Multi-Index Regional Forest Fire Ratings Appraisal Platform Design and Implementation

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Abstract. At present, the appraisal of forest fire danger degree is the base for all the forest fire management system. Because of the difference in the appraisal standards and regional environment, the index system, index weight, and quantitative index value will vary. The paper set up six categories of 16 basic indexes and introduced space index concept considering with the natural environment, social and economical environment, and forestry resource in Lin’an city comprehensively. The paper developed the regional forest danger rating appraisal system with ArcGIS and C#, and realized the dynamic appraisal for forest danger degree. The result is: in Yuqian town, the area of rank IV of forest fire danger covers about 5% area of forest, so the strict fire prevention measures should be adopted; 13% of the area has potential forest fire of rank III of forest fire danger, so people should strengthen their fire accident consciousness; about half of the area is of the rank II of forest fire danger, and 32% of the area is of rank I of forest fire danger, so people should take the daily fire prevention measures.

Keywords: regional forest fire; index system; spatial index; appraisal of the degree

1. Introduction

The appraisal of regional forest fire danger rank is the description of the potential forest fire danger status in regional forest under the condition of current situation [1], so it is a comprehensive process of analyzing and evaluating for forest fires caused by the combination of natural environment, forest resource, and social economic condition. The forest fire is a complex caused by the material of combustible, the fire environment, the fire source condition, and it is yielded in three fire action factors. At present, some relatively influential forest fire prediction modules include the Australian Plain and Forest Fire Danger Meter [2], the National Fire Danger Degree Prediction of the United States [3], National Fire Danger Prediction System of Canada etc [4-9]. Due to the difference in the research region and the scale, those prediction modules and methods cannot easily be introduced to China [10-11]. At the meantime, the rank prediction of domestic forest fire danger only considers the weather factor, so it has limitation in itself. Analyze natural environment, social environment, economic environment and forest resource condition synthetically, the paper builds up six categories of 16 basic indexes. The paper developed the regional forest fire danger rank appraisal system and realized the dynamic appraisal and the timely forecast of the forest fire with ArcGIS and C#.

2. The general situation of research region

The research region is located in Yuqian town in Lin’an city, Zhejiang Province, China, its total area is 2027 km², and it is the 5th largest town in Lin’an city. Its urban area is 47 km², it has 53 administrative villages and 575 villager (residerenter) groups. And the total population of the town is 32175, including 32552 farming populations. The natural growth rate of the population is 0.118%. The farming land is about 27396 hectares, including 25846 hectare paddy fields; forestry area is 220370 hectare. From the year of 2001 to 2005, the city took place eight forest fires, and some survey data of the fire shows as table 1.
### Table 1 The forest fire record of Yuqian Town from 2001 to 2005

<table>
<thead>
<tr>
<th>Data</th>
<th>Danger rank</th>
<th>Slope degree</th>
<th>Main tree species</th>
<th>Forestry age</th>
<th>Canopy density</th>
<th>Fired area</th>
<th>Damaged area</th>
<th>The causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>20010314</td>
<td>General fire</td>
<td>0</td>
<td>Fir</td>
<td>Middle</td>
<td>0</td>
<td>4.7</td>
<td>4.7</td>
<td>Others</td>
</tr>
<tr>
<td>20020309</td>
<td>General fire</td>
<td>0</td>
<td>Pine</td>
<td>Young</td>
<td>0.7</td>
<td>2</td>
<td>2</td>
<td>Others</td>
</tr>
<tr>
<td>20020319</td>
<td>General fire</td>
<td>0</td>
<td>Pine</td>
<td>Young</td>
<td>0.7</td>
<td>3.5</td>
<td>1.7</td>
<td>Unclear causes</td>
</tr>
<tr>
<td>20030326</td>
<td>General fire</td>
<td>0</td>
<td>Fir</td>
<td>Middle</td>
<td>0.7</td>
<td>3.9</td>
<td>3.3</td>
<td>Unclear causes, Burning of grass and charcoal</td>
</tr>
<tr>
<td>20040102</td>
<td>General fire</td>
<td>0</td>
<td>Pine</td>
<td>Middle</td>
<td>0.7</td>
<td>1.3</td>
<td>1.3</td>
<td>Burning of grass and charcoal</td>
</tr>
<tr>
<td>20040309</td>
<td>General fire</td>
<td>0</td>
<td>Pine</td>
<td>Young</td>
<td>0.6</td>
<td>6.6</td>
<td>6.6</td>
<td>Grave visit</td>
</tr>
<tr>
<td>20050402</td>
<td>Fire alarm</td>
<td>22</td>
<td>Pine</td>
<td>Middle</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>Grave visit</td>
</tr>
<tr>
<td>20050405</td>
<td>Fire alarm</td>
<td>23</td>
<td>Pine</td>
<td>Middle</td>
<td>0.6</td>
<td>0.8</td>
<td>0.8</td>
<td>Grave visit, burning of Grass and charcoal</td>
</tr>
<tr>
<td>20051223</td>
<td>General fire</td>
<td>18</td>
<td>Fir</td>
<td>Middle</td>
<td>0.8</td>
<td>1.9</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

