GIS-BASED FUZZY COMPREHENSIVE EVALUATION OF FOREST FIRE-POTENTIAL ZONE-GRADING

Wen-bo Wu[a], Ming-zhou Ma [a, *], Kai-xuan Zhang[a], Shuo Fan[a]

[a] School of Geomatics, Liaoning Technical University, 47 ZhongHua Road, Fuxin, Liaoning, China – (wu_wenbo, ma_mingzhou, fan_shuo, zhang_kaixuan)@126.com

KEY WORDS: Forest Fire-danger Division Scale; Fuzzy Comprehensive Evaluation; Subordinate Function; Expert Evaluation Methodlogy; GIS; Visual Basic

ABSTRACT:

Forest fire-potential is natural disaster that breaks out strongly , destructs largely and is difficult to dispose and rescue, its destructive power has a serious threat to the security of society and human living environment, moreover, it does greatly damage to natural ecological environment. Therefore, the study on forest fire prediction and prevention is a main job. In fact, it is complicated to be carried out, fire-potential zone-grading for forest region is an important method to prevent the occurrence of forest fire, and is one of the foundations to carry out other preventive measures. This paper puts forward the concept of GIS-based fuzzy comprehensive evaluation of forest fire-potential zone-grading. The principle of the fuzzy comprehensive evaluation is expatiated, the choice of the forest-potential factors and the obtainment process of factor weights and subordinate function are studied. Combining with the spatial features of forest-potential evaluation, the feasibility of GIS is analyzed and the structure chart of GIS-based fuzzy comprehensive evaluation of forest fire-potential zone-grading is put forward. Finally, an experiment system is developed with Visual Basic and GIS component technology, which takes some forest region as study area.

1. INTRODUCTION

According to rough statistics, in the 47 member countries of World Food Organisation, the average forest-fire area is 6.73×10^6 hm^2 (Accounted for 0.47 percent of the world's forest areas). August 2008 24 to 26, due to the reasons for the hot weather and man-made, Greece has happened more than 170 forest-fires, the forest-fire area is about half of its land area. In China, forest-fire is an important threat to the forestry ecological environment. 1950~1997, more than 14300 forest-fires have happed, the fire area is about 8.22×10^6 hm^2. At the same time, forest-fire take serious damage to people's lives and property security.

At the present time, most countries in the world, the primary means of forest fire prevention and fire management is the forest fire-potential zone-grading evaluation. Forest fire-potential is the potential risk of forest fire. The potential risk is the objective description of the uncertainty of the subjective object. In practice, usually taking advantage of the method of grading to descript the size of the risk. Forest fire-potential zone-grading is that the forest fire is divided into different levels by zoning, based on the foundation of the forest combustible classifying and combined with other fire circumstances. It is easy to grade management and prevention. The forest fire-potential zone-grading not only indirectly affords the information of the fire-potential evaluation and forecasting for the manage department, but also directly participates in the customization of plans, the deployment of resources and the human resource arrangement. If the forest fire was happening, the forest fire-potential zone-grading could afford effective decision Support Services.

The primary method of the forest fire-potential zone-grading evaluation gives a qualitative and quantitative index of the fire-potential, according to the assessment of the fire change impact factors. Then the fire-potential state could be expressed, according to the rules classifying some zones and corresponding levels. There are many ways of the assessment of fire-potential factors, but this paper aims at fuzzy characters in the forest fire-potential zone-grading evaluation and offers the method that adopts the fuzzy comprehensive evaluation and GIS to realize the visual operation and expression of the forest fire-potential zone-grading evaluation.

2. THE INTERVENTION OF THE FUZZY COMPREHENSIVE EVALUATION MODEL

The fuzzy comprehensive evaluation uses the fuzzy mapping principle and the maximum membership principle, takes into account each factors (or primary factors) of the evaluated object and makes a comprehensive evaluation.

The fuzzy comprehensive evaluation model is composed by the factor set: X，the evaluation set: Y and fuzzy transformation matrix: R.

If there is one set of evaluation factors which compose the factor set: $X=（x_1,x_2,\ldots,x_n）$, one set of potential evaluation results which compose the evaluate set: $Y=（y_1,y_2,\ldots,y_m）$.

