Dynamic Response of Shrubbery Fire to Meteorological Changes in Yunnan Province

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Abstract. This paper takes shrubland fires as the research object and selects typical shrubland forest fire cases that occurred throughout Yunnan Province from 1954 to 2018 as the research samples, and the shrubland fire loss elements and meteorological data are studied by SPSS correlation analysis and MATLAB gray prediction model to analyze shrubland fires and meteorological elements. The results showed that there were significant correlations between shrubland fires and meteorological data; the shrubland fire over fire area, forest damage area, and economic loss composite data index showed positive correlations with annual maximum temperature, annual average minimum temperature, annual average temperature, and annual sunshine hours; the annual average relative humidity, precipitation days, and the composite index of the same day meteorological data showed significant negative correlations, etc. In exploring the main meteorological factors affecting the distribution of forest fires, we establish a meteorological fire model to provide a real and credible scientific basis and theoretical foundation for future forest fire prevention and prediction.

1 Introduction

Forest fire is a natural disaster that occurs widely, suddenly and destructively in the world today, and is more difficult to deal with and fight. Control of forest fires is a global problem and is receiving more and more attention from the world. The high temperature and drought conditions in Yunnan forest area for half a year, the overload of combustible materials on forest land, the high density of fire sources and the threat of foreign fire sources are all potential hazards for serious and large forest fires, the complex terrain conditions of high mountains and deep valleys make it impossible for firefighters to reach the fire site at the first time and miss the best time to put out the fire, the complex fire conditions of surface fire, canopy fire, underground fire burning in three dimensions and the influence of fire microclimate are very easy to The complex fire conditions of surface fires, canopy fires, underground fires and fire microclimates can easily lead to casualties. In recent years, the number of forest fires in Yunnan, the area of affected forests and the number of casualties due to forest fires have been decreasing significantly, but it is still the province with the highest number of fires in China.

Depending on the data of the fourth forest resources survey in Yunnan Province, the forest land in the province covers 26.07 million hectares, accounting for 68.0% of the national land area; shrubland accounts for about 15% of the national land area. Several major forest fire caused by shrublands occurs in Yunnan every year, bringing huge economic losses and serious damage to forest resources. Forest fire in Yunnan is concentrated in areas such as Kunming, Yuxi, Dali, Chuxiong and Qujing, where large areas of flammable shrubs are distributed. The dense irrigation area is mostly composed of ground pine and dong type shrubs, with a high density of forest trees and concentrated contiguous, once a fire occurs, the burning intensity is high and direct fighting is difficult, which can easily lead to major fires and cause casualties. In addition, the region belongs to the major urban centers in Yunnan Province, with high population density and complex human activities, increasing the possibility of forest fires. It is important in order to conduct research on shrubland fire prevention and control, forecasting and prediction, and fire spread and potential fire behavior to reduce the number of fires and fire losses in Yunnan forest areas.

2 Research Status

2.1 Status of foreign research

The combination of meteorological data with forest fire warning was initially explored by experts as early as the 1940s in Japan, and after the 1950s, further research on forest fire forecasting began in an increasing number of countries.M. D. Flannigan[1]and others also used a Canadian forest fire risk rating system in the future to simulate changes in forest fire, and the results matched paleontological information, showing that the system can predict future fire. Showed that the system can predict future fire conditions.Timothy J. Brown[2]used a parallel climate model to forecast changes in forest fire risk due to climate change in the western United States in the 21st century.Jesper Rydén et al[3]used the Poission model and the zero-inflated Poisson model to simulate the

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relationship between forest fire occurrence and meteorological factors. Long-term and ultra-long-term trend projections of forest fire risk states based on the prediction results of the General Circulation Model (GCM) and Regional Climate Model (RCM), combined with the forest fire risk hierarchy through mathematical analysis and inference, are also part of climate change and forest fire research.