3. Research measure

3.1. Establish appraisal index system

3.1.1 Index system and index weight

The forest resource administration system integrates the natural environment system, forest resource system, and social economic system. Regional forest fire appraisal system aims to analyze and evaluate the regional forest fire danger considering with regional natural environment, forest resource, and social economic conditions. After investigated and analyzed forest fires data of Zhejiang province the years, and referred to the features, causes, happening and development theories of forest fires, the paper build the index system showing as figure 1. In accordance with expertise, the paper fixes the weight values of every index with improved hierarchy analysis method according to the importance of indexes \[12,13\], these indexes weights show as Figure 1.

3.1.2 Quantification index

The principal regional forest fire appraisal index can be classified into two types: spatial index and non-spatial index. The spatial index is related to spatial structure directly, for example, to the forest fire, the deterioration caused by paddy fields near the village and farming lands near the forest is different. Fixing values of these indexes are realized by the nearest-neighbor analysis and buffer analysis, the indexes values show as table 2 and table 3.

Non-spatial indexes include qualitative index and quantitative index in tradition. Because of the discontinuity of most indexes, the quantify indexes are measured by rank of universe of discourse. Values of these indexes are classified some levels according to their comment level, and every level has a value range. To qualitative indexes, it can be determined directly by the experts, it also fixes the index value with classified attribute value of quantitative indexes; To quantitative indexes, firstly making the non-dimensional treatment, secondly classifying attribute value by determining critical value of the comments level respectively, finally fixing the indexes value.
Fig. 1 Index system and weight of regional forest fire danger appraisal

Table 2 The fire hazard of burning the grass on waste land

<table>
<thead>
<tr>
<th>No.</th>
<th>The location of subcompart ment and farming land</th>
<th>Rule(m)</th>
<th>Value</th>
<th>Danger degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spatial distance</td>
<td>&lt;15</td>
<td>1</td>
<td>Extremely dangerous</td>
</tr>
<tr>
<td>2</td>
<td>Spatial distance</td>
<td>[15, 30)</td>
<td>0.7</td>
<td>Dangerous</td>
</tr>
<tr>
<td>3</td>
<td>Spatial distance</td>
<td>[30, 45)</td>
<td>0.4</td>
<td>Relatively dangerous</td>
</tr>
<tr>
<td>4</td>
<td>Spatial distance</td>
<td>&gt;=45</td>
<td>0.1</td>
<td>Not dangerous</td>
</tr>
</tbody>
</table>

Table 3 Tomb-sweeping of slash burning and forestation

<table>
<thead>
<tr>
<th>no.</th>
<th>Attribute of subcompart ment forest type</th>
<th>Neighbor subcompart ment forest type</th>
<th>Ratio</th>
<th>Value</th>
<th>Danger degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Economic forest</td>
<td></td>
<td>1</td>
<td>m/N</td>
<td>Extremely Dangerous</td>
</tr>
<tr>
<td>2</td>
<td>Others</td>
<td>Economic forest</td>
<td>m/N</td>
<td>m/N</td>
<td>m/N dangerous</td>
</tr>
</tbody>
</table>

Notes: Economic forest includes fruit forestry, raw food material forestry, chemical raw material forestry, pharmacological forestry etc.

3.2. Establish the appraisal module

Appraisal model includes single factor appraisal module, thematic appraisal module and comprehensive
appraisal module. Single factor appraisal fixes forest fire danger rank with each index using subcompartment as an appraisal unit. Thematic appraisal includes the thematic appraisal of fire hazard distribution with farming activity, the thematic appraisal of fire hazard distribution with visiting a grave and the thematic appraisal of fire hazard distribution with tourist midseason. Comprehensive appraisal includes comprehensive appraisal with the first levels, comprehensive appraisal with the rule levels, and comprehensive appraisal with the object level. The paper adopts addition combination as the appraisal module:  

\[ y_i = \sum_{j=1}^{p_i} w_j x_{ij} \]

In above formula, \( y_i \) is the appraisal levels number \( i \), \( w \) is the weight of number \( j \) in the appraisal levels, \( x_{ij} \) is the appraisal value of index levels number \( j \) base on levels number \( i \), \( p_i \) is the number of levels \( i \).