According to the individual subjective judgment or the experts judging and marking, the fuzzy subset A (In the X set, the set of each factor weight) is enacted, as: $A=（a_1,a_2,\ldots,a_n）$, therein a_i represents the weight of the x_i, and accords with the statistics principle:

* Corresponding author. 15292091@163.com

$$\sum_{i=1}^{n} a_i = 1 \tag{1}$$

where a_i= right of the weight of the x_i

The single factor fuzzy evaluation of the i factor is a fuzzy subset in the *Y*.

$$R_i = (r_1, r_2 ....., r_n) \tag{2}$$

where R_i = fuzzy subset in the *Y*
r_i = single factor fuzzy evaluation

Then, the single factor evaluation matrix R is:

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{1m} \\ r_{21} & r_{22} & ... & r_{2m} \\ ... & ... & ... & ... \\ r_{n1} & r_{n2} & ... & r_{nm} \end{bmatrix} \tag{3}$$

where R = single factor evaluation matrix
r_{ij} = single factor fuzzy evaluation

The fuzzy comprehensive evaluation *B* is a fuzzy subset in *Y*.
The fuzzy features of the forest fire-potential zone-grading evaluation perform in the following aspects:
First, the evaluation factors have the fuzzy feature. Such as the meteorological factor (the temperature, the rainfall), the terrain factor (the gradient, the hillside aspect) and the vegetation density, all have the fuzzy feature, their value have uncertainty.
Second, the evaluation process has the fuzzy feature. It don't depend on the absolute index, it can not use the accurate math method to evaluate, it can make the warp of the evaluation result by the factor indeterminacy.

Third, the choice of arithmetic operators and the confirmation of membership function relation in the fuzzy comprehensive evaluation, which builds the system contact between the indexes that participate in the evaluation and urges the evaluation result to reflect the whole feature of the evaluated object more factually.

3. THE BUILDING OF THE FUZZY COMPREHENSIVE EVALUATION MODEL OF FOREST FIRE-POTENTIAL ZONE-GRADING

3.1 The choice of the evaluation factor

There are many factors to impact the forest fire such as: the vegetation flammability, the terrain, the vegetation density, the rainfall, the temperature and so on. Point of view from the property, it divides into the spatial factor and the non-spatial factor. The spatial factor is directly related with the spatial position, such as: the terrain and the precipitation. The non-spatial factor is not related with the spatial position, such as: the forest flammability. Combining with the traditional fire insurance evaluation method, Table 1 describes the indexes of the forest fire-potential factor.

Forest factor	Combustible style
	Tree age
	Density
Meteorological factor	Average rainfall
	Average wind speed
	Average temperature
Terrain factor	Gradient
	Hillside aspect
	Height
Other nature factor	Surface and ground water
	Road density
Social and human activity factor	Population density
	Agriculture activity
	Tour activity
	Other activity

Table 1. The classifying of the fire-potential factor indexes

3.2 The ascertaining of the factor weight

According to the classifying of the factor indexes, factors are divided into the inner layer factors and the outer layer factors, such as the average rainfall, the average wind speed and the average temperature are the inner layer factors, the meteorological factor is the outer layer factor. Then each factor is marked by the expert evaluation methodlogy, the weight of each factor is ascertained.

3.3 The ascertaining of the evaluation group

This paper adopts the evaluation result indexes of Prof. Tang_jili's study, the forest fire-potential is classified to four degrees: I most flammable, II more flammable, III flammable, IV hard burn.

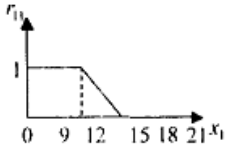
3.4 The ascertaining of the subjection function

Such as the temperature, the subjection function is ascertained by first-order linear trapezoidal method. Table 2 expresses the relationship between the average temperature and the evaluation result.

Forest degree	Ⅰ	Ⅱ	Ⅲ	Ⅳ
Average temperature/℃	≤12	12.1~15	15.1~18	＞18

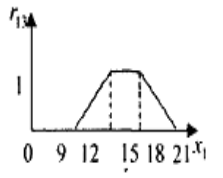
Table 2. The relationship between the average temperature and the evaluation result

According to the classifying, the subjection function is ascertained as following:

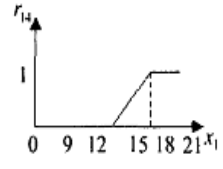


$$r_{11}\begin{cases} 1 & x_i \le 12 \\ 5 - \dfrac{x_i}{3} & 12 < x_i \le 15 \\ 0 & other \end{cases}$$

$$r_{12}\begin{cases}\dfrac{x_i}{3}-3 & 9\le x_i\\ 1 & 12<x_i\le 15\\ 6-\dfrac{x_i}{3} & 15<x_i\le 18\\ 0 & other\end{cases}$$



$$r_{13}\begin{cases}\dfrac{x_i}{3}-4 & 12\le x_i<15\\ 1 & 15<x_i\le 18\\ 7-\dfrac{x_i}{3} & 18<x_i\le 21\\ 0 & other\end{cases}$$



$$r_{14}\begin{cases}0 & x_i\le 15\\ \dfrac{x_i}{3}-5 & 15<x_i\le 18\\ 1 & other\end{cases}$$