In shrub research, overseas research has also been conducted earlier and certain research results have been achieved. Burner J M et al[4]shrub forests are characterized by high regeneration ability, rapid reproduction and certain fire resistance after fire. In addition, Clarke P J[5]et al. studied the fire resistance of shrubs and showed that the fire resistance of shrubs is not only related to the structure of the tree species, but also closely related to the shrub density and shrub age. Finances et al[6]found that understory shrubs connect to surface combustibles and can increase the intensity of the fire head and the rate of spread of forest fires, thus increasing the risk of surface fire evolving into canopy fire. Shive et al[7]showed that the growth status and spatial distribution of shrubs have a momentous influence on forest fire spread.

2.2 Status of domestic research

Meteorological information has been used recently in China to develop the fire risk law method, the wind speed correction composite index method and the standard method of double finger method, etc. Chen Feng et al[8]selected annual average wind speed and annual average daily temperature difference as meteorological factors indicators to study the relationship between meteorological factors and forest fires in various ecological zones in Yunnan Province from 1982 to 2008. In addition, it was shown that precipitation, temperature and wind speed were the three main meteorological factors that had significant effects on forest fire occurrence. Drought, high temperature, and high wind is important conditions for major forest fire [9-11].

2.3 Development trends

The advantages of satellite monitoring system, such as comprehensive monitoring range, high temporal frequency and timeliness, make it widely used in forest fire monitoring [12]. Kezhen Liu et al[13]established a fire trend regression model for hotspot concentration areas by extracting spatio-temporal factors of files and combining them with meteorological data. The results showed that the forest fire data from satellite monitoring statistics were in good agreement with data from local forestry bureaus.

3 Shrubbery status in Yunnan Province

Shrubbery is a vegetation type was controlled by shrubs. It has a definite canopy/story height of about 5 m, no main trunk but clusters, and a cover of more than 30-40%. The ecological range is wider than that of tree forests, and the distribution range is often larger than that of three forests. Shrubbery are usually found in dry or cold climates where trees are not suitable for growth.

Shrubbery is dwarf forests with well-developed root systems, strong sprouting ability, tolerance to barrenness, cold, drought, and adaptability. Shrubs are woody perennials, and their growth and distribution also affect durability. Usually clumps of shrubs spread more quickly than scattered shrub forests, and shrub forests combined with weeds are more flammable.

Depending on statistics, the earlier shrubbery area in the province increased from 1.814 million hectares in 1964 to 4.985 million hectares in 1975, and to 5.530 million hectares in 1980, showing an increasing trend year by year. 2017 saw an increase in the shrubbery area in Yunnan Province. Such a trend of change is caused by the weak management of forest resources, for forest fire prevention, lack of awareness of resource protection, relevant protection measures are not in place, etc. After the destruction of the forest, the secondary species dominate, the residual forest phase increases and the storage volume per unit area decreases. The shrubbery area has increased considerably and the forest quality has decreased.

4 Research method

4.1 Correlation analysis method

4.1.1 Data sources

Shrubbery fire data in Yunnan Province from 1954-2018: books such as "Typical Cases of Forest Fires in China" and "Review of Typical Battle series of Forest Fire Fighting", Yunnan Forestry Bureau website, Fire Prevention Office website and other news media.

Meteorological data of some areas (Kunming, Yuxi, Dali) in Yunnan Province from 1954-2018: annual value dataset of Chinese toponymy climate data from China Meteorological Data Network, including monitoring statistics of annual maximum temperature, annual average minimum temperature, annual average temperature, annual average relative humidity, sunshine days and other relevant regional ground stations.

4.1.2 Data processing

This paper studies the correlation between brush fire and meteorological data as well as the prediction of meteorological trends, and then a comprehensive prediction of future trends of a brush fire. The first step is to start with the brush fire cases occurring in Yunnan Province, select typical brush fire cases as the analysis samples, and collect and organize their relevant data. The meteorological data were divided into two major groups: current daily meteorological data and current year meteorological data. The correlation analysis is done with the forest fire data respectively.

The following is a detailed description of each of these elements:

(1) brush fire data: fire area (hm2), forest damage area (hm2), and economic loss (million yuan).

