Research of Forest Fire Prediction Method

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Abstract. In order to achieve the predicted speed, high accuracy, the use of simple purpose, forest fire prediction of the key issues is to choose the main predictors. Currently leading factor in the prediction of forest fire is often used in the fuel moisture, precipitation or dry days, relative humidity, temperature and wind five factors. In this paper, some of the data Yichun fire nearly a decade predict the forest fire meteorological data analysis, using multivariate linear regression to derive forest fire prediction method in the wireless sensor networks.

Keywords: wireless sensor network, forest fire prediction, Multivariate Linear Regression

1 Regional Overview Research

Yichun is the northern of Heilongjiang Province in China. Geographic coordinates of longitude 126°03′-126°24′, latitude 47°22′-47°36′, Area of 36,400 square kilometers. Territory is hilly areas, thus extending the main vein Xiaoxing'anling to the southeast. It is the temperate continental monsoon climate, annual rainfall 630 mm, with an average annual temperature of 1 degree, in January average temperature of minus 25 degrees, in July the average temperature of 21 degrees above zero. Throughout the Yichun area, the area of the fire occurred Wuyiling, Jiayin and Hongxing, which happens to be in three places with frequent forest fire area.

Table 1. Yichun forest fires occurrence

<table>
<thead>
<tr>
<th>Year</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-1069</td>
<td>372</td>
</tr>
<tr>
<td>1970-1979</td>
<td>488</td>
</tr>
<tr>
<td>1980-1989</td>
<td>312</td>
</tr>
<tr>
<td>1990-1999</td>
<td>93</td>
</tr>
<tr>
<td>2000-2009</td>
<td>225</td>
</tr>
</tbody>
</table>
2 Analysis of Factors Affecting the Occurrence of Forest Fires

Forest fires have more factors, such as the maximum temperature of the day, the day the humidity, Diurnal temperature range, wind speed, precipitation and their synthesis. This section discusses the contribution of meteorological factors on the occurrence of forest fires through a single evaluation model proposed by Dong Guangsheng.

2.1 The contribution of the daily maximum temperature on forest fire occurrence

The daily maximum temperature on the impact of forest fires (formula 1):

\[ r_1 = \begin{cases} 
1 & s_i < 20 ^\circ C \\
\frac{1}{1 + \left(\frac{1}{5} \cdot (20 - s_i)\right)^5} & s_i \geq 20 ^\circ C 
\end{cases} \]  

(1)

\( r_1 \) is determined by a single factor in determining the contribution of high fire risk value(%). \( s_i \) is the highest temperature of the day, where the temperature is 14:00 as the maximum temperature of the day. At 14:00 the temperature is low; especially in the following 8°C the risk of fire basically no; temperature is between 8°C and 12°C, the degree of risk of fire is gradually increasing; at between 12°C and 20°C, the rapid changes in the risk function, in the low to high transition phase fire should pay particular attention to possible fire; special attention will be above 20°C.

2.2 The contribution of diurnal temperature range on forest fire occurrence

The diurnal temperature range effects on forest fires (formula 2):

\[ r_2 = \begin{cases} 
1 & (s_1 - s_2) < 12 ^\circ C \\
\frac{1}{1 + \left(\frac{1}{10} \cdot (25 - (s_1 - s_2))\right)^5} & (s_1 - s_2) \geq 12 ^\circ C 
\end{cases} \]  

(2)

\( (s_1-s_2) \) is the single factor reflected by the diurnal temperature high fire risk contribution value(%). \( s_i \) is the highest temperature of the day, and \( s_2 \) is the lowest temperature of the day, where the temperature of 2:00 is the minimum temperature of the day. Under normal circumstances, when \((s_1-s_2)<12^\circ C\), cloudy, rainy and foggy weather phenomenon more, so difficult to fire; while \((s_1-s_2)\) is between 12°C and 20°C, the great increase in the degree of risk of fire; when\((s_1-s_2)>20^\circ C\), weather controlled by high pressure situation, the performance of sunny, daytime warming intense , afternoon the wind speed increases, the fire to maintain a higher state.

2.3 The contribution of diurnal temperature range on forest fire occurrence

The relative humidity affect the occurrence of forest fires (formula 3):
2.4 The average relative humidity of the air three days before on forest fire occurrence

Three days before the average relative air humidity on the impact of forest fires (formula 4):

\[
    r_3 = \begin{cases} 
    \frac{1}{1 + \left( \frac{1}{10} \left( E - 20 \right) \right)^4}, & E > 15 \% \\
    1, & E \leq 15 \% 
    \end{cases}
\]

(3)

\( r_3 \) is the relative humidity reflects the contribution of a high fire risk value (%). \( E \) is the relative air humidity of 14:00(%). When the relative humidity is greater than 45%, chance of a fire occurring is low. While between 10% and 45%, the ratio of high fire risk begins to increase. And when the relative humidity is below 15%, fires will occur at high risk.

2.5. The contribution of 24 hours of precipitation on forest fire occurrence

24 hours precipitation effects on forest fires (formula 5):

\[
    r_5 = \begin{cases} 
    \frac{1}{1 + x_5}, & x_5 > 0 \text{ mm} \\
    1, & x_5 = 0 \text{ mm} 
    \end{cases}
\]

(4)

\( r_5 \) is reflected in the 24 hours of high fire risk precipitation contribution value (%). \( x_5 \) is precipitation of 24 hours. Changes in precipitation curve was smooth downward trend, with increasing precipitation, fire danger index declining. When rainfall is less than 1mm, you are in a high fire danger and fire trend will not significantly decrease. At this time if precipitation decreased, it will again appear high fire condition.