3.3. The appraisal system

3.3.1 Organize the data

According to the division of the forest fire danger rank and the survey data we get during the “tenth five-year planning”, we build three-leveled resource database (county, town and village), including the following types of data: (1) fundamental geographical data: water system, way and residents dwelling; (2) district, forest subcompartment boundary data. (3) the data of the subcompartment property: the gradient, direction of the slope, the position of the slope and the altitude; the area of the subcompartment, storage, tree species, the component of the tree species, the age of the tree, age group, thickness of the material on the earth’s surface, which reflect the connotation of the forest resource. (4) the data of the human activities: the number of regional residents and the basic traveling data; (5) historical fire data includes the forest fire record data in Lin’ an from 1998 to 2005 and the forest fire data in Zhejiang Province from 2000 to 2005. The data logical structure of comprehensive appraisal method is shown in the figure 2.

3.3.2 Design the structure of the index system

The structure of the index system includes the table structure of the index classified, the table structure contrasted with basic index and the table structure of the index system. All these table structures use “appraisal region code” or “appraisal region code” + “annual” as their key words.

(1) The table of classified indexes, used as the storage for the users to define the basic indexes and the value of the basic indexes, contains terrain index, population quality, social economic data index, human activities index and the forest resource index. The users can make, revise, delete and compile them themselves.

(2) The table contrasted with basic index are used to store all the index and the item in every item. It is used as a index selection for the basic index’s generation in the system, which is generated by the platform itself.

(3) It is used for the generation of the index system and the storage for the structure of the index system. The users can build many index systems.

(4) Matrix results table: used for the weight after calculated the indexes.

(5) The classification table of the appraisal value: it is used for the classification of the appraisal value.

3.3.3 Design the structure of the regulation table

The regulation table is the base for the index quantization, which can not only input the value of the index directly, but also can calculate the value of the index by search data from the existing data resource automatically. By analyzing the index quantization regulations, we can define the regulations in three ways.

(1) Gain the regulations of the spatial index data

Spatial index, such as interference index of human activity, interference index of water system and path, interference index of farmland and economic forest distribution and interference index of grave sweeping, includes factors concerning with the direct spatial index like nature, human activities and forest resource. All these indexes quantization have the connections not only with the values gained from the property data, but also with the goal objects and the interference objects. These space indexes can be divided into four usual forms.
1. Gain the data based on two layers overlay analysis and Buffer analysis
   The value of this spatial index proceeds is as follows: firstly, analyze and build the spatial regulations; secondly, match the two layers together to gaining the relation layer; thirdly, analyze the buffers of each object in different scale; fourthly, confirm the index value of the object. In this paper, we confirm the indexes of grass burning, grave sweeping, water system and path in the forest fire dagger appraisal index system. For the layers that have more than two layers we should respectively analyze several two layers then repeat the above process.

2. Gaining data Based on the buffer analysis
   We calculate the value in the following process: firstly, analyze and build the spatial regulation relations; secondly, analyze the buffers of each object in different scale; thirdly, confirm the index value of the object.

3. Gaining data based on nearest-neighbor analysis
   Calculating the value in the following process: firstly, analyze and set up the spatial regulation relations; secondly, solve the nearest-neighbor object of each goal object; thirdly, analyze the related property of the object.
nearest-neighbor object, solve the ratio of the sufficient nearest-neighbor object with all the nearest-neighbor objects; fourthly, confirm the spatial index on the basis of the regulation table. In this paper, the example is agriculture and forestation in the forest fire appraisal index system.

(2) Regulations for gaining the subsection index data
For all the data indexes, we can classify all of them in different sections. Then, confirm index value of each section. In this paper, we set the degree of the slope, altitude, forest canopy density, population density, the number of traveling, human power invested, capital invested and the storage in the system. The generation of all these regulations consists of the names of the indexes, index property sections and the index value. So, we can build similar regulation tables and the users can delete or add the contents.