(2) Meteorological data of the year: annual maximum temperature (°C), annual average temperature (°C), annual average relative humidity (percentage), annual average minimum temperature (°C), daily precipitation ≥ 0.1 mm days (days), annual sunshine hours (hours).

(3) Meteorological data of the day: the highest temperature of the day, the highest wind of the day, the fire danger level of the day.

4.1.3 Analysis methods

The first group: the current day meteorological data and forest fire data are analyzed, and the current day meteorological data, the highest wind of the day, and the current day fire danger level are regarded as three vectors and measured by length. A comprehensive descriptive data x1 was calculated and named as meteorological data. Then, large comprehensive indicator Y of the occurrence loss and probability of occurrence of the brush fire under study is named as fire occurrence loss. The correlation between meteorological data x1 and fire occurrence loss y was studied by spies correlation analysis method, and icons were made.

The second group: correlation of each small index such as meteorological data of the year: Annual maximum temperature x2, annual average temperature x3, annual average relative humidity x4 with fire occurrence loss y was analyzed and icons were made.

Data processing approach: two kinds, fire occurrence loss indicators, choose information that integrates three small indicators (burnt area, forest damage area, economic loss); meteorological data indicators, choose information that integrates three small indicators (highest temperature of the day, highest wind of the day, fire danger level of the day); specific collated data are shown in the appendix.

Using the data in the summary table of brush fire losses and climatological data can be analyzed using SPSS for correlation analysis to derive descriptive statistics, person correlation coefficient table for analysis to derive results.

4.2 Trend Forecast Analysis

4.2.1 Analysis objects

The forecast indicators are forest damage area, annual average temperature, annual average relative humidity, and annual sunshine hours. The predicted areas are Kunming, Yuxi and Dali in Yunnan Province.

4.2.2 Analysis method

Gray forecasting refers to the use of GM models to estimate and predict the development pattern of system behavioral characteristics, as well as to estimate and calculate the time when anomalies in behavioral characteristics occur, and to study the future time distribution of events occurring within a specific time zone. In essence, these works treat "stochastic processes" as "gray processes" and "random variables" as "gray variables These works essentially treat "stochastic processes" as "gray processes" and "random variables" as "gray variables" and deal with them mainly with the GM(1,1) model in gray system theory.

According to the GM (1,1) gray prediction model for software programming, the programming data used in the program are as follows, where the data for the next three years were predicted using matlab programming, and the original data and the predicted data were plotted to see the fit effect, and then analyzed and illustrated in detail.

5 Result analysis

5.1 Results of correlation analysis

5.1.1 Descriptive Statistics

Using the attached table, the data in the summary table of using the attached table, the data in the summary table of brush fire losses and meteorological data can be analyzed by SPSS. The results of correlation analysis are as follows: losses and meteorological data can be analyzed by SPSS. To keep the table simple, the following abbreviations are used instead : Fire loss(FL), Annual maximum temperature(AMMT), Annual mean temperature (AMT), Annual mean relative humidity(AMRH), Annual mean minimum temperature (AMNT), Precipitation Days(PD), Annual sunshine duration(ASD), Meteorological data(MD).The results of correlation analysis are as following.