2.6. The contribution of wind speed on forest fire occurrence

The wind speed effects on forest fires (formula 6):
$r_s = \begin{cases} 
\frac{1}{1 + \left(\frac{x_s - 7}{12}\right)^2} & x_s < 7 \text{ m/s} \\
1 & x_s \geq 7 \text{ m/s} 
\end{cases}$

$r_s$ is the single factor reflecting the contribution of high fire risk value (\%). $x_s$ is as measured ground 10m–12m height average wind speed at 14:00. In the north the wind and precipitation generally occur simultaneously, so the wind speed measurements to eliminate the influence of its precipitation. When the wind speed 3m/s or less, have little effect on the occurrence of forest fires; wind between 3m/s and 7m/s, the impact of forest fires started its rapid growth; when the wind speed reaches 8m/s, once the forest fires difficult to control.

The main contribution of meteorological factors from forest fires occur above analysis point of view, there are certain factors that affect every single occurrence of forest fires, but not the causes of forest fires can be one factor in the decision, but a number of result of factors working together.

### 3 The Achievement of Integrated Meteorological Indicators to Predict Forest Fire Method

A single meteorological factor has poor predictive accuracy characteristics in affecting the occurrence of the forest fires. The forest fire prediction requires the combined effect of a number of meteorological factors. After analysis of the previous sections, integrated meteorological indicators include the maximum temperature at 14:00, diurnal temperature range, the average of three days minimum humidity and wind speed, in order to determine the method for predicting the occurrence of forest fires, according to a large forest fire occurred before the meteorological data, using multiple linear regression method to establish the occurrence of forest fires of linear equations, the four meteorological factors as independent variables linear regression equation.

According to the analysis, the meteorological factors in forecast of forest fires have included the daily maximum temperature at 14:00, the daily diurnal temperature range, the average of three days minimum humidity and wind speed, thus using the data in Yichun and regression models to predict the establishment of forest fires based on the above four factors regression equation 7. $y$, representatives of fire danger rating, $x_i$ is the maximum temperature at 14:00, $x_7$ is the daily diurnal temperature range, $x_9$ is the average of three days minimum humidity and $x_4$ is wind speed.

$$y_i = \beta_0 + \beta_1(x_{i1} - \bar{y}) + \beta_2(x_{i2} - \bar{y}) + \beta_3(x_{i3} - \bar{y}) + \beta_4(x_{i4} - \bar{y}) + \epsilon_i$$

(1) Calculating the sum, the arithmetic mean, the cross product of the variables.

(2) Calculating the coefficient matrix $A$, the constant matrix $B$, and the inverse matrix $A^{-1}$.
(3) Calculating the regression coefficients and regression equations.

\[
\hat{y} = 3.125 - 0.0643 (x_1 - 16.643) + 0.1446 (x_2 - 13.799) + 0.0871 (x_3 - 18.339) + 1.2272 (x_4 - 4.619)
\]

From the calculations, forecast fire rating with linear regression equation is shown in Equation 8:

\[
\hat{y} = -5.066 - 0.0643 x_1 + 0.1446 x_2 + 0.0871 x_3 + 1.2272 x_4
\]

The regression after significant inspection meets normal distribution $F$ table. Therefore there is a linear relationship between $y$ and $x_1, x_2, x_3, x_4$. The occurrence of forest fires can predict the fire danger rating, fire danger rating table as shown in Table 2:

<table>
<thead>
<tr>
<th>Fire danger rating</th>
<th>Regression equation</th>
<th>Degree of risk</th>
<th>Forest flammability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 1$</td>
<td>$&lt;1$</td>
<td>No danger</td>
<td>General nonflammable</td>
</tr>
<tr>
<td>$1$</td>
<td>$1$</td>
<td>Rarely danger</td>
<td>After the fire spread very slowly</td>
</tr>
<tr>
<td>$2$</td>
<td>$2$</td>
<td>Medium danger</td>
<td>Quick flammable</td>
</tr>
<tr>
<td>$3$</td>
<td>$3$</td>
<td>High danger</td>
<td>Spread faster</td>
</tr>
<tr>
<td>$&gt;4$</td>
<td>$&gt;4$</td>
<td>Extremely danger</td>
<td>Fire was fierce and difficult to save</td>
</tr>
</tbody>
</table>

4 Conclusion

Since the meteorological factors on forest fires are an important role. So in this paper, the contribution of the various meteorological factors on the occurrence of forest fires is compared to select the probability of an impact on the larger fires factors as regression factor. According to a large meteorological data in front of forest fire has occurred, the use of multiple linear regression equation forecast fire danger rating.
In comparison with similar prediction methods, the method than the relative humidity, temperature and humidity prediction method, and so comprehensive index method has higher prediction usefulness and predictive reference, suitable for promotion method according to different regions, has a good practical application value.

Acknowledgements. This paper is supported by “the Fundamental Research Funds for the Central Universities”------2013CBQ01 and Key Laboratory of Database and Parallel Computing, Heilongjiang Province.

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