Research and Application of Fire Risk Assessment Based on Satellite Remote Sensing for Transmission Line

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***Abstract*—Forest fire risk estimation is essential for China national grid company for their routine transmission line maintenance. The risk assessment model needs both remote sensing and meteorology data as input. This paper showed a wildfire risk assessment system which has been successfully applied in Hubei province covered all the 500kV transmission power lines and towers. This system has realized the classification of risk for different areas in transmission line. The results have shown that, combined with data fusing methods, such as, internet technology, remote sensing technology, expert system and data mining, areas along transmission line with high wildfire risk can be effectively obtained by the proposed system. This system could be used as a guide for forest fire and wildfire estimation which will be useful for the Hubei grid company to arrange their routine maintenance.**

***Index Terms*—transmission line; forest fire; remote sensing; meteorology; risk assessment; data fusing**

I. INTRODUCTION

In recent years, Hubei Province grid suffered lots of forest fire accidents that interconnected power grid 500 kV and above transmission lines due to fires which caused line outage, dropping operation, tripping accidents. During those periods, the operation and maintenance unit investigated large amount of manpower and materials to carry out inspections, key sections and squat hill site monitoring and so on. But it still remains many problems, e.g. the efficiency of work is low, the cost is huge.

With the fast development of remote sensing technology, image resolution, computer technology and information processing technology, the utilization of satellite remote sensing monitoring technology becomes an effective tool to overcome the shortcoming of artificial forest fire monitoring and power lines maintenance. The introduction of satellite remote sensing of transmission line corridor area monitoring data for wildfire risk assessment can be viewed as an effective tool with wide range to monitor the region condition, to access the macro information on the ground rapidly. Combined with meteorology data and geographic information, the fire risk area could be estimated well-founded. Therefore, the wildfire risk assessment system for transmission line based on satellite remote sensing technology could monitor the large scale area and also improve the monitoring efficiency.

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II. RELATED WORK

According to the properties of forest fire, the prediction can be divided into weather forecast, fire forecast and wildfire behavior forecast[1-2]. Bushfire weather forecast does not consider the fire seat, only for the possibility of fire under weather condition. The wildfire occurrence forecast is considering some factors, such as, weather conditions, dryness of combustible material and appear pattern. The hill fire behavior forecast is the prediction of fires spread speed and direction, release of energy, fire intensity and difficulty of firefighting when the fire has been occurred[3]. The fire risk assessment of transmission line corridor belongs to the category of fires forecast.

The first quantitative forecast fire risk rating system has been used in United States since 1975[4]. In 2001, the system had more power to forecast the danger of forest fire, which provided the important basis work for the fire prevention[5-7]. In recent years, with the rapid development of 3S technology, the system has been developed and improved [8-11]. The “forest fire weather index system” was proposed in Canada in 1972, which was based on data of years of fire, meteorological data and field test data. It was established upon the water and heat balance principle and could forecast for the next three days of forest fire[12].

III. THE IMPACT FACTOR ANALYSIS OF FIRE RISK IN HUBEI PROVINCE

A. *The impact factors*

According to the data collection of fire fault in Hubei Province since 2008, the grid fires point distribution can be proposed, as shown in figure 1. It can be inferred that the fire pints are mainly distributed in the east area of Hubei, such as, Xianning, Huangshi, Huanggang, wildfire has occasionally happened in Yichang, Jingmen, whereas in the west of Hubei province has not occurred.

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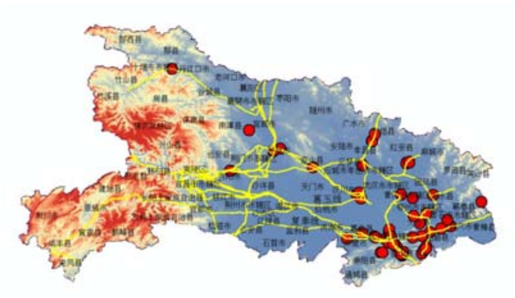

Figure 1. The distribution diagram of breakdown caused by wildfire of Hubei Power Grid since 2008

The happened wildfire has three basic conditions, namely, weather, combustible material, and fire seat. in Hubei area of continuing fine The dry weather and geographical environment of Hubei Province in autumn and winter have provided fire weather and dry combustible for outbreak of wildfire. The burning custom of farmers in winter is also the dangerous sources of ignition for wildfire. A comprehensive analysis of all wildfires tripping and danger events have shown that, it could be caused not only by the weather conditions and the geographical environment, but also by activities of human.