(3) Regulations for the qualitative index data
For some of the qualitative index, firstly, we should classify the property of each index; then, confirm the index value of each property, which has one to one relation with their index value. In the paper, we have the terms like the slope direction, slope position, combustible types and the age group. The generations of all these regulations consist of the names of the indexes, index property sections and the index value. So, we can build similar regulation figures and the users can delete or add the contents.

3.3.4 The appraisal function
The comprehensive appraisal platform of the forest fire danger includes data management module, index management module, basic index quantization module, regulation definition module, index weight calculation module, forest spatial structure analysis module, fire danger rank appraisal module, special fire danger appraisal module and the dynamic fire danger layer generation module. The functional module of system and interface is showed in Figure 3.

4. Results and analysis
4.1. Single factor appraisal
Single factor appraisal means evaluating each of the fundamental indexes directly to gain the impact of each factor on the forest fire, which is also the foundation for the comprehensive appraisal. According to the
quantization and the regulation generation measurements of the basic indexes, we divide the single index appraisal into three parts.

4.1.1 The appraisal of qualitative index
The qualitative index includes combustible type index, forest age index, slope direction index and slope position index. Take the evaluating process of the combustible type index as an example. We do it as follows: firstly, we get the subcompartment data named Yuqian town from the subcompartment property figure of forest resources in Lin’an City and list the data out; secondly, according to the combustible type, the terrain and the good tree species, we calculate the property value of the combustible type; thirdly, we gain the fire danger value of combustible type for each subcompartment via the data from the table of qualitative index regulations; and at last, we write the data down on the table of forest fire danger appraisal at the right place.

4.1.2 The appraisal of subsection index
Subsection index includes forest canopy density, volume index, traveling index and basic activity index. Take the forest canopy density for example. We do it as follows: firstly, we get the mini class data named “Yuqian town” from the mini class property figure of forest resources in Lin’an City and list the data out; secondly, according to the fire danger value of each sub district from the table of sub district index rules, we calculate the fire danger value of forest canopy density and write them down on the right place.

4.1.3 The appraisal of spatial index
Spatial index appraisal includes water interference index, roadway interference index, manpower index, investment index, agricultural burning index, agricultural forestry index and grave visiting index. The basic analysis method is the buffer first and space enquiry latter. Take the appraisal of water interference index as an example. We do it as follows: firstly, we make a buffer for the water system diagram; then we search out all the subcompartment subjects from the forest resources layer that intersect the buffer; at last, we get the counterparts of the water index fire danger value for the subcompartment and write them down at the right place.

4.2. The appraisal of comprehensive index
The comprehensive appraisement includes all sorts of appraisements and the general appraisements. For the limit of the paper length, we only analyze the results of the general appraisement. We employ plus appraisal model in each value of fire danger index and weight to get the final appraisal map of forest fire danger in Yuqian town, which shows in figure 3. We get the several conclusions.

1) The rank IV fire danger area takes up only 5% of the total forest land. All the combustible types are pure young horsetail pines and pure firs, which locate at the sides of the roadways, low hills and the sun-orientation slope.

2) The rank III fire danger area takes up 13% of the total forest area. The combustible types are pure young horsetail pines, pure firs and part of the mixed conifer, which locate near to the economic forest and the farmland. All the terrain is steep low hills.

3) The rank II fire danger area takes up 50% of the whole forest area. The combustible types are adult horsetail pines, pure firs and part of the broad-leaved forest and the bamboo forest. The difference among each other is not so obvious.

4) The rank I fire danger area takes up 32% of the whole forest area. The combustible types are broad-leaved forest, bamboo forest, a small quantity of grass and bush. They are distributed on the 200 altitude hidden hill where are all rivers and gullies.

According to the historical fire diagram and the fire danger rank layer, we can find that the four fire dangers happened in the IV fire danger area, making up 50% of the eight fire dangers. Five fire dangers happened in fire danger area, making up 50% of the whole fires. The occurrence of the fire all happened in the high fire danger area, which proves the evaluating results equal to the fact.

5. Conclusion
According to the second surveying data in 2005 in Lin’an, Zhejiang Province, the content of this paper contains some degrees of the forest fire danger. Since the basic spatial data regards one village or town as an
unit as well as the appraised results displayed, the results is basically in accordance to the probability of historical fire occurrence, compared with the data from 2000 to 2005 in Yuqian town. Sub district is considered to be as one unit for the basic appraisal model, but synthetic problems still needs to be further explored on the similar appraisal unit.

6. Acknowledgements

This paper is partially supported by Science and Technology Foundation of Zhejiang, China (No. 2008C22005, No. 2008C23036, No. 2006C12109).

7. References