4. THE APPLICATION OF GIS IN THE FUZZY COMPREHENSIVE EVALUATION

The factors of the fuzzy comprehensive evaluation are related with the spatial position directly or indirectly. The spatial factors not only participate in the evaluating as the evaluation factors, but also are the carrier for other non-spatial factors. Therefore, through the functions of the spatial expression, the spatial data management and the spatial analysis in GIS, the information such as the distribution, the amount, the density, the scale of the evaluation factors and results are expressed intuitively and factually.

Finger 1 is the flow chart of GIS-based fuzzy comprehensive evaluation of forest fire-potential zone-grading.

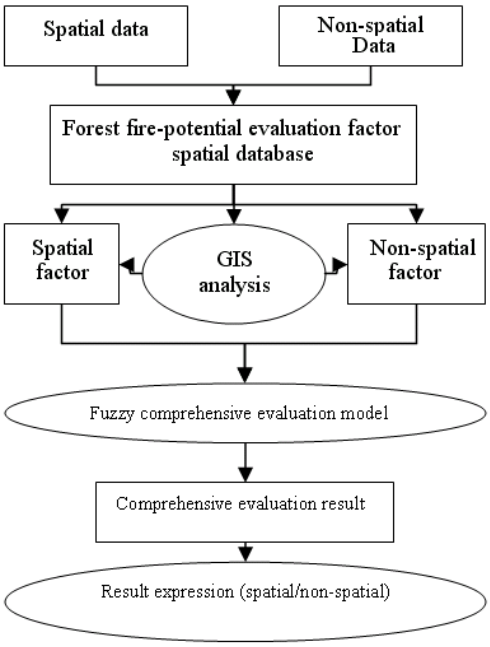


Figure 1. The flow chart of GIS-based fuzzy comprehensive evaluation of forest fire-potential zone-grading

5. THE DEVELOPED EXAMPLE AND THE RESULT

GIS-based fuzzy comprehensive evaluation system of forest fire-potential zone-grading is developed by the computer developed environment of Visual basic6 and the Arc Engine component technology.

This system has the following functions: the forest roaming, the forest attribute querying, the evaluation factor weight setting, the linearity subjection function setting, the expression and output of the result.

The study forest is one forest in Daxinganling forestry authority, Heilongjiang province. This study area is about 1.27×107 m2, its primary terrain is hilly and its primary plant are Larch, Mongolia, Birch.

Finger 2 is the result of the fuzzy comprehensive evaluation of forest fire-potential zone-grading. The deep color indicates the high danger class of fire-potential zone-grading.

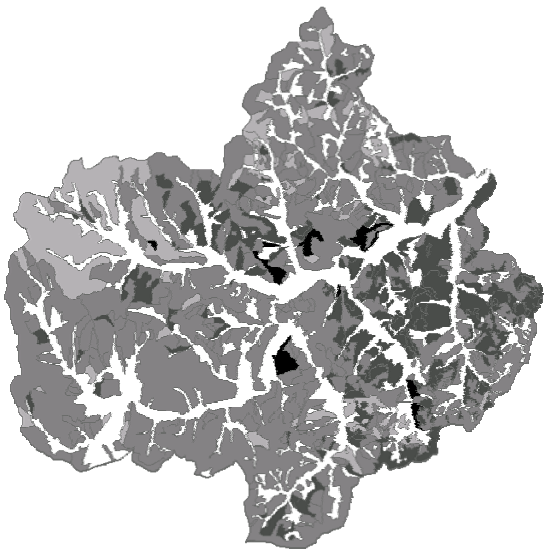


Figure 2.

6. CONCLUSION

This paper analyzes the background that forest fire happens more frequent and the hysteresis quality of the forest fire-potential zone-grading method, studies GIS-based fuzzy comprehensive evaluation of forest fire potential zone-grading. There are some contributions for fire-potential factors comprehensive analysis and forest fire prevention. In China, the forest resource is not plentiful. Therefore, how to prevent the forest fire happening scientifically and effectively, it plays an important role to protect the sustainable use of ecological resources. Along with the deep step of the digital earth construction, the prevention of the forest fire would be a very important development direction.

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