B. *The calculation of factors*

According to the analysis of the factors that affecting the fire risk, the influencing factors of wildfire in transmission line corridor includes topography, weather conditions, vegetation and grade of drought. Moreover, according to the risk assessment, historical fire and trip information, line height and insulation information must also be considered. The whole fire risk assessment model can be written as:

$$g = \sum_{n=1}^{m} C_n P_n \tag{1}$$

Here, C_n denotes the impact factor, P_n denotes the weighting factor, m is the number of impact factors.

IV. CALCULATION OF DROUGHT INDEX

A. *Calculation of drought index of line corridor*

This work is based on the calculation of several index, such as, TVDI, VSWI, which can be obtained from MODIS satellite, at the same time, the rainfall data of nearly a hundred weather stations in Hubei Province is also the basis for the calculation. The meteorological drought index is calculated by means of the meteorological rainfall. This paper mainly explains the drought index of VWSI and TVDI from MODIS. Before the calculation, several pre-processing work are needed to be done, such as, the geometric correction of MODIS image, and remove the Bow-tie effect.

B. *Geometric correction*

The MODIS data itself includes the band information of latitude and longitude. The corresponding pixels of data have the longitude and latitude information with 1km resolution, which are stored in the form of the band. So these data can be used for correction without artificial selection of ground control points. With the secondary development provided by ENVI software, geometric correction of image can be processed with the geographic information in MODIS data, which is shown in Figure 2. This method has not only a high precision, it also omits the selection of control points, which can be regarded as one of the highlights of the MODIS data.

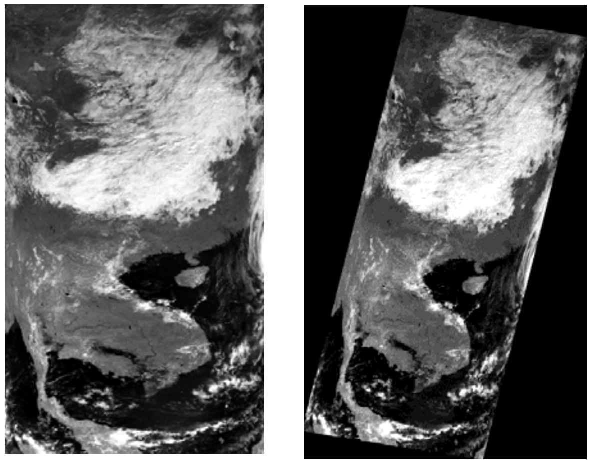

Figure 2. The comparison of the effect of geometric correction

C. *Remove the Bow-tie effect*

Due to the changes of curvature of the earth and the scanning angle, the closer to the edge of the image, the larger actual size of the pixel is. Thus, the edge pixel size can reach two times than the sub satellite point, so that it can lead to overlapping images between the adjacent scanning lines. This phenomenon is called Bow-tie effect, which makes the edge portions of the data cannot be used. This problem can be solved by modification of the position from the overlapping data, which is obtained by resampling of the revised data.

D. *Destriping*

As shown in Figure 3, interpolation is the mostly used for destriping at present. The algorithm only makes interpolation for the line where strip locates, and do not affect the area which do not belong to strip. The basic principle is to make a positioning line of noise strip, using the interpolation calculation results of two rows in data, instead of noise line. The strip of MODIS image has shown certain regularity, e.g. the interval of 500 m resolution, 1000 m resolution and 250 m resolution are 20, 10 and 40 respectively.

