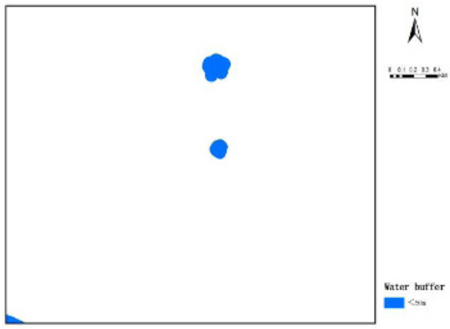

Fig. 9. Water buffer factor level.

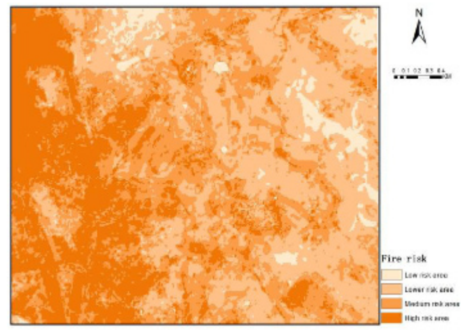

Fig. 10. WUI fire risk level zoning.

3.2.3 Weighting of fire risk impact factors.

In this paper, we use AHP to calculate each fire risk influence factor in the WUI, and the final index weights are shown in Table 4.

Table 4. Weighting table

Target layer	First grade indexes	Second index	Weights
	Human factors	Temperature	0.0369
		Vegetation type	0.1044
		Vegetation cover	0.0821
WUI		Slope	0.0926
		Slope direction	0.0854
	Natural factors	Road buffer	0.1969
		Resident buffer	0.2405
		Water buffer	0.1612

3.3 Fire risk level zoning

Based on the weights of each influence factor, the burning probability of the WUI was calculated using the method of factor-weighted superposition analysis with the following formula 1. FFR is forest fire risk; w_i is the category of different fire risk factors; x_j is the weight of fire risk factors.

$$FFR = \sum_{i=1}^{8} w_i x_j \quad (1)$$

Using the modelling tool in ArcGIS, the fire risk class of WUI was zoned according to the zoning scale based on the burning probability calculated by the weighted overlay of different impact factors, and the zoning map of WUI fire risk class was drawn, See Figure 10. The areas of different fire risk levels in the WUI and the level criteria are shown in Table 5.

Table 5. WUI fire risk zoning scale and area of fire risk rating.

Fire risk	Value interval	Area (ha)	Percentage
Low	0.24＜FFR＜0.45	36.67	4.57%
Relatively low	0.45＜FFR＜0.55	284.05	35.32%
Medium	0.55＜FFR＜0.65	270.34	33.62%
High	0.65＜FFR＜1.0	213.02	26.49%

4 Conclusion

Compared with traditional forest fire risk assessment and zoning, WUI fires need to consider not only the occurrence of forest fires, but also the influence of human factors on fires. In this thesis, when selecting fire risk influence factors for WUI, natural and human influences were considered and used as primary indicators, and temperature, vegetation type, vegetation cover, slope, slope direction, watershed buffer, road buffer and residential buffer were selected as secondary indicators.it can be obtained that the medium and low risk and lower risk areas are scattered within the Qingyuan Mountain area. The results are basically consistent with the fire statistics of Quanzhou City in recent years, indicating that the WUI fire risk level zoning after weighted overlay processing is closer to the actual situation and can provide a reference method for WUI fire risk assessment and zoning.

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