Table 1. Table of person correlation coefficients

		FL	AMMT	AMT	AMRT	AMNT	PD	ASD	MD
FL	C	1	0.53	0.82	-0.878	0.415	-0.824	0.54	-0.922
	S		0.034	0.024	0.011	0.045	0.044	0.043	0.087
AMMT	C	0.53	1	0.088	0.233	0.102	-0.093	-0.223	-0.092
	S	0.034		0.675	0.263	0.629	0.659	0.284	0.663
AMT	C	0.82	0.088	1	0.039	0.15	0.072	0.086	0.395
	S	0.024	0.675		0.853	0.475	0.732	0.682	0.05
AMRT	C	-0.878	0.233	0.039	1	-0.012	.451*	-0.04	-0.063
	S	0.011	0.263	0.853		0.954	0.024	0.851	0.765
AMNT	C	0.415	0.102	0.15	-0.012	1	0.05	-0.042	0.363
	S	0.045	0.629	0.475	0.954		0.813	0.842	0.075
PD	C	-0.824	-0.093	0.072	.451*	0.05	1	-0.123	-.399*
	S	0.044	0.659	0.732	0.024	0.813		0.558	0.048
ASD	C	0.54	-0.223	0.086	-0.04	-0.042	-0.123	1	0.12
	S	0.043	0.284	0.682	0.851	0.842	0.558		0.567
MD	C	-0.922	-0.092	0.395	-0.063	0.363	-.399*	0.12	1
	S	0.087	0.663	0.05	0.765	0.075	0.048	0.567	

Significance test results, namely sin (bilateral). Can be used to show whether the correlation analysis results you get are statistically significant. Usually, sign<0.05 is considered significant and has statistical significance. If it is not meaningful, even if the correlation coefficient is large, it cannot show that the correlation is significant, and the correlation may be caused by sampling error. The asterisk after the correlation value also reflects the significance, with a * indicating significant at the 0.05 level and ** indicating significant at the 0.01 level.

The correlation coefficient indicates that all the diagonal elements are 1, indicating the correlation between the variable and the variable itself. The elements in the lower left corner and the upper right corner are symmetric, so only one side is needed in order to be be looked at. Since the research is on the correlation between the fire loss of dependent variable and each independent variable, only the first column of data needs to be looked at, Pearson correlation is the correlation coefficient, which is used to measure whether two data sets are on the same line. It determines the linear relationship between the distance variables. The larger the absolute value of the correlation coefficient is, the stronger the correlation is: the closer the correlation coefficient is to 1 or -1, the stronger the correlation degree is, and the closer the correlation coefficient is to 0, the weaker the correlation degree is. In general, the correlation strength of variables is assessed by the value range in the following table.

Table 2. Correlation intensity judgment

Correlation coefficient	Correlation intensity
0.0-0.2	Extremely weak correlation or no correlation
0.2-0.4	Weak correlation
0.4-0.6	Moderate correlation
0.6-0.8	Strong correlation
0.8-1.0	Extremely strong correlation

Through correlation data analysis of 100 brush fire samples in Yunnan Province from 1954 to 2018, the annual maximum temperature, the annual mean temperature, annual mean relative humidity, number of precipitation days, and sign significance test of daily meteorological data have statistical significance. The meteorological data of that day is less than 0.05, indicating that the meteorological index is significantly higher than that of brush fire loss data of 0.05. The average annual relative humidity was close to 0.01 level.

Through data processing, among various elements of meteorological data, the correlation index of annual maximum temperature, annual mean minimum temperature and fire loss is 0.53 and 0.415, indicating that there is a certain positive correlation with brush fire loss. The correlation indexes between annual mean temperature and annual mean relative humidity and fire loss are 0.82 and -0.878, indicating that the two indexes have a strong linear correlation with the bush fire loss, indicating that the annual mean temperature and annual mean relative humidity have a great impact on the bush fire in the fire area. There was a significant negative correlation between the annual mean relative humidity and the bush fire loss, and a significant positive correlation between the annual mean temperature and the fire loss. The correlation index of precipitation days and meteorological data on that day is -0.824 and -0.922, which are significantly negative correlated with the brush fire loss. The results showed that the fire loss in the sample area was negatively interfered by the number of annual precipitation days and the comprehensive meteorological data of that day.

5.2 Dali City Trend Forecast Results

Grey prediction results of forest affected area in Dali in the next three years are 114.7302, 99.61871 and 86.49757. The affected area of the forest in Dali was significantly different from that in previous years, and the affected area of the forest decreased dramatically from 1954 to 2018. Grey forecast in the next three years predicted value has reduced trend, but the base is still large, the situation is not optimistic.