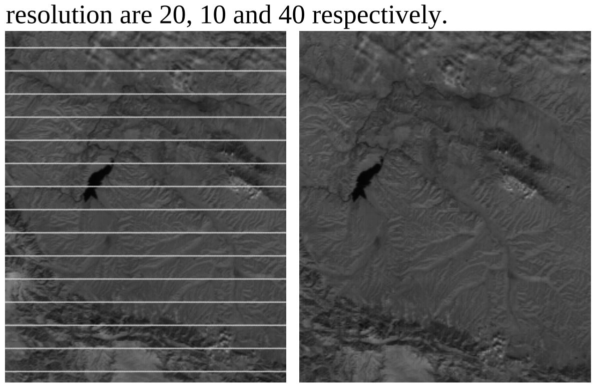

Figure 3. The comparison of effect of destriping

E. *Calculation of TVDI*

The vegetation index and canopy temperature during growth period will be stable in a certain range, when water supply of the crop is normal. The transpiration will be inhibited under the condition of drought, which leads to the lack of root water. Then the crop canopy temperature will arise due to the close of leaf stomatal, the vegetation index will also decreas, which is affected by the growth of crop. Therefore, the combination of surface temperature and

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vegetation index can make better monitoring for the drought. The the VI-Ts method based on combination of land surface and vegetation index has been widely used and studied.

The NDVI-TS feature space can be constructed based on normalized difference vegetation index and land surface temperature (LST), then the temperature vegetation dryness index (TVDI) model can be inferred, so the TVDI of each pixel can be calculated at different times in different climate zones. The calculation formula and process are written as follows:

$$TVDI = \frac{LST - LST_{NDVI\,i.\min}}{LST_{NDVI\,i.\max} - LST_{NDVI\,i.\min}}$$

$$LST_{NDVI\,i.\max} = a_1 + b_1 \times NDVI_i$$

$$LST_{NDVI\,i.\min} = a_2 + b_2 \times NDVI_i \quad (2)$$

F. Calculation of VSDI

The Vegetation Support Water Index (VSWI) is based on the vegetation and temperature monitoring, is defined as follows:

$$VSWI = NDVI / T_s \quad (3)$$

Here, T_s denotes the canopy temperature, NDVI is the normalized difference vegetation index. The bigger the VSWI, the more severe the drought is.

The land surface temperature retrievaled from satellite of (LST) is all kinds of surface objects of integrated temperature. The surface temperature can be used instead of canopy temperature only under dense vegetation conditions (i.e., the vegetative pure pixels), and for sparse vegetation surfaces, a strong background radiation produced from bare soil surface will increase to the radiation signal of the vegetation, which will lead to a higher inversion of surface temperature in the daytime than the actual canopy temperature. According to our experiment, the linear mixed model has been proposed to describe the vegetation canopy temperature, which can be wriiten as follows

$$T_{canopy} = \left[T_{surface} - T_{soil} \times \left(1 - P_v\right) \right] / P_v \quad (4)$$

$$P_v = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \quad (5)$$

Here, $T_{surface}$ is the mixed surface temperature, T_{soil} adb T_{canopy} are canopy temperature and bare soil temperature respectively, and P_v is the crop coverage. The $NDVI_{min}$ and $NDVI_{max}$ are results from the vegetation coverage of 5% and 98% respectively. The distribution of vegetation water supply index of Hubei province during a certain period is shown in Fig.4.

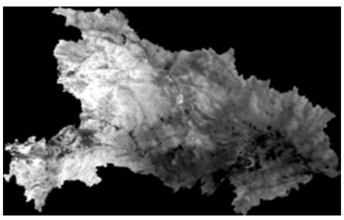

Figure 4. The distribution diagram of VSWI in a period of Hubei Province

V. THE FIRE RISK ASSESSMENT SYSTEM FOR HUBEI POWER GRID TRANSMISSION LINE CORRIDOR

A. The goal of system

the main goal of this risk assessment system is to achieve the monitoring for the transmission line corridor forest vegetation and drought index normalization based on MODIS, "ZY-3" satellite data and aerial image(AI). Then the arid index distribution map of forest vegetation and wildfire risk level distribution map of transmission lines in Hubei Province can be real-time produced. The wildfire risk level distribution map will be then produced according to the distribution map of drought index, and line corridor biological monitoring, and a strong suggestion for anti-fires isolation will be further made. The effectiveness and accuracy of fire prevention can be improved, based on the MODIS and "ZY-3" satellite monitoring results after fires occurred.