Grey prediction results of the annual mean temperature in Dali in the next three years are as follows: 15.0544, 15.101 and 15.1476. From the grey prediction results, the average annual temperature in Dali from 1954 to 2018 showed a discrete division between 13 and 16 degrees Celsius. The grey prediction curve of the average annual temperature showed a slow rising trend, while the grey predicted value of the average annual temperature in the next three years showed a slight rising change rule.

Grey prediction results of the average annual relative humidity in Dali in the next three years are 75.0958, 75.777 and 76.4643. From 1958 to 1980, the average annual relative humidity in Dali was mostly between 68% and 72%. From then on, the average relative humidity showed a slow rising trend, and the three-year Gray predicted value was close to 76%, showing little change.

Grey prediction results of sunshine duration in Dali in the next three years are: 2046.8112, 2033.5312, 2020.3374. The annual sunshine duration in Dali fluctuated greatly from 1962 to 2005, with a maximum of 2650 hours and a minimum of about 1600 hours. In the next three years, the annual sunshine duration showed a downward trend, but basically stabilized at about 2000 hours, with little fluctuation.

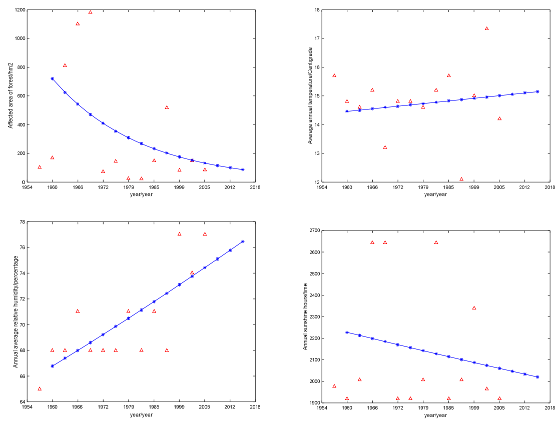

Fig. 1. Trend and forecast of indicators in Dali City

Grey prediction results of the bush damage area in Yuxi in the next three years are : 153.22679, 404.40529, 1067.3306. Yuxi shrubbery affected area from 1990 to 2018 showed multiple growth. Grey prediction value changes greatly, and the data analysis results show that the prediction data of the victim area will increase greatly in the next few years, which needs to focus on prevention and protection management.

Grey prediction results of the average temperature in Yuxi City in the next three years are as follows:14.5286, 13.8891, 13.2777. Yuxi annual average temperature between 13℃-16. Results of grey prediction show that the annual average temperature of Yuxi City will decrease in the future.

Grey prediction results of annual average relative humidity in Yuxi City in the next three years are as follows: 64.2072, 60.6411, 57.2731. In general, the average annual relative humidity in Yuxi City shows a certain downward trend, and the forecast results in the next three years are still consistent with this trend.

Grey prediction results of annual sunshine duration in Yuxi City in the next three years are: 2060.6617, 2115.5688, 2171.9388. The annual sunshine duration of Yuxi City has shown a certain upward trend since 1950, which is exactly opposite to that of Dali City, and the predicted results in the next three years are consistent with this trend.

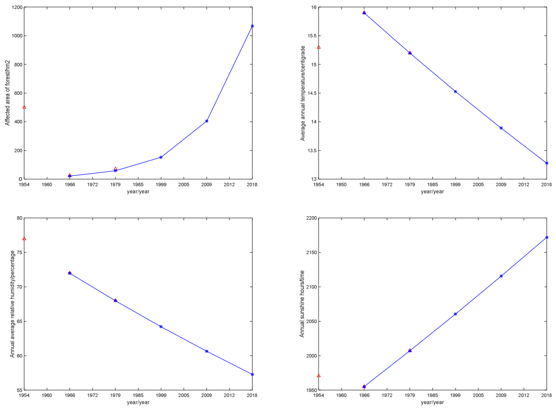

Fig. 2. Trend and forecast of indicators in Yuxi City

Grey prediction results of shrub damage area in Kunming City in the next three years are: 297.0346, 328.2397, 362.723. The affected area of shrubbery in Kunming fluctuates greatly over the years. The grey forecast curve shows a slow rising trend, and the grey forecast value in the next three years is about 300 hectares, showing an increasing trend year by year.

Grey prediction results of the annual mean temperature in Kunming City in the next three years are: 16.2663, 16.252, 16.2376. In general, the annual mean temperature in Kunming is relatively stable except for some extreme weather years.

Grey prediction results of annual sunshine duration in Kunming in the next three years are: 2490.857, 2528.0767, 2565.8527. It is similar to the sunshine duration in Dali, and has certain fluctuation. But in general, there is a certain upward trend.

Grey prediction results of the average annual relative humidity in Kunming in the next three years are: 74.1295, 75.5726, 77.0438. The average annual relative humidity in Kunming has a great difference over the years, but it can be analyzed from the forecast results that it has a certain rising trend.

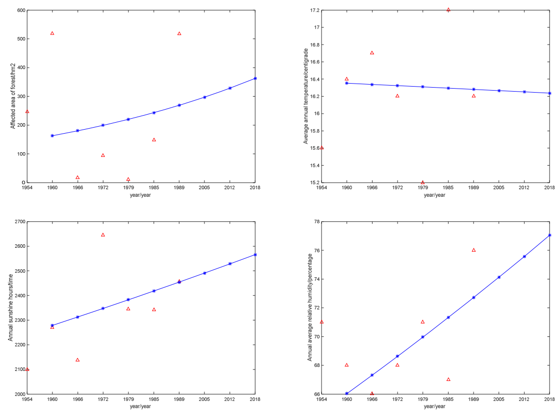

Fig. 3. Trend and forecast of indicators in Kunming City

5.3 Verification of Prediction Results

In order to verify the accuracy of the prediction results, another group of brush fire forest affected areas in Kunming, Yuxi and Dali from 1954 to 2017 and three indexes of meteorological data (average annual temperature, average annual relative humidity and annual sunshine duration) were analyzed with the same software data processing method to obtain the predicted values in 2018. After comparing the predicted value with the actual value in 2018, it was found that the prediction error of the gray prediction GM (1.1) model was large. The prediction error of annual sunshine number and annual mean temperature is small. The analysis error of annual mean relative humidity is minimum. The results show that the prediction results of yearly sunshine number, annual mean temperature and annual mean relative humidity have a certain accuracy, and the prediction trend of future forest affected area has a certain reference value for forest fire prediction.

6 Conclusion

This paper analyzed the change pattern and correlation between brush fire data and meteorological data in Yunnan Province from 1954-2018. The temperature in Yunnan Province has increased significantly and rainfall has decreased in the last 50 years. Against the background of the overall warm and dry trend of the province's climate, shrubbery vegetation types are used to study the dynamic relationship between changes in meteorological data and forest fire. Due to the complex topography and local microclimate differences in Yunnan, in order to reduce the combined effects of regional climate, altitude, latitude and longitude differences as well as data errors, the brush fire case in Yunnan province was used as a data sample to extract each relevant index with the climate data of the case area for analysis and research.

Through the correlation analysis, the brush fire area, forest damage area, economic loss composite data indicators and annual maximum temperature, annual average minimum temperature, annual average temperature, annual sunshine hours show positive correlation, with the annual average temperature correlation is the most significant; annual average relative humidity, precipitation days, the day meteorological data composite index shows a significant negative correlation.

under the climate change scenario of Yunnan Province, trend prediction results of mathematical nature were obtained by the software analysis of gray prediction mathematical model for three regions, Kunming, Dali and Yuxi. The annual average temperature, annual average relative humidity and sunshine hours of the three regions were predicted mathematically in nature. The gloomy prediction model indicated that the shrubbery forest damage area in Kunming and Yuxi showed a multiplicative increase in the next three years. The forest damage area in Dali shows a decreasing tendency, but the base is still large.

Acknowledgments

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