B. The classification of satellite image

There is a close relationship between fire and vegetation in transmission line corridor, so it is needed to obtain the classification result for transmission line corridor from image data. In this paper, the ZY-3 satellite and aerial image have been used. ZY-3 satellite images contain panchromatic image with 2.1 m resolution and multi-spectral image with 5.4 m resolution. The resolution of aerial image is 0.5m. It has several objects in the image: housing, water, farmland, grassland, woodland, shrub, bare land and reed. The comparison of classification results is shown in table 1.

Table 1. The classification accuracy comparison between ZY-3 data and aerial image

Overall Accuracy(%)		Kappa coefficient
ZY-3	90.0162	0.8848
AI	92.4906	0.9021

C. Meteorological data

Meteorological data can be divided into three types: temperature, humidity, and rainfall. The most important influence factor is the rainfall. According to our experiment, the rainfall flat distance percentage distribution map with 30m of grid size has been produced, which is based on 30 years of rainfall observations that collected from nearly 100 ground meteorological stations, as shown in Fig.6.

Figure 6. The distribution diagram of average precipitation in one day of Hubei Province

D. Historical fire data

The data of fire points, which is sent by national forestry bureau forest, has been pushed into the system, and it has been marked on the GIS platform to form a corresponding map. The fire point statistical results mainly come from meteorological satellite and MODIS satellite monitoring results, which has a low spatial resolution. However, based on the superposition of many years of data, it can be

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concluded that the fire point is more intensive in the southeast and northeast of Hubei Province, but in west less relatively, which is shown in Fig.7.

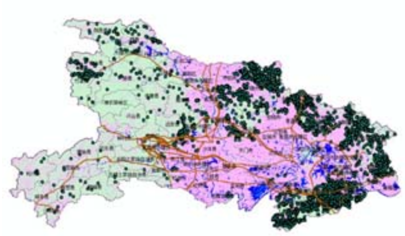


Figure 7. The distribution diagram of fire point monitored by satellite in Hubei Province (2010~2014)

E. Fusion of multi-source data

The regional fire risk rating chart can be obtained by wildfire risk assessment system, based on the collection and modeling of the above mentioned data, which are shown in Fig.8 and Fig.9.

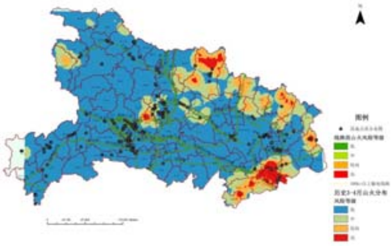
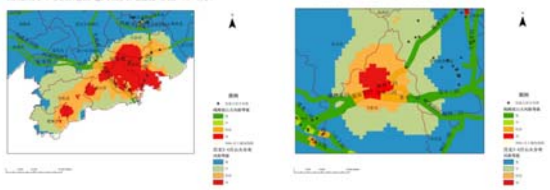


Figure 8. The distribution diagram of region along transmission lines with high risk in wildfire in Hubei Power Grid



(a) The channel with high risk in Xianning and Huangshi
(b) The channel with high risk in Jinmen
Figure 9. The diagram of channel with high risk obtained by multisource data

VI. CONCLUSION

The techniques of monitoring wildfire along transmission line corridor area could be effectively improved, based on the near realtime satellite remote sensing, which can quickly access to macro information on the ground. Combined with the geographic information, the fire risk level could be accurately assessed, and the cost is relatively lower. In this paper, the proposed wildfire risk assessment system can combine with the satellite remote sensing data and meteorology data to carry out fire risk level assessment. The risk level in different areas can be quantitive classified. The passive control of transmission line fires monitoring can be thereby changed to active identification on high risk areas through wildfire risk assessment. The result can be subsequently used to provide strong technical support for integrated vegetation management, line reconstruction and monitoring enhancement. In this manner, the operation reliability of the important lines and high risk of line section can be improved